
THE ARCHITECTURAL REVIEW
CONCRETE AND STEEL

LINES

The horizontal lines in this view of the new Hammersmith Station on the *Underground* are carried on by the running and live rails, and brought out by the colouring and fenestration of the Piccadilly Tube train pausing inside it, before proceeding to the centre of London. The lines on the *Underground* form the link between home and office, and for this reason its rolling stock and stations are long and low, rightly emphasizing the horizontal—the line of motion.

The flat-roofed canopies and over-bridges of this station, which was designed by the Architectural Department of the *Underground*, are of steel frame construction squared off in concrete, faced with granite grit from the St. Austell quarries in Cornwall, and white Portland cement, rubbed smooth with a carborundum. Pre-cast concrete beams were used for roofing the canopies between the skylights.

The tube train shown is of all-steel construction. More than one train every minute passes each of the four platforms of this station.

FRONTISPIECE *November*, 1932

STEEL

By C. J. KAVANAGH

IN considering the potentialities of steel and concrete in the constructional arts, one is brought face to face with certain static concepts of architectural form, despite the vast resources which metallurgical and chemical science have put at the disposal of the age.

One's own experience emphasizes the evanescent nature of almost everything touching our daily life. Objects which we were taught to regard, through the march of centuries, as stationary and immobile, are now subject to constant and rapid change, and today we are confronted by forces, technical and economic, which compel an entirely new outlook upon building. The development of transport media alone has altered the tempo of life fundamentally, whilst other phases of scientific achievement have given new meaning to everything touching upon the constructional arts.

For instance, the earning life of a building has hitherto been rather too closely associated with the length of the lease. So long as the urban system in our civilization predominates and the centre of the town becomes the most desirable place to erect a commercial structure, just so long will it be necessary for the architect to make fullest use of limited sites. But if he is to be limited only by site—and, for the present, by building laws—he need feel no other limitations if he chooses steel-frame construction for his building. All that the present dynamic age requires in the way of commercial buildings is speed of construction to render the building profit-earning as quickly as possible, accuracy of design to permit economy of construction and —most important—adaptability to possible requirements in the future. These features are assured and can best be attained by building on the steel-frame principle.

The steel-frame building is, in fact, analogous to a gigantic meccano model, scientifically designed for the loads the structure will be called upon to bear.

The special characteristics of steel construction lead to a form of unit construction, factory made, which makes for reliability, thus relieving the architect of a meticulous examination for quality on the site, such as is required under other methods of construction. The component parts are fabricated at the factory while the site is being prepared, and when the foundations are made, the steelwork is ready for immediate erection.

The actual making of the steelwork is a straightforward operation to the engineer, who can produce the various units to the exact requirements of size and strength called for by the architect's design. Economies are therefore not only in erection time and in adaptability, but in the lightness of construction which obviates heavy and expensive foundations. Moreover, further economies can be effected by the use of hollow block panel walls, large window areas and standard floor and partition construction.

Problems which confront the architect are principally those where provision must be made for large and unobstructed floor spaces, in cantilever construction for balconies, etc., and other architectural features.

It is here that the accumulated experience of the structural engineer is at the service of the architect. The principles underlying the design of the Forth Bridge are now applied to buildings—only the scale is different, but this should not obscure from the architect the fundamental principles of construction.

Indeed, there is no doubt of the immense advantages of steelwork in its application to static as well as to dynamic construction.

Steel is used in the constructional arts in two distinct and separate forms as shown in the illustrations. The one in which the steel members or components are exposed to view, as in a bridge or an industrial building : the other in which the steel is the carrying or structural element for the building and in which it is obscured from the view by the weather and fireproof enclosing fabric. With this enclosure steel disappears from view, and the connection between the steel structure and the building can only be sensed by a logical development of the completed design.

This development, however, is yet in its infancy because the other components of building have lagged behind in technical progress and the ideal curtain wall has yet to be discovered—the wall combining lightness with resistance to temperature changes and sound transmission, and providing an adequate grade of weather resistance. The science of acoustics has much before it. Next to the old massive stone structure, the steel-frame building provides the best background for the proper acoustical safeguard in domestic, commercial, and factory buildings—a matter of prime importance.

Today we are confronted with two distinct types of building. Side by side with the heavy, massive building of stone and brick, we have the light steel structure in which the loads and forces are cared for and transmitted to the foundations in a simple and direct manner. In the earlier epochs of construction the play of forces in the huge vaulted and domed constructions required a buttressing and massiveness of material which today is superseded by steel components of astounding slenderness. The high resistive nature of steel, its homogeneity, the precision of its manufacture, the soundness of the material, the accuracy of the assemblage of the steel structure, its flexibility to take up load-shocks, are qualities which will continue to force a full recognition in architecture.

The naval architect, the bridge designer, the locomotive engineer, and those who use steel as the logical material calculated to attain the maximum efficiency, constantly revise their practice in the effort to increase this efficiency and to be in the van of all progress.

Traditional trappings have robbed architecture of much of its flexibility, and its language of " post and lintel " is insufficient and out-worn in these days of high tensile steel.

What was impossible a decade ago is today a commonplace. We stand now before a revaluation of values, and nowhere more than in architecture, sheltered from the urge of international competition, is a fundamental searching of the heart necessary.

A CONCRETE THOUGHT

By SIR E. OWEN WILLIAMS

IF we must think of time other than the present, is today the effect of yesterday or the cause of tomorrow ?

It would seem that effect has the power of influencing its cause—that seeing many moves ahead, Nature arranges its causes accordingly, being not the slave to cause and effect, but commanding the law. It follows that there is not always a reason for the existence of anything on the basis of a prior cause, it may be introduced from the blue to anticipate effect—a twist in the steering to avoid the corner ahead. Skill in play is ability to see by intuition many strokes ahead and to play to them. Nature is at least as good a player as the best of us. The periodic interposing of new causes to anticipate effect is the continuance of creation.

It is not an exaggeration to regard our time as the end of the ice age. The ice age caused the sharp demarcations of colour and other characteristics of the white, yellow and black sections of the human race, and for ages maintained their complete separation. In our time transport and communications have short-circuited these lines of vastly different potential and with corresponding explosiveness. It was like removing a dam separating three or more rivers of vastly differing levels, and until the flood subsides who can say to which of the original levels the final level will approximate. In the faith that the world is an harmonious entity, one would say the resultant level will be datum—the levels will be mutually corrective.

World conferences pay tribute to the unity of man—they fail when they handicap today with yesterday instead of playing up to tomorrow with the newnesses of today.

The short-circuiting of mankind by transport and communications results in world-thinking as distinct from country-thinking, district-local-thinking. It may appear to lead to lack of outward variety, but the loss, if values can be assigned to such movements, is offset by the magnificence and power of the world-thought.

It is not to be imagined that in playing up to some future effect of world unity Nature forgets any move, however apparently insignificant. Every lever and every switch moves over in response to the new impulse. So in construction we can look confidently for the signs of effect predicating its cause.

Gone are the days when local materials were the only suitable. Transport has enlarged locality to the size of the sphere. Regrets for local colouring must be tempered with faith in a more comprehensive view, in the power of one great stream which assembles the countless rivulets.

In the realm of materials and of science the unity of man is already achieved, as though it were the vanguard already arrived in the Promised Land.

It is great reward and corroborative encouragement to the adventurer on the front line to hear that far away in a foreign section another has made the clearance. It is the joy of contact with a universal material. To the worker in concrete this joy is bountifully offered. Throughout the world similar thoughts, similar experiments, similar applications in a profusion which eclipses the interest in any other building material. Any construction publication proves this at a glance. It must be so. The constituents of concrete: gravel, sand, water and cement (chalk, clay and heat) are of a universality which compels.

And with universality comes an increase in scale. The local unit is no longer the universal. The virtues of concrete render it inapplicable to small scale. The gigantic constructions needed in East and West to preserve human life are built equally everywhere of concrete. Bricks and stone, and wood and paper are of the locality—concrete of the earth, alike in swamp or mountain, in earthquake or windswept country. Its use gives a unity of universal interest.

Today we apply it to replace the older materials, and not yet has it achieved its own scale. It is serving apprenticeship to its part to play in world unity—in the time when it is determined that " local " interest must give place to " world " existence. Now is the time of thought and much experiment—cause. Then will be action and result—effect. Without one not the other. Now all is fluid—then will be the measurable solid.

In the economy of concrete is the safety of economy. It scales the precipice between need and effort.

Façade-ism is its present enemy. Kreuger-ism, faking of balance sheets to look right, is no better or worse than faking materials to look otherwise—both forgeries. He who has no faith that a material needs little of himself except understanding had better leave it alone. Façade-ism is bad in that it causes neglect. It drugs where there should be quick enquiry. The apparent failure of a material to satisfy should lead to investigation of the real failure of its user. Anything less is cheating. To *look better* is just as likely to *be worse* unless it comes unconsciously.

However, it is all in the experiment, and ultimate triumph will wipe out much.

THE BRITISH ENGINEERING TRADITION. THE OLD CRUMLIN VIADUCT ON THE GREAT WESTERN RAILWAY. ERECTED BY T. W. KENNARD IN THE EIGHTEEN-FIFTIES

TRADITION SPEAKS

By SIR EDWIN LUTYENS

STEEL and concrete have, without doubt, greatly widened, and thereby disturbed, our building outlook; but as to architecture itself, the effect of this disturbance is obviously negative. With their adoption the architect has resigned the more serious constructional problems to his colleagues, the engineers and iron masters. He feels freed from traditions, and his ideas seem to breed flippancy, which, to save his face, or rather his buildings, he acclaims as new.

An architect, be he young or old, must persevere in his effort to produce the best within his power; age but gathers with it the pollen of knowledge and experience, and it is for the older man to hand on to the junior the honey made.

New materials cannot change the outlook, for the principles of design have been, and are for all time, unchangeable. New ideas are but thoughts—generally unhappy ones—and are like imps of mischief rising from our hearths to tease and worry us all.

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The prototype of the steel-framed building is to be found at Bath, and other places as well, where the timber frames of terraced houses—greatly admired—are hung with mechanical slabs of stone to represent ashlar.

Many of the so-called modern concrete buildings are of brick and plaster and in appearance are as much in fancy dress as when clothed in more traditional costumes.

The bridging of wide spans with a steel beam saves much trouble and fine labour, and our ever growing streets proclaim in their presence the saying that we are but a nation of shopkeepers. Our patrons and masters seem to be just showmen, and it is surely these good folk who now occupy the citadel of our brains.

* * *

Architectural aspiration should remain constant, and our great traditions maintained; and it should be our endeavour to hand on to our sons a world at least as fair as, if not more beautiful than, what our fathers gave us. A greater trabeation makes no greater change than that created by the invention of the arch. It is not wise to discard the " secrets " of the past—the " how " and " why," with the sequence of rhythm and cadence of a style.

To be original in the company of Callicrates, Vignola, Bernini, Wren, is no mean achievement, and new materials make such originality possible without resort to revolution, with its riot and red-capped crowds escorting the tumbrils of destruction.

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Why should some new method or new materials scare our poor senses? Rather let us by real endeavour do the fine thing based on the humanities, and reverence in deed all that is best within our great heritage. It is hard, working on traditional lines, to attempt to do as well as has been done, not only by the acknowledged masters, but by all those anonymous craftsmen who adorned our country with their work. There is no excuse possible for error by neglect. New materials and conditions bring original solutions in their wake. The advertisement is small except to the few who know. Is it to save trouble and essential erudition that invention without responsibility jumps blindly to results ?—results for which there are no precedents and consequently no comparative values.

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New materials have been made the excuse for bad design. Architecture should be the master and not the servant of material. The repetition of classic forms without knowledge is like the chatter of the parrot house. Thus the public turns with relief from the old tradition. But the new materials, with their facility in giving greater and most welcome trabeation, present new problems which the architect, trained by the letter of cap and column and not by the principles underlying their development, is still unable to meet. So they seize upon foreign solutions, or else are merely content with a new terminology which was thought to presage the birth of a new art. But a new art is a fresh art, and not merely an art practised by freshmen who have yet to win their honours, and that with no Domine to hand on to them the torch.

Nor will the new materials cloak their inexperience; and, in any case, they as yet know too little of the new materials they flaunt. Cracking glass and crazing cements are not worthy materials on which to base a style, nor is it possible to achieve with them a proud permanence.

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Because the architect knows so little of these materials, as well as of the conditions under which he should now do his work ; and because he is too impatient even to learn his limitations, he has capitulated to the engineer, who has become the staunch authority. The engineer and the chemist should be the servants of good architecture ; they should be the architect's friends and colleagues, and should be men of experience and true to his needs. But, ultimately, the architect should leave nothing either to them or to anybody else. Nothing prejudices the position of an architect more than thoughtlessness and its offspring ugliness. The engineer should not be expected to think in terms of architecture.

* * *

It is the architect alone, as trustee of the public interest, who should watch and safeguard the traditions of the country he builds in, and the locality with its personality. Truly, there is nothing, save parliamentary interference, to prevent any one engineer being a better trustee in the wide architectural sense than any one architect. Sir Benjamin Baker achieved a great architectural triumph in the Forth Bridge ; and if engineers paid as much attention to avoiding distress and strain to the eye as they do to the stress and strain of their construction, architects would vaporize under the agency of a greater heat. It is up to architects. Let them acquire knowledge, and this by experience, point by point, not by a compilation from text-books. It is for them to triumph or for them to go under. They must learn from all trades, and of such the engineer is surely one.

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Who can say how much Wren's artistic achievement was due to his study of the accurate sciences and astronomy ? One can well imagine the interest he would have taken in these new materials—steel and cement. He would have controlled them to his own purpose and would not have been content to leave them to a middle man who voices his wares, not in terms of ascertained facts, but by displaying their patents with pæans in their advertisement.

* * *

Quick-setting cements and steel sensitive to temperatures, with their scarcely foreseen chemical action, make our building world one of great hazards. The engineers and chemists on whom we rely should manufacture only for experiment or instruction, and not for profits. One of England's glories is those men called scientists who toil that we may know.

Unless the architect is proficient in all the elements which constitute his art he is lost. Let him be a General commanding trained battalions. Let him seek the assistance of honourable allies and eager subalterns. But let him not surrender the command. Let him not be a dabbler ; for if he dabbles he may but win a chill with a chance of being " found drowned," and to show his deep appreciation of art may appease his nasal irritation with a coloured handkerchief !

* * *

There is only one thing that can affect an architect adversely, and that is bad architecture.

Our silver lining is but clouded and a cloud is but ephemeral. The old patronage is passing, and what the new will bring is difficult to foresee. But I have faith that respect and reverence for all that is best in the past will reflect into the future ; and, in architecture, it is for the older men to hand on what they believe to be fine and true and not to be dismayed at the epidemics and distempers ever prevalent amongst the very young.

Democracy has to learn, and for its experience pays the cost in blood and being.

What architecture requires is patrons, and I pray they be so kindly and so wise as to lead and bind us to the highest level.

Any man attempting to design must stand in reverence before that beauty that lies in all things in nature, no matter how small, untouched by man.

RESPONSE TO TRADITION

By WELLS COATES

"*What is important for me above all else is to obtain* from that which is going to be, *that it should with all the vigour of its newness satisfy the reasonable requirements of* that which has been. *How can one help being obscure?*"—PAUL VALÉRY, *EUPALINOS, OR THE ARCHITECT.*

"*The arrangement seems to be that you spend half your time destroying the cheap, the foolish, the repellent; and the other half enjoying what is left after your efforts! This evidently being how we are intended to live, there is no excuse for slackness in the carrying out of your unpleasant duty: that is, to desire equity, mansuetude, in human relations; fight against violence; and work for formal beauty, significance and so forth, in the arrangement and aspect of life.*"—WYNDHAM LEWIS, *THE CALIPH'S DESIGN.*

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I. The Word-Cannibals' Feast

It is commonly assumed that to ask a definite question is to be entitled to a definite answer, and not merely to a *response*.

Thus an architectural critic,* who, more than anybody else these days, is beset by innumerable gaping questions, sets out a feast of words on which the hungry reader fastens—never, alas, to be satisfied. So long as a belief in the all-importance of verbal sustenance is maintained, a profitable trade will be plied.

Words are a justification for themselves, sometimes. They are most usually justified by the function of communicating experience. Therefore, if we direct our questions towards experience and not towards another word (the word "functionalism" for instance, and "what is functionalism") we are more likely to find an answer *of some sort*.

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In a book *Among Congo Cannibals*, by J. H. Weeks,† we read:

> "I remember on one occasion wanting the word for Table. There were five or six boys standing round, and, tapping the table with my forefinger, I asked, 'What is this?' One boy said it was a *dodela*, another that it was *etanda*, a third stated that it was *bokali*, a fourth that it was *elamba*, and the fifth said it was *meza*. These various words we wrote in our notebook, and congratulated ourselves that we were working among a people who possessed so rich a language that they had five words for one article."

A short analysis of this apparently simple sign-and-word situation might have saved the reverend gentleman the trouble of finding out later that:

> "One lad had thought we wanted the word for tapping; another understood we were seeking the word for the material of which the table was made; another had an idea that we required the word for hardness; another thought we wished for a name for that which covered the table; and the last, not being able, perhaps, to think of anything else, gave us the word *meza*, table—the very word we were seeking."

The name of the "experience of a Table" was, of course, Table, for ordinary purposes. It was also an experience of tapping, etc. The answers were all to the point, so far as it was defined.

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Let us imagine a similar situation among the modern Word Cannibals we are now observing.

A foreigner, let us say, on a tour of London walks to the top of Regent Street, and finding there four or five architectural critics standing about, points to a building on the corner and says, "What is that?"

The variety of possible responses to his question might include that it was a building which "expressed its purpose" or its "construction"; or that it displayed very bad manners indeed; or that it "expressed" an important aspect of the national life; or that it was an example of unsymmetrical design carefully adapted to an irregular site; or that it "looked like a ship" and was built of Portland Stone, a material particularly suitable (or unsuitable) to the atmosphere of London; or he might be told what he probably wanted to know, that, indeed, it was "Broadcasting House."

Such a collection of verbal responses does not suggest an unfair picture of the state of architectural criticism today, in which mere opinions are made to take the place of technical investigation of visual and material scenes; or else technical facts made to assume the role of critical values, so that discussion is impossible or useless unless preceded by interminable definitions of terms.

There is no common norm of speech about architecture. Evidence of this lack is everywhere available.

* * *

Two common verbal strategies—plausible and persuasive in their superficial way—may here be cited as examples of the sort of writing that passes for criticism today.

In the first place, there is the practice of disposing of ultimate critical difficulties by the method of Verbal Identity. In answer to the question "What is Architecture?" you are told that all building is not Architecture, but architecture is the Art of building. What is Art? Art is the expression of Beauty, and that particular way of building which we call Architecture is therefore beautiful building; or it is building which gives us Pleasure, for one of the qualities of Beauty is that it is pleasurable. All of which, of course, tells you less than nothing: all the difficulties remain when this has been written.

In the second place there is the method of Verbal Invention: to dispose of your difficulty you invent a new word; or you seize upon a word which can be used exactly only in a specific context, and you make it include a lot of other things: you make it a "portmanteau" word.

Your "artistic" training and experience has taught you that "beautiful" buildings have certain features in common, that they conform, perhaps, to some *style*, which is—after all!—*well known* to be "beautiful."

And then suddenly you notice a new kind of building which disturbs your "artistic" ideas: you no longer recognize the familiar features, it's a bit *odd*, or "bare." What you *know* to be the outward forms and lines of "beautiful" building simply aren't there! To dispose of your problem shortly, you may say that it reminds you of something—something which has nothing at all to do with buildings, such as an aeroplane, or a ship.

But somehow the new designs keep on cropping up, and they are hailed and approved in the most *respectable* quarters. You are a writer, a critic, you *must* find a word for this new thing, which disturbs your critical equilibrium. You look about, and find a word which is already an important one in the vocabulary of architecture—one which has been used too freely and too loudly, perhaps, by some *vrai romancier*—you add an "ist" or an "ism" to it, and you call it "functionalism."

The new word has a "modern" ring about it, it's "smart" and "hard," and perhaps a bit "bolshy" too. (That will be very useful later on.) And thus, for the time being, the critical balance is restored, by a fresh bright word.

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Another dimension of this obscurantist technique closely follows the word-making strategy. Nothing is more natural than to suppose that there is a new and high-sounding theory behind the type of design which has been labelled "functionalist" indiscriminately. But authentic details are lacking. In theory, theory comes before practice, so that (to the amusement of the architects concerned) it will be said that they are "functionalists" according to the theory gratuitously specified for them—by the writers!

This *genre* of critic is well experienced in the methods of assuming an air of "spurious aloofness," of sheltering himself in the verbal thickets of critical jargon. It is not as difficult as it might appear at this stage to invent even the architects on to whom the theory is fixed. It is only necessary to write in this way: *In certain quarters* the view is stoutly held that a building has some special quality of beauty if it can be designed in such a way that it "expresses its functions."

* If I may be permitted in a footnote to borrow a strategy from Mr. Osbert Sitwell, I should like to say that any writer (or architect) recognizing himself in the words of these notes will be immediately prosecuted for libel.

† Quoted by Ogden and Richards in *The Meaning of Meaning*, Kegan Paul, 1925.

One after another the little ninepins are carefully set up. And then—down they go!—with such style, such a *charming* style!

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Perhaps we have already over-eaten at the Word-Cannibals' Feast. As a corrective, let us take the following authentic physic:

> "It is often easy enough to find something which we can suppose to be what we know. Belief feelings . . . are *parasitic*, and will attach themselves to all kinds of hosts. In literature it is especially easy to find hosts. But . . . in the non-representative arts . . . in architecture for example, the task of finding something to believe, or to believe in, is not so easy. Yet the 'feeling of significance' is as common in these arts as in literature."*

and *pour les beaux yeux de votre vrai romancier*, one more:

> "To excite a serious and reverent attitude is one thing. To confuse forth an explanation is another. To confuse the two and mistake the incitement of an attitude for a statement of fact is a practice which should be discouraged. For intellectual dishonesty is an evil which is the more dangerous the more it is hedged about with emotional sanctities."†

* * *

It is in man's nature to cling to what has once been defined, and to believe, that whatever receives a name must be an entity or being, having an independent and somewhat mysterious existence of its own. There is no limit to the disparity that is allowed between a word and a fact.

In no branch of discussion is this tendency more acutely found than in controversies on the æsthetics of form in architecture, and these constantly resolve themselves into differences about the meaning of words.

A verbal discussion may be important or unimportant, but it is essential at the outset to realize that it *is* verbal, and to avoid, so far as we are able, the many attractive and accommodating loopholes which words provide, by their very nature, for the access and intrusion of persuasive errors in thought.

In the remainder of these notes an attempt will be made to set down (for what it is worth in the common hurly-burly of words which surround our life today) a sketch plan for a fresh critical approach to the architect's formal problems. For it must by now be apparent to everybody that the new conditions of social life and the new materials of construction *do* present—gratis and post free—fresh problems to the architect.

We shall be well advised to begin with a more or less abstract analysis of the *response* to works of art, and to call in the assistance of experts.

* * *

II. The Analysis of Response

"*Toutes choses sont dites déjà, mais comme personne n'écoute, il faut toujours recommencer,*" says André Gide.

And if an idea has once been well stated, and well tried, let it be used again as *material*, so that formal and authoritative significance may be given to the construction of some new whole. An architect may perhaps be allowed to do this.

A first step may at once be taken with James Joyce, in the pages of his early and important book, *The Portrait of the Artist as a Young Man.*

He writes: ". . . though the same object may not seem beautiful to all people, all people who admire a beautiful object find in it certain relations which satisfy and coincide with the stages themselves of all æsthetic apprehension."

"Stages" and "apprehension" are the operative words in that sentence. Joyce goes to Saint Thomas Aquinas for, as he says, "a pennyworth of wisdom." Aquinas wrote: *Ad pulcritudinem tria requiruntur integritas, consonantia, claritas.* Joyce's gloss on Aquinas reads as follows:

> "Look at that basket. In order to see that basket, your mind first of all separates the basket from the rest of the visible universe which is not the basket. The first phase of apprehension is a bounding line drawn about the object to be apprehended. . . . You apprehend it as *one* thing. You see it as one whole. . . . That is *integritas*." (Wholeness.)

That is the first stage of æsthetic apprehension.

> "Then you pass from point to point, led by its formal lines, you apprehend it as balanced part against part within its limits: you feel the rhythm of its structure. In other words, the synthesis of immediate perception is followed by the analysis of apprehension. Having first felt that it is *one* thing, you feel now that it is a *thing*. You apprehend it as complex, multiple, divisible, separable, made up of its parts, the result of its parts and their sum, harmonious. That is *consonantia*." (Harmony.)

The connotation of the word *claritas*, says Joyce, "baffled me for a long time. It would lead you to believe that he had in mind symbolism or idealism, the supreme quality of beauty being a light from some other world, the idea of which the matter was but the shadow, the reality of which it was but the symbol. . . ." But that, he adds, is "literary talk," and writes:

> "When you have apprehended that basket as one thing and have then analyzed it according to its form and apprehended it as a thing, you make the only synthesis which is logically and æsthetically permissible. *You see that it is that thing which it is, and no other thing.* The radiance of which he speaks is the scholastic *quidditas*, the *whatness* of a thing. . . . This supreme quality is felt by the artist when the æsthetic image is first conceived by his imagination."

That is as good a statement as we shall find in contemporary writing of the *stages* of æsthetic apprehension, from the point of view of an artist. An analysis of a different kind may now be outlined.

* * *

Psychological analyses of responses to works of art have often been attempted, and as often failed, by a preoccupation with the necessity, expected of a writer, of providing a "solution" in so many words (or books). First a preoccupation with the *means*, and then the easy substitution of the *means* for the *end*, that is the common practice.

The technique of psychology has advanced far enough today to enable a vigilant investigator to *identify* and classify the elements of a response, and to mark out the paths where visual and verbal errors are commonly made.

The *valuation* of these elements, which is the proper function of the critic as a mind-physician, is not so easily accomplished by professional psychologists.

Mr. I. A. Richards, from whose brilliant and original book, *The Principles of Literary Criticism*, we have already quoted, is a critic who has the peculiar distinction of being also a psychologist. We shall find in him a valuable guide on the next stages of our approach.

Mr. Richards is, of course, concerned chiefly with the analysis of response to literature, but as he himself says:

> "The differences between separate arts are sometimes no greater than the differences to be found in each of them; and close analogies can be discovered by careful analysis between all of them." (p. 147.)

Mr. Richards first makes a clear distinction between what he calls "technical" and "critical" remarks. Thus:

> "All remarks as to the ways and means by which experiences arise or are brought about are technical; critical remarks are about the values of experiences and the reasons for regarding them as valuable." (p. 23.)

In analyzing the experiences of the visual arts, he says, the first essential is to avoid the word "see"—or to know what you are doing when you use it.

> "The eye, as is well known, is peculiar among our sense organs in that the receptor, the retina, is a part of the brain, instead of being a separate thing connected with the brain more or less remotely by a peripheral nerve." (p. 150.)

Thus, when we say that we "see" a building, we may mean we see (1) the actual materials of its surfaces; (2) the image cast by these surfaces on the retina; or (3) certain planes or volumes in the space occupied by the building.

> "In the first case we are speaking of the sources of the stimulus; in the second, of the immediate effect of the stimulus on the retina; in the third we are referring to a complex response made up of perceivings and imagings due to the intervention of mental structures left behind by past experience, and excited by the stimulus." (p. 149.)

The intervention of these "mental structures" of past experience energizes a vast store of impulses and what he calls "appetencies" or "seekings after," which Mr. Richards analyzes with fascinating detail, and which he concludes are the essential and fundamental things in any experience.

As the parts of a growing response modify one another, and attention passes successively from one complex of expectations and satisfactions to another complex of disappointments and surprisals, so an "attitude" is evoked, and

> "it is upon the texture and form of the attitude involved that its value depends. It is not the intensity of the conscious thrill, its pleasure or its poignancy, which gives it value, but the organization of its impulses for freedom and fullness of life." (p. 132.)

It will be seen that we have arrived into the category of value—of "critical" remarks. Mr. Richards outlines a Theory of Value, without introducing any special ethical or "revelational" doctrines, which may now be briefly exposed to view.

The first step, he points out, is to agree that "apart from consequences, any one

* I. A. Richards, *The Principles of Literary Criticism*, Kegan Paul, 1925.

† Op. cit. p. 286.

will actually prefer to satisfy a greater number of equal appetencies rather than a less."

> "Anything is valuable which will satisfy an appetency without involving the frustration of some equal or *more important* appetency." (p. 48.)

The word "important" is the operative word in that sentence. Mr. Richards reminds us that there are certain evident priorities among impulses, certain primary wants and secondary wants. We must eat, drink, sleep, breathe, *shelter* ourselves, etc. But we do not yet know enough about the precedences, the modes of systematization in the mind, to say what order actually exists. "We only know," he says, "that a growing order is the principle of the mind, that its function is to co-ordinate." The "importance" of an impulse can be defined as

> "the extent of the disturbance of other impulses in the individual's activities which the thwarting of the impulse involves." (p. 51.)

The next step is to estimate the relative merits of different modes of systematization of impulses, appetencies, attitudes. It is obvious that no human being could live for one minute without a very intricate and—so far as it goes—very perfect co-ordination of impulses. "It is only when we pass from the activities which from second to second maintain life to those which from hour to hour determine what kind of life it shall be, that we find wide differences." And so

> "By the extent of the loss, the range of impulses thwarted or starved, and their degree of importance, the merit of a systematization is judged. That organization which is least wasteful of human possibilities is, in short, the best." (p. 53.)
>
> "The most valuable states of mind are those which involve the widest and most comprehensive co-ordination of activities and the least curtailment, conflict, starvation and restriction." (p. 59.)

And where may we find the most valuable states of mind? Where, the widest and most comprehensive co-ordination? Mr. Richards replies:

> "Among all the agents by which 'the widening of the sphere of human sensibility' may be brought about, the arts are the most powerful, since it is through them that men may most co-operate and in these experiences that the mind most easily and with least interference organizes itself." (p. 133.)

Until recently, in all the arts we have tried to find value in conformity to abstract prescriptions for Design, and to general rules of conduct, instead of recognizing that value lies in the minute particulars of response and attitude.

> "The artist is an expert in the 'minute particulars' and *qua* artist pays little or no attention to generalizations which he finds in actual practice are too crude to discriminate between what is valuable and the reverse." (p. 61.)
>
> "The artist departs from the average, but so do other people. His departure, however, is one of the reasons why we attend to his work, other people's departures may be reasons why we should not." (p. 194.)

Because the artist has always tended to depart from the average, and to pay little or no attention to high-sounding generalizations about Beauty, Goodness, and so forth, the moralist (and that term includes, of course, a lot of people who call themselves "artists" or "architects") has always tended to ignore or distrust the artist.

A new morality, in which the artist plays his proper function as the possessor of the most highly ordered mind, as expert and man of action in that sense (and not a big-black-hatted, eccentric, "temperamental" sort of fellow, the chap who puts the "pretties" on after the *real work* has been done), seems to indicate itself as a real twentieth century necessity. "None of the afflictions of humanity," concludes Mr. Richards, "are worse than its obsolete moral principles."*

* * *

The fallacies of contemporary architectural criticism are contained in the processes by which mental effects are projected and made to appear as qualities of the objects "seen." On the other hand, a "purely visual" approach to the problem of form is usually pure nonsense. The apprehension and appreciation of creative forms in architecture—an art which in its imitative forms continues to uphold "obsolete moral principles—" becomes a very difficult affair indeed. Again, Order and convenience, Plan, and what Mr. Howard Robertson calls "perfected organization," are seldom taken into account at all, as an equally important part of the experience.

III. Voice for Reconstruction

Human conditions and possibilities have altered more in a hundred years than they had in the previous ten thousand.

But customs change more slowly than conditions.

Every change in conditions brings with it new possibilities of systems of impulses, needs, expectations, attitudes; and the necessity to order them anew, to give them form, and freedom, and fullness and richness of life.

And to be able to do that, in our own age, is to carry on the great Tradition of Art.

The great principles of art have always remained the same, at least for artists. To deny that; or to affirm, because the characteristics of contemporary creative work are different from those of the eighteenth, the sixteenth, or some even more remote century—to affirm that therefore contemporary art belies the great principles, is to be blind to all principle. There are no *eyes* in that philosophy.

The social characteristics of an age determine the characteristics of its art, and this more so in architecture than in any other art. And by "characteristics" we mean the diversity of form over and above the sameness of *essential intention*. The true tradition of art lies in the essential intention.

* * *

This intention must include a horror of embalming, in vast academic morgues, built of the most alarmingly durable materials, the characteristics of an architecture once noble, grand, all-powerful, but incapable of life amid the new social and material characteristics of the twentieth century.

One feels that the verbal prescriptions that are handed out, and the praises that are given and received—so very politely, and with such *charming* style—for the raising up on frames of steel these immense theatre-sets for architecture, these vast scenic displays of architectural pomp and inaccessible meaningless grandeur—one feels that these prescriptions are but the "shuffling and matching of pedantic dictionary adjectives. Verbality has slipped into the place of vision, professionalism into that of life."†

Theatrical sets for "architecture" raised up, by prescriptions for the paraphernalia of gunmetal cramps and hook-bolts, steel bands and stays, angle cleats, brackets, plugs, dowels and reinforcements; held up, by calculations for all the extra steel and concrete required to carry their *literally* dead weights. Theatre-sets, raised up and held up by steel and concrete. Theatre-sets, raised up and held up to praise by the academic undertaking professors, designed to prescription by the property-men of architecture, and so often scarcely *visible* even (for all the gold and labour spent on them) in the narrow, unlit, unplanned, sordid streets of a contemporary city.

* * *

Let us make a tour, then, "in a tobacco trance" round about the built-up centres of Bond Street, Park Lane, or High Holborn. And let us take as guide one who is a stranger to the West, one born and brought up according to the inflexible customs of an ancient civilization of the East.

The "inheritance of culture" by the children of our epoch is a glib phrase inaptly applied to the study of, say, the novel writers of a certain era, coupled with a brief visit or two to the more important art galleries of Europe. In the East it is not so. The cultured man is one who is himself an artist of living; one who has been trained sensually to the æsthetic apprehension, who inherits a culture perpetually resurrected in his own eyes, voice, hands and movements.

Our imaginary guide has travelled to Europe. His preparations have been simple. He has been told that a man whose eyes have been trained in the East will only rarely want to open them in the West. He has provided himself, therefore, with a temporary substitute for sight, with a kind of æsthetic X-ray. Indifferent to the confusion of appearances and re-appearances, the accretion of layer upon convoluted layer of architectural growth, he is able to track down its underlying shape, the sources of its traditions.

Gradually there becomes perceptible to him a basic pattern. Its grandeur calls forth his admiration. This and this only

* I have exposed to view only the essential variables and quotients of Mr. Richards's fine and intricate equation. Its real values have not, it is to be hoped, been discounted or lost thereby.

† William James, writing in another context in *The Varieties of Religious Experience*.

of European traditions is the one comparable to his own. He describes it as at once rich and severe. It is the tradition of Greece.

Here and there a fully rounded and complete pattern makes its appearance (he has arrived into the 18th century)—the true derivatives of Greek traditions, each characteristic of its age and purpose. . . . . But the pattern, blotted and marred, and finally debased, disappears behind the monstrous banality of a commercial city.

Our Eastern guide speaks . . . .

How barbaric is your habit of overloading ! How seldom does an object stand in the place which correlation appoints to it ! What is the meaning of this ugliness, banality and squalor which meets the eye as it travels up practically any street in London, or wanders round any hotel lounge or restaurant or delects itself along the façades of buildings in Bond Street ?

You Englishmen are naturally averse to asking these questions. But there is a point in your anti-intellectual armoury that has been severely pricked. Your sense of order, of comfort, of practical life, that is. The disagreeable litter of the countryside, the posters, the excrementa of undigested form-content and colour-content, all the objectionable " bits and pieces " and their alarmingly rapid increase by new methods of reproduction —all these have begun to be nuisances, and you have formed societies for the mitigation of nuisances. A great deal of influential patronage has condescended to give its name to these societies ; remarks have been made, money has been raised.

But these societies for the preservation of this, the conservation of that, who say to the commoners : " You must not erect your sham Tudor tea-shop, your sham Greek details all over your petrol station . . . " all this is based on a completely wrong psychology. For *you* have debased the great traditions. *You* have converted a Greek temple into a banking-house ; *you* have plastered the second-hand columns of the ancients on to the grocers' shops of Oxford Street. The ugly petrol station is the logical conclusion of your efforts. To abuse these petty tradesmen, simple and ignorant as they are, anxious to make an honest living and knowing no other necessity, is the most foolish of all possible proceedings. . . .

* * *

Our Eastern guide's indictment is unanswerable. The whole standard of art, whether academic or popular, in our commercialized centres of population, is of the basest and most vitiated kind.

How are these false standards to be destroyed ? Our cultured Easterner would tell us that the method proper to the West and its own great age of scientific invention, gradually will accomplish this. And he would see, not among the high-brows, the professional moralists of Church, Art, and State, but among those others, inarticulate as yet, the young active men of all classes, whose interests lie all ahead, the leaders and the beginnings of a new order.

Evidence of the necessity of a new order reveals itself every other day, in some new social or economic " crisis." As young men, we are concerned with a Future which must be *planned*, rather than a Past which must be *patched up*, at all costs.

As architects of the ultimate human and material scenes of the new order, we are not so much concerned with the formal problems of " style " as with an *architectural* solution of the social and economic problems of today. And the most fundamental change in our technique is the replacement of natural materials by *scientific* ones, and more particularly the development of steel and steel-concrete construction.

* * *

The invention of steel and the elaboration of systems of construction based on its properties and those of its satellite materials, has in itself been responsible for the most spectacular changes in our social life. Steel, which made the nineteenth century in England the era of Railways and Steamships—the era of Communication and all its attendant *social* discoveries—is making the twentieth the era of Reconstruction all over the world. Steel, it might be said, is the operative word behind any sentence which describes our mode of life today.

Steel affects all aspects of architecture, external form as well as internal organization ; steel and steel-concrete create unknown possibilities of freedom and economy in planning. Before our age the technical problems of architecture were concerned chiefly with the piling up of weights. Great buildings were really " stately piles " raised up and supported by heavy masonry walls. But now the wall, no longer an essential element of structure, becomes (truly considered) an expression of its thermal and other insulating functions—to include or exclude the light, the view, the weather, or the public—functions whose separate and relative values are to be determined by the conditions of the specific purpose of the building. Apertures are not so much cut out of the walls as left out of them. And without steel none of the machines, engines and processes incorporated into the modern building, such as heating, lighting, ventilating, refrigerating and sanitary processes, and the machines for vertical circulation, could be made, could move, or have their being.

The age of Science and Steel is differentiated fundamentally from all other ages. The new conditions of life create not only the possibility, but the necessity, for a new dimension of Plan and Order in the arrangement and aspect of life. The function of integrating, unifying and synthesizing a multitude of new material details, processes and conditions, and of new human desires, needs and appetencies, and of giving to the whole a formal aspect of significance, presents itself to the creative architects of today.

To assume the survival of a society already dead in order to bring to life what Lethaby called a " pretence to beauty at second-hand " ; or to raise up altars to what Mr. John Gloag calls " ancestor-worship in design," is to urge the continuance of a stupid and meaningless torture.

The common lag of people have had the common sense to see that : but they lack the opportunity and the creative capacity to make for themselves as they did in less complex ages, the forms which serve life. The Tradition of Architecture is to seek the response that leads to freedom and fullness of life. Architecture has to serve the purposes of the people as well as the purpose of beauty. Thus will it " serve life."

It is for architects to invent, and to exhibit, a new architecture which will quite naturally be accepted and demanded by the people.

* * *

Fortunately for even the youngest architects, the " effects " in us of all the " functions " and " qualities " of all the old architectures can be imagined, experienced, remembered, or reconstructed. Never has knowledge of these " effects " been so all-inclusive of world-culture.

To remember and experience them again is one thing ; to " fall in love with the Elgin marbles " and to spend the remainder of your life trying to copy them, or *to be* them, is another.

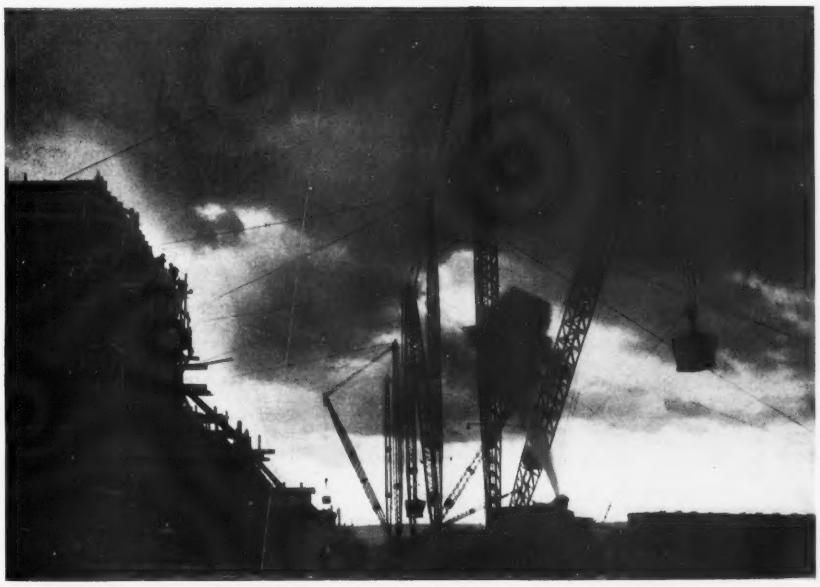
But to respond to the old forms and materials and to perceive their true intent *in their own age*—to know the difference in value between a merely surprising trick and a noble invention ; to know what subtle combinations and resolutions of human impulses make up the values of an enclosed and habitable space ; to know what are the ingredients in the further response—then to start anew, and, *remembering everything*, to depend upon the virtue in yourself and " obtain from *that which is going to be* that it should with all the vigour of its newness satisfy the reasonable requirements of *that which has been* "—is to hold the essential intention of Tradition in Architecture.

Or, at closer range, to see your design as *one* thing marked off from the rest of the universe ; then to see it as a *thing*, " complex, multiple, divisible, separable, made up of its parts, the result of its parts and their sum, harmonious " ; then to see it as that thing which it is, and no other thing ; so that if you removed a single part of it, it would not be that thing, but become another lesser thing, or become nothing.

* * *

To this attainment there are requisite Science—the science of the *inside* of things: science the *identifier*, measurer and calculator ; and also Art—the science of the *outside* of things : art, the *differentiator*, selector and maker.

For Architecture—the surest and completest art—is both science and art. It is between these two—Science and Art—that architects must find a way for the reconstruction of the modern world. And it will be between these two, also, that architects may lose themselves, perhaps for ever.



(1) STEEL HOISTING CONCRETE—Sunset over the Cranes of the Dnieperstroi "Front." The Dnieper Dam, which impounds 850,000 h.p. of electric energy, and cost £22,000,000, was inaugurated on October 11th.

Steel and Concrete

A Historical Survey

BY P. MORTON SHAND

"Every building that is treated naturally, without disguise or concealment, cannot fail to look well." A. N. WELBY PUGIN.

"As soon as we know how to use the materials which industry supplies us with we shall be able to create an architecture of our own." THÉOPHILE GAUTIER in 1850.

A FEW outstanding dates may help us to summarize the history of iron and steel in relation to construction before we begin to trace the steps that marked their development in terms of men and buildings.

The need for standardized sections was felt, however dimly, long before machinery for producing them existed. The rail preceded the girder as the street precedes the house. The triumph of the railways inculcated a growing consciousness of the universal adaptability of iron. Cast-iron was the precursor of steel in most of the uses for which the latter is now almost exclusively employed. Things that are cast in the same mould are interchangeable with one another.

Flat-bottomed rails (the chaired, or double-headed, type is peculiar to Great Britain) were rolled in South Wales at least as early as 1832. The rail represents the embryo of the girder, because it established the first standards for length, breadth, and depth; and embodied a grooved, instead of a solidly rectangular, cross-section.

Ferdinand Zores is supposed to have introduced I *beam rolled iron joists in 1847, though Boileau, a contemporary French authority, claims they were used two years previously as an expedient for breaking a bricklayers' strike in Paris. In any case there is definite evidence that by 1855 double T sections were being rolled by Dorman Long, of Middlesbrough, and also in America. Some rather heavier French sections of the same type were shown at the Paris Exhibition of that year.*

In 1859 Otis Tufts installed the first lift—or, as it was then called, "vertical screw railway"—in the Fifth Avenue Hotel in New York.

In 1871 one Balthasar Kreisher is said to have invented hollow tile flooring: a new use for one of the oldest of materials. This solved the deadweight and fire-resisting problems of the steel-framed building.

In 1885 the pioneer skyscraper, the ten- (subsequently twelve-) storied "Home Insurance Building," was finished in Chicago. It is significant that Tuft's and Kreisher's patents, without which the skyscraper could never have materialized, preceded the first steel-framed structure by a quarter of a century and well over a decade respectively.

In 1894 the Carnegie-Phipps Company of Pittsburg circularized the first trade-catalogue of standardized steel sections.

In 1904 the British Engineering Standards Association was formed.

In 1909 the London Building Act (now in course of its first revision), permitting the erection of steel-framed buildings in the Metropolis, was passed: a tardy admission that modern constructional technique is based, not on the laws of that static branch of palæolithic geology known as "the Orders," but on the sciences of metallurgy and dynamics.

Architecture and Engineering

THAT the chaos manifested by our urban civilization is the direct result of the unnatural separation of the two branches of architecture is a simple statement of fact. Every year it becomes clearer that its annulment is our only chance of a return to civic order. But the essential preliminary to reunion is the recognition that engineering is as much architecture as architecture is engineering, and an unreserved acceptance of all that this implies. It is necessary to insist on their irrefragable identity because under existing conditions in England it is more and more being lost sight of.

Various explanations have been given for this disastrous schism between architecture considered as one of the fine arts and architecture regarded as an exact science. The most specious, because the most flattering to architects and engineers alike, is the continuous increase in "specialization": an explanation which confuses cause with effect. But what actually brought it about is sufficiently obvious. During the nineteenth century architecture with a capital "A" became more and more academic, and proportionately sterile; whereas engineering, called upon to solve industrial problems for which no precedents existed, had freedom thrust upon it, and made amazing progress in consequence. The nineteenth century architect, whose training incapacitated him from keeping abreast with the scientific discoveries which the engineer was turning to practical account, found comfort in the reflection that he was an artist and a gentleman. His structural methods continued to be such as he had been taught: the imitative reproduction of the different traditional styles in the materials traditionally proper to them. Untraditional types of construction and construction in untraditional materials he left to the horny-handed Philistine. The result was that the Philistines prevailed, and drew apart to found an exclusive and untraditional profession of their own. Art could have nothing to do with industry, though it could be patronizingly polite to genteelly amateurish handicrafts; for art meant looking steadfastly backwards, and mirroring the present in the past. Unlike the Lady of Shalott, the Victorian architect was never "sick of dreams." In dreams of "the glory that was Greece and the grandeur that was Rome," high chivalry, or Renaissance splendours he lived, wrought, and had his being. Within that ivory tower, the studio, mechanics could be ignored; and the sacred flame, however dim, had no physical connection with the local gasometer. Architecture was aristocratic and feudal; engineering irredeemably plebeian or blatantly plutocratic. A formal letter of introduction, an engraved card, and correct calling clothes might allow a prospective client to be received by Messrs. Gargoyle, Palladianissimo, and Wrenkin; a knock at an office door enabled business to be done with young Mr. Fitz-Archimedes.

In the course of the last decade architects have become more and more dependent on engineers, and engineers less and less dependent on architects. The only occasions on which engineers still have to call in architects is when public opinion demands that some new bridge, considered of more than local importance, or likely to jeopardize "existing amenities," shall be suitably architecturalized "so as to harmonize with its surroundings." In plain language this means that after appointing an engineer to be *responsible for the design*—that is to determine the type of construction to be adopted, and the material most appropriate for its execution—an "eminent architect" has to be found willing to fill the somewhat humiliating *rôle* of adding "architectural" trimmings to a design already structurally complete in itself. Thus two men are paid for what is really the work of one. Doubtless many qualified English architects could design a light stone or brick bridge single-handed; but there is hardly a single one living, however eminent, who could design an ordinary steel or concrete bridge unaided. Were one invited to do so he would probably answer rather indignantly that it was not his job; but that he was quite ready to "collaborate" with an engineer. Now the word "collaborate" implies joint, but approximately equal, participation. We do not speak of a dresser "collaborating" with a surgeon, because the surgeon could, if necessary, do his own dressing, whereas the dresser is a subordinate who could not be trusted to perform an operation single-handed. Put bluntly, the architect acts as dresser to the engineer, covering up the engineer's work as soon as it is finished. Since he no longer commands the necessary technical knowledge or experience to co-operate in the essentials of the design, his "collaboration" is confined to supplementing them with non-essentials, and masking certain conventionally "objectionable" structural features by impeccably conventional ornament. Even as the engineer's professional decorator the architect's share in the design is being progressively restricted by economic circumstances. Sir Reginald Blomfield's original elevations for Lambeth Bridge envisaged a complete stone veneer of the steelwork. As a result of revised estimates the use of stone was relegated to the piers and approaches. Though not very many people regard this bridge as an outstandingly successful monument of collective thinking, the design has undoubtedly gained in sincerity and simplicity in consequence.

We often hear the complaint that architects are too much preoccupied with form, and engineers too exclusively concerned with materials. How should this be otherwise when the training of each virtually ignores what is the life-study of the other? But whereas profound knowledge of a material sometimes enables those unversed in the laws of formal design to mould it into magnificently expressive forms, the profoundest knowledge of abstract form cannot achieve significant, or even economical, expression in an unfamiliar material. As long as building materials were confined to brick, stone, and timber, engineers and architects were working on common ground with a common fund of experience. The introduction of new materials, cast iron, steel, reinforced concrete, changed all that. The engineers were quick to exploit them successively; the architects took their stand on tradition, confined themselves to the old materials, and refused to study the formal possibilities of the new. So science monopolized one field, "art" another. Unfortunately art (especially reproductive art) has more need of science than science has of art. As one of our wittiest anonymous critics has put it: "The engineers carried off the swag, but the architects were left with the swags." Willy-nilly the architect has been forced to use the new materials, but he uses them without understanding their structural and formal potentialities. He can clothe these materials but he cannot wield them. Every time he adopts steel or concrete the engineer has to be consulted; and the engineer speaks a language the architect has never learnt to understand.

The remedy for this state of affairs seems a simple one. An architect's training should proceed from a study of materials to that of form; and not, as at present, inversely. Then, and only then, will he be of real use to the engineer, and able to "collaborate" with him in big things. And he will also be of far more use to himself because in his ordinary routine work he will need the engineer far less: an independence that will save both his own and his client's pocket. It may be objected that this reversal of the established order of things in the curriculum of our architectural schools will inevitably increase the term of the young architect's already long and expensive training. This need not be so. English architectural education is still hopelessly encumbered, not to say obscured, by a pedantic insistence on what, under modern conditions, has become archæological lumber. Its elimination would stimulate a sense of architectural realities, and leave time for an adequate instruction in subjects more germane to them. Cambridge did away with compulsory Greek some years ago, and Oxford has recently abolished "Divvers."

In England the dual qualification of architect-engineer or engineer-architect is almost unknown, although no one has ever disputed the right of marine engineers to call themselves "naval architects." There are very few F.R.I.B.A.'s who are M.I.C.E.'s as well, or M.I.C.E.'s who are also F.R.I.B.A.'s—perhaps on account of the embarrassment of having to decide which of these hieratic groups of initials to give precedence to on note-paper headings. Even the Institution of Structural Engineers, which is exclusively concerned with building, cannot boast many members who are incidentally either A., or L., R.I.B.A.'s. Not being "artists", engineers must humbly submit to the deprivation of that ennobling "R" which even veterinary surgeons are entitled to. The only "Royal" engineers are the pucka "*ubique*" sahibs who have graduated from "The Shop." With such persistent snubbing it is little wonder that engineers are popularly supposed to lack the finer artistic sensibilities which scholarly concentration on "the Orders" imparts. Just think of the difference it would make if they could be "finished" at the A.A. On the Continent, particularly in Germany, the architect who has thought it worth his while to become a qualified engineer and the engineer who has acquired a recognized architectural qualification are almost as common as permanent working partnerships of architects and engineers. These joint capacities and collaborations are reflected in industrial landscapes that are infinitely more seemly than our own, and in towns in which order is steadily vanquishing disorder instead of the reverse. Rennie and Telford and Eiffel were great architects for all that they were "only engineers"; just as engineers like Freyssinet, Dischinger, and Maillart have been among the truest architects of our own age. The Brothers Perret were Beaux-Arts-trained, but they have designed buildings which, like the pit-head structures of that gifted architect, the late Adolf Meyer, Poelzig's gas-works, and Gropius's and Mendelsohn's factories, engineers enthusiastically acclaim as superb engineering. None of these men found it necessary to "collaborate with specialists," whether formal or structural. They were sufficient unto themselves.

(2) The Paris "HALLES-AU-BLÉ," 1811. Bellangé *architect*, Brunet *engineer*.

Across the Channel the divorce never became anything like as absolute as over here. The result is that foreign architects are rather better engineers, foreign engineers rather better architects, than their English colleagues. On the mainland they have been quicker to see that since building in the near future is bound to approximate far more to what we have hitherto called structural engineering than to what was till yesterday architecture (but is already only architecture in an obsolescent sense), the rift must be closed if the architect is not to be squeezed out altogether.

*   *   *

The mutual antagonism of two French institutes, the Ecole Polytechnique, founded during the Revolution in 1794, and the Ecole des Beaux Arts, founded by Napoleon in 1806, is usually supposed to have been the immediate cause of the emergence of engineering as a separate profession. The spirit of the first was realistic, speculative and scientific; while that of the second was romantic, and traditional, and reactionary from the outset. In the Polytechnique men were trained in applied mechanics and technical processes. In the Beaux Arts, which promoted architecture to academic parity with painting and sculpture, budding artists were constrained into the fossilizing formulas of reproductive classicism. The former prepared the world for the advent of the modern spirit; the latter led it firmly backwards along the trodden path of the *ancien régime*.

The first known instance of an architect and an engineer being employed on the same "job" was in the rebuilding of the Paris Halles-au-Blé in 1811 (2). Their names were Bellangé and Brunet. It is significant that the old corn-market, which was erected in 1783 and burned down in 1802, had a wooden roof, and that the new had a complicated copper and iron dome. It was nearly half a century later before architects began to feel that their position was seriously threatened, and to insist with almost morbid emphasis on their special status as art-workers. In 1864 we find the Beaux-Arts-trained Anatole de Baudot, who was far freer from æstheticism than either Ruskin or Corbusier, writing:—

> We see how frequently the public prefers engineers to architects, and day after day we have to listen to its complaints about the latter. The reason is that the engineers do not assume a chilling attitude of academic correctness, but are ready to confine themselves scrupulously to fulfilling the programme set them; whereas architects only too often act at variance to their clients' reasonable demands on "æsthetic" pretexts.

And again, addressing the International Congress of Architects in 1889, he said:

> For long the influence of the architect has been waning and the engineer, *l'homme moderne par excellence*, is beginning to take his place. Were the latter in the position to replace the architect altogether, the former could doubtless disappear without art being extinguished as a result. Form will no longer be the basis of the new architecture. It will find its expression in the laying-out of the plan, and in the structural system which it necessitates: a general expression from which individual expression will proceed. But, it may be objected, the method you suggest is the engineer's method. I do not deny it, for it is the right one.

César Daly, in the *Revue Générale de l'Architecture* of 1867, was no less outspoken:

> Is architecture destined to yield its place to civil engineering? Will the engineer absorb the architect? We speak of the organic art of the future, and yet we affect to have no illusions as to the present state of affairs. Where is this eclecticism, which fogs the whole modern world, leading us to? We breathe it in with our lungs; it mixes with our blood, and affects both our hearts and brains.

Davioud, the joint architect of the Trocadéro, won a prize offered by the *Institut* in 1877 for the best dissertation on "Ought the architect and the engineer to be one and the same person, or ought they to be members of two separate professions?" Davioud maintained that:

> We shall only succeed in arriving at proper solutions when architect and engineer, artist and scientist, are united in one person. For too long we have been living in the fond belief that the nature of art differentiates it from all other forms of human intelligence; and that being wholly separate and apart from other activities its only source is in the capricious imagination of the artistic temperament.

Where does architecture begin or end? Was the man who in 1772 built the purely functional double-armed iron crane at Würzburg, and the lovely Baroque stone pediment it stands on beside the River Main, an architect or an engineer? And would he have minded very much which he was called, having an equal proficiency as each? The conception of architecture has grown too narrow ; or, put in another way, too many new forms are arising which have nothing to do with the old formalizations in brick and stone. Each new model of the same type of machine is a new example of architecture. Every new class of machine represents the emergence of a new architectural "style." The machine has come to stay, but the conventional forms which stone evolved so long ago are passing away. Modern quarries furnish raw material for concrete, not cornices. Architecture has ceased to be exclusively, or even predominantly, a question of " building " in the old primary, site-and-scaffolding sense of the word. In the past it has constantly changed its skin. Now, like a chrysalis, it is changing its body ; and with its body the nature of its being.

Iron and Steel

"*Pendant que l'art cherche l'intimisme ou s'attarde aux vieilles formules, le regard encore tourné vers le passé, l'industrie marche de l'avant, explore l'inconnu, conquiert des formes. Ce n'est point dans les ateliers des peintres et sculpteurs que se prépare la révolution tant prédite et tant désirée : c'est dans les usines !*"

(Octave Mirbeau in the *Figaro* in 1889.)

The product of men's labours in the Europe of 1800 was almost as overwhelmingly agricultural in nature as that of South America in 1900. Yet in 1820 the Comte Henri de Saint-Simon, the St. John the Baptist of Karl Marx, uttered the now obvious platitude *la société toute entière repose sur l'industrie*. A society based on industry is bound to be one based on mechanics. We, who live a hundred years later than Saint-Simon, and belong to the Second Iron Age, or, more properly, the First Steel Age, are fond of saying that industry has revolutionized society. The sociological difference between a steel and an iron civilization is the same as that which distinguishes collectivism from individualism, urbanism from tribalism, organized from unorganized production, and domestic handicrafts from factory mass-production. Industry = steel ; steel = the machine ; the machine = industry. The high-priest of this inseparable trinity is the engineer. He is the demigod who alone has power over the machines he calls into being or perfects. The rest of us, rich and poor alike, are as impotent as cave-men without him. He is the arbiter of our destinies, the inspired, *deus ex machina* Aladdin who every now and then rubs his magic lamp to give us another new world for one that has barely had time to grow old. But the new worlds he periodically brings into being are not always the direct expression of his own volition, for the character of the steel unconsciously shapes the mind of the engineer far more than the character of the engineer consciously shapes the form of the steel he handles. Unlike stone or wood, steel has not yet yielded up all its secrets, or revealed the ultimate bourne of its potentialities.

The wheels of industry—a phrase that had a literal meaning long before it acquired a figurative one, for all industry turns on, or is turned by, wheels—are made of steel because there is no substitute for steel. The screws that propel ships and aeroplanes are merely wheels of another kind—wheels which move by creating immaterial circumferences in space instead of revolving through it on materialized circumferences like those of trains and lorries. Speed depends on wheels, wheels on mechanical accuracy, mechanical accuracy on steel. Without wheels industry could not have been endowed with the circulatory system that we call transport, coal could not have been hoisted to the surface, or iron rolled. Locomotive tyres cannot be forged peripherally true by manual labour, or propeller-blades ground to a mathematically precise pitch of concavity. Hand tools do not suffice to tooth cog-wheels to exact fractions of angular degrees, draw wire to a millimetric uniformity of thickness, or stamp out steel sections that are interchangeable as linch-pins. Without mechanical production, and the automatic control of machines by machines, there could be no progress in technique ; and consequently no progressive liberation of man from mechanism. The nineteenth century began by callously sacrificing its sons to the machine as to a Moloch, and ended by building pathetic towers of refuge to escape the dreadful Frankenstein its poets proclaimed had been recklessly set at large. The twentieth century is turning the imaginary monster into an obedient Robot that can be put to move mountains or left in charge of children.

* * *

Three Englishmen, two French brothers, and a German who became a naturalized British subject were between them responsible for all the major technical discoveries in the evolution of the steel industry. It is true that an American, James Aston, invented Mechanical Puddling in 1927 ; but this was only a minor modification of the original Bessemer process.

* * *

The raw material of pig-iron is one or other of the natural forms in which iron oxide is found, such as hematite, magnetite, limonite, siderite, etc. Steel is simply smelted iron in which most of the carbon content has been absorbed by tempering : that is by successive heatings and coolings. Moulded pig-iron that has not been tempered, and therefore retains most of its carbon content, is termed cast-iron. Cast-iron is hard and brittle ; steel tough and elastic. Up to the fourteenth century the only known form of iron was wrought-iron. Wrought iron is pig-iron that has been hammered out when red-hot instead of being tempered or cast. It is tougher than cast-iron, but has little elasticity. The art of tempering iron into steel was a Saracen discovery, and the first use to which it was put was naturally the forging of better and brighter blades. The two towns earliest associated with steel-making were Damascus and Toledo.

Till the end of the eighteenth century iron was smelted in small "open-hearth" ovens called Catalan forges. The earliest English ironworks of this type were situated among the oak forests of the Sussex Downs, where the winning of iron ore and charcoal burning could be carried on side by side. In 1784 the "Puddling" process, which is still employed for certain qualities of iron, was discovered in England. In this process a forced draught is blown *across* the mouth of what is now called a blast-furnace charged with a mixture of ore and limestone so as to expedite the liberation of the metal. But the most important and significant innovation introduced by " puddling " was that coke-firing took the place of charcoal fuel : a substitution which enabled smelting to be conducted on a semi-industrial scale of 6,000 to 8,000 lb. of pig-iron per twenty-four hours in countries where coking coal was available.

In 1855 Henry Bessemer invented his celebrated "Converter". By substituting a reliable chemical process for a rough-and-ready manual treatment, Bessemer quadrupled the capacity of blast furnaces ; and thereby made possible the mass-production of steel. The direct result was that steam rolling-mills began to replace the old methods of hand-forging, and the change over from the domestic to the factory system, which had begun twenty-five years previously, was enormously accelerated in all branches of industry. In the Bessemer process the partly calcinated impurities suspended in the molten metal are removed by currents of air passed *through* it ; and an alloy of manganese and pig-iron, called " Spiegel," is added at the end of the blow to degasify the artificially aerated " bath " before running it off the precipitated " slag," or non-metallic residue.

The drawback of the Bessemer system—a drawback which established the industrial supremacy of this country—is that it is only applicable to ores free from phosphorus, or having a very low phosphor content. The ores of the Cleveland Field in Durham (like most American ores, and those mined in Spain and Sweden) could be, and still are, smelted in Bessemer converters ; but what are known as " basic ores " (including the " Minette " of the Longwy, Briey, and Nancy basins in Lorraine, the richest deposits in the whole of Europe) could not be because of their highly phosphoric nature. By the eighteen-sixties Great Britain was producing 43 per cent. of the world's iron and 31 per cent. of the world's steel—figures which have since fallen to well under 13 per cent. and 10 per cent. respectively.

In 1856 Wilhelm Siemens, a Hanoverian who originally came to England to sell his electro-plating patents to Elkington's, the silversmiths, invented regenerative firing for blast-furnaces at Birmingham. Sir William Siemens (as he subsequently became) was a brother of Werner von Siemens, the founder of the German electrical industry. Their family belonged to the Harz Mountains, one of the oldest mining centres in Europe. Regenerative firing had only a limited practical scope until Pierre and Emile Martin discovered their complementary process for recovering scrap iron for steel making at Sireuil in 1864. Today the Siemens-Martin system is almost universal on the Continent.

In 1879 Thomas and Gilchrist (or " Sidney G. Thomas and Percy G. Gilchrist " as they are grotesquely dubbed by that 100 per cent. American, Mr. E. E. Thum, in his article on " Iron and Steel " in our 100 per cent. British-and-proud-of-it-too national encyclopædia) succeeded in adapting the Bessemer process for smelting basic ores. But the Thomas-Gilchrist process went much further than that. It trapped the gases rising from the fluid metal and energized their heat for the different operations of steel making. Rails, beams, rods, bars, billets, and plates—bars become sheets ; rods, wire ; plates, pipes or poles—could now be rolled " in a single heat." The working of adjacent seams of coal and iron ore grew general in proportion as the increasing interdependence of these two raw materials became obvious. The " industrial landscape " emerged. Blast-furnaces, steel-works, and rolling-mills were erected in immediate proximity to each other as co-ordinated parts of single economic units. Thus the first self-contained, large-scale modern industry came into being. But the effect of Thomas and Gilchrist's joint discovery was to sound the knell of England's virtual monopoly of iron and steel. Instead of being dependent on British supplies as hitherto, Germany (which had become possessed of the lion's share of the Lorraine ironfield as a result of the Franco-German War of 1870–1) was free to develop the largest steel industry in Europe.

Since the eighteen-eighties the progress made in the metallurgy of steel has been mainly in the direction of securing greater hardness, lightness and tensility ; and in imparting various subsidiary properties by the incorporation of certain alloys. But for these alloy-steels the development of the motor industry would have been impossible : a fact demonstrated by the continuous reduction in the size of engine parts. Thus steel for marine engineering can be rendered non-magnetic by the addition of a substantial percentage of manganese ; while alloys of other metals enable it to withstand temperatures of over 400 degrees Centigrade, the pressure of hundreds of atmospheres, and the action of the most corrosive chemicals. Stainless steel that will resist rust, acids, and smoky atmospheres was patented in 1916 by the Englishman Brearley, who had started working on nickel and chromium alloys in 1912, when Strauss was beginning similar experiments in the Krupp Works at Essen. Finally, autogenous welding enables railway lines to be laid in mile-long lengths without intermediate fish-bolts, and ships, bridges, or the skeletons of frame-buildings to be constructed without a single rivet. Besides considerable saving in material, welding offers the great æsthetic advantage of allowing unbroken uniformity of surface.

* * *

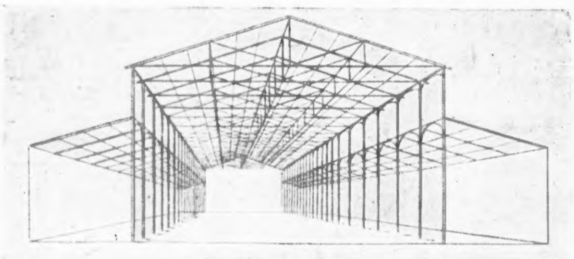
A Swiss critic has said that " construction in the nineteenth century was made to assume the *rôle* of the unconscious." Outwardly it piously perpetuated " traditional " decorative shams and sentimental plagiarisms. Inwardly it was busy prognosticating forms peculiar to the modern world, which occasioned such moral alarm that they were hurriedly squeezed into masonry stage properties, or bundled out of sight, as soon as their significance was appreciated. The century suffered from a bad structural conscience. Where there was little chance of a Paul Pry being able to peep behind the historicizing masks with which it cloaked its resourcefulness and explained away its inventions it could be bold, even magnificently audacious. Provided the building was of a temporary (or what, by a later stretch of casuistical cant, came to be described as " utilitarian ") nature, the engineers might have licence to thin down walls to curtain thickness, and open out their

(**4**) GALERIE D'ORLÉANS in the Palais Royal, Paris, 1829-31.
Fontaine, *architect.*

" unsubstantial " halls to light with wide expanses of glass. Yet notwithstanding a rigid adherence to bygone cultural conventions, in which the twentieth still follows in its footsteps, nineteenth-century construction triumphed over nineteenth-century architecture ; steel over stone. The victory was due, though only indirectly, more to Stephenson than to any other man. The railways blazed the trail.

Though France was decades behind England in industrial development she showed herself superior in constructional skill, thanks to the fact that in the Ecole Polytechnique she possessed a school for engineers such as did not exist elsewhere. The daring and the lightness with which French engineers built in iron, while our own persisted in an excessive and unimaginative solidity, were the direct result of the theoretical training it provided. It would be hard to exaggerate the influence of the Polytechnique in France during the first thirty years of the nineteenth century.

The first structural use of iron was for roof support. By the end of the eighteenth century cast-iron columns supporting wooden beams had become the general practice for building factories. Boulton and Watt are known to have employed cast-iron columns with cast-iron beams in one they built at Manchester during the early years of the nineteenth. Louis Victor made partial use of iron in the roof of his large theatre in Bordeaux, and also used a wrought-iron framework for the dome of the Théâtre Français (1786) a few years later. The iron drop-curtain of the Théâtre de l'Ambigu-Comique in Paris, which dates from about 1824, is said to have been installed on Hittorf's advice. The massive cast-iron roof of the Alexandrine Theatre in Leningrad (1833) was the work of an English engineer, like that of Hittorf's Rotonde des Panoramas in the Champs Elysées (1838) : one of the first exemplars of iron misused as an ornamental substitute for stone.



(**3**) VEUGNY'S MARCHÉ DE LA MADELEINE, Paris, 1824

In 1824 Veugny erected the Marché de la Madeleine in Paris (**3**) : a thin rectangular metal framework like the skeleton of a large modern tent. Charles Eck* described it enthusiastically as

> " *une des plus gracieuses productions de ce genre. On ne saurait imaginer rien de plus élégant ou de meilleur goût* "

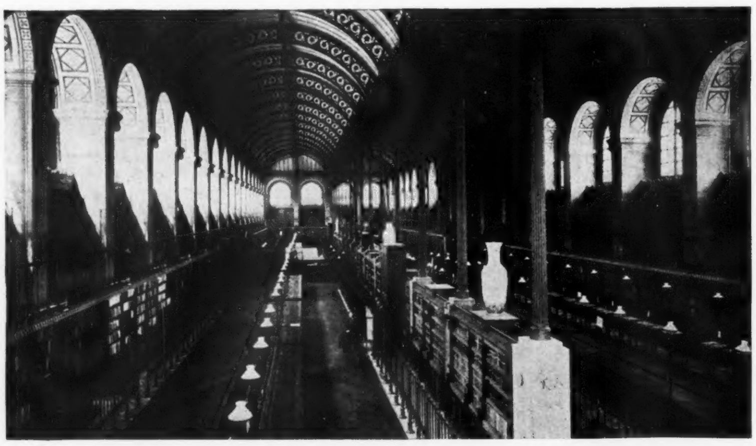
Fontaine, one of the founders of the Empire Style, used iron roofing for the Galerie d'Orléans of the Palais Royal in 1829 (**4**) : a model that was extensively imitated in Italy, notably in Milan.

The first French engineer to break away from fettering subservience to wooden forms was Camille Polonceau (1813-1859), whose father, Antoine Polonceau, designed the old cast-iron Pont du Carrousel in Paris (1839). Polonceau set himself to devise a type of iron roofing which would fulfil the several conditions of " durability, economy, and simplicity, with the smallest possible dimensions." About 1837 he succeeded in combining these requirements in a light self-supporting framework, based on the principle of resistance to pull, which exerted no lateral thrust because its full weight rested on iron columns. The Polonceau truss was (and still is) used for market-halls, railway stations, exhibition buildings, etc. Though it was first adopted for roofing an 8.5 metres wide shed on the Paris-Versailles Railway, the platform canopies of the Gare du Nord provide the best early example of its application to wider spans.

Pierre François Henri Labrouste (1801-1875), a " *Prix de Rome* " at 23, and the incarnation of *l'esprit nouveau* according to his contemporaries, was the first architect to consider a façade as a mere envelope. His architectural philosophy was summed up in a maxim he was fond of repeating: *condenser le sens de toutes choses* — as good a definition of the function of steel construction as one could want.

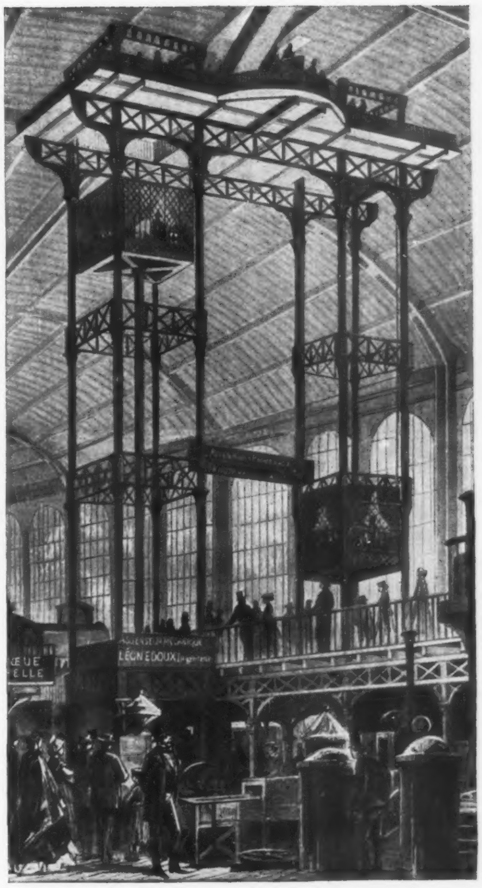
For twelve years after his return from Rome Labrouste never had a single commission. Then, when already over forty, and consequently presumed to be past " the dangerous age," he was unexpectedly entrusted with the design of the important Bibliothèque de Sainte Géneviève in Paris (**5**). The central reading room in this library (1843), which measures 84 by 21 metres, is divided up the middle by a row of cast-iron columns. These are employed to sustain parallel series of semi-circular, fretted metal arches, which spring from them to the walls so as to avoid the necessity for counteracting their lateral thrust. Iron columns are also used in the smaller ground-floor reading-room known as *La Reserve*. Giedion's *Bauen in Frankreich* shows a photograph of this room opposite one of the living-room in Corbusier's Villa Cook at Neuilly. In the former the main rafter is supported by two slender columns which pass through the centre of a large working table. In the latter (which represents 80 years of progress, and not a little heady rhetoric of the *Une Maison—Un Palais !* type to explain how immense this not always too obvious progress has been) the only difference—apart from the substitution of horizontal for vertical windows, and a low ceiling for a high—is that one equally plain and flangeless, though much shorter and thicker, round column supports the beam instead of two. Labrouste was also the architect of the French Bibliothèque Nationale (1854), in which he considerably developed his system of iron framework, and left much more of it exposed.

The central market of a large capital city is a type of building which requires abundance of light and air combined with complete protection from the elements, and the maximum freedom for circulation. Its plan is one in which, as Flachat said, it is necessary to *sacrifier le plus possible le plein au vide, de grandir l'un au dépens de l'autre* by reducing the number of columns to a minimum so as to secure the widest possible spans. The controversy that for years raged round the problem of providing Paris with new *Grandes Halles* was an event of capital importance in the history of what the



(**5**) THE BIBLIOTHÈQUE SAINTE-GÉNEVIÈVE, Paris, 1843.
Henri Labrouste, *architect.*

* " *Traité de l'application du fer, de la fonte et de la tôle.*" Paris, 1841.



(6) The "GALERIE DES MACHINES" at the Paris Exhibition of 1867, showing the lifts. J. B. S. Krantz, *engineer*.

French call "metallic architecture." In 1849 Hector Horeau (1801-1872), an architect who won the first prize in the competition for the London Exhibition of 1851, submitted a scheme for an iron and glass structure in which the main nave had a span of no less than 86 metres. The following year the engineer Eugène Flachat (1802-1873)* sent in a design (which was the model for many French provincial markets) in the same materials with a main span of 80 metres supported on Polonceau trusses. Meanwhile the official architect, Victor Baltard (1805-1874), had begun a ponderous stone edifice which fully satisfied the municipal authorities. As soon as it was finished, Haussmann, the new *Préfet de la Seine*, to whom Paris later owed her boulevards, had it pulled down. Thereupon Baltard went over to England in search of fresh constructional inspiration. Having apparently found none, he set to work on a fresh set of plans based on Flachat's design. The new building was a timid compromise compared to it, but it at least represented a complete triumph for the advocates of glass and iron. When Napoleon III inaugurated it in 1853, he expressed amazement that two such utterly dissimilar designs could have been the work of one architect. "The architect is the same, but not the *Préfet*," Haussmann answered drily.

EXHIBITIONS

It would be hard to overestimate the sociological and structural importance of the nineteenth-century exhibitions as international clearing-houses for new mechanical uses and ideas, They represented the earliest attempts at an optical synthesis of the modern world. But they did not merely manifest contemporary progress in industry and engineering; they helped to anticipate their future developments. The exhibition provided the only practice ground in which ambitious engineers were free to try their hands. Being built by engineers and mechanics instead of architects and masons, these impermanent pavilions were able to circumvent the æsthetic prejudices of the period. Like tropical bungalows they were designed for rapid erection and dismantling, but unlike bungalows the prerequisite demanded of them was a vast enclosed area of sky-lighted space. When industry had ceased to inspire men's imaginations, the first flush of dynamic boldness went out of their construction; and they became stereotyped, and overwhelmingly ornamental. 1889, the greatest of the "Great" exhibitions, was the last to deserve the name.

Paris claims a prescriptive right to be the scene of international exhibitions. It was here that *Une Exposition des Produits de l'Industrie Française*, the first exhibition ever organized, was opened in 1798 during the early years of the French Revolution. Its site, like all but one of the many subsequent Paris Exhibitions, was the Champ de Mars. The next, held under Napoleon in 1801, was no longer confined to things in daily use; and *des découvertes nouvelles* were announced as one of its principal attractions.

The Hyde Park Exhibition of 1851 was the first that was called, or could pretend to be, international. The building in which it was housed is often described as the prototype of the modern steel-framed building. The prototype of Paxton's "Crystal Palace" (26) was the conservatory. Joseph Paxton was an expert gardener, who had built several large glass greenhouses for the Duke of Devonshire at Chatsworth between 1837 and 1841. In these he had used timber ribbing, whereas a hothouse in the Paris *Jardin des Plantes* built in 1833 had an iron framework.† Almost at the eleventh hour the committee of the Exhibition decided not to carry out Horeau's premiated design, and Paxton stepped into the breach with an offer to improvise one of his own. In Paxton's building, which is supported on 3,230 cast-iron columns, the construction is clearly shown; though the "style" of the galleries was obviously inspired by late Gothic. The great nave, however, is only 72 ft. wide—or 16½ ft. less than that of the wooden span of the famous *Salone* of the Palazzo della Ragione at Padua, built in 1420.

In the Paris Exhibition of 1855 there was a *Galerie des Machines*, 1,200 metres long by 48 metres wide, which had no cross-bracing. Wrought-iron was used instead of cast-iron, but most of the arched sections seem to have been hand-forged. These two pioneering exhibitions were only tentative experiments. Thereafter the international exhibition became a regular event, synonymous with a fresh achievement in constructional technique.

The Paris Exhibition of 1867 was held in an immense elliptical glass building consisting of seven concentric rings. J. B. S. Krantz was the chief engineer. The *Galerie des Machines* was 35 metres in width by 25 metres in height, the horizontal thrust of the roof being taken up by exterior ties masked with conventional trophies. The dimensions and weights of the main beams were worked out by a young engineer named Gustave Eiffel. This was the first instance of the verification of the coefficient of elasticity of the steel used in any large building. The "principal attraction" was a pair of hydraulic lifts giving access to a platform on the roof (6).

The main building of the Paris Exhibition of 1878 was rectangular in shape, and covered an area of 245,000 square metres. Eiffel designed the long *Vestibule* facing the Seine (7), but not the decoration of its three monumental metal domes. The "architecture" of these, which even contemporary "modernists" considered *fort discutable*, contained the seed of that luxuriantly botanical "style" which was to blossom into the splendour of a pantomime transformation scene in the Exhibition of 1900. A *Galerie des Machines* (8), of the same proportions as in the 1867 Exhibition flanked the *Vestibule* on either side. In these twin halls the iron framework of the penthouse roofs was for the first time supported direct from the foundations; the necessity for interior or exterior ties being avoided by the use of lattice ribs superimposed on solid rectangular stanchions of the modern flanged girder type sunk into invisible U-shaped iron sockets beneath the floors. As Boileau said of them :

> les toitures et les plafonds vitrés ne supportent pas une construction d'apparence massive ou compliquée. Le spectateur n'admet pas la pesanteur des surfaces transparentes. Pour lui ces surfaces représentent de l'air et de la lumière, c'est à dire des fluides inpondérables.

Henri de Dion (1823-1878), their designer, was a great metallurgist as well as a great engineer; a pioneer in the spanning of wide spaces, and the scientific investigation of the laws on which modern steel construction is based. By an irony of fate his name is now almost exclusively identified with that of one of the first types of motor-car, which the firm he founded did not begin to manufacture until long after his death. Although these halls evinced the first recognisable emergence of the modern steel-framed building, their construction had been to some extent anticipated in an extension of Menier's Chocolate Works at Noisiel-sur-Marne (1871-2). This factory, which was cantilevered out over the water front on four columns, had a complete metal skeleton; but the cross-bracing between the stanchions was of the diagonal pattern common in timber framework. It has also some claim to be regarded as the prototype of the flush-fronted "functional" building of today since the architect, Jules Saulnier, expressly stated that :

> le système de la construction employé pour les façades donnait du haut en bas une surface entièrement plane, sans aucune saillie horizontale ou verticale.

The Paris Exhibition of 1889 was the real turning point in the evolution of steel construction. Here its "history" ceases and modern practice begins. The cynosure and symbol of this exhibition still soars 300 metres above the Seine; and but for what Frantz Jourdain described as "an act of sheer artistic sadism" Cottancin's *Galerie des Machines* (9)—pulled down in 1910—would be standing by its side. The Eiffel Tower (24) was built in seventeen months "according to plan." Its 9,000,000 kgs. of fabricated steel sections fitted with mathematical exactitude to the tenth of a millimetre. The Eiffel Tower demonstrated that there were no longer any hard and fast limits to architecture.

Dutert was the official architect of the 1889 Exhibition, Cottancin the chief engineer. The *Galerie des Machines*, 420 metres long, 115 wide, and 45 high, was supported on twenty three-pin, arched steel trusses; each of which consisted of a pair of segmental lattice-work ribs, 3.5 metres wide and 75 cms. thick, that took up a lateral thrust of 120,000 kgs. These ribs were hinge-jointed along the ridge of the elliptical roof. At floor level they narrowed down to peg-top, bolt-headed bases resting on small roller sockets. The effect produced by this vast interior is described in A. Alphand's monograph :

> la grande ferme a un profil hardi et grandiose. . . . Partout les formes du métal étaient étudiées de façon à ce qu'il trouvât en lui-même sa propre décoration.

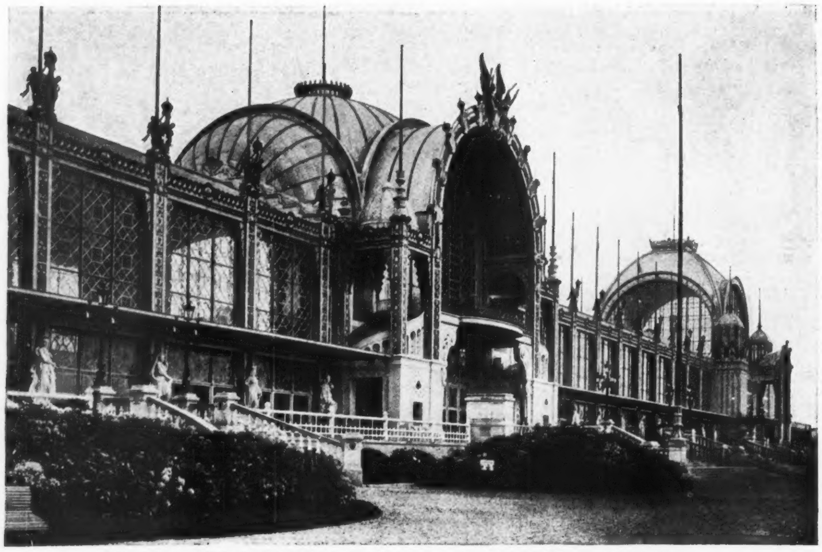
Against this encomium on its total lack of adventitious embellishment can be set the more cultured opinion of a contemporary academic architect, the Belgian A. Vierendeel, who voiced the heavy critical artillery of the Beaux-Arts :

> Ce hors de proportion produit très mauvais effet. La poutre n'est pas pondérée, elle n'a pas d'assiette, l'œil n'est pas rassuré . . . les sommiers présentent encore un autre défaut, ils sont trop évidés. . . . La courbure de l'arc des voûtes est aussi très défectueuse au point de vue esthétique. Elle commence trop bas.

Æsthetically these arches were about as wrong as they could be. They took a "low"

* Flachat, the French Brunel, began as a railway contractor. In 1837 he built the Paris-Saint-Germain Railway, the first passenger railway in France, in association with the banker Emile Péreire. Flachat had his own house built in the angle formed by the junction of two railway lines "so that he could always hear the trains whistling past him on either side." The writer has a sneaking sympathy with Flachat's choice of site because as a boy he was for ever being dragged away from rapt contemplation of the locomotive just as the train was starting by an exasperated Ruskinian father, who used to say he was "only fit to live at Clapham Junction."

† As originally erected in Hyde Park, the central barrel vault, or cupola, of Paxton's building had also a wooden framework. Boileau goes so far as to say that the Crystal Palace was simply a gigantic enlargement of this hothouse in the *Jardin des Plantes*. The charge of plagiarism is unjust, for what is remarkable about Paxton's work is far less the design than the scale of its construction.



(7) The "VESTIBULE" of the Paris Exhibition of 1878. Gustave Eiffel, *engineer.*

spring* (and low, like its antithesis gentle, is as low does); they looked light instead of heavy; and it was impossible to indicate any point in their continuous curves where the functions of load and support separated. The last trace of a column had disappeared, and with the column that comfortingly traditional sense of rigidity. There were no connections with the ground, and there was a conspicuous absence of any wallage more solid than glass. The result was an impression of a limitless spatial avenue which, like Euclid's perpendicular lines, could be protracted to infinity. Equilibrium was maintained between constantly changing forces without, within, and beneath it—changes in the molecular structure of the steel; changes in the force of the wind blowing about it, and its concomitants rain, hail and snow; even earthquakes upheaving the earth's crust were provided for—by what, like the balance of a pair of scales, was almost a state of perpetual oscillation. Steel had found its form at last. Construction had once again become its own expression, its own "style." Cottancin's *Galerie des Machines* was one of the loveliest shapes in which man has ever enclosed space; but whereas hitherto it had always been imprisoned like a bird in a cage, here it floated free as the circumambient air. Supreme architecture, it was (and still is) denied that name.

* The form of Cottancin's arches had been adumbrated, but not fully realized, in De Dion's halls eleven years earlier.

* * *

As a child I used to watch the circle of the Great Wheel at Earl's Court (which my father dismissed as "a hideous, Philistine atrocity") grow segment by segment from my nursery window, till the orbit was completed and it began to revolve a chain of coffins with the slow, painful hesitancy of a dredger sucking up sludge in its buckets. Not long afterwards I was told that Queen Victoria was dead and that though she had had many critics in regard to her taste she had been a very good woman. I remember I felt dimly that this apparently impossible demise meant that the world had been set free from the fetiches of taste and no taste, being good and not being good. Somehow I always associated these two events.

STATIONS

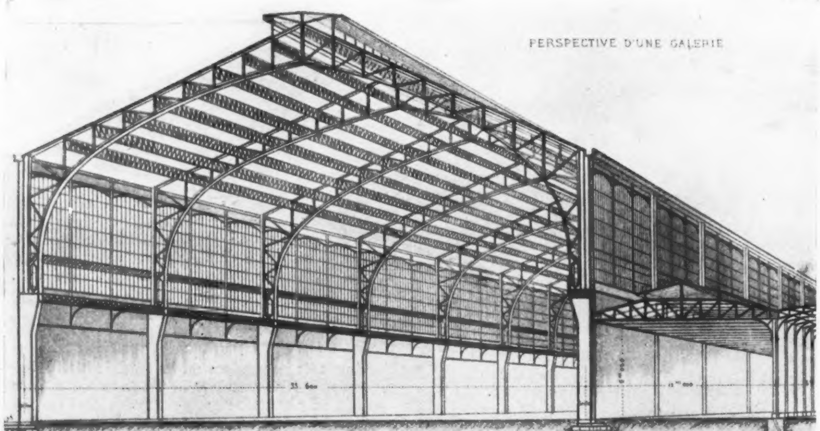
The Romantic (not, as might have been expected from this utterance, Realistic) novelist, Théophile Gautier, wrote in *La Presse* in 1850: "cast-iron allows, and indeed compels, us to adopt new forms: as can be seen in large hot-houses, the roofs of railway stations, and suspension bridges." It is significant that he makes no reference to the many misguided decorative uses of this all too adaptable material which were the pride of his period. Railway engineering, like marine engineering, is a subject in itself. We must confine ourselves to its "incidental structures": that is to stations and bridges. The iron roof of King's Cross, built by Lewis Cubitt, dates from 1852: the year in which L. A. Boileau completed Saint-Eugène in Paris, the first church to have columns of (it is true Gothicized) cast-iron. Paddington, designed by Brunel the Younger and Matthew Wyatt, was finished two years later. Here the iron columns are rather trunk-like in their massiveness, but there is much greater clarity and a minimum of solid wallage. The Paris Gare du Nord (1862), in which the architect Hittorf collaborated with the engineers Couche and Boucher, is the most notable early Continental example. Even today it seems amazingly light and spacious. The first outstanding English barrel roofs were Cannon Street (1866) and St. Pancras (1868), designed by Edward Myddleton Barry, son of Sir Charles Barry, and Peter William Barlow respectively. Although the latter does not actually rest on supporting columns, the weight of its 240 ft. span is rigidly borne by heavy anchors which, like the transverse ties that take up the arch thrust, are firmly embedded in the foundations. From Cannon Street and St. Pancras to the huge single vault of the Hamburg *Hauptbahnhof* (1908), and the immense triple spans of the new Leipsic terminus (1916), or the still newer Central Station in Milan (1932)—where the clean, delicate beauty of the steel is in nicely adjusted inverse ratio to the turgid hideousness of the stone and stucco of its Fascist-Augustan outer shell—is simply a sequence of steps each a little bolder than the last. The German engineer T. W. Schwedler (1823–1891), who designed the iron framework of the Frankfort-on-Main terminus (1888)—186 metres long, by 56 wide and 29 high—deserves to be mentioned in this connection. Schwedler patented a system of light enclosed framework for flat domes which was first employed in a large gasometer at Berlin (1863). Otto Wagner, the Austrian architect who was the master of most of the first Continental pioneers of Modernism, broke fresh ground in 1898 by using flat plates of sheet steel as a walling material for the stations of the Vienna City Railway (10) at a time when English manufacturers were just beginning to popularize galvanized corrugated iron.*

BRIDGES

Iron and steel bridges are of five main types: arched-span, flat (plate or lattice) girder, lattice-work cantilever, suspension; and the development of the suspension principle known as reversed arch, or "bowstring," which can be either way up.

What is often described as "the first bridge ever constructed of iron" was that at Coalbrooke Dale (designed by Rowland Burdon) in the North of England (1776), in which cast-iron voussoirs were experimentally substituted for stone. The famous Wearmouth Bridge at Sunderland, built twenty years later, has a much better title to the claim. This bridge, 236 ft. long, was supported on six cast-iron ribs. That great engineer, Telford, who, in 1800 submitted a design for a new single-span London Bridge (12), which is still extant, completed his wrought-iron suspension bridge over the Menai Straits (579 ft. long) in 1818. During the next few decades a very large number of suspension bridges were built in different countries, particularly France (some of which Stendhal found "really beautiful"). The best English examples are probably Marlow Bridge (1830), designed by William Tierney Clark (1783-1852), Telford's pupil, and Brunel the Younger's lovely bridge of 702 ft. span over the Avon gorge at Clifton (1832–1864). For sixty years the highways were neglected, and

* The genesis of corrugated iron was the desire to find a light, vermin-proof material, suitable for the erection of collapsible bungalows in tropical climates, which could be manufactured in standardized sheets. It is certainly devastatingly hideous—a hideousness that seems to be due to the closeness and regularity of the corrugations, which make it ideal for transport, rather than the colour of its zinc coating. From the practical point of view its great drawback is the alarming rapidity with which it rusts away. It is curious that a more durable, and at the same time prepossessing-looking, type of iron sheeting has not yet been produced.



(8) The "GALERIE DES MACHINES" of the Paris Exhibition of 1878. Henri de Dion, *engineer.*

nearly all the important bridges were built to carry railways.

The first remarkable railway bridge was Robert Stephenson's Britannia Tubular Bridge between Wales and Anglesea, opened in 1850 : a totally enclosed plate-girder design 459 ft. in length. Brunel's Saltash Viaduct—two 455 ft. spans—(1859) is an early example of the " bowstring." The greatest name after Telford among bridge-builders is Alexandre Gustave Eiffel (1832–1923), the founder of the science of aero-dynamics, who discovered *la ferme en arc :* the sickle-shaped rib, or parabolic arched support, which combined the hitherto separate functions of bearing and sustaining weight. His earliest bridge was that carrying the Paris-Orleans Railway across the Garonne at Bordeaux (1858). This, like another over the same river at Langon with 77 metre spans built four years earlier, was of plate-girder design. Eiffel's first realizations of the *ferme en arc* principle were the Sioule and Neuvial Viaducts in the Massif Central of France (1862) ; but the single-span bridge of 160 metres over the Douro (1875), and the 175 metre span of the Pont du Garabit (1879–1882), in which he collaborated with Léon Boyer, are more important examples. An outstanding instance of the French genius for astoundingly light and audacious solutions in bridge-building, the elegant Pont du Bellon (1868–1871), belongs to the same period (11). This is a flat, lattice-girder structure, 231 metres long, supported on two slender lattice-work towers 48 metres in height. The base of the Eiffel Tower, the classic embodiment of the grace which steel construction can (but all too rarely does) achieve, is formed by four immense parabolic arches. The first iron cantilever bridge, which is still in use, was that built across the Rhine at Hassfurt in 1866.

One of the most deliberately " beautiful," and consequently sublimely hideous, bridges on earth is the Pont Alexandre III in Paris (1900). Few who have contemplated those gross rhetorical pylons, the paunch-like indecency of those festooned balustrades, and the ghastly virtuosity of their candelabra can have realized that its hidden structure is memorable for having the flattest gradient ever embodied in an arched steel bridge : a rise of only 1/17 per cent. in a span of 107.50 metres. The architect's name was J. Résol ; the engineer's, being the engineer's, is not usually mentioned. Probably he died of shame, praying it might be speedily forgotten. As long as the Pont Alexandre III stands it will remain the perfect cautionary example of how easy it is for a seasoning of architect's architecture to ruin the finest constructional architecture of the engineer.

Concrete

In* 1855 *Portland cement concrete could withstand a pressure of* 157 *lbs. per square in. after* 7 *days.

In* 1880 *Portland cement concrete could withstand a pressure of* 222 *lbs. per square in. after the same interval.

In* 1930 *concrete made with Super-Portland cement could withstand a pressure of* 5-6,000 *lbs. per square in. after* 4 *days.

In* 1930 *aluminous cement concrete could withstand a pressure of* 8,000 *lbs. per square in. after* 24 *hours.

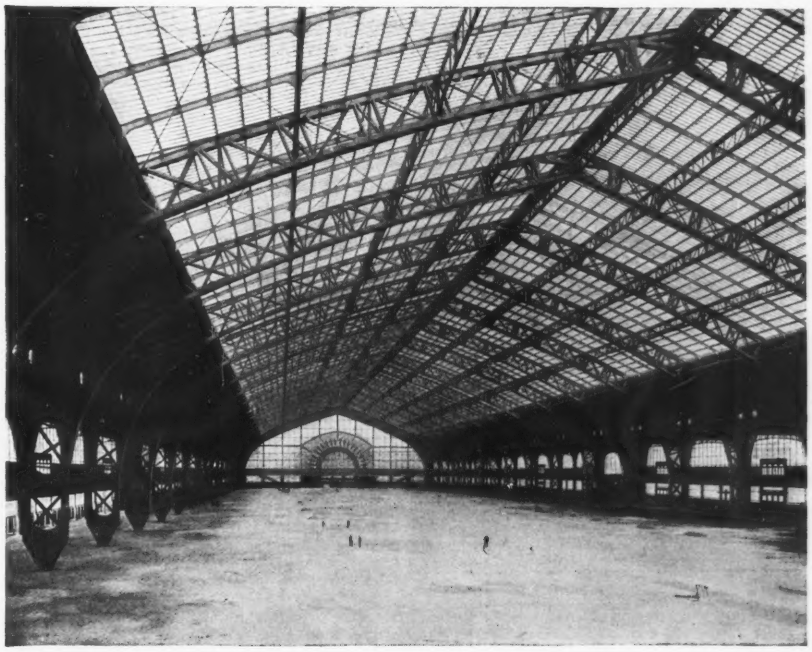
* * *

Comparative figures for St. Peter's in Rome, the "Jahrhunderthalle" at Breslau, and the Leipsic Markets will help to explain the revolution in the science of building brought about by reinforced concrete.

In St. Peter's* (1506-26) 10,000 *tons of material were required to cover a superficial area of* 1,600 *sq. metres with a masonry barrel dome* 40 *metres in diameter.

In the " Jahrhunderthalle "* (1914) 6,340 *tons of material were required to cover a superficial area of* 4,200 *sq. metres with a massively-ribbed reinforced-concrete dome* 65 *metres in diameter.

In each of the three continuous halls of the Leipsic Markets* (1929) 2,160 *tons of material were required to cover a superficial area of* 5,700 *sq. metres with a " Dywidag " reinforced-concrete dome* 75 *metres in diameter ; or* 4/5 *less material than in St. Peter's to enclose* 3½ *times St. Peter's area.



(**9**) The " GALERIE DES MACHINES " of the Paris Exhibition of 1889. Cottancin, *engineer.*

When the average educated Englishman wants to know something about a fairly weighty or technical subject he turns, not to text-books, but to the *Encyclopædia Britannica.* If he takes down the Sixth Volume of its current (Fourteenth) edition, and looks up " Concrete," he will find a sketchy sort of article, neither very readable nor very informative, that tells him little or nothing about the history and development of the type of construction with which the word has become synonymous. Apart from the way it is written, the reason why it is not very helpful is because it is almost entirely based on American practice ; and Americans have had comparatively little to do with the evolution of this branch of structural engineering—far less, anyway, than Frenchmen or Germans. The *Encyclopædia Britannica* boasts that it is not merely up to date, but that it employs all the best-known international specialists to write on their own pet subjects. When reinforced concrete engineers as eminent as Herr von Emperger, Monsieur Freyssinet, and Sir Owen Williams were presumably available it is somewhat disconcerting to find that the article referred to was entrusted to nobody in particular.

The eleven columns (less diagrams) to which it runs are supplemented by a single page of photographic reproductions almost worthy of the daily picture press. Into it are dovetailed ten very small illustrations of (exclusively American) uses of concrete, of which only one typifies (and that indifferently) a form of construction peculiar to that material. The centre and cynosure of this extraordinary scrap-album selection is a " monument " at the entrance of Valhalla Park, Burbank, California : an example of Neo-Spanish-Mission exhibition architecture which ought never to have been built of anything more durable than lath and plaster, but was for some quite unaccountable reason carried out in solid concrete. A naïve, though illuminating, caption explains that " the intricate outer decoration was made of precast *architectural* concrete " and not, as it appears, of icing sugar. It is only fair to add that if it was necessary for this *British* publication to confine itself to the United States, a wide choice of infinitely worthier and more interesting examples could easily have been obtained from that country.

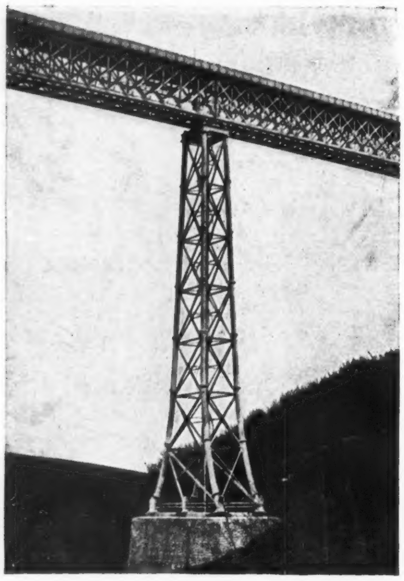
What follows is an attempt to piece together such information about concrete as one might have hoped to find in the latest edition of the *Encyclopædia Britannica.*

* * *

Sir Owen Williams has pointed out that reinforced concrete was " mentally born in the brains of mathematicians and physicists long before it became a substantial fact," while Siegfried Giedion calls it " a laboratory product which has made the architect with his sketch-book look rather ridiculous." Why ridiculous ? Because reinforced concrete has changed the optical impression of buildings to an even greater extent than steel. To those brought up in string-course constructional methods the entirely new equilibrium it establishes between support and load seems a wilful architectonic anachronism.

The riddle reinforced concrete is apt to present to all except the engineer trained in its use (and sometimes even to him) is " Where does technique end and form begin ? " A good example of the

(**10**) The Karlplatz " STADTBAHN " STATION, Vienna, 1898. Otto Wagner, *architect.*



(11) The "PONT DU BELLON," 1868-71.

way in which it deranges all pre-existing architectural values was furnished by Sir Owen Williams's scheme for a new structure in this material to replace Rennie's Waterloo Bridge. The writer sent the drawings when they were published to M. Robert Maillart—a famous Swiss engineer who has probably had wider experience in designing reinforced-concrete bridges than any man living—and invited his comments. M. Maillart replied that he very much admired the "elegance" of the design, but was rather doubtful about certain of its structural features—which meant that he fully shared what we might call Sir Owen Williams's "concrete æsthetics." Now the almost universal "architectural" criticism of this design, whether "professional" or amateur, was that, ingenious as it might be as engineering, it was very bad as architecture because the spans were quite flat, and the piers, instead of being at least as wide as the platform, were simply cylindrical stanchions propping up the middle of it. In other words, our eyes have grown accustomed to arched spans because brick and stone bridges can only be built in this manner. When, therefore, we are brought face to face with a design in another material that is able to ignore the arch convention, we upbraid the author's choice of medium, his lack of "taste," or his inexcusable disregard for the æsthetic susceptibilities of others. This, if we only knew it, is equivalent to lauding reminiscence over resource, approximate over precise design, amateur capacity over technical proficiency, and waste of space and material over exact calculation of how much of each is required. Thus are passions aroused under democracy in defence of that higher *bonum publicum* which transcends reason! Yet when no calls to arms to succour outraged "art" are sounded the British public is as willing to become interested in the "marvellous" potentialities of reinforced concrete as in any other of the manifestations of material progress which fill it with such a pleasantly personal pride. This was demonstrated clearly enough on what was probably the first occasion for the daily press to draw attention to the subject. Towards the end of the war two "mystery ships" were under construction on slips in Shoreham Harbour. Actually they were huge reinforced concrete caissons intended for anchoring the ends of a great submarine net that was to be stretched across the Straits of Dover. The Armistice found them still under construction; and the only one to be completed was eventually towed to Portsmouth, and sunk on a predetermined site, where its superstructure was afterwards adapted to replace one of the old Spithead forts. For days the papers devoted nearly as many photographs to this operation as to the rumps of Southsea bathing belles snapped as "interested spectators." Some even printed columns of descriptive "copy."

(a) Cement.

The forty-four metre span of the Pantheon's dome still stands to remind us that concrete of a kind—that is, an amalgam of sand and some sort of liquified binding material which will harden in setting and coagulate a hard core, or, as it is more often called, aggregate, of broken stone or shingle—has been known since the days of the Romans. Like the pigments of the Italian Primitives, the famous Roman cement is popularly supposed to be "one of the lost secrets of antiquity"; though even if this precious formula could be rediscovered, its value would be purely archæological. Roman cement was probably some kind of hydraulic lime, for the adhesive and hardening properties of lime and gypsum were appreciated by the Egyptians and Babylonians, if not the Sumerians. It is fairly safe to say that the cements used early in the eighteenth century (for until then there was practically no improvement) were lime cements, but we have hardly any information as to how they were made. What we do know is that they had little, if any, affinity with the kind of cement which has been called "Portland" for well over fifty years the whole world over. The term "Portland Cement" seems to have originated in a chance remark uttered by Smeaton, who built the first Eddystone lighthouse in 1756. Before starting on its construction, Smeaton made experiments to determine the best type of lime cement for hardening under water, and noted that the kind he eventually selected "would equal the best merchantable Portland stone (which is a limestone) in solidity and durability"—a statement that was probably inspired by its appearance after setting. The first commercial use of the name was due to Aspdin, who in 1824 began to manufacture a brand of cement at Gateshead and Wakefield which he sold as "Aspdin's Portland Cement." This was what is now called an "artificial cement"—i.e. one made from a mixture of two separate ingredients as opposed to a single raw material (such as is found in some places, notably in parts of Belgium) in which both are combined in a natural form. Aspdin had been preceded by Parker, who started to make his patent "Roman Cement" at Northfleet in 1796, and by Frost, who began to manufacture his "British Cement" at Swanscombe, close by, in 1822. Both were artificial cements, based on marl or noddles of clay and chalk subjected to what were virtually vitrifying temperatures before milling. Hitherto far lower temperatures had been employed, as all that was required for the preparation of hydraulic lime was sufficient heat to decompose its calcium carbonate content. Where all three of these proprietary cements differed from modern Portland cements was that they were submitted to a degree of heat which was sufficient to calcinate, but not to clinker them: clinkering heat being the *sine qua non* of Portland cement manufacture. It is interesting to note that the Lower Thames, which has remained the principal centre of English cement manufacture, was the original cradle of this worldwide industry. The French claim that artificial cement was invented by Louis-Joseph Vicat (1786-1861) in 1813. Though Vicat's very valuable researches were continued by eminent French chemists like Le Chatellier there seems to be no evidence that he himself ever attempted to manufacture it. The chief raw materials from which cement is made are limestone, chalk, clay, marl, shale, silica, alumina, and furnace slag. All modern Portland cements of the best quality are "artificial" cements.

In 1845 I. C. Johnston produced what is generally agreed to have been the first true Portland cement at the works of Messrs. White and Sons, Swanscombe. The result of Johnston's technical perfections (chiefly finer grinding and the employment of "clinkering heat") was that Portland cement, like manufactured steel, soon became an important British export. In 1850 Dupont and Demarle started the first French factory at Boulogne. The first factory in Germany was built five years later.

Just as the development of reinforced concrete would have been impossible without the invention of Portland cement, so its more recent progress has been largely the result of the perfection of "rapid-hardening" cements: a French discovery, which has an interesting history. The hydraulic lime used by De Lesseps in the construction of the Suez Canal (1859-1869) was supplied by the French firm of Pavin de Lafarge. It was noticed that certain pours of the mass concrete made with this lime set with astonishing rapidity, while others only hardened long after the normal period. The investigation of the data derived from these discrepancies ultimately led to the discovery of aluminous rapid-hardening cement by Pavin de Lafarge's chemists in 1913. Up to the war there was no commercial demand for a rapid-hardening cement, but in the course of it an urgent military one arose. Aluminous cement is said to have been first employed for the construction of "pill-boxes" on the Western Front. Though not introduced into England till 1923, it was put on the French market in 1918. Aluminous cement is the result of the fusion of impure bauxite and limestone. The rapidity with which it hardens is chiefly due to the action of the mono-calcium-aluminate content of the former causing a considerable rise of temperature during, and immediately after, setting. In countries devoid of bauxite deposits, like Great Britain, immense progress has been made by improving the technique of manufacture without changing the nature of the raw materials employed. Fibrous cement (based on asbestos) was first introduced under the name of "Eternit" by Hatschek in 1900, though Albert Kühlewein had anticipated his combination in 1892.

(b) Mass Concrete

Up to the discovery of Portland cement the history of concrete—concrete, that is, made with gradually improved hydraulic lime—is very largely a blank, though a number of examples are extant of its use throughout the intervening centuries. The purposes for which it was employed in the eighteenth century were usually mass foundations, abutments, retaining walls, sea defences, small jetties, or canal locks. These were also roughly the only uses to which it was put between the perfection of Portland cement and the more general introduction of metallic reinforcement. An exception must be made in the case of what is now known as "artificial" or "precast" stone: a purely imitative material often preferred by English architects because it requires no technical knowledge of concrete. A proprietary composition of this kind called "Lithodipra" was being made at Lambeth as early as 1765, and was adopted by Horace Walpole for the piers of the garden gateway at Strawberry Hill. Adam used a cement-like material of his own for much of his decorations. Antoine Polonceau (1778-1847), who built many of the French Alpine roads for

(12) Telford's single-span design in wrought iron for the new LONDON BRIDGE, 1800.

Napoleon experimented with concrete for heavy foundations. In 1829 he published "*L'emploi du béton en remplacement du pilotis*," the first technical work dealing with this material.

Lambot exhibited a monolithic boat at the Paris Exhibition of 1855, and Coignet, who had employed Portland-cement mass concrete for beams as early as 1861, used the same material for roofing the basement floor of the semi-circular row of "Restaurants of the Nations" which was a feature of the Paris Exhibition of 1867. This may be considered the first large-scale employment of concrete since Roman times. A mass concrete bridge at Sidmouth, believed to be the first of its kind built in England, and a "folly" tower on the south coast near Christchurch, both of which are still standing, probably belong to the same decade.

Reinforced Concrete

The frigidarium of the Baths of Caracalla are roofed with lime concrete strengthened by bronze rods, but it would be as idle to deduce that the Romans understood the principle they had accidentally embodied in this building as to pretend that the iron chains Sir Christopher Wren encased in concrete in the dome of St. Paul's provide an early example of reinforced-concrete construction. These chains, which were intended to resist the lateral thrust of the dome, act in pure tension, and therefore do not reinforce the structure at all; while the concrete was used simply to protect the links from rusting.

England can claim a good deal of pioneer work in reinforcement as well as cement. J. C. Loudon's *Encyclopædia of Cottage, Farm and Village Architecture*, published in 1830, contains the suggestion that roofs might be constructed of concrete with tie-rods embedded in it so as to form a lattice-work mesh. There is also evidence that fireproof floors were laid about this time which were made of concrete stiffened by flat iron bars. Reinforced-plaster floor-slabs were made experimentally in France circa 1840. Realization of the basic principle of reinforcement was advanced a step further by the patent taken out in 1854 by W. B. Wilkinson, a north-country plasterer, for constructing fireproof floors with a network of flat iron laths laid on edge in concrete. Wilkinson lived in Newcastle, and one of Aspdin's "Portland Cement Works" was at Gateshead, just across the Tyne. Mr. R. V. Chate, the Secretary of the Reinforced Concrete Association, to whose researches most of these particulars about English pioneers are due, says that Wilkinson

> "had an intelligent grasp of the principles of modern reinforced-concrete construction. His specifications were drawn up from thoroughly practical experience, and perhaps some theoretical understanding of the subject as well. His drawings for the reinforcement of floor slabs show the reinforcement bent down at the centre of the span, where the maximum bending moment occurs; whereas in continuous spans it is carried to the top, and over the supports, so as to resist the negative bending moment."

Wilkinson put up a number of buildings in the North of England in which reinforced concrete of a kind was pretty certainly employed, but no record of them now exists.

In 1862 Matthew Allen, a London builder, patented a system of iron-bound concrete floors and staircases (very similar to that patented by Monier in 1873), which was adopted in the construction of the Columbia Market at Shoreditch. The possibility of constructing girders of cement moulded round a hoop-iron framework was put forward by Frederick Ransome in 1865. Two years later this embryo system of reinforcement was taken perceptibly nearer practical realization by the patent taken out by H. Y. B. Scott for concrete flooring strengthened with interlacing bands of hoop-iron, and supported by completely-embedded tie-rods instead of on independent joists. Though there is nothing to show that Scott's floors were ever used in any building, his specification clearly states that the tie-rods and hoop-iron were intended to take the tension, and the concrete the compression: fairly conclusive evidence that he anticipated Hennebique by some decades in mastering the theoretical basis of reinforced-concrete construction. But all that can be said with certainty in regard to the rival claims to priority put forward on behalf of various French and English engineers is that the principle (and part of the technique) of reinforced-concrete construction was invented and reinvented several times over during the middle years of the nineteenth century.

1867 is the first real "date" in the history of reinforced concrete. It had occurred to Joseph Monier, a small French market-gardener, that if the kind of tubs in which orange- and bay-trees are planted out could be made of cement stiffened with metal they would prove much more durable than wooden ones. Like Scott, Monier took out his first patent in 1867; and some of his "improved" garden-tubs and flower-pots were shown at the Paris Exhibition of the same year. This is usually regarded as the first deliberate application of reinforcement, though there is some doubt whether what Monier used as such was wire netting or a bracing of isolated iron rods. In any case he employed metal simply as a sort of whale-bone backing to help shape his pots, and the cement merely as a filler, very much as plaster is laid on laths. Monier thought out the rest of his system step by step, taking out successive patents for pipes, slabs, steps, and even bridges up till 1875. He died in 1906, poor and forgotten.

Though Monier had sufficient intelligence to foresee its more immediate possibilities, he never realized the implications of his discovery, or understood the separate, yet complementary, functions of the iron and concrete he had succeeded in uniting. This was left to the German engineer G. A. Wayss, who acquired the German rights of Monier's patents about 1880, and founded the celebrated firm of Wayss and Freytag of Frankfort-on-Main. Reinforced-concrete construction was for long known as *Monierbau* in Germany, and this term is still sometimes employed. The first British Monier patents were not taken out till 1883. Though they failed to occasion any immediate repercussion, a block of offices in Lincoln's Inn Fields, erected in 1885 (of which a Mr. William Simmons was the architect), combined mass-concrete walls with floors reinforced on this system. It would, perhaps, be juster to consider Monier as the founder of the precast concrete industry (in which reinforcement has been increasingly adopted) than as the actual pioneer of reinforced-concrete construction.

The specification of the patent taken out by Phillip Brannon in 1871 for floors and sea-defence works shows that he had grasped the principle of reinforced concrete just as clearly as Scott before him. Brannon's patents were acquired by the Monolithic Fireproof & Sanitary Construction Works, Ltd., which erected several buildings partly embodying them. Brannon is said to have been the first engineer to advocate the use of reinforced-concrete piles. During the eighteen-seventies Thaddeus Hyatt, an American who had settled in London, took out over 30 patents relating to reinforced concrete. Hyatt did not achieve commercial success, but the series of tests he conducted with sections containing both single and double reinforcement were instrumental in helping engineers to understand the theory of the reinforced-concrete beam.

We now come to the first two significant names in the history of this material: François Hennebique (1842–1921) and Edmond Coignet (1850–1915). The former, who began designing in masonry but soon abandoned stone in favour of steel, did not turn his attention to concrete until 1879. It was only in 1892 that he took out his famous patent for "compound beams," which some authorities consider had been largely anticipated by those of Hyatt in 1877 and Meyenberg in 1891. In any case its practical effect was to transform what had hitherto been at best a subsidiary building material into a full-fledged form of construction with immense architectural possibilities. Up till now its cardinal weakness had been that there were no means of making monolithic joints between floors and beams, or beams and stanchions. Hennebique solved the difficulty by employing a reinforcement of round bars which could be bent back and hooked together (or, as they are called in his specification, "*étriers en feuillards*") at the junction of two separate members. This allowed reinforced-concrete columns to be substituted for the structurally unconnected cast-iron supporting stanchions hitherto used. Once the problem of the monolithic joint had been overcome, the monolithic frame-building could be realized. In 1897 Hennebique introduced that important practical simplification of reinforcement known as crank-up rods.

Hennebique created the prototype of the large-scale industrial organisation which both steel and reinforced-concrete engineering necessitates. He sold the "service" of a patent method of construction all over the world in much the same way that English manufacturers had sold their patent machines—either direct, or by granting licences to foreign firms. A born "business man" and an able propagandist, Hennebique achieved considerable commercial success in obtaining big contracts. Among these were the now famous mill at Nantes (1895), with its widely cantilevered-out floors (a form of construction repeated in a warehouse in the Port of Liverpool built under his patents a few years later); silos in Strassburg; harbour works in England; transit sheds in Genoa; and the bridge over the Vienne at Chatellerault (1898). Hidden away behind the flamboyant worls of the *art nouveau* plaster-pastry at that "macaroni" Paris Exhibition of 1900 Paul Morand has described so inimitably was the lean geometric functionalism of the supporting reinforced-concrete skeletons which Hennebique and Coignet had collaborated in designing. Architects welcomed a new "style" in the former; engineers saluted a new construction in the latter.

The principal contributions of Coignet were a fairly accurate method for calculating stresses and strains, based on known mechanical principles; and various patents for vaults, arches, etc. Up to this time no tables for calculation existed, and there was virtually no literature on reinforced concrete. In order to arrive at the most suitable arrangement of the steel and concrete, and determine the best proportions for the reinforcement, engineers were obliged to rely on rule of thumb, or make their own trial and error experiments for each new job. The result was that the use of the material was restricted to a few individuals, each exploiting his own "system." In 1890 Paul Neumann published a mode of calculation based on the relation between the different coefficients of elasticity of the two materials. The treatise published by Melan (who patented the system of uncentred vaults which bears his name in the same year) bore out Neumann's hypothesis that the degree of elasticity in reinforced concrete was not the same under compression as under tension. Both Neumann and Melan, however, had been to some extent anticipated by M. Koenen in 1886. The Memoir written by Coignet in collaboration with N. Tedesco, which was published in the proceedings of the *Société des Ingénieurs Civils de France* in 1894, is sometimes referred to as the first notable attempt to formulate the theory of reinforced-concrete construction. In 1889 Bordenave and Cottancin had shown some reinforced-concrete drain-pipes at the Paris Exhibition held in that year, which seem to have interested Coignet. When the Achères section of the Paris main drainage network was thrown open to tender in 1892, he was able to get reinforced-concrete construction adopted by guaranteeing a very considerable saving in time and cost: an adoption that was abundantly justified in the result.

Armand-Gabriele Considère (1841–1914), the next "name," may be regarded as the first engineer to have achieved important practical improvements in the design of reinforcement: the most valuable being a properly articulated system of cross-wiring and transverse tieing. All the early attempts to deduce mechanical laws from a co-ordination of the separate tests carried out by Hennebique and Coignet had failed owing to variations in the density and hardness of the concrete used. Considère's series of tests on small specimens, or "gels," made under uniform conditions enabled him to discover the laws governing the deformation of concrete under stress.

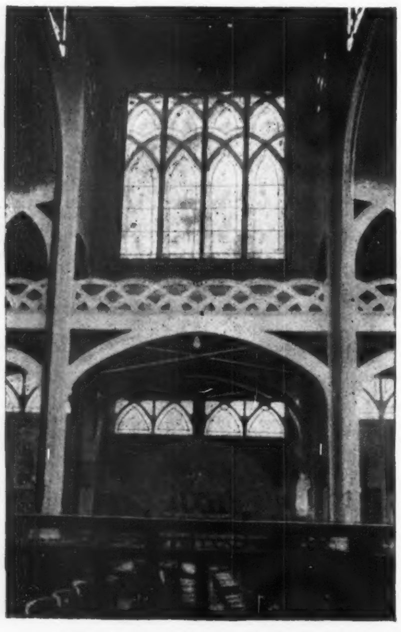
The Hennebique system was introduced into Great Britain in 1897 by L. G. Mouchel, who had been Hennebique's partner in France. From 1897 to 1904 the history of reinforced-concrete construction in this country is the history of the firm of L. G. Mouchel & Partners, which built the first English reinforced-concrete road bridge at Chewton in 1901; and a more ambitious one of 60 ft. span at Purfleet two years later. In 1904 Coignet opened his English branch, followed by the Trussed Concrete Steel Company (working the American Kahn system) in 1906; and Considère Constructions, Ltd., in 1908.

In the United States progress was also slow during the last century, largely owing to the fact that until 1895 all Portland cement of reliable quality had to be imported from Europe; though W. E. Wood is said to have built a house entirely of reinforced concrete as early as 1875. A more important pioneer was E. L. Ransome, who patented a twisted square-bar reinforcement in 1884. Ransome built several factories and warehouses, his two most ambitious undertakings being the Californian Academy of Science, which triumphantly withstood the San Francisco earthquake of 1906 (1888); and the all-concrete Museum of the Leland Stanford Junior University (1892). The first reinforced-concrete bridge in America, which had a 100-ft. span, was built at Stockbridge, Mass., in 1897. It was designed by the famous Austrian engineer Fritz von Emperger.

The Architect Steps In.

The first architect who deliberately chose reinforced concrete for any major use was Anatole de Baudot (1834-1915). By a strange irony of fate this "revolutionary" was the pupil of Viollet-le-Duc (though he also worked under Henri Labrouste), and continued his master's restorations at Blois, Clermont-Ferrand, and Le Puy. Till the end of his life Baudot remained an active and zealous official member of the French Commission for the Preservation of Historic Monuments. To these he added one of his own design, which is not likely to be "scheduled" in the immediate future. In 1894 he was allowed to begin the construction of Saint-Jean-l'Evangéliste at Montmartre (13), where he was able to halve the original estimate by the substitution of reinforced-concrete beams and arches for stone. The City of Paris for long refused to sanction his plans on the grounds that such a building would be bound to collapse. Needless to say the church still stands quite solidly. Baudot was the author of *L'Architecture et le Ciment Armé,* the first architectural book on the subject.

The next architect to turn his attention to reinforced concrete was the Beaux-Arts-trained Auguste Perret, who first used this material in 1899 for roofing the Casino at St. Malo. A house he built for himself in Paris in 1903, the famous 25 bis (now 70) Rue Franklin (14), was destined to become a landmark in the history of architecture. In the façade of this narrow but lofty *immeuble* the reinforced-concrete construction was openly shown, so that anyone with eyes in his head could "read" it. The banks refused a mortgage because their experts assured them that the slender stanchions on which it was supported must inevitably give way. Two other important concrete buildings were designed by the brothers A. and G. Perret before the war: the Garage Ponthieu (the prototype of all large modern garages) in 1905, and the Théâtre des Champs-Elysées in 1911. The latter is a very complicated frame building, faced with marble inside and out, in which one theatre is superimposed upon another. After the war came the two well-known "openwork" churches at Le Raincy and Montmagny. If it were not for the fact that for all his daring originality Auguste Perret has never quite freed himself from the influence of traditional styles, the interior of the Esders Ready-Made Clothing Factory in Paris might be considered his most characteristic as well as his best design. Tony Garnier, a former *Prix de Rome* of the Beaux-Arts, is another architect-engineer of the same type. Le Corbusier, a Swiss by birth and a Parisian by domicile, is a post-war name its bearer has been at some pains to make familiar to all and sundry. The only French architect who can be said to have succeeded in combining grace with functional sincerity in concrete is André Lurçat; and unfortunately he has never had the chance of designing an important building.



(13) CHURCH OF SAINT-JEAN-L'EVANGÉLISTE, Montmartre, 1894. Anatole de Baudot, *architect.*

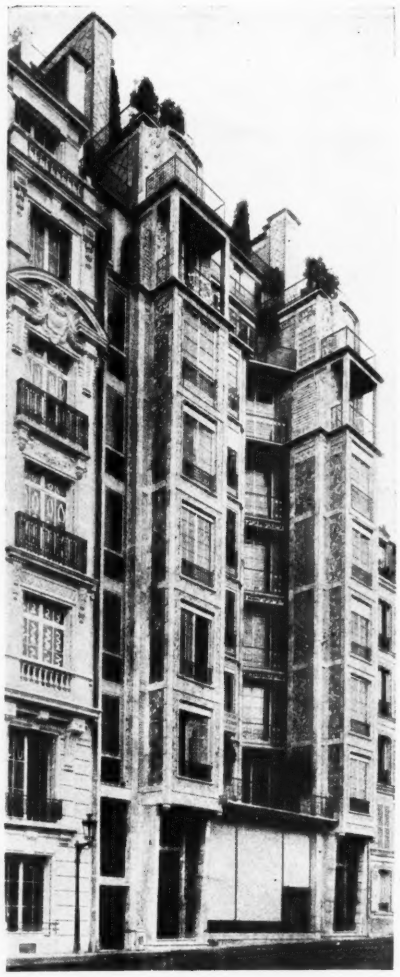
The lead given by Perret was followed by men like Josef Gočár, Adolf Loos, and Hans Poelzig. After the war, concrete architecture rapidly began to come into its own, thanks to the initiative of the late Adolf Meyer, Walter Gropius, Eric Mendelsohn, and many other Austrian, German, Dutch, Belgian, Scandinavian, Finnish, Italian, Swiss and Russian architects whose names and principal buildings are too numerous to mention. An exception must be made in the case of a pre-war building which has been so painstakingly photographed by Mr. Yerbury—Max Berg's *Jahrhunderthalle,* at Breslau, the largest example of the ribbed dome in concrete: a type of construction that is now entirely superannuated. Like Elsaesser's romantic Stuttgart Market Hall, its structure has been entirely masked by an external "architectural treatment" that lacks any true relation to the interior. An even more glaring example of art abjectly apologizing for science is Wilhelm Kreis's Planetarium at Düsseldorf, where the 16 slender concrete columns supporting the cupola have become 48 purely decorative brick buttresses.

Constructional Technique.

The earliest type of construction employed in reinforced concrete, beam and post and its various combinations, was identical with that used in iron and steel. The first real differentiation was the supporting, or, as it is more often called, "mushroom," slab; which does away with the necessity for floor beams. This was an American discovery, although its fuller development and subsequent refinement, in which the slab itself is suppressed altogether, were chiefly the work of the Swiss engineer, Robert Maillart. After that came the supporting surface (Freyssinet and Dischinger), in which the most momentous peculiarity of this material was first revealed: namely, that from elements which themselves need support, support itself can be obtained.

The first attempt to make surfaces that require support yield support was in the twin airship-sheds at Orly, outside Paris (58), which were built by Freyssinet — probably the greatest genius that reinforced-concrete engineering has yet produced—for the French War Office in 1916. In these sheds every ounce of material is turned to structural account owing to the corrugation of the continuous series of hollow ribs—which, in describing their parabola, form walls and roof as one. This *Hallenbau* system, which was subsequently adopted for the new Rheims Market (60), reappeared in a somewhat modified form in the Gothenburg Exhibition of 1923. The Gothenburg hall was in turn faithfully re-embodied in the Haslach Swimming Baths at Stuttgart and the new Horticultural Hall in London. All three are lit by clerestories notched into the outer curve of a row of flattened ribs that stand some distance apart. A more original variation of this design is to be found in the great Exhibition Hall at Brünn in Czechoslovakia.

The logical development of the supported-yet-supporting principle is the Zeiss-Dywidag system of roofing—invented by the German engineer Dischinger, and Carl Zeiss, of the famous firm of optical-instrument manufacturers— first employed for the double-domed planetariums that were built in various German towns in the nineteen-twenties. The Dywidag system was originally only practicable for circular domes, but it has since been made applicable to polygonal ones, and the roofing of large rectangular spaces with successions of transverse barrel vaults. The outstanding example



(14) HOUSE IN THE RUE FRANKLIN, Paris, 1903. A. & J. Perret, *architects.*

of the latter is the great hall of Elsaesser's Frankfort Markets (57), which, with a continuous floor area of 11,300 sq. metres free of any intermediate supports or subdivisions, represents one of the largest enclosed spaces in the whole world. In the Dywidag system the walls themselves become the only ties. This enormously simplifies construction by doing away with countless ribs, beams, struts, and stanchions; enables roofing of almost egg-shell thickness to be used; and leaves the whole of the space spanned entirely unencumbered.

The bridge was one of the earliest forms in both mass and reinforced concrete. It is also one in which the latter is an ever greater competitor of steel. Concrete bridges are divided into three main classes: those with flat spans (the equivalent of plate-girder bridges in steel); those with arched spans (corresponding to masonry construction); and those having reversed elliptical spans from which the platforms are suspended—known (as in steel) as "bowstring" bridges.

Up to the beginning of the present century reinforced-concrete construction was a sort of guild mystery controlled by a very few people. Though this is no longer true to-day, the history of its technical developments since the war has been that of well under a score of large firms of contractors. International in their organization or activities, these are directed by, or else employ, the leading designers in this branch of civil engineering. They are the true master-builders of our age, and their names are deservedly more universally known than those of any living architect. That none of them are English is humiliating. Though British structural steel is being erected in every continent to-day as it was sixty years ago, no British firm has ever had a look in outside the British Empire in the design or execution of any big public works for which reinforced concrete was specified. Nor does the skill and experience of our own much smaller firms suffice for the Empire. Messrs. Rendell, Palmer and Tritton, our foremost consulting engineers, had to entrust the design of the big dam for the Chernadoh hydro-electric scheme in Malaya to the Vattenbyggnadsbyrån of Stockholm. One result of the comparatively slight use made of concrete *as concrete* in this country—slight because absurdly antiquated regulations either restrict its use or make it artificially dear, and the public has been encouraged to have a holy horror of concrete unless its shameful identity is cloaked by a veneer of the materials traditionally associated with "existing amenities"—is that nearly all our older engineers have been brought up as "steel men." Lacking that wider experience in concrete construction which comes the way of their Continental colleagues as a matter of course, they usually retain a prejudice in favour of steel throughout their lives.

Comparative Advantages and Disadvantages of Steel and Concrete.

Steel and concrete, the materials which have allowed the function of support to be separated from the function of containing space, are largely interdependent in use. Owing to its high conductivity, steel, when attacked by flames, soon attains a temperature that causes it to twist, and eventually collapse. That is why steel girders in buildings are almost invariably squared off with a solid layer of concrete, or encased in a sheathing of some other fire-proof material. Concrete, being really reconstituted stone, is a poor conductor of heat and an excellent insulator. The outstanding quality of steel is high tensile strength. That is to say it excels in resisting tearing and splitting strains. The outstanding quality of concrete is great compressive strength. That is to say it excels in resisting the crushing stress, or pressure, of heavy weights. And just as, economically, the compressive strength of steel is insufficient to make it a serious rival to concrete in this respect, so the tensile strength of unreinforced concrete is too low to enable it to compete with that of steel. Reinforced concrete unites the merits peculiar to steel and stone construction and to a very large extent overcomes the intrinsic defects of each. Though quantitatively unequal, and unevenly distributed, the steel rods and rubble and cement amalgam which constitute this composite material form a compact and coherent mass. But if concrete that is reinforced combines most of the advantages of masonry and metal, it does not combine them all. It is true that in ordinary buildings the cost of carrying a given load is 150-200 per cent. more with steel girders than reinforced-concrete beams and stanchions, and that the latter need not be more numerous than the former. There remains the important question of speed in construction. The rate of progress on a building is in direct ratio to the number of men who can work on it simultaneously without impeding one another.

In the case of a reinforced-concrete structure virtually the whole work has to be done on the site itself. That means the raw materials for its elements are assembled there instead of finished fabricated sections embodying these elements. Carpenters are engaged in sawing up and bolting together the lengths of timber shuttering required for each successive pour, and unbolting and striking those in which other pours have already set; artificers in bending and interlocking the metal rods, and cross-tieing them with wire at intervals according to the engineer's drawings; labourers in mixing aggregate, sand, and cement with water in specific proportions, shovelling the liquid concrete into fresh sections of shuttering waiting to be filled, and tamping it home round the naked bones of the articulated reinforcement. Though rapid-hardening cements allow fresh pours to be made about every 24 hours, the difficulty is to have the new lengths of reinforcement connected up, and the new forms completed round them, within that period with men continually moving backwards and forwards across a generally cramped working space.

With steel construction the work proceeds on two sites simultaneously: the building site proper and the fabricating shops. At the former soil is being dug away from between supporting points that may be already fixed in position; girders are being encased in concrete and hollow-slab floors laid between them; walls are being bricked in and tile partitions run up; stone facing is being hitched on to the outside of the rising skeleton; finished beams and stanchions are being hoisted out of lorries and swung into their appointed places by cranes and shears perched high aloft on tripod gantries; while those already lowered on to their sole-plates, or fitted into their spans, are being bolted together and riveted into the framework. At the steel shops, perhaps some hundreds of miles away, the various fabricated sections are being rolled, built up, painted, and numbered according to specification; and then despatched to the site on a time schedule, so that delivery is neither earlier nor later than the particular day, or even hour, when they are wanted. The result is the minimum encumbrance on the building, and the minimum of involuntary interference between the different gangs of skilled and unskilled workmen. These are the outstanding advantages of construction based on the progressive assembly of ready-made parts, or, as it is called on the Continent, *montage*. The drawbacks of *montage* are continuous dependence on transport (which is very expensive for heavy out-of-gauge girders that have to be sent by rail) and the employment of a much higher proportion of skilled labour. Moreover, when deliveries are behindhand, substantial losses in wages are apt to be incurred. With reinforced-concrete construction the whole of the materials required are grouped ready to hand before the ground is broken, and drawn on as required.

The advantages of *montage* are not, however, necessarily confined to fabricated steel; but it must be admitted that in practice steel has hitherto enjoyed a monopoly of them: a monopoly which is pretty certain to be challenged before long. Concrete beams are just as suitable for mass-production as steel girders. As early as 1914 the dome of a big circus in Copenhagen was roofed with precast concave segments, though a better-known and more recent example of *montage* in concrete is the ribbed cupola of the Gebrüder Einmal Garage at Aix-la-Chapelle. Factories in Brazil (a country where steel is expensive) have been erected with precast stanchions and roof-trusses, almost identical in form with light standard steel-frame sections, in which the reinforcement was only partially encased so as to leave about a tenth of it protruding at one or either end. As soon as a couple of these had been hoisted into position by windlasses, the main crank-up rods were interlocked and cross-wired in the usual manner, shuttered together, and then poured so as to form a monolithic weld with the rest of the framework. The French *Ponts et Chaussées* have employed standardized precast members in bridge-building for several years; while Corbusier, Gropius, and others have experimented with standardized precast sections for small dwellings. Examples of the latter can be seen in Pessac, near Bordeaux, the Torten suburb of Dessau, in Germany; and at least one L.C.C. building estate (where elements of this type are rather grotesquely combined with timber rafters and tiled gable roofs).

A poured concrete structure has the advantages and disadvantages of being a monolith, while for all their homogeneity the parts of a steel-frame structure remain separate and separable entities. The rivets and bolts of steel construction might be compared to the mortar joints of masonry. In both the multiplication of imperfect articulations is a source of structural weakness. Autogenous welding, which is still in its infancy, promises to make a steel skeleton as monoferric as a concrete one is monolithic. Yet even so, concrete will still have the advantage of plasticity and requiring much simpler and less expensive plant. It is easier and cheaper to pour and mould than to hammer and bend. Once set, a complex of monolithic elements can withstand an earthquake in which, as experience in San Francisco, Tokio, and New Zealand has proved, a steel frame crumples up like a wicker basket. The worst enemy of concrete is the magnesium sulphate present in sea water; but this can be successfully kept at bay by very rich 1 : 1 : 2 mixes made with aluminous cement. Though more resistant to weak acid solution than ordinary steel, it is liable to be attacked by stronger ones, liquids containing alkaline salts, and certain vegetable oils that unite with its lime content.

The point at which work on a concrete building is really as good as finished is the point at which half the work still remains to be done in a steel-framed one. Ultimately, no doubt, rustless steel will become an economic material for both structural and facing uses. Ordinary steel, however, rusts when exposed to air, earth, or water; and therefore requires regular painting, or encasing in another material, to preserve it from erosion. The fact that steel is a rigid material, pieced and not poured together, makes it less flexible for "out-shapes"; and entails a waste of space, and, above all, surface. Ideal for rapid handling, the I girder presents no less than eight corrodible surfaces; whereas a concrete beam, which presents no cavities requiring subsequent filling, and is impermeable to erosion, can be moulded into any section, angular or round, *in situ*. The only waste with concrete is in the sizing of the shuttering. At present it seldom pays contractors to stock standardized steel frames.

One of the admitted (though considerably exaggerated) drawbacks of a monolithic building is the difficulty and expense of altering, or adding to, it subsequently: though, if it comes to that, steel is only easy and cheap to replace or extend where, as in station roofs or bridges, the elements remain exposed. Loose strands of reinforcement can be curled up and hidden away under tidy circular bosses of mortar, so that when the structure is to be built on to, all that need be done is to uncover the spare ends, straighten them out, and link them up with the armature of the new connecting elements. An important road bridge over the River Ruhr at Mülheim provides a good illustration of how easily future requirements can be provided for in reinforced-concrete construction. This bridge, which crosses a wide expanse of water meadows subject to periodic flooding besides the river itself, at present consists of twelve eliptical arches. Ultimately these twelve spans are to be increased to seventeen; and the existing pavements, which are 1·50 metres wide, will be taken into the roadway and replaced by others double their width, cantilevered out from the parapets. It will be just as simple to make these extensions (for which provision has been duly made in the design of the reinforcement) as it would be to bolt on fresh sections of girders in the case of a steel bridge.

It is no doubt perfectly true, as Dr. Oscar Faber says, that the steel frame of a relatively "plain" building represents only $\frac{1}{10}$ to $\frac{1}{15}$ of its total cost; and that though concrete (or rather shuttering) is 50 per cent. dearer since the war, the price of structural steel has remained practically stationary. (His figures, of course, only apply to Great Britain, where steel is artificially cheap in relation to reinforced-concrete construction.) We all deplore the decay of British shipbuilding, but the very natural desire of our steel millowners to roll more structural girders, to compensate them for a continually decreasing demand for ship's plates and bulkheads, is not a valid reason in itself for cold-shouldering a form of construction which has proved essential to the industrial expansion and economic re-equipment of other nations. Steel and concrete have their separate spheres, where each is admittedly either economically or structurally supreme. But there is also a sort of neutral no-man's-land between them—where either is theoretically equally suitable, and local conditions, or individual requirements, may happen to make now one and now the other the more advantageous—in which they inevitably compete. On the Continent—even in countries like France and Germany which have just as important and well-organized steel industries as our own—the economic factor decides the choice. In England it is no exaggeration to say that steel is frequently employed where on logical, economic, engineering, or æsthetic grounds (or a combination of any or all of them) concrete ought to have been adopted. That it so seldom is need occasion no surprise. Many of our local authorities (to say nothing of the Ministry of Health) insist that in cases where concrete beams are used instead of steel girders, they must be of equal, or even greater, thickness. The London Building Act—which dates from 1909, and is only now in process of modernization—allows reinforced concrete to be stressed to a maximum of 600 lb. per sq. in., when modern cements enable it to be safely stressed to as many thousands. It is true that steel construction is also made needlessly solid and extravagant by superannuated regulations, but steel is not penalized to anything like the same extent as concrete, and never to its profit.

The Evolution of Design in Steel and Concrete

BY WALTER GOODESMITH

Whilst no one with a correct knowledge of the potentialities of the two materials will disagree that there is a definite sphere for the application of each, there is doubtless a common meeting ground where from the purely practical point of view either steel or concrete may with advantage be used according to the exigencies of the circumstances.

The evolution of design in steel and concrete has been governed by their historical development, by the perfection and progress in manufacture, and the ability, ingenuity and foresight of designers and executants, though held in leash by taskmasters of governing bodies and their fettering utterances.

A skeleton comparative summary is given hereunder which by no means attempts other than a cursory invasion into the arena of the contentious " steel or concrete " controversy.

STEEL

" TENSION "

Greater speed of erection is possible because the largest part of the work is done in the fabricating shops, and the speed of erection is generally limited to working space and the mobility and number of cranes. Fire resisting cover, if in concrete, of course, adds to the time through the necessary formwork reinforcing, pouring, setting, and stripping.

In buildings where floor space is valuable structural steel, especially the constant dimension stanchions of the Americans, takes very much less space, and in the section of the structure, less floor to floor height is required to give the desired headroom. These constant dimension stanchions are a wonderful aid to the standardization of materials adjacent to the stanchions in a structure, as the number of variations in " cover " sizes is brought to an absolute minimum.

For height steel cannot, of course, be rivalled with its record structure over 1,200 ft. high.

Steelwork has to be protected for fire-resisting reasons in certain classes of structure, but where left bare has to be painted, this maintenance charge adding considerably to final cost.

The great possibilities for standardization in steelwork have been realized and exploited and have proved to have been one of the main factors of its success, they have, however, placed a somewhat limiting restriction upon flexibility where the structure is also the expression of the finished mass.

Greater skill and exactitude are obtainable with steel for it is under control from conception to final erection, and is handled by skilled workmen in every branch. The whole industry is organized throughout, even in the matter of the exploitation of its by-products.

Comparison on approximate cost basis of structural steel :—

Cost per unit volume	=	£50x
Compression value	=	30c
Cost per unit load in compression	=	£1.7c
Tension value	=	300t
Cost per unit load in tension	=	£.17t
Cost structural steel in compression (Sir Owen Williams)	=	£3w

Added to this is the extra cost of encasing.

The subject matter has been subdivided as hereunder :—

CONCRETE

" COMPRESSION "

Less speed is possible, for with the exception of rods the reinforced concrete is " made " on the job and construction of formwork, laying rods, pouring concrete, setting and stripping, cannot be hurried faster than practical limitations.

Many concrete structures are not dependent upon minimum floor obstructions, but where this is required a concrete column often appears as a buxom lass alongside her slender partner in steel. Depth of floor structure has, however, been reduced from original beam and slab results, by the development of the mushroom head and drop panel methods.

Whilst at present the highest practicable concrete framed building is about 20 stories (some 200 odd feet), and the economical height is only 12 stories, it would be interesting to see what could be produced by a Freyssinet not hampered by quite so many regulations as exist today.

Concrete as a finish in itself when not covered with flaking renderings, should require the very minimum of maintenance.

Standardization in concrete has received much thought and achieved some interesting results, but its weakness in this direction is its strength in another, for the amazing flexibility of concrete has brought into being perhaps the finest masterpieces of modern architecture.

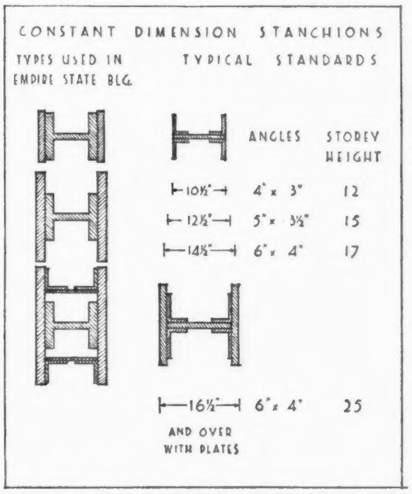
The manufacture and sale of cement, which has reached a high standard, seems to be the only portion of the industry that can compare favourably with the organization of its steel rival. The chances for error and bad workmanship are great, through so much dependence on the human element, yet we find generally that there is no craft of concrete maker as skilful and as full of pride in his work as his steel rival.

Comparison on approximate cost basis of concrete (not reinforced) :—

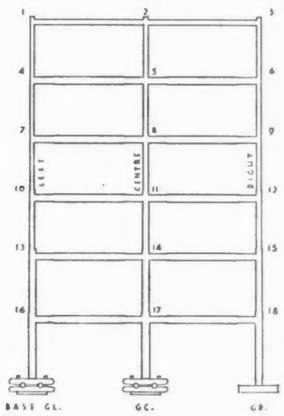
Cost per unit volume	=	£x
Compression value	=	c
Cost per unit load in compression	=	£c
Tension value	=	t
Cost per unit load in tension	=	£t
Cost reinforced concrete in compression (Sir Owen Williams)	=	£1w.

The following subdivisions deal further with the subject :—

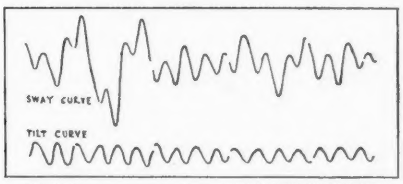
• THE EVOLUTION OF DESIGN IN STEEL •



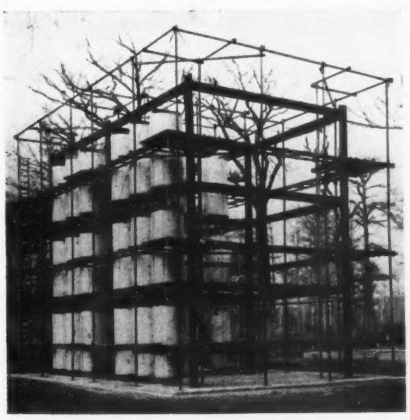
(**15**) CONSTANT DIMENSION STANCHIONS.



(**16**) Diagram of a model for tests by the DEFORMETER APPARATUS.



(**17**) A sway curve of a tall STEEL TOWER.



(**18**) The three storey experimental steel frame building of THE BUILDING RESEARCH STATION.

Iron, though dating back some 3,400 years, was not converted into steel until some 76 years ago by Bessemer, since when it has become man's most important servant, with ramifications enormous and unlimited.

Structural steels, with which we are most concerned herein, are of such a uniform and known standard of perfection that the belated step taken in February of this year in revising existing regulations as a code of practice for the use of structural steel, etc., was long overdue.

The constant section stanchion has been a most important development in American steel practice, and has helped immensely in standardization and saving in time—note the typical sections used in the Empire State Building.

Skyscraper structures in America have given rise to a new feeling of " air sickness " in susceptible people; so much so, that research into the sway of tall towers has been carried out by the Wind-Bracing Research Committee of the American Institute of Steel Construction.

These results are interesting and the diagram herewith indicates the record of motion of a building having 15 vibrations per minute. The sway curve shows the horizontal motion combined with a long-period swing of the pendulum itself. The tilt curve shows that the building is bending like a true cantilever, and not simply lurching to and fro. The breaks in the curve are made by a clock which cuts the light off every 15 seconds.

The subject of earthquakes and their resistance by steel structures is receiving the attention of experimenters, and some very interesting papers and results have been produced. In the past, steel structures have not stood up well under earthquake shocks, mainly on account, however, of the absence of the application of scientific principles to their design.

The statically indeterminate frame structure is a never-ending subject for thought, and one of the most interesting experiments in this direction was first mooted by Professor Beggs (of Princeton University), who invented a deformeter apparatus to give a mechanical solution of a statically indeterminate structure.

A full scale experimental steel frame, three storeys in height, has been erected at the Building Research Station, and analysis of results should help materially in solving many problems of structural frames.

Welding.—A more universal appreciation of the possibilities of electric welding is desirable, for one finds so many architects and engineers with no knowledge at all of its application to structural steelwork.

It has been used extensively in France and Belgium, where it has not been hampered by regulations. The first structures in this country were by Murex, Ltd., who erected their electric welded steel factory some ten years ago with 160 ft. span trusses. A London borough surveyor has now given his sanction for extensions to a works being carried out in welded structural steel, which case should prove a valuable precedent.

The future development of steel would seem to lie in the direction of greater strength.

Higher tensile steels have passed the experimental stage, and are used extensively in Germany and America and to a lesser extent here. Extensive research is, however, still being carried out in this direction.

German experiments with nickel steel and other alloy steels produced some interesting results, and led finally to the production of carbon steel St. 48 in 1924, and high-tensile silicon steel St. Si. in 1926, the latter being used for the new suspension bridge over the Rhine at Mülheim (Cologne), whilst the earlier bridge in Cologne itself, built in 1914, is of nickel steel.

Steel alloys used in America, which does not use nickel steel to any great extent, are a similar silicon steel to the German and a copper manganese steel.

Great interest is now being taken by the steelmakers and the Iron and Steel Institute in experiments with the object of producing a corrosive resisting steel.

COMPARISON OF ROLLED STEEL JOISTS

BRITISH		AMERICAN	
SECTION	Z	SECTION	Z
24 x 7½ 100	221·0	24 I 94	225·0
24 x 7½ 90	203·6	24 I 84½	200·5
22 x 7 75	152·4	22 I 73 22 I 67½	161·5 148·1
20 x 6½ 65	122·6	20 I 62 21 I 60	123·6 124·0
18 x 6 55	93·5	18 I 52	94·3
16 x 6 50	77·2	18 I 47 16 I 45	85·2 73·8
15 x 6 45	65·6	16 I 40 15 I 42½	65·8 65·2
14 x 5½ 40	53·9	16 I 35 15 I 36 14 I 37½	55·1 55·1 54·3
13 x 5 35	43·6	14 I 30 14 I 33	42·5 47·8
12 x 5 30	34·5	12 I 28	35·6
10 x 4½ 25	24·4	10 I 23½	24·6

PERMISSABLE STRESS IN WELDED JOINTS

	AUTHORITY	SPECIFIED	TONS PER SQ IN
TENSION	AM. WELD. SOC.	13,000 lb. sq. in.	5·70
	SAN FRANCISCO		
	VER. DEUTS. ING.	850 kg. cm²	5·39
	PRUSSIA	720 kg cm²	4·57
	LEIPZIG	600 kg cm²	3·81
COMPRESSION	AM. WELD. SOC.	15,000 lb. sq. in	6·70
	SAN FRANCISCO	6,000 lb. sq. in	2·68
	VER. DEUTS. ING.	1,100 kg cm²	6·98
	PRUSSIA	900 kg. cm²	5·71
	LEIPZIG	600 kg. cm²	3·81
SHEAR	AM. WELD SOC.	11,300 lb sq. in	5·05
	SAN FRANCISCO	6,000 lb sq. in.	2·68
	VER. DEUTS ING.	750 kg. cm²	4·76
	PRUSSIA	600 kg. cm²	3·81
	LEIPZIG	500 kg. cm²	3·17
FLEXURE	AM. WELD. SOC.		
	VER. DEUTS. ING.	850 kg. cm²	5·39
	PRUSSIA		
	LEIPZIG	600 kg cm²	3·81

STEEL

MANUFACTURE·FABRICATION·ERECTION

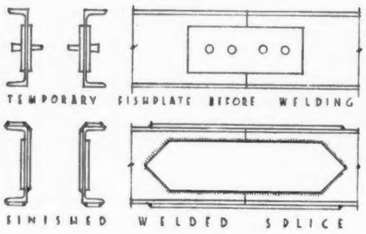
Four main stages mark the manufacture of finished steel (neglecting all minor operations) :—

1. The mining or quarrying of the minerals (iron ore, limestone, and coal).
2. Iron ore to pig iron.
3. Pig iron to ingot steel.
4. Ingot steel to the finished product.

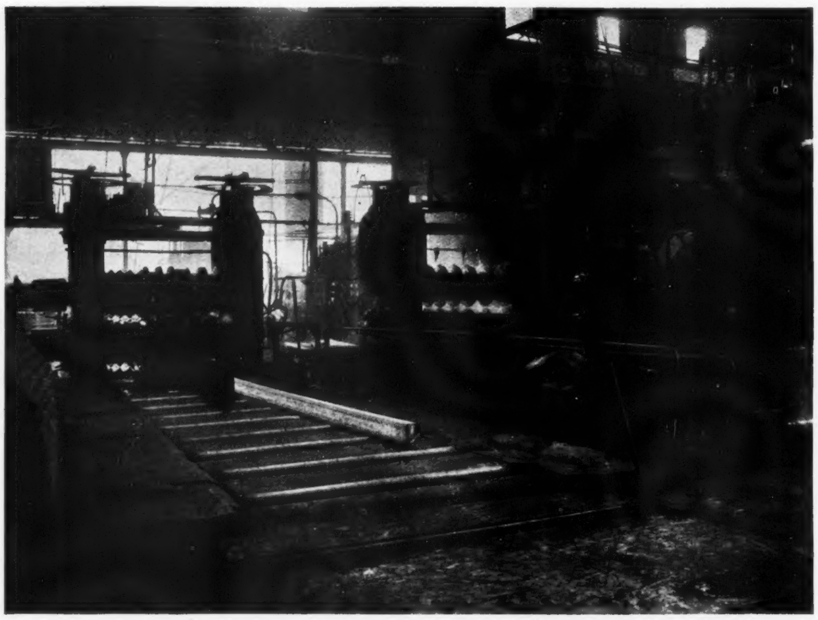
Speed of fabrication and erection are two of the most important factors in steel construction, and they have certainly been exploited by our friends the Americans. Amazing progress records have been established with the methods of riveted and bolted connections, and it now remains to be seen how serious a rival the welded joint will become when this method of joining structural members becomes organized on a large scale. The present contention by structural steel welders is that, apart from any question of quality or strength, welding is very much speedier than riveting.

Welding practice is gradually becoming standardized, and should be on a similar basis to standard connection practice in a few years. A practical difficulty that presents itself is that of the temporary connections necessary to hold members in position whilst welding takes place, but some very ingenious solutions have been arrived at.

The largest testing machine in the world is the 1,250-ton universal testing machine, and is an indication of the completeness with which composite members of steel frame construction may be tested under service conditions. It will accommodate a built-up compression member 50 ft. long by 45 in. sq., and a lattice girder for transverse stress 20 ft. long by 42 in. deep.

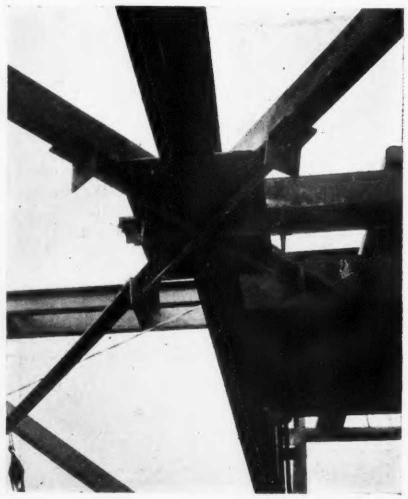


(**19**) A WELDED BEAM SPLICE.

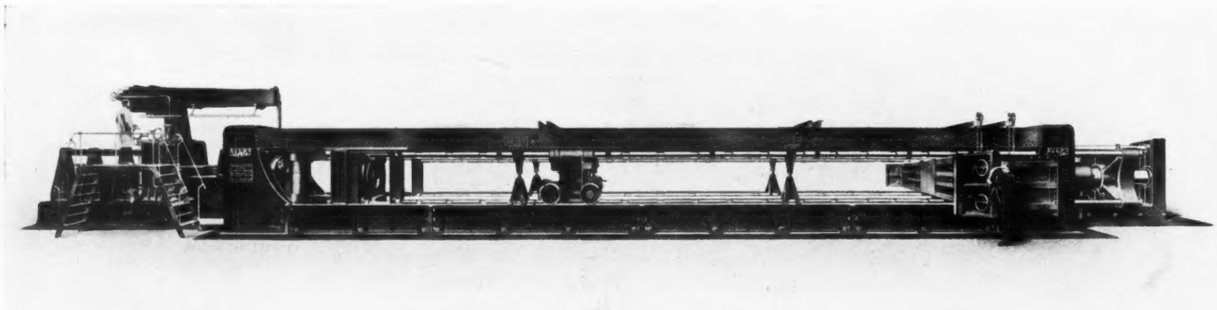


(**20**) THE ROLLING MILL. A white hot section is seen in the foreground resting on rollers which manipulate it backwards and forwards through the mill as required. The mill is at the Redcar Works of Messrs. Dorman Long & Company.

(**21**) THE TALLEST WELDED STEEL STRUCTURE IN THE WORLD. The nineteen storey (245 ft. high) building in Dallas, Texas. Mosher Steel & Machinery Company, *engineers.*

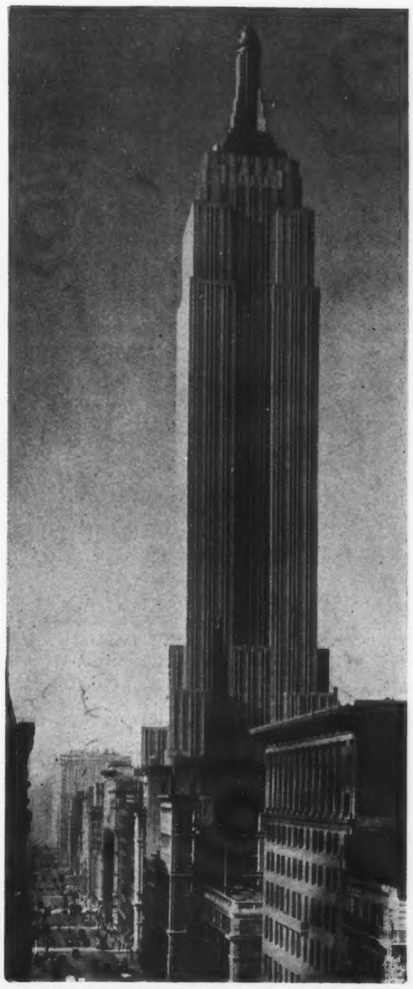


(**22**) A WELDED CONNECTION IN A ROOF TRUSS. Note the projecting angles and bolts for temporary erection. Murex Company, *engineers.*

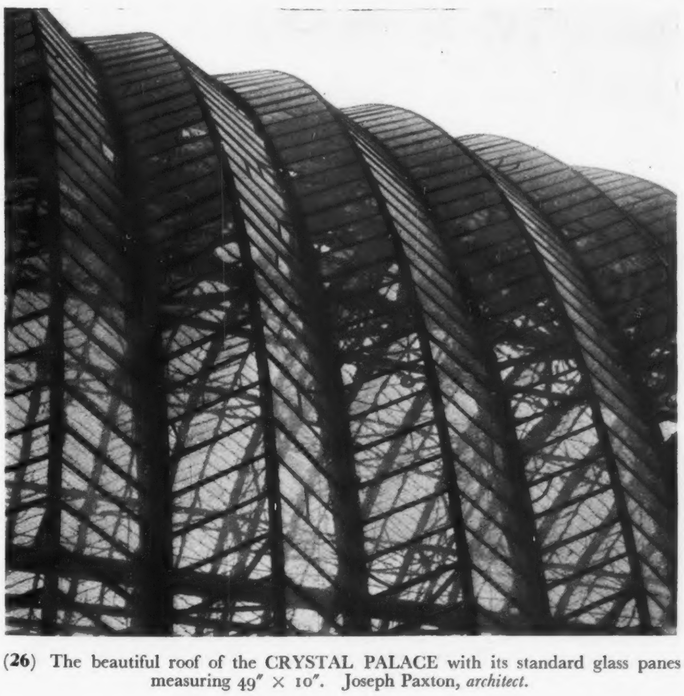


(**23**) THE WORLD'S LARGEST UNIVERSAL TESTING MACHINE, with a capacity of 1,250 tons, is owned by Messrs Dorman Long & Company, but is available to all authorities for important testing.

(**24**) THE EIFFEL TOWER, bold, original and unsurpassed.
Gustave Eiffel, *engineer*.



(**25**) THE EMPIRE STATE BUILDING, NEW YORK, to the same scale as the Eiffel Tower.
Shreve Lamb and Harmon, *architects*.



(**26**) The beautiful roof of the CRYSTAL PALACE with its standard glass panes measuring 49″ × 10″. Joseph Paxton, *architect*.

STEEL

STRUCTURES · PUBLIC BUILDINGS

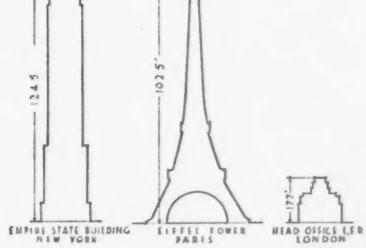
What lack of foresight to destroy that masterpiece of steel construction, the Galerie des Machines of the Paris Exhibition of 1855, (9). We are lucky that the same fate did not befall Paxton's Crystal Palace structure, which is now generally accepted as a landmark in design (26). How thrilled would some of the sponsors of standardization be were they to get an order for 956,194 sq. ft. of glass measuring 49 in. by 10 in.! This unit of glass is perhaps the most outstanding feature of the design. Some of the English railway stations advanced the design of steel until the decadent period when the steel became "architected." The Eiffel tower masterpiece of the genius whose name it bears is only one of many triumphs by him in the field of French engineering. It is compared in scale photograph with the latest and largest American example—the Empire State building (24) and (25).

The American contribution to the architectural history of the world is her skyscrapers, for they have produced entirely different problems without any precedent, and full credit must be given her architects and engineers for the way they have solved them.

The knowledge gained by them in standardization, fabricating, erection, wind bracing, etc., is invaluable and could only have been obtained under conditions similar to theirs.

The beautiful clean lines of some of the German steel frames are due to a multiple unit plan, standardized sections, and often welding in preference to riveting. Particularly noticeable in this direction is the Columbus Haus, by Mendelsohn, in Berlin.

There seems something radically wrong with the design of most public buildings which use structural steel as their skeleton and blossom forth with all the fripperies of a decadent classical or other style revival. One realizes that very seldom can the actual frame express itself as in the Money Order Office extension (30), but when this is not possible is it not more logical to express the surface as either a shell, or skin, or boldly express the panel filling? Not until such problems are squarely faced can we truthfully express modern façades.



(**27**) A comparison of famous AMERICAN, FRENCH AND ENGLISH STRUCTURES.

STEEL

STRUCTURES · INDUSTRIAL

Structural steelwork can always hold its own in industrial buildings of an engineering nature with their overhead cranes, shafting, etc., for it is the nature of things that this should be so.

The Air Ministry's airship sheds at Cardington afford an example of the possibilities of dismantling, removal and re-erecting of steel sheds, for this example of 812 ft. length, span of 180 ft. and a height of 160 ft., was dismantled at Pulham and re-erected at Cardington.

It is a pity that the wonderful opportunity offered by the new Ford works at Dagenham did not produce a better result from the point of view of design. The most interesting parts seem to be the jetties, as illustrated in (29.)

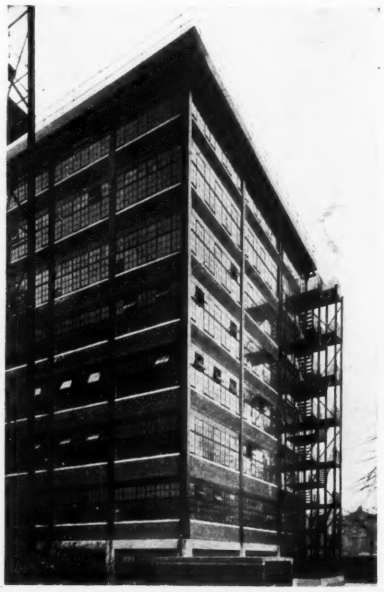
An extremely interesting example of construction has been carried out in the rear portion of extension to the Money Order Office building (30). The steel frame has been left exposed to express the frame structure, with the brick panel filling brought up to the same surface. The result is a complete success, giving an indication of great strength, and surety and truth of expression in construction, whilst the saving in cover to stanchions is considerable, both in actual cost and floor space. The main front of the building, however, pays homage to traditional treatment, with consequent results.

The steel masts of wireless transmitting stations are in many cases most beautiful and elegant in their conception and add greatly to the prestige of steel (31). The illustration of the B.B.C. North Regional Transmitting Station indicates two masts, the nearest of which gives a fine sense of poise at the point of insulation. Some excellent wireless towers and transmission line towers for grid systems of electric supply have been erected, but many atrocities have also sprung up, indicating the need for supervision of the design of such important structures which stride across the land from coast to coast (see illustrations on page 237).

Wind-bracing connection of girders to stanchions has received much thought, with the object of eliminating the large web plate and angle connections that have been popular for so long. The most interesting result is perhaps that given by the utilization of R.S.J. sections, instead of the usual angle cleats and seatings, see (28).

(**28**) WIND-BRACING CONNECTIONS:
left: cut from R.S.J. sections.
right: normal, clumsy seating bracket.

(**29**) Jetty at the FORD WORKS, DAGENHAM, showing the largest unloaders in the world. Chas. Heathcote & Son, *architects*, H. J. Deane, *engineer*.

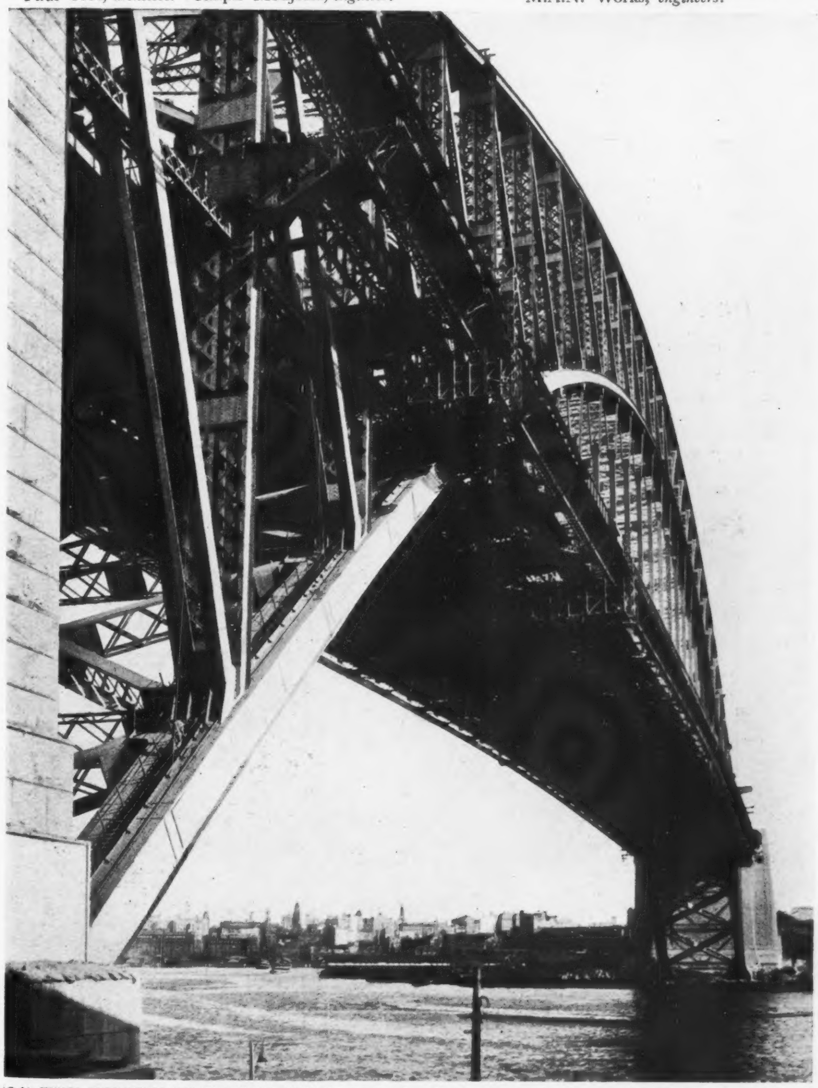


(**30**) MONEY ORDER BUILDING, HOLLOWAY; note the exposed stanchions. F. A. Llewellyn, *architect*.

(**31**) A graceful 500 ft. mast with insulated base of the B.B.C. NORTH TRANSMITTING STATION. M. T. Tudsbery, *engineer*.

(**32**) DELAWARE RIVER BRIDGE, New Jersey. Paul Cret, *architect*. Ralph Modjeski, *engineer*.

(**33**) COLOGNE (MULHEIM) BRIDGE. M.A.N. Works, *engineers*.



(**34**) THE SYDNEY HARBOUR BRIDGE with city skyline in the background. Dr. J. J. C. Bradfield and Ralph Freeman, *engineers*. T. S. Tait, *architect*.

STEEL

STRUCTURES · BRIDGES

Steel Bridges.—In 1779 the first metal bridge of cast iron was built across the River Severn at Colebrookdale. It had a span of 100 ft. and was designed by Pritchard. Several others followed in quick succession, but it was not until 1840 that the first iron bridge was built in America. Many historical bridges followed Colebrookdale, including Telford's Menai Straits suspension bridge of 570 ft. span, but it was not till 1832 that the first wrought iron girder bridge of only 31½ ft. was built by Thomson near Glasgow.

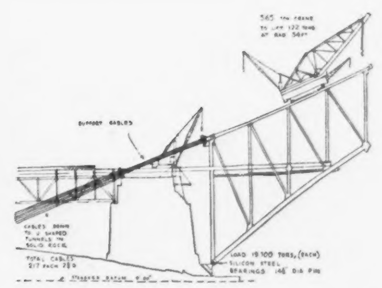
The repeal of the Board of Trade regulations against the use of mild steel in bridges in 1877 paved the way for the adoption of mild steel for the Forth Bridge, commenced in 1880, finished 1890, in which the designers, Baker and Fowler, and the constructor, Arrol, excelled themselves in producing one of the world's finest conceptions.

In the new suspension bridge over the Rhine at Cologne the suspension cables are anchored to the stiffening girder, not, as usual, to land anchorages, it is built of silicon steel. This delightful bridge is one of the most beautiful structures ever erected in steel and contrasts to advantage with the Delaware River bridge of nickel steel at Camden, N.J. (32) and (33).

The Sydney Harbour bridge of carbon steel, with a span of 1,650 ft. and a width of 159 ft. 6 in., is the heaviest bridge in the world and would be a complete success but for the pylons. Its method of construction is one of the feats of the engineering world (34) and (35).

In general it consisted of building out an arch from two sides and holding the portions in equilibrium by means of cables passed over the abutment to anchorages in the rock. Upon meeting, the two half arches were forced together against resistance from the cables, to stress the members to working load conditions, the joint was then riveted, thus losing it and forming a two-pinned arch, the cables then being dismantled.

An experiment with this method of erection was carried out by Messrs. Dorman Long on the Newcastle bridge with the object of proving its efficiency, and fortified by excellent results, the hazard of experiment on the larger structure was eliminated.



(**35**) THE SYDNEY HARBOUR BRIDGE. Explanatory diagram of the method of erection.

STEEL

STRUCTURES · RESIDENTIAL · GENERAL

Structural steelwork for the framing of buildings generally, has been adopted so extensively throughout the whole world that it is surprising that so little advancement has been made in regard to steel framed houses. Isolated cases have appeared from time to time, and a number of tenement buildings and housing schemes have adopted it on the Continent.

Mendelsohn has used the steel frame with great success in constructing his own house on the outskirts of Berlin.

Messrs. Luckhardt and Anker, also of Berlin, have erected some of the most delightful modern houses, using the steel frame with slabs as infilling.

The French, led by Corbusier, have also contributed their share.

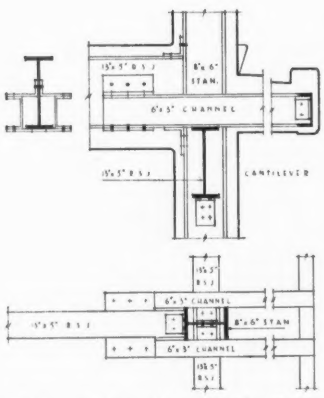
In England, however, apart from experiments by manufacturing firms to build employees' houses, little has been done. A house and hangar has been designed in steel frame construction by Raymond McGrath. It is apparent, however, that the scientific outlook towards the house as a modern structure has not yet been universally developed.

Of all interiors that have benefited most from structural steelwork the cinema and theatre certainly hold first place. With the rapid advancement in planning and span it was necessary to support balconies over great widths in as little depth as possible. These conditions have led to ingenious framing plans which generally consist of main girder, wing girders, and balcony rakers with fascia girder.

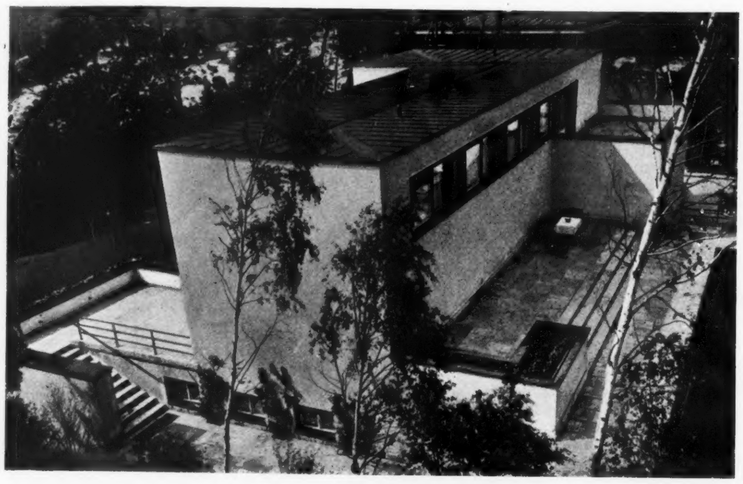
Light steel framing, steel doors and tracks have proved admirable for aerodrome buildings, including hangars, sheds, control towers, etc., and some very light and elegant structures have resulted.

Interesting developments in steel have taken place in the construction of aircraft carriers with their steel decks and rolling shutters to hangars placed immediately below decks, H.M.S. *Hermes* being an example in point.

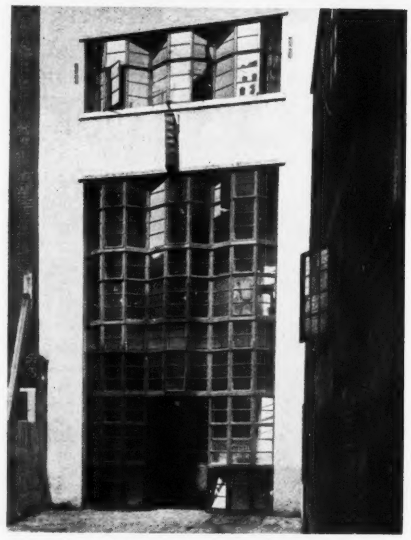
Great advancement has been made in roller shutters both in perfection and size, one at the National Physical Laboratory, Teddington, measuring 35 ft. by 35 ft.



(36) STEEL FRAME FOR HOUSE WITH CONTINUOUS CANTILEVERED BALCONY CONSTRUCTION



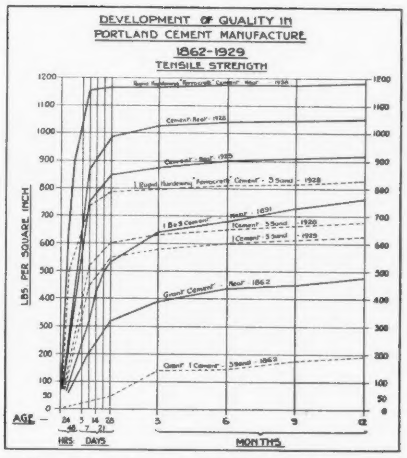
(**37**) (*above*). PRIVATE HOUSE overlooking forest and water near Berlin for own use by Erich Mendelsohn, *architect*.



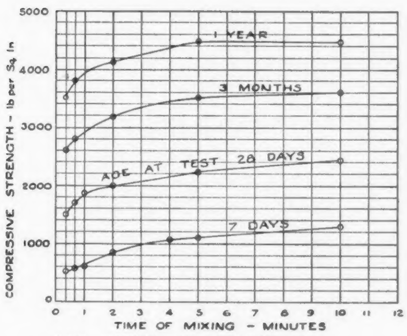
(**38**) (*right*). STEEL AND GLASS FACADE to a fishshop in London. Forbes and Tate, *architects*.

(**39**) (*below*). An unusual view of the FORTH BRIDGE.
Sir Benjamin Baker
Sir John Fowler } *engineers*.

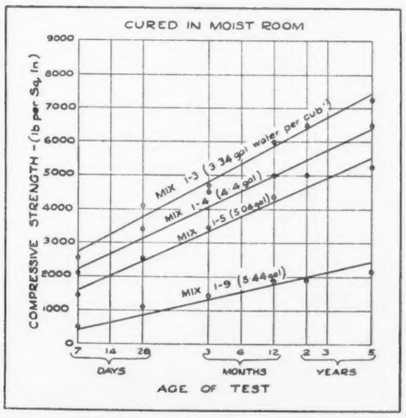
• THE EVOLUTION OF DESIGN IN CONCRETE •



(40) Chart showing DEVELOPMENT OF QUALITY.



(41) TIME OF MIXING Chart.



(42) STRENGTH-AGE Chart.

(43) Making the "SLUMP" TEST.

Concrete as the Romans knew it was a very different material to its present-day namesake. Its formula not being exactly known has caused mystery and glamour not justified by the probabilities that it was but a hydraulic lime. The historical progress is dealt with elsewhere, but it is well to note that in 1845 finer grinding, "clinkering heat" and other technical and chemical perfections, as well as lay-out of works, took place by Johnston at Swanscombe, from which time and place we can date the first true Portland cement.

The concrete designer, unlike the steel engineer with his single material in standardized sections, has to think in terms of six materials—namely, stone or other aggregate, sand, cement, water, steel and timber, and the apparently abstruse calculations of the elastic theory.

The personal element enters very strongly into the problem of perfect result, so much so that good judgment is as essential to success as mathematical skill.

Skilled concrete operatives are scarce and precious.

Keen, efficient and relentless supervision is essential for all concerned if every advantage of increased knowledge, research and improvement of materials is to be fully realized.

Four main types of cement are now used in concrete work.

Natural Cement.—Is now little used, and was the forerunner to Portland cement, to which it bears an inferior resemblance. It should not be used in reinforced concrete work.

Portland Cement.—The standard cement used here, and when up to British Standard Specification, the best for general use.

Aluminous Cement, with a different chemical composition to Portland cement, although a recent innovation, has an initial setting time of about three hours, with a rapid hardening within 24 hours, producing 5,000 lb. sq. in. compressive strength for a 1–2–4 mixture, as against a similar period of about 28 days with Portland cement to produce the same result.

Rapid Hardening Cement, on the other hand, is exactly similar in chemical composition to Portland cement, but is ground much finer, producing increased strength and a reduction of setting time to 48 hours before stripping.

It is now more generally realized that proper grading is absolutely necessary for economy alone. Cement should not be used as a void filler, as it usually costs 10 to 12 times as much as sand.

The use of aggregate should be limited to $\frac{3}{4}$ distance between reinforcing rods.

The subject of lightweight aggregates has been receiving more attention, and the water cement ratio is more acceptable as a generalization that the effect of water on the strength of concrete is much greater than the grading of aggregate, within the range of normal mixes. Laitance or scum will only appear in the case of usage of excessive water. Water-measuring tanks are now fitted on many mixers, as also time devices to ensure correct duration of mixing.

Cement Tests.—The present manner of testing samples of cement according to B.S.I. specification are :—

(*a*) Fineness.
(*b*) Chemical composition.
(*c*) Tensile strength (cement and sand).
(*d*) Setting time.
(*e*) Soundness.

It is interesting to record the support and encouragement to all forms of progress that is given by the very well organized and virile Institution of Structural Engineers. A specification for High Alumina Cements has been prepared by them and is an important step forward.

A progressive step was made in 1930 by the holding of the first international Congress for Concrete and Reinforced Concrete at Liege. Many excellent papers were given and discussions held between leaders of many nationalities.

Perhaps the least said about the L.C.C. regulations of 1915 the better. They cannot, however, be accused of encouraging progress in design. It is with great relief, therefore, that one learns of the appointment of a Reinforced Concrete Structures Committee by the Building Research Board of the Department of Scientific and Industrial Research at the request of the L.C.C. for the purposes of formulating a new code of practice.

Concrete has withstood the shocks of earthquakes very well in the past, and the introduction of hinged joints into concrete structures to resist earthquakes has ensured its pre-eminence in this sphere.

Resistance to Compression of Concrete,
M. E. Freyssinet,
Compte Rendu Société des Ingénieurs Civils de France, 1930.

Kind of Concrete.	lbs. per sq. in.
Ordinary	2,844
Carefully prepared and tested at one year from mixing (about 1910) [density 2350 k/m³ = 147 lbs./ft³]	7,110
In posts, pipes, ties and kerbs... ...	14,220
Probable achievements in near future	21,330 to 28,000
Concrete employed at Plougastel Bridge	
Concrete guaranteed by contract at 90 days	4,266
Plain concrete, using course aggregate of crushed quartzite held on 5mm. (0.195″ = 5 per inch) screened, with smooth regular pit sand of 1 mm. grains (.039″ = 25 per inch) consolidation in the moulds being by hand rammer	5,688
Estimated crushing resistance of concrete determined from calculated Young's modulus (5 to 6 × 10⁹ kilos per sq. metre = 7.1 to 8.5 × 10⁶ lbs per sq. in. for the whole arch	8,532

CONCRETE
MANUFACTURE

Portland Cement.—The most important individual item in ordinary concrete work, has to have the cementitious property, upon which designers rely, brought to the highest standard possible.

The main essential elements in the raw materials used are lime (CaO), silica (S_1O_2), and alumina (Al_2O_3).

Silica and alumina are both found pure in nature, but it is only in the form of clay or shale that they are useful. Lime, however, is not found free, but combined with carbon dioxide forming calcium carbonate ($CaCO_3$), which is found all over the world in limestone, chalk, and marl.

The raw materials are classified under two headings :—

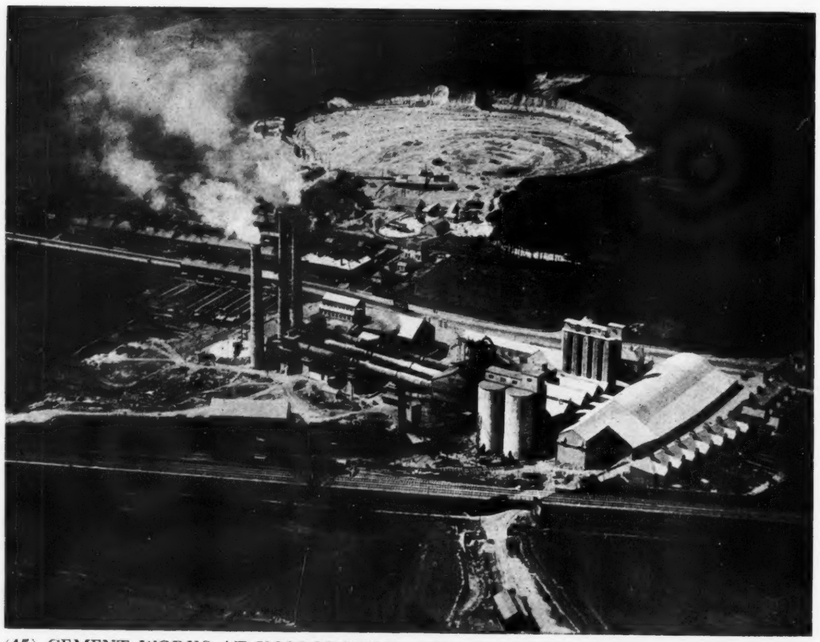
Calcareous.	Argillaceous.
Limestone.	Clay.
Marl.	Shale.
Chalk.	Slate.
Marine shells.	Blast furnace slag.

Two processes are adopted in making Portland cement, the "wet" and the "dry."

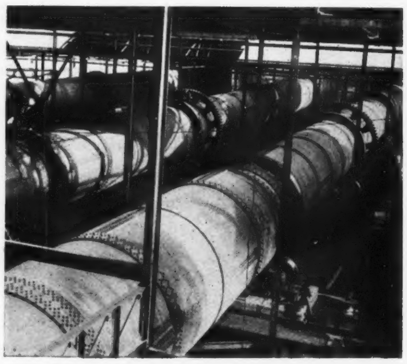
The Wet Process handles everything wet from quarry, as slurry to the rotary kiln for clinkering, with an addition of gypsum, and ground to the fine powder known as Portland cement.

The Dry Process requires the services of a crusher followed by drying in special dryers, then grinding to a fine powder termed "meal," which is afterwards housed in silos, from which it is drawn as required either from one silo or from several simultaneously to produce a mix, and placed into the kiln in dry powder form. It is then ground in the usual manner. Only the wet process is operated in the United Kingdom, but a greater number of plants in Canada use the "Dry" than the "Wet," although the U.S.A. is at present more "Wet than Dry."

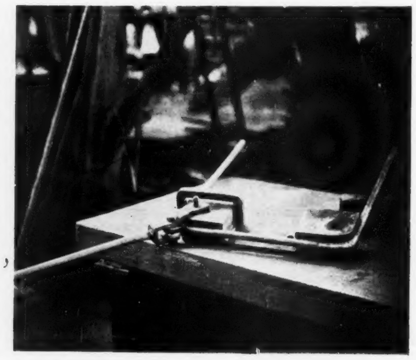
(**44**) Table of progressive steps in the MANUFACTURE OF PORTLAND CEMENT under both the Wet and Dry Processes.



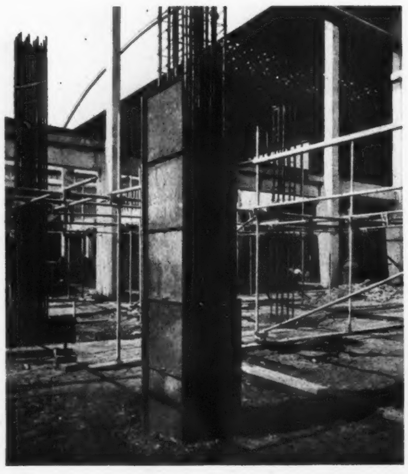
(**45**) CEMENT WORKS AT HOLBOROUGH. In the distance is the quarry and the slurry tanks. In the foreground are chimney stacks, grinding plant, rotary kilns, silos and despatch sheds.



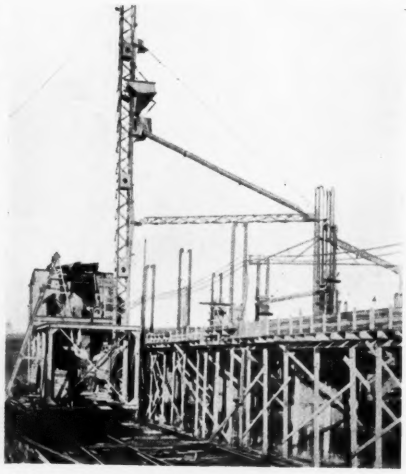
(**46**) THE ROTARY KILNS at Bevans works, in which the "clinkering heat" takes place.



(**47**) A small BAR BENDING BENCH. Larger and more complicated sets are available, but this indicates the procedure clearly.

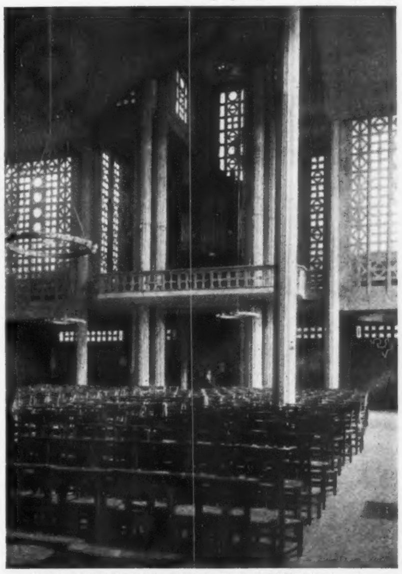


(**48**) METAL UNIT SHUTTERING, which can be used over and over again, and is an attempt to solve the problem of waste in formwork.

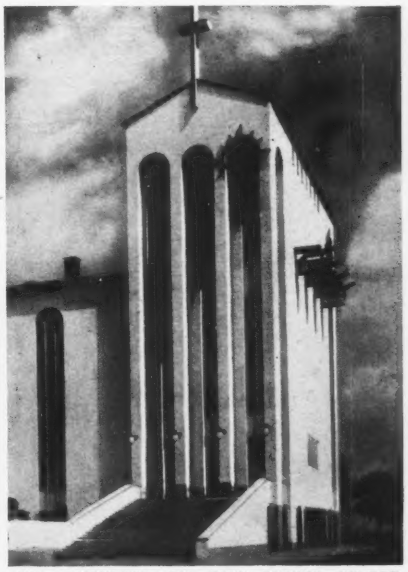


(**49**) A large MIXING PLANT, in which is incorporated a mixer on a track, with hoist, chute and distributing arms.

Photograph by F. R. Yerbury, Esq.



(50) CHURCH AT LE RAINCY, Paris. Perret Bros., *architects.*



(51) CHURCH OF THE HOLY CROSS, FRANKFURT a/M. Martin Weber, *architect.*

(52) CHURCH OF ST. BONIFACE, FRANKFURT a/M. Martin Weber, *architect.*

(53) THE KLAVINHO PALACE at the Brunn Exhibition. Fucho, *architect.*

CONCRETE

STRUCTURES . PUBLIC . CHURCHES

Very few important public buildings have been erected in concrete and left to express themselves as such. The nearest approach is often cast concrete facing blocks under the heading of reconstructed stone, whilst others are too often rendered with a skin that chips at the corners and flakes at every soffit or other condensation surface as at the G.P.O., Stuttgart.

Churches easily head the list of experiments in concrete design in buildings of a public nature.

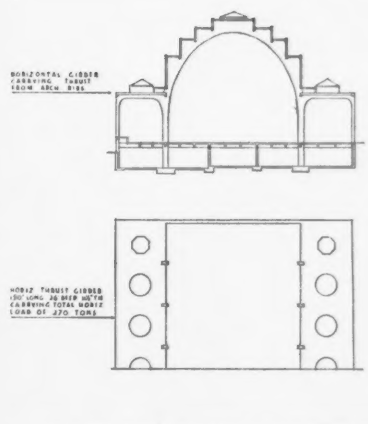
One of the most outstanding works is that of the famous Le Raincy Church at Paris, by the Perret Bros., with a barrel-vaulted roof, the side thrust being taken by deep beams over the aisles ; dead load only is imposed upon the internal columns, enabling them to attain the slender proportions that have been so much admired.

The Church of the Holy Cross at Frankfurt a/M. by Martin Weber is one of the most successful German efforts, being constructed of a reinforced-concrete frame and filled with concrete blocks. Weber is also responsible for a fine interior in another Frankfurt church, St. Boniface, the vaulted ceiling of which springs from the floor. The exterior, however, is of brick, which same habit is a common one with the Dutch.

As the science of acoustics is now affecting the third dimensional planning of churches, concrete, with its plastic-form, seems to be the most fundamentally adaptable material for the expression of new shapes, and avenues for expression in this material must open up for exploitation by those who really do understand the art of designing in concrete.

The very elegant parabolic arches of the Klavinho Palace of the Brunn exhibition are a true expression of concrete design, for one could not imagine them built in any other material.

A great field opens up for development in surface finish of concrete *in situ*, so that the material may then truthfully express itself.



(54) THE ROYAL HORTICULTURAL HALL, LONDON.
Easton & Robertson, *architects.*
Dr. Oscar Faber, *engineer.*

CONRETE

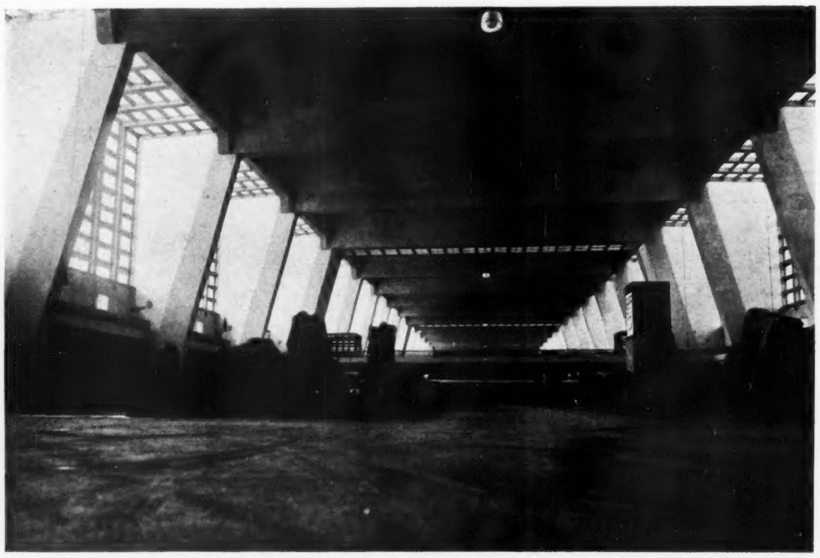
STRUCTURES . INDUSTRIAL

Two great names stand out in connection with industrial concrete buildings, namely, Freyssinet and Zeiss-Dywidag, the latter of which is the combination of the firms of Messrs. Zeiss, of optical fame, and Messrs. Dykerhoff-Widman, whose respective engineers, Dr.-Ing. Bauersfeld and Dr.-Ing. Dischinger, evolved the now famous Zeiss-Dywidag system of dome and vault construction to solve the problem of producing a light shell roof for planetariums. It is really daring in its conception, certainly economical, and has proved to be absolutely practicable and sane. The most interesting planetarium dome is that of Jena, which is 131 ft. diameter, 26 ft. rise, a radius of curvature of 93 ft. and a thickness of only 2.4 in., which is lighter in proportion than the shell of an egg. Leipzig Great Market has two octagonal ribbed domes of 249 ft., with shells of only 3½ in. and are the largest domes ever built.

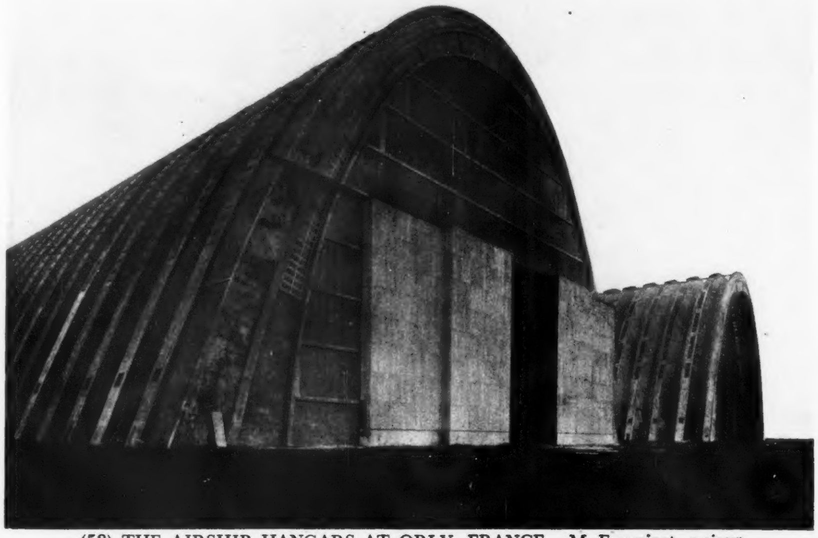
The Market Hall, Frankfurt, is the masterpiece of the barrel-vault type of the Dywidag system; it is a pity, however, that the exterior of the building does not fully express the construction. It consists of 15 barrel-vaulted shells of pumice concrete 2.8 in. thick, covered with insulation and composition roofing. In the construction a travelling scaffold was used, with movable steel vault forms; concrete being applied with a gun. The barrel vaults have solid ends and spring from rigid concrete frames.

Freyssinet's airship hangars at Orly are surely a masterpiece. Beautiful and original, they are also very sane in construction, for a bomb could drop through the envelope, or it could be riddled with shells without collapsing. Proof was obtained of this inherent collateral strength when, desiring to enlarge the side doors in height and width, the corrugated rib was cut through without needles or shores, the load distributing itself diagonally into the adjoining ribs. These qualities are unfortunately all too rare in reinforced-concrete construction.

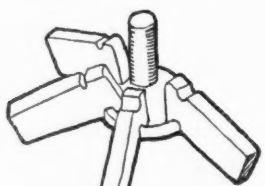
In the Market Hall of Rheims Freyssinet has again demonstrated his daring skill.



(57) Interior of the FRANKFURT MARKET HALL. Professor Elsaesser, *architect*. Dr.-Ing Dischinger, *engineer*.



(58) THE AIRSHIP HANGARS AT ORLY, FRANCE. M. Freyssinet, *engineer*.



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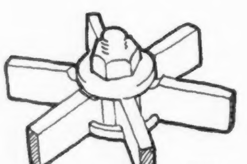
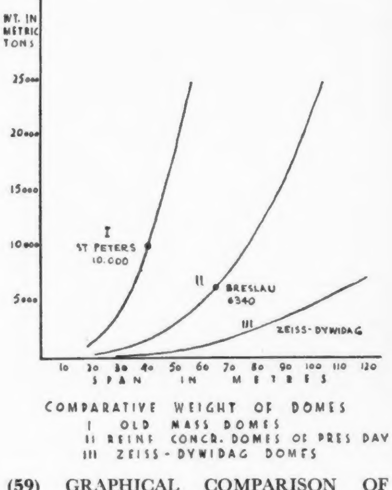
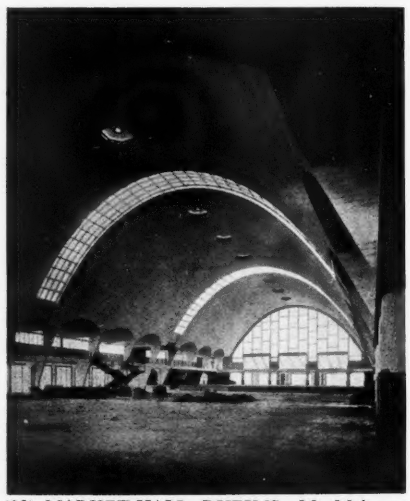


(56)

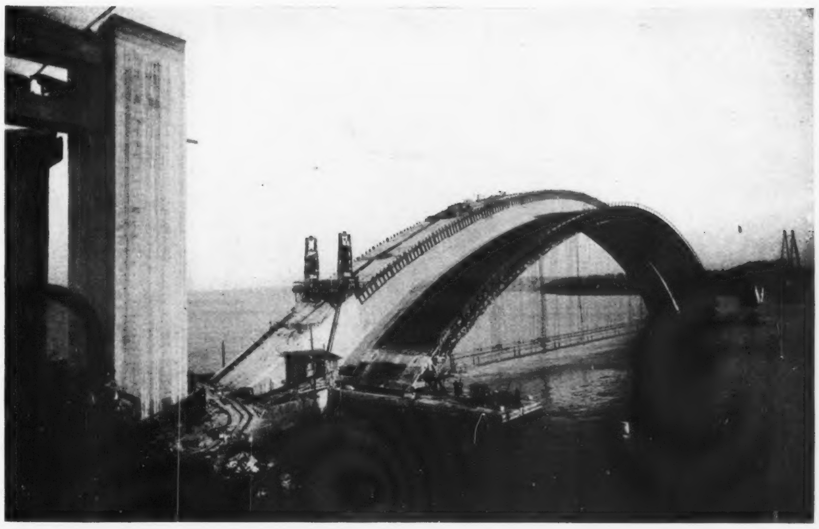
Sketches, before and after fixing reinforcing rods to obtain the THIN ROOF CONSTRUCTION (Zeiss-Dywidag) of the Frankfurt Market Hall.



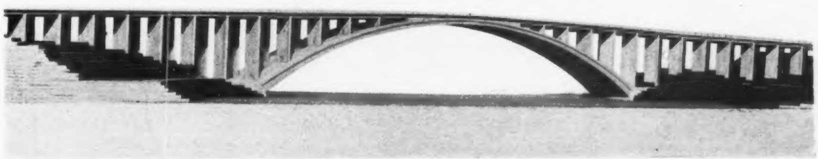
(59) GRAPHICAL COMPARISON OF DOME WEIGHTS.



(60) MARKET HALL, RHEIMS. M. Maigrot, *architect*. M. Freyssinet, *engineer*.



(**61**) THE ELORN-PLOUGASTEL BRIDGE AT BREST, showing the arched formwork being floated away after the erection of the first arch span. On the tower at the left can be seen the roadway (*above*) and railway approach spans, these carry across from arch to arch at this level. M. Freyssinet, *engineer*.



(**62**) A model of the new TRANEBERG BRIDGE which is being constructed in Stockholm from the designs of Ernst Nilsson, it has a span of 181 metres.

CONCRETE

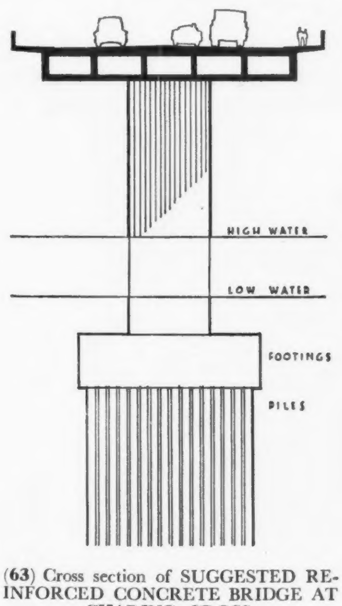
STRUCTURES : BRIDGES

At mention of the subject of concrete bridges one immediately conjures up the Elorn-Plougastel at Brest, and that ever recurring name Freyssinet, the greatest genius that concrete has produced.

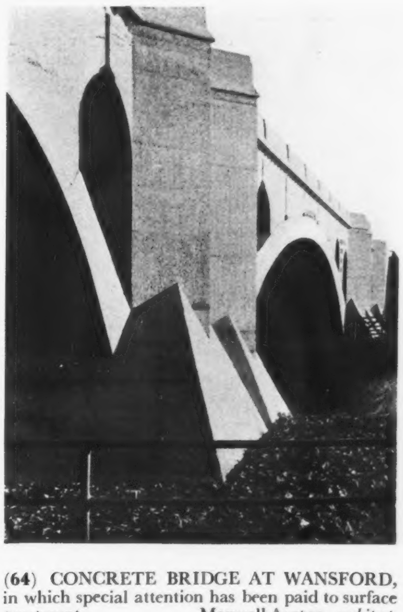
One of the most successful items of this achievement was the centring which was of wood, in preference to steel, as the elastic deformation was much greater than that of riveted steel and could withstand deformations ten times greater without rupture. This arched timbering rearing up from two pontoons was a thing of great beauty in itself, and was also economical, being used for the construction of all three arches. The great compressive strengths obtained (see page 187) were due to intensive laboratory and field tests. An interesting point in regard to the strength of the concrete was that early tests showed too great a sharpness of aggregate which prevented close packing between the constituents of the cement. By adding to the part of the crushed quartzite very small round sand, the crushing strength was increased enormously.

The largest reinforced-concrete bridge in England is the Berwick, with four unequal spans, the largest of which is 361 ft. 6 in.

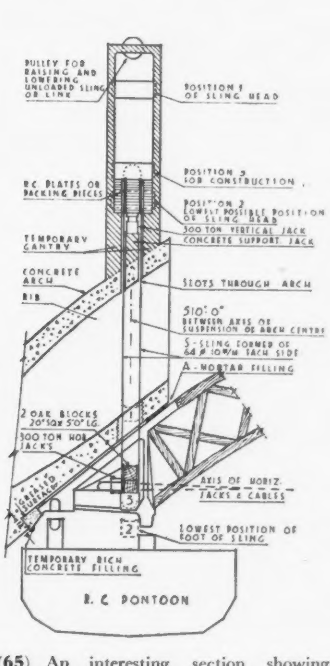
A very interesting partnership in concrete architecture and engineering is that of Maxwell Ayrton and Sir Owen Williams, who have to their credit quite a number of very fine road bridges in concrete throughout Great Britain, and it is gratifying to know that experiments have been carried out by them on the facing of these structures to express the natural qualities of aggregate used.



(**63**) Cross section of SUGGESTED REINFORCED CONCRETE BRIDGE AT CHARING CROSS.
Sir Owen Williams, *engineer*.



(**64**) CONCRETE BRIDGE AT WANSFORD, in which special attention has been paid to surface treatment. Maxwell Ayrton, *architect*.
Sir Owen Williams, *engineer*.



(**65**) An interesting section showing ARCH FORMWORK WITH POURED SECTION OVER.

CONCRETE

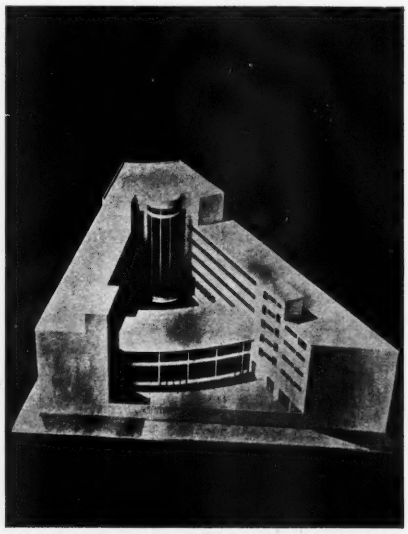
STRUCTURES · RESIDENTIAL · GENERAL

Concrete for residential work has not made the advancement it might have for several reasons. It is generally expensive to do properly and pour a monolithic job on account of the cost of formwork and the time taken in forming, pouring, stripping, etc., unless more than one house is needed, although advancement in the art of formwork has minimized these objections quite considerably. The use of the concrete block house unless done with the object of finishing with a rendered coat presents an unwholesome imitation of a stone house which, of course, is a retrograde step and does more harm than good to the advancement of concrete in this field. The solution seems to lie either in the cheapening of formwork, with a monolithic pour and treated surface, or in some form of unit slab precast in large sheets and joined *in situ*. Whatever the final solution, however, the problem is an interesting one for architects to tackle.

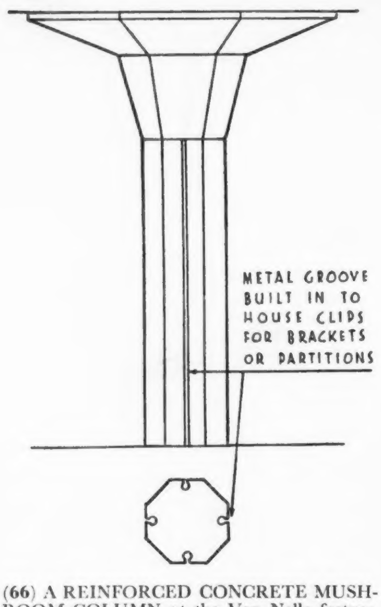
For speeding up concreting whilst eliminating the necessity for placing large spaces at the disposal of cumbersome mixers, a method of mixing the concrete "off site" came into being, this being supplied by special contractors. At first it was mixed in a stationary mixer and delivered in lorries to the job, being kept from segregation by large revolving paddles. The limitations of this method brought into being "transit" mixing which was virtually a complete mixer mounted on a lorry with a mix hauled dry. A few minutes before reaching the site, gear mechanism actuated by the driver throws the whole into motion, adding the required water and producing a perfectly fresh mix upon arriving at destination. Hundreds of these concerns are now operating in the U.S.A. and Canada.

(**67**) A BUNGALOW AND BOATHOUSE AT BOURNE END, Buckinghamshire, in concrete. Lucas Lloyd and Company, *architects*.

(**68**) The CONCRETE STAIRCASE at "High and Over," Amersham. A. D. Connell, *architect*.



(**69**) MODEL OF METAL WORKERS' UNION BUILDING, BERLIN. Erich Mendelsohn, *architect*.



(**66**) A REINFORCED CONCRETE MUSHROOM COLUMN at the Van Nella factory, Rotterdam.

(**70**) (*right*) VAN NELLA TOBACCO FACTORY AT ROTTERDAM. A night view showing the excellent design to advantage. This example is perhaps the most beautiful factory in the world. It is wonderfully conceived, planned and constructed and has aptly been termed an epic in concrete, steel and glass. J. A. Brinkman and L. C. Van der Vlugt, *architects*.

(71). THE CLASSIC TRADITION. A Greenhouse. Steel, Concrete and Glass in its Simplest Terms.

PREFACE TO THE ILLUSTRATIONS

IN fifty years time, should neither "civilization" nor the china-clay surface of this paper have perished, someone may look at this number of THE ARCHITECTURAL REVIEW. He will find the illustrations in the following pages interesting only as early examples in the history of architectural development. Today the reader may regret that these examples of steel and concrete construction are not confined to England. But neither are steel nor concrete, and since they are used more often and with more boldness abroad than as yet in England, the illustrations have been chosen to show the development of what is fast becoming an international style. In fact, internationalism characterizes their choice as it characterizes the style of architecture which steel and concrete are evolving. The organization of the industrialized part of the world does not admit of national boundaries and national styles: nor is the building of a church, as it was in mediæval days, the chief architectural accomplishment of the community by which it is surrounded: today the race-track, the sports ground and the theatre have taken its place. The illustrations have been set in an order intended to show this modern industrialization. Amusements come first, as they do in modern life. Then follow domestic and public buildings, and factories; the means of transport coming last.

Although many may criticize a civilization which has made of human existence an endless round between workshop and dormitory, whose monotony is relieved by sport, unless they are deliberate escapists, they cannot fail to recognize the beauty of the architecture which expresses it. Race-tracks, flats and houses, offices, factories, locomotives, roads, bridges and pylons, are as sincere an expression of contemporary ways of living as were the country houses of the eighteenth century and the cathedrals and castles of the middle ages.

This selection of illustrations has been made from thousands, and it was felt that the plan of illustrating modern industrial conditions would have been spoiled if the photographs had been divided under the separate headings of steel and concrete. For the lay reader it might be well to mention that because a building looks "white" it is not necessarily built entirely of reinforced concrete. Many steel-framed constructions are clothed in concrete; indeed, nearly all are covered by some facing material.

In a compilation such as this it would have been absurd to attempt to be too technical. The sole aim of this issue of THE ARCHITECTURAL REVIEW is to stimulate a wider recognition of the new conditions of building.

The illustrations numbered 74, 96, 147, 149, 167, 171, 192, 199, 206, 208, 212, 215, 217, 223, 228, 255, 275, 289, 290, 291, 293, 294, 296, and "The Human & Monkey Staircases" on page 264 are reproduced by courtesy of "The Concrete Way." Other acknowledgments appear under their illustrations.

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(**72**) and (**73**) THE COVERED TENNIS COURTS, STOCKHOLM (1930), Ture Wennerholm, *architect*.

Reinforced-concrete buildings are divided into two main types : structures poured as monolithic entities, including their roofs and walls (such as coal-bunkers or silos) ; and frame structures which are designed to be filled in and faced with other materials (like blocks of flats or offices). The barrel-vaulted building shown above is to some extent a hybrid example. In the galleries the ribs are isolated as in frame construction, while the continuous concrete in fillings of the rest of the vault make a monolith of the whole. In THE COPENHAGEN COURTS, built in 1912, illustrated in (**74**) on page 196, the galleries are placed much lower, and the skylighting is directly overhead instead of from both sides.

The simplest illustration of how the respective properties of steel and concrete supplement and counterbalance each other in combination can be seen in the cross section of an ordinary reinforced-concrete beam. Here the steel reinforcing rods will be found grouped to a greater extent in its lower than in its upper area. This is because, when loaded, a beam has to sustain pressure from above and counteract pull from below. In cantilever construction, on the other hand, the pressure zones lie underneath and the tensile strains are encountered above ; so that cantilever spans for balconies, etc., have to be designed as reversed beams. For flat roofs, however, the position of the reinforcement is the same as in an ordinary supporting beam. Inversely to steel, the bigger a reinforced-concrete member, the less it costs per cubic foot.

One of the characteristics of reinforced-concrete construction which enables it to be distinguished from steel construction squared off in concrete, is the noticeable

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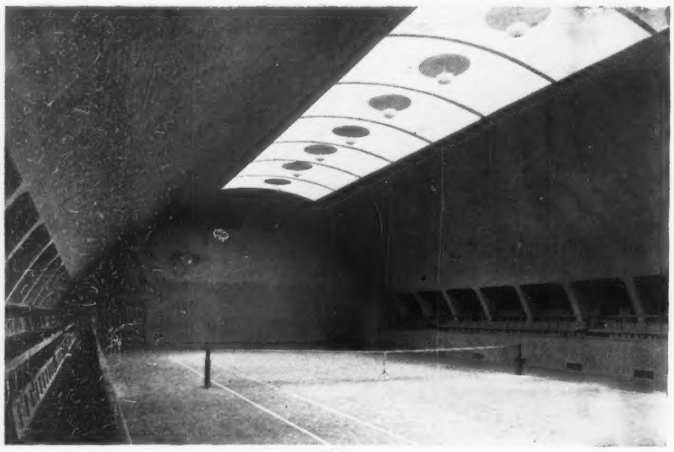
swelling at the junctions of stanchions and beams. This is due to the fact that the strength of the reinforcement in these ligaments has to be increased to take the "shear." The principal differentiation between frame construction in reinforced concrete and timber is that in the former main and subsidiary beams are directly connected instead of being superimposed as in the latter. Both space and material are economized as a result, and better lighting is ensured.

Unless considerable height is required, roofing supported by a framework of beams is seldom employed; but what is called "shed-construction," which is really a ridge-and-furrow variety of it, is common enough in factories owing to its lightness and cheapness. Shed construction is also ideal for long uninterrupted expanses of skylighting. Arched construction has many advantages over beam construction, and can be adopted for either ribbed or flat roofs; the span required being the determining factor. In the former, which is usually preferred in France, the strengthening ribs are generally carried outside the vault; but the arch thrust has to be taken up by connecting transverse struts, or counteracted in the foundations. In semi-circular roofing, which offers still greater advantages and simplifications, the impost can lie at floor level, the ties being placed in the flooring so as to leave an unencumbered interior; or here again (as in Freyssinet's airship-sheds, and the Rheims Market Hall) the arch thrust can be provided for in the foundations. In ribbed dome construction the cupola is supported by a series of converging beams (which are interconnected by a complex of transverse ties) united by one ring at the crown and another linking the piers they spring from, or embedded in their foundations. At the *Jahrhunderthalle* in Breslau the lower ring is carried on four huge arches utilized to form four large exedræ.



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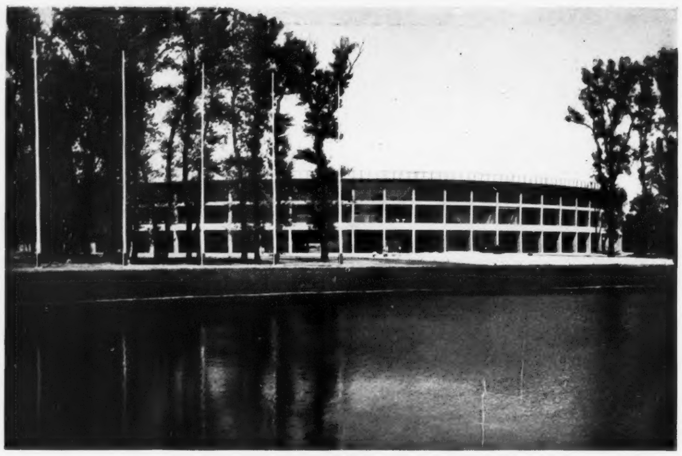

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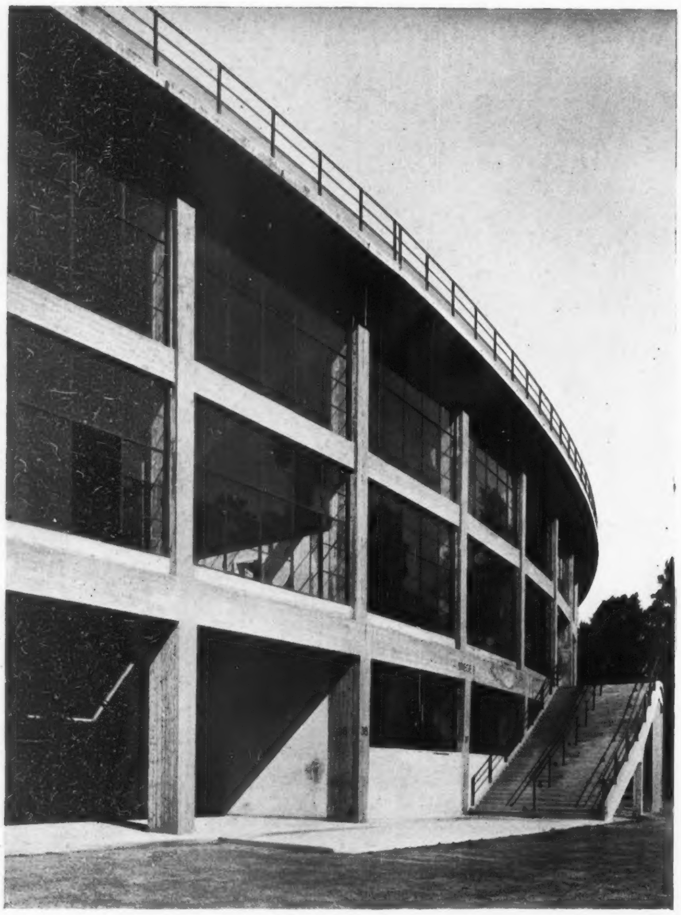

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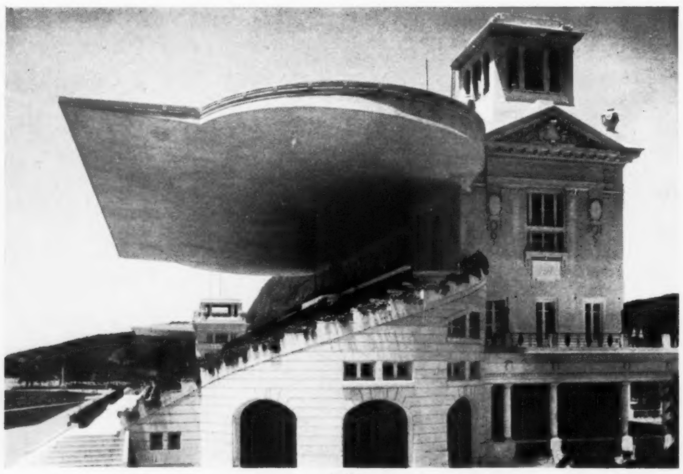

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STADIUMS AND GRAND-STANDS.

Illustrations (**75**) and (**76**) stand in forcible contrast to (**77**) and (**78**). The former show the exterior of the NEW STADIUM IN THE PRATER AT VIENNA, designed by Professor Ernst Schweizer, the architect of the even better-known Nuremberg stadium; the latter a general view of the four GRAND-STANDS AT RIO DE JANEIRO RACECOURSE, and a detail of one of the two larger canopies. The old world evinces a deliberate preference for the utmost simplicity; the new parades its morbid craving for bygone European splendours. In Vienna the design is based purely on structural elements—beams and posts with equally-spaced windows between them. In Rio de Janeiro the effect of some of the most magnificently audacious cantilevering in the whole world is irredeemably vulgarized by "architectural" reminiscences of all that is worst in Paris boulevards. (**74**), (**77**) and (**78**) are reproduced by courtesy of Christiani & Nielsen, Copenhagen.

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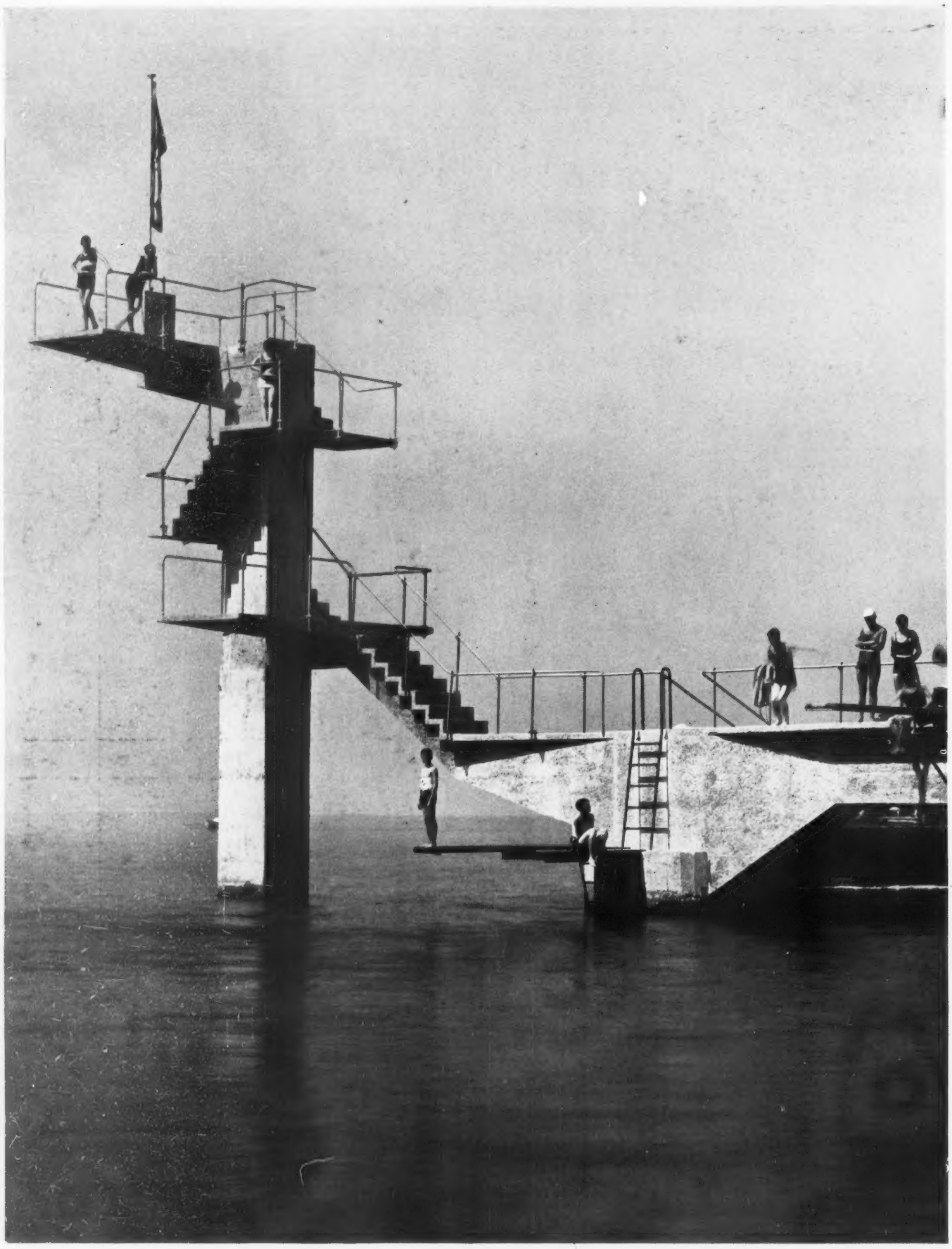
(79) shows a section of the seating accommodation of a vast AMPHITHEATRE photographed by Imogen Cunningham. The entire structure was carried out in concrete so that the audience, of necessarily immense proportions, should be less conscious of the physical "break" separating their serried rows of seats from the spectacle below them. Miss Cunningham chose to photograph the auditorium steps alone in order to give her composition "poetic functionalism." To understand the full pictorial significance of her photograph the picture should be held upside down so that the sweeping lines of shadow can be studied in their most intriguing aspect. Then the bands of white concrete steps, being suddenly divorced from all relation to reality, become the crochets of a musical notation in a great descending scale. The musical symbol for the curving concrete notes is rather striking, considering that these tiers of steps were adopted by the architect for the convenience of those attending massed orchestral concerts, or musical pageants. **(80)** is a cycling track—or, as the French call it, a VELODROME—IN BERLIN. The roof is supported by ribbed-steel, three-pin, webbed-plate roof-trusses; and the track on an amazingly slender triangulated framework.



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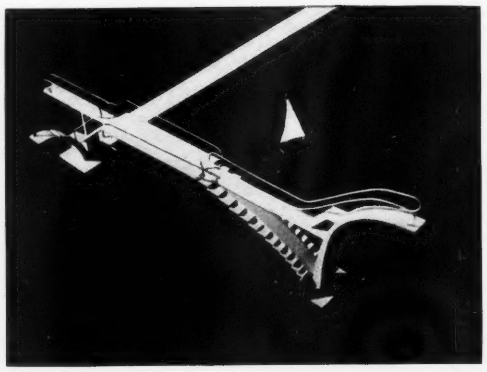

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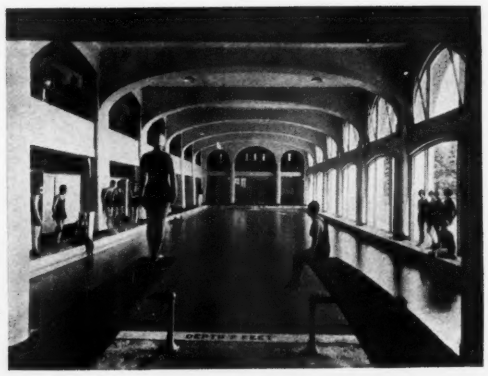

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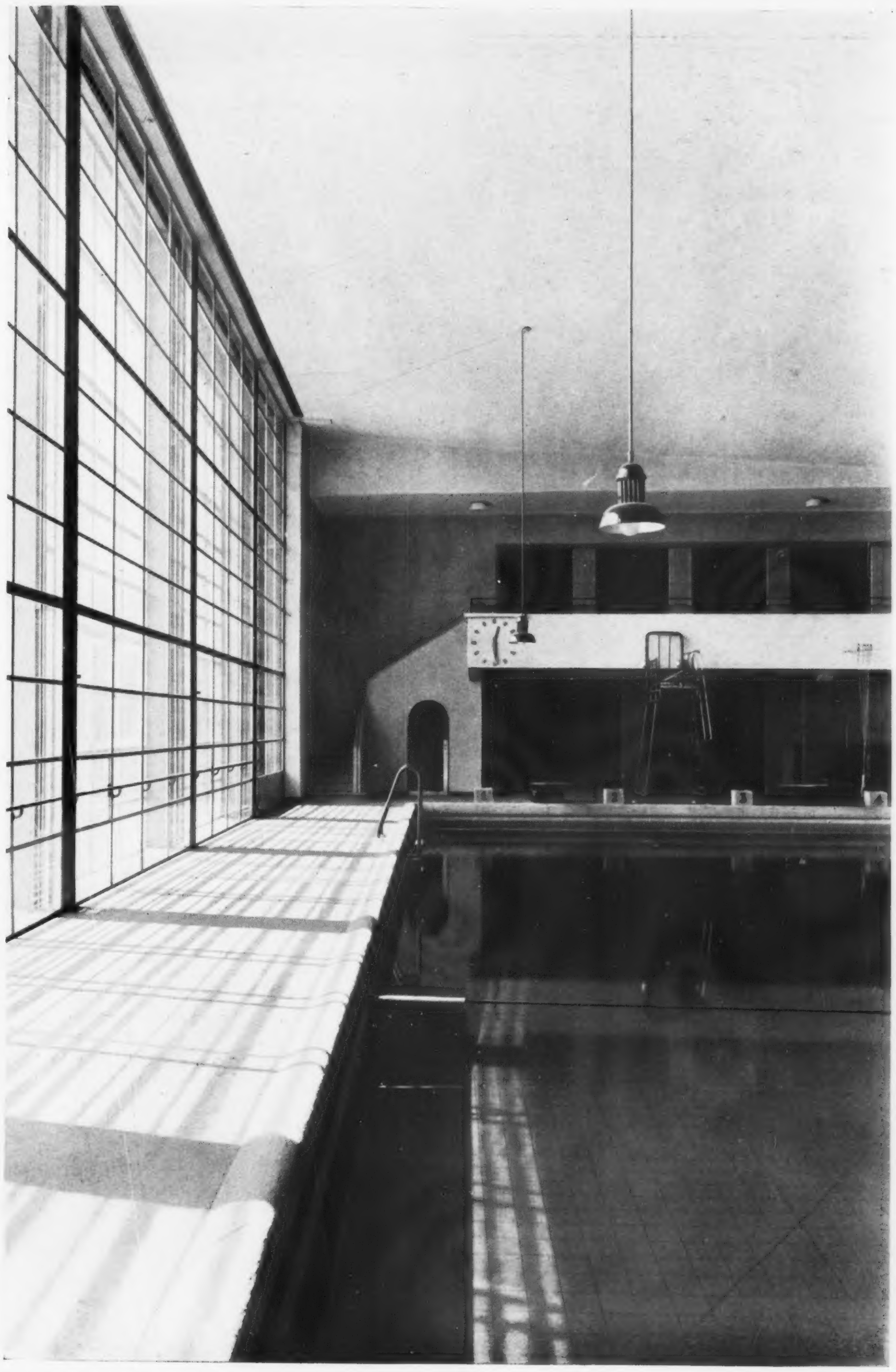
BATHING PLACES AND DIVING PLATFORMS

The sudden popularity of swimming, the result of a tidal wave of mass-suggestion, created an apparently insatiable demand for what stalwart Victorian pioneers used to call "bathing facilities," both under cover and in the open air. Concrete provides the most economic and satisfactory material for all types of waterside and underwater construction like piling, locks, moles, quays, sea-walls, etc. Being non-erosive and easily waterproofed, it is the most practical means for making an artificial pool. The earliest precedents for this particular use are to be found in nineteenth-century exemplars of our English "public baths."

(85), **(86)** and **(87)** show different aspects of the FECHENHEIM MUNICIPAL BATHS, FRANKFORT-ON-MAIN—perhaps the most perfect example of the indoor swimming bath yet built—designed by Professor Martin Elsaesser. As in Mallet-Stevens's bath at the Comte de Noailles's villa at Hyérès, and the rather banal enclosed bath of the Canadian Pacific Railway's HOT SPRINGS HOTEL, BANFF, ALBERTA **(83)**, one of the longer sides can be thrown open in warm weather. The adjacent open-air bath at this hotel **(84)** has been spoilt by the sort of finicking treatment that is conventionally described as "architectural."

One of the finest, because simplest, open-air baths is the Rappenwört



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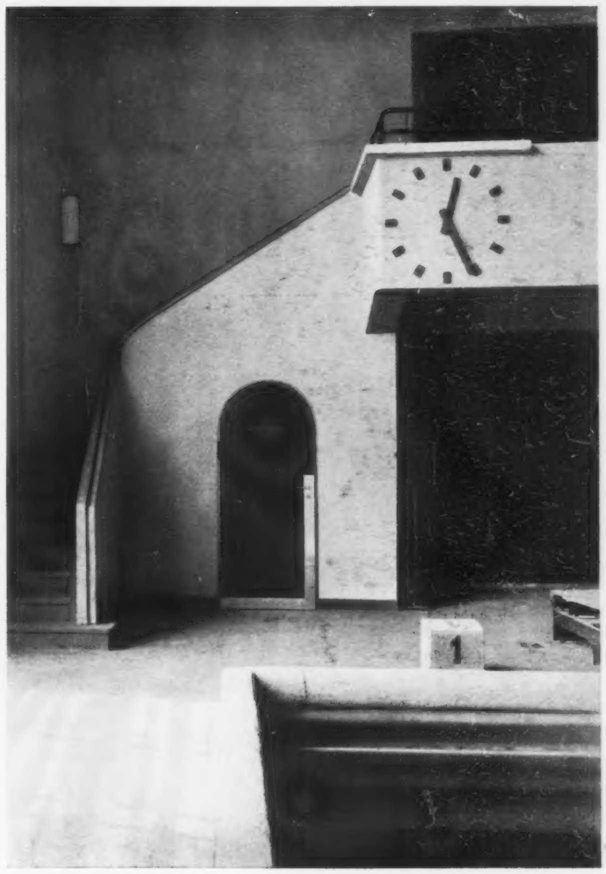

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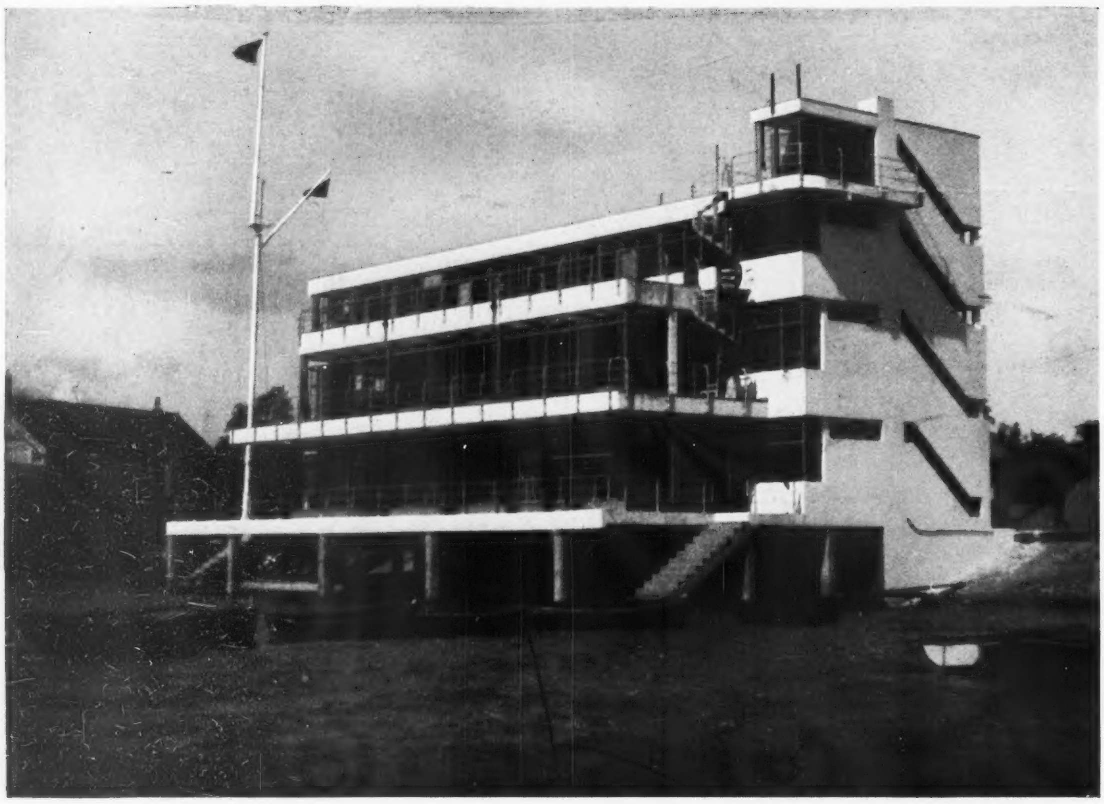
Rheinbad, Karlsruhe, which has a scimetar-shaped basin 500 metres long that widens to 140 metres in the middle. The total cost, including buildings, was £54,000; as compared with £75,000 spent on the 376 by 172 feet basin and pseudo-classical fripperies of the grotesquely-named "Natatorium" at Blackpool.

Perhaps the most extraordinary example of cantilevering ever built was the belvedere eyrie erected for a local exhibition at Köslin, in Pommerania, in 1912, where two open staircases met in mid-air at an angle of 45 deg. like a capital "V" lying on its side. The same principle of aero-dynamic equilibrium is embodied in the diving-board of Hermann Tamussino's Mödling *Freibad,* Vienna. Otto Zollinger's well-known spring-board at the CORSEAUX "PLAGE" NEAR VEVEY, on Lake Geneva (**81**), is another good example of the curious staircase patterns that are quite naturally evolved in solving cantilevering problems. An even better and more recent one is that at Ascona, on Lake Maggiore, designed by the same architect, which rises over the water in the form of a gigantic bowsprit fraught with a triple tier of overhanging platforms. (**82**), reproduced by courtesy of *Arhitektura* of Ljubljana, is the model of another finely imaginative DIVING PLATFORM that has been designed by N. Dubrović, a leading Jugoslav architect, for a new bathing-place on the Dalmatian coast.



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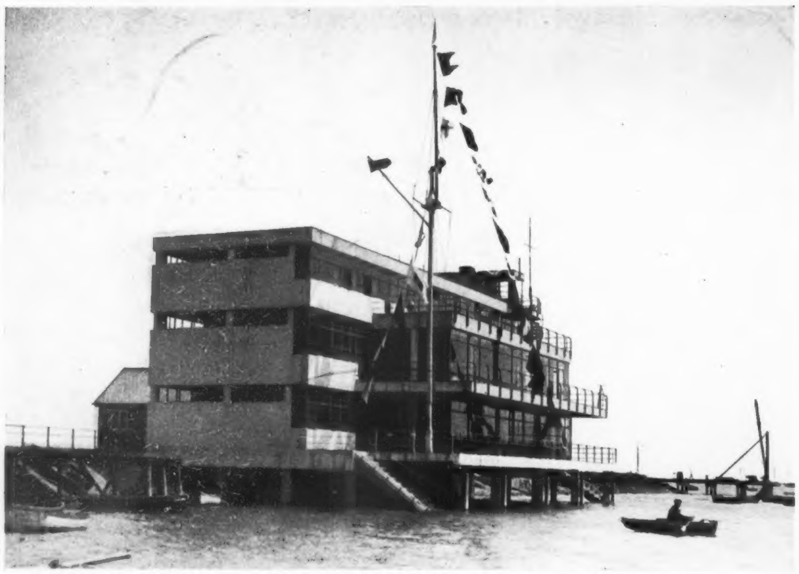

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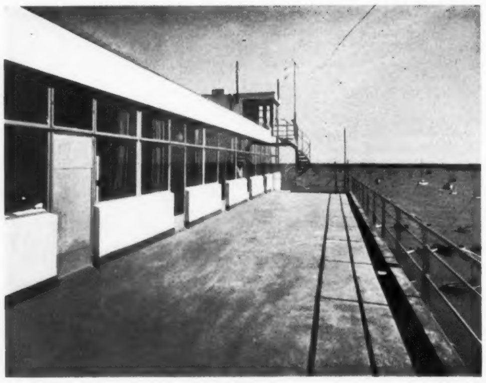

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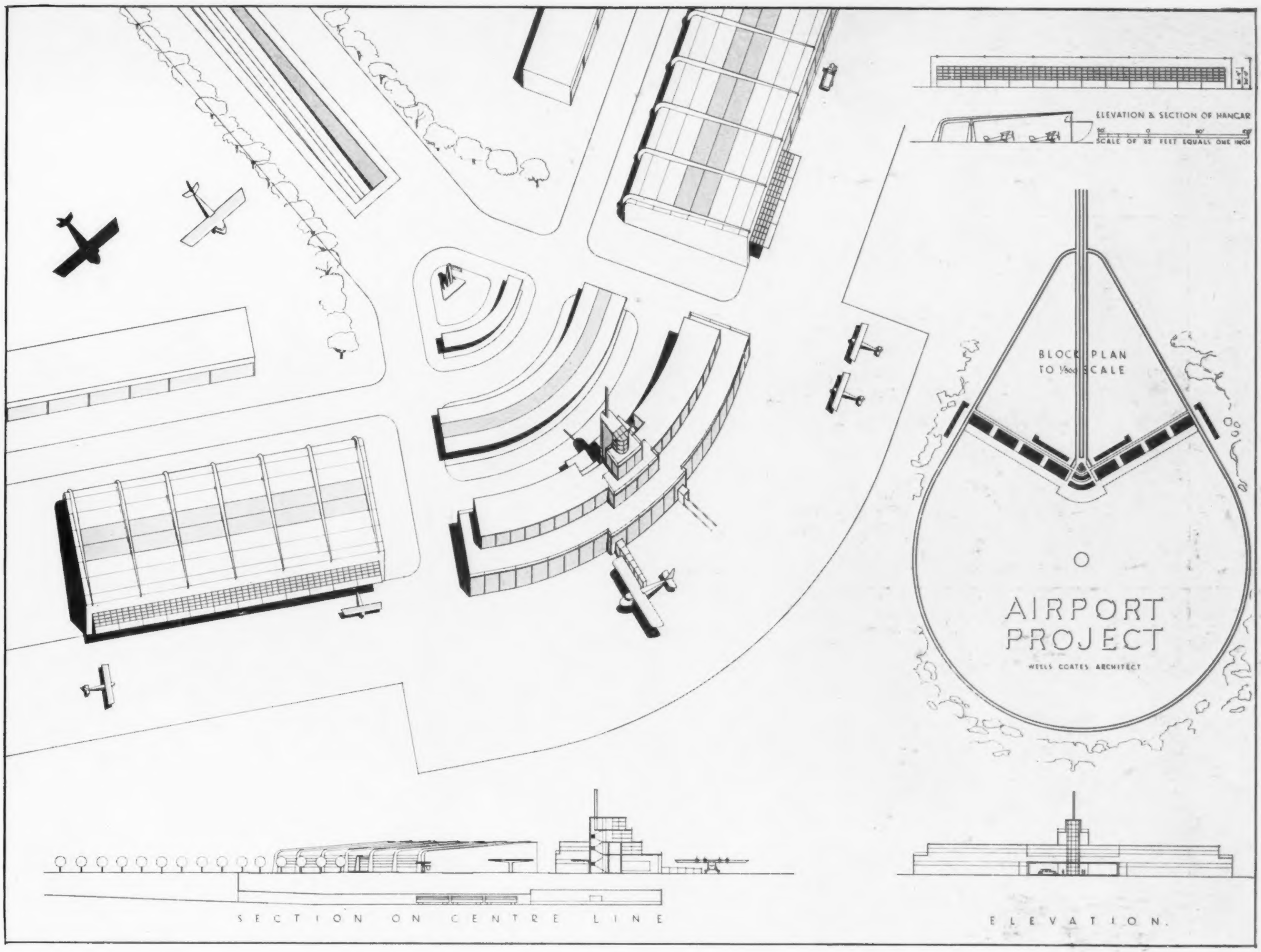
The cast-iron shelter on the Esplanade wriggling with decoration, the deserted prickly bandstand and the Tudor Boat Club, familiar results of municipal effort at the seaside, compare unfavourably enough with the YACHT CLUB AT BURNHAM-ON-CROUCH, ESSEX, Joseph Emberton, *architect*. This yacht club is dignified and serviceable. The architect has made a building as useful on shore as the yachts of its members are on the water.

An interesting point about the building is that it has been found when keeping the interior at 60 deg. F. the heat losses are balanced by the sun gains at a temperature of 35 deg. F. (a very cold winter temperature) when the sun is shining. As Burnham-on-Crouch is one of the sunniest parts of England, and has an average of 800 hours of sunshine from October to May, the considerable amount of glass, which at first sight would appear a liability from a heating point of view, is, in fact, an asset. **(88)** is a view of river front taken from the south-west, showing the reinforced concrete piles carrying the reinforced concrete slab which provides the foundation for the steel frame structure of the building. The panel walls are of 4½ in. cavity brick, rendered with white Portland cement. **(89)** the river front from the south-west, showing the whole of the south front glazed with steel casements, the stanchions being set back from the face of the building in order to provide unobstructed view both up and down the river. The whole of the South wall and the protected east and west faces of the projecting main rooms are entirely of glass. The north, north-east and north-west walls which are exposed to the prevailing cold winds, have been provided with very little glass in order to minimize heat losses. **(90)** shows the projecting balcony of the starting box, from which a view of the Thames Estuary, 30 miles away, can be seen. **(91)** is the terrace outside the bedrooms on the third floor; the starting box can be seen in the distance.



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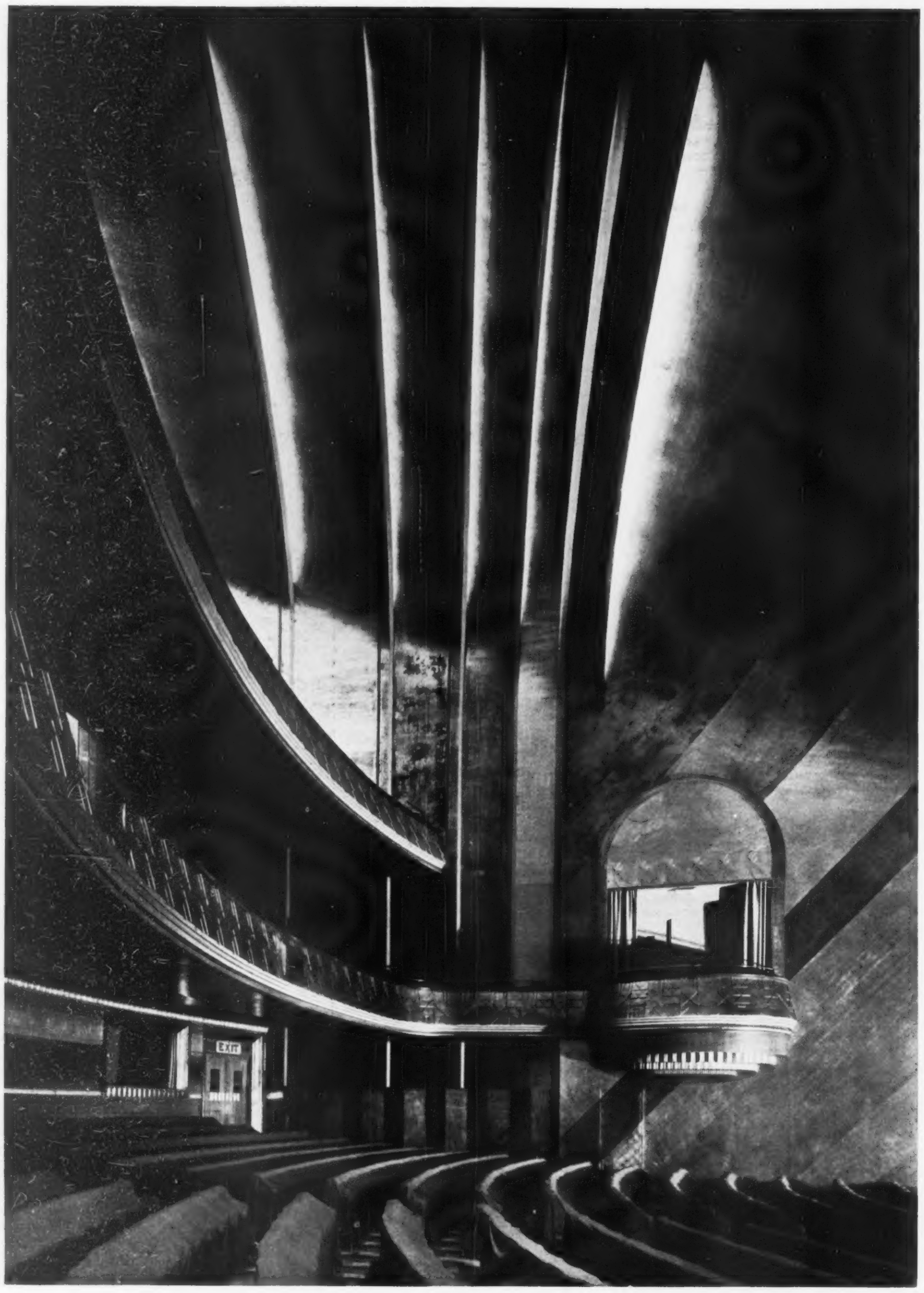
(92) DESIGN FOR AN AIRPORT, Wells Coates, *architect. The Block Plan* shows the layout of Station buildings, aeroplane sheds, manufacturers' shops, Flying Club and Hotel, etc., and the landing field. The main one-way approach roads, with electric railway between (arriving *under* the Station—see section), are on the central axis, and the prevailing winds are at right angles to this axis. The secondary approach road for spectators, etc., describes a pear-shape round the airport and passes by the Flying Club and quarters at one end of the aeroplane sheds, and the Hotel and Golf Course at the other.

The Isometric illustrates the Station buildings and the layout of roads and "aprons" round it; the covered car park, petrol pumps, etc.; the first floor restaurant and terrace, with the Control rooms and tower over; the telescopic "loading canopy" extended to the doors of a large passenger plane about to leave the airport; and two of the main aeroplane sheds.

Construction. The main buildings are designed to be constructed of steel, pumice concrete and "aero-gell silicon"—a material recently produced in the laboratory—which is (*a*) the most highly insulating and (*b*) the *lightest* material so far discovered, and can also be made in *opaque* and *transparent* forms.

The aeroplane sheds have an unrestricted opening 288 ft. long facing the landing field, and are provided with electrically operated and balanced "canopy doors" which give a normal opening 20 ft. 9 in. high. To reduce overall heights and to save space all round, these doors are designed to be lifted vertically when in a fully "open" horizontal position, to provide a maximum opening 25 ft. 9 in. high for the access of the largest land planes.

The main structural elements of the aeroplane sheds are designed to be constructed of sheet magnesium alloy built up and specially braced and anchored, in tubular forms, with light lattice girders of the same material acting as tie-beams. Magnesium alloys 40 per cent. lighter than aluminium have already been produced with tensile properties almost equal to steel. The raw material—magnesium—will eventually be electrolytically extracted from sea-water. The roof-slabs and "canopy doors" are built up in frames of magnesium alloy and "glazed" with "aero-gell silicon." The extremely light weights, and strengths, of these materials allow a 100 ft. cantilever to be constructed without difficulty; and it is assumed that the sheds would be made up in easily assembled parts, by aeroplane manufacturers, the details and materials of construction being similar to aeroplane construction. At the back of the sheds are the machine shops and repair shops, etc., 30 ft. deep.



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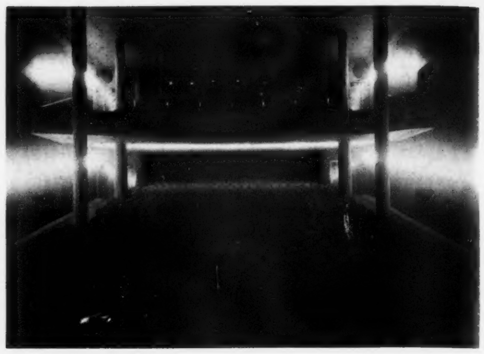

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T H E A T R E S   A N D   C I N E M A S

In theatres and cinemas steel and concrete galleries seating hundreds of spectators now span what are, optically, " impossibly " wide spaces between wall and wall without any visible sign of bracket or pillar supports. (93), the CAMBRIDGE THEATRE, LONDON (of which Messrs. Wimperis, Simpson and Guthrie were the architects, and Mr. Serge Chermayeff the interior decorator), shows a sickle-shaped balcony slung on steel-girders; whereas the balcony in Professor Hans Poelzig's " BABYLON " CINEMA, BERLIN (96), like that shown in (94) and (95), Uno Åhrén's " FLÄMMAN " CINEMA, STOCKHOLM, is an example of reinforced-concrete cantilevering. (The four columns in the latter support not the balcony, but a six-story building on top of the roof.) As both serve working-class districts, they naturally embody the cheapest possible type of construction; yet, for all their plainness, both have far more effective interiors than the usual lyrically " atmospheric " or fulsomely gaudy " super-cinemas." Each is the logical consequence of allowing the type of æsthetics peculiar to concrete to dictate the type of decoration. In other words, structural and acoustic features become decorative motifs that only need to be completed by the judicious colouring and lighting of their surfaces—which is, of course, equally true of the steel-framed Cambridge Theatre. An even finer vindication of the absolute purity of form that can be

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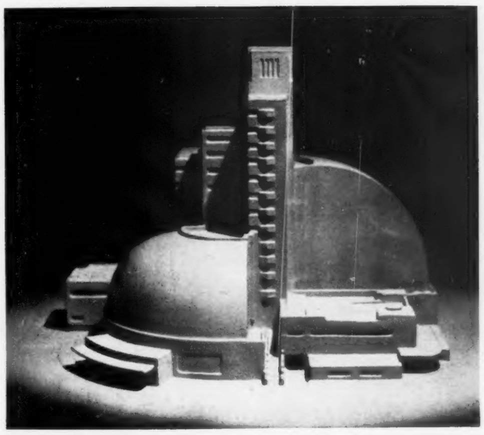

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achieved by uncompromising acceptance of the nature of concrete as a material, and the æsthetics it implies, is the interior view of the UNIVERSUM CINEMA, STUTTGART (**98**), designed by Herren A. Eitel, P. Schmohl and G. Stachelin, reproduced by courtesy of *Moderne Bauformen*.

(**97**), an example of the reverse of the medal, shows a model of Norman Bel Geddes's "NO. 6 REPERTORY THEATRE" FOR THE CHICAGO EXHIBITION OF 1933. In this design a large and a small theatre, seating 1,700 and 500 spectators respectively, are asymmetrically combined in a building 84 ft. long by 56 ft. wide by a central tower. The tower, which is 210 ft. high and has 19 stories of an average area of 2,848 sq. ft., contains 100 dressing rooms, besides rehearsal rooms, scenery store-rooms, offices, workshops and water tanks. There are no prosceniums, transverse aisles or galleries in either theatre; and every seat has plenty of leg room, and direct access to the exits. In each a single dome, which forms a vast cyclorama embracing walls and ceiling, spans stage and auditorium; with the result that the back of the stage can be kept entirely clear of ropes, battens, drops, borders, etc. The stage of the larger theatre is 52 ft. wide, and that of the smaller 24 ft. Included in the same building are a cabaret hall for 250 persons, a children's theatre seating 200 (with a separate gallery for 60 adults), and a roof garden that can be used for open-air rehearsals.

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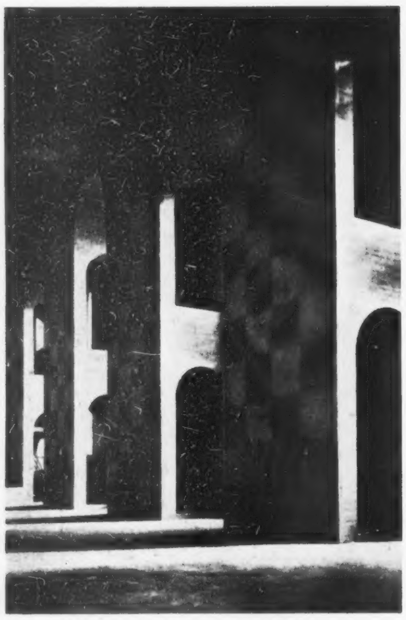

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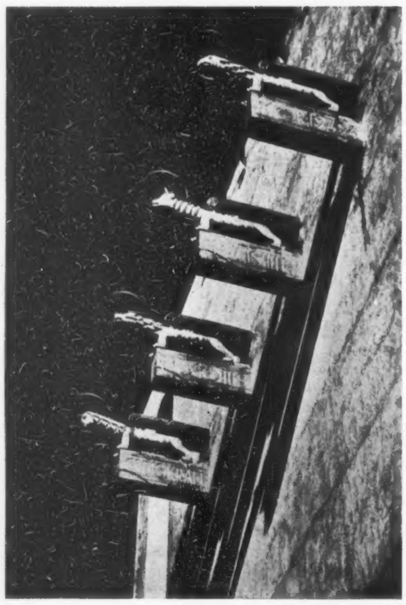

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CHURCHES IN CONCRETE

Roman Catholicism has never identified itself with any one architectural style (perhaps because Victorian Protestant communions have so seldom swerved from their allegiance to Gothic), and it is interesting to find that the church which is based on the most immutable traditions in doctrine and ritual was the first to patronize architects working in modern materials and modern idioms. All the "sacred edifices" illustrated on these pages serve Roman Catholic congregations. The first in point of time were the Brothers Perret's famous NOTRE-DAME DU RAINCY (**104**), and Sainte-Thérèse at Montmagny, built in 1923 and 1926 respectively. An even finer design by the same architects for a basilica dedicated to St. Joan of Arc has unfortunately remained on paper. The Czech architect, Josef Gočár, whose "stepped" CHURCH AT VRSOVICE, NEAR PRAGUE (1930), is reproduced in (**106**), had realized the true æsthetics of concrete in his monumental screen and staircase to the old Marienkirche at Königgrätz as far back as 1910. Dominikus Böhm, the most prolific and original designer of concrete churches in Germany, is well represented here by the interiors of those he has built at BISCHOFSHEIM and NEU-ULM (**103**) and (**107**). Otto Bartning's "Sternkirche," which may be described as an attempt at "Expressionist" architecture that subordinates certain structural potentialities

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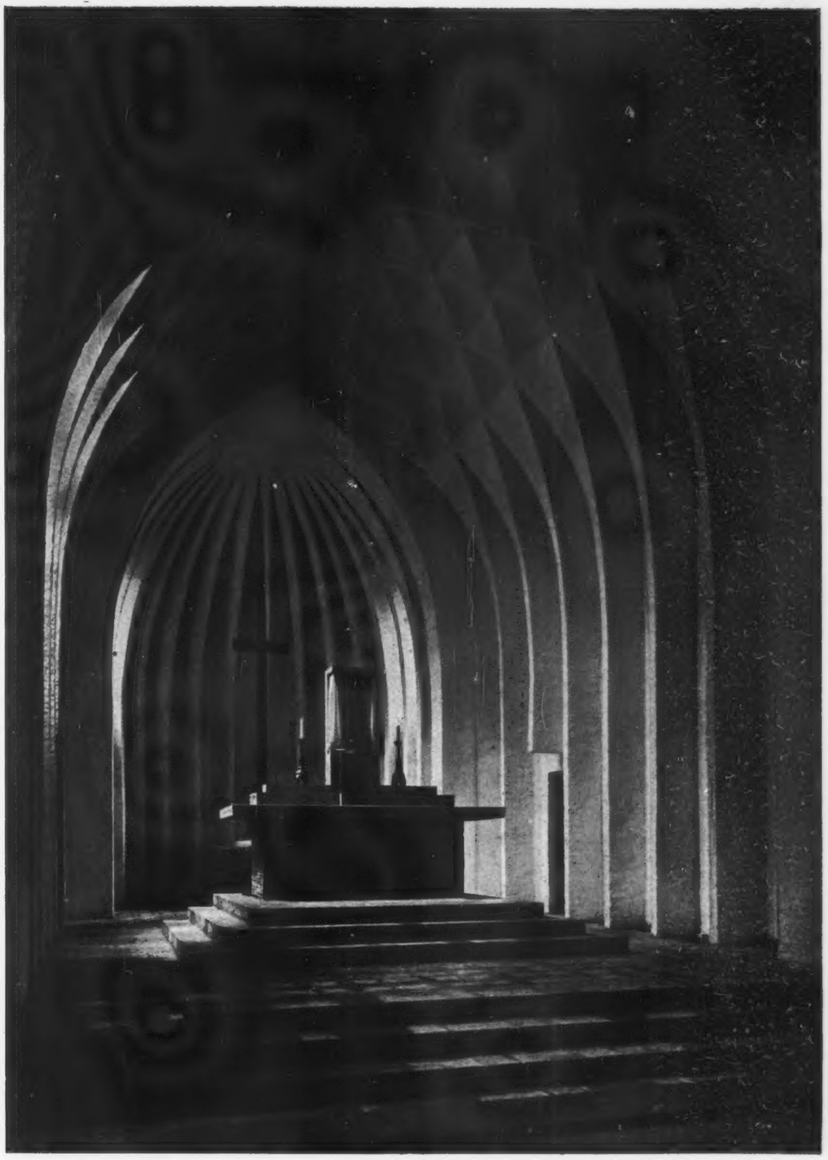

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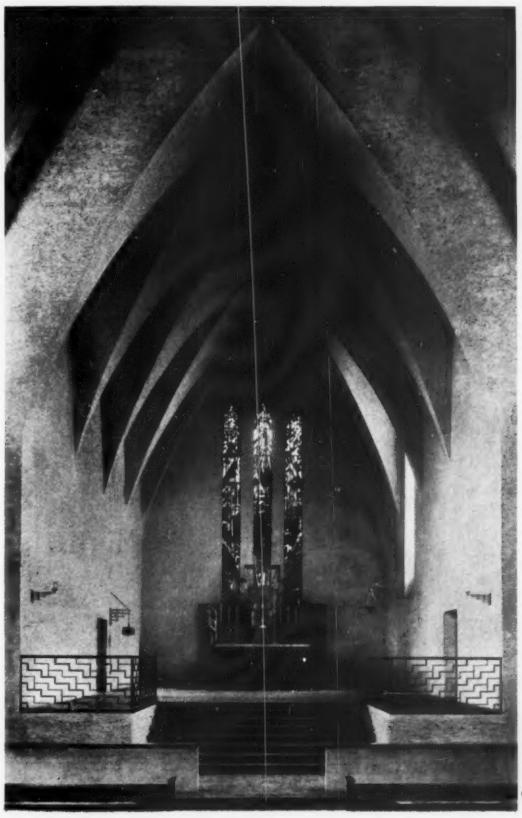

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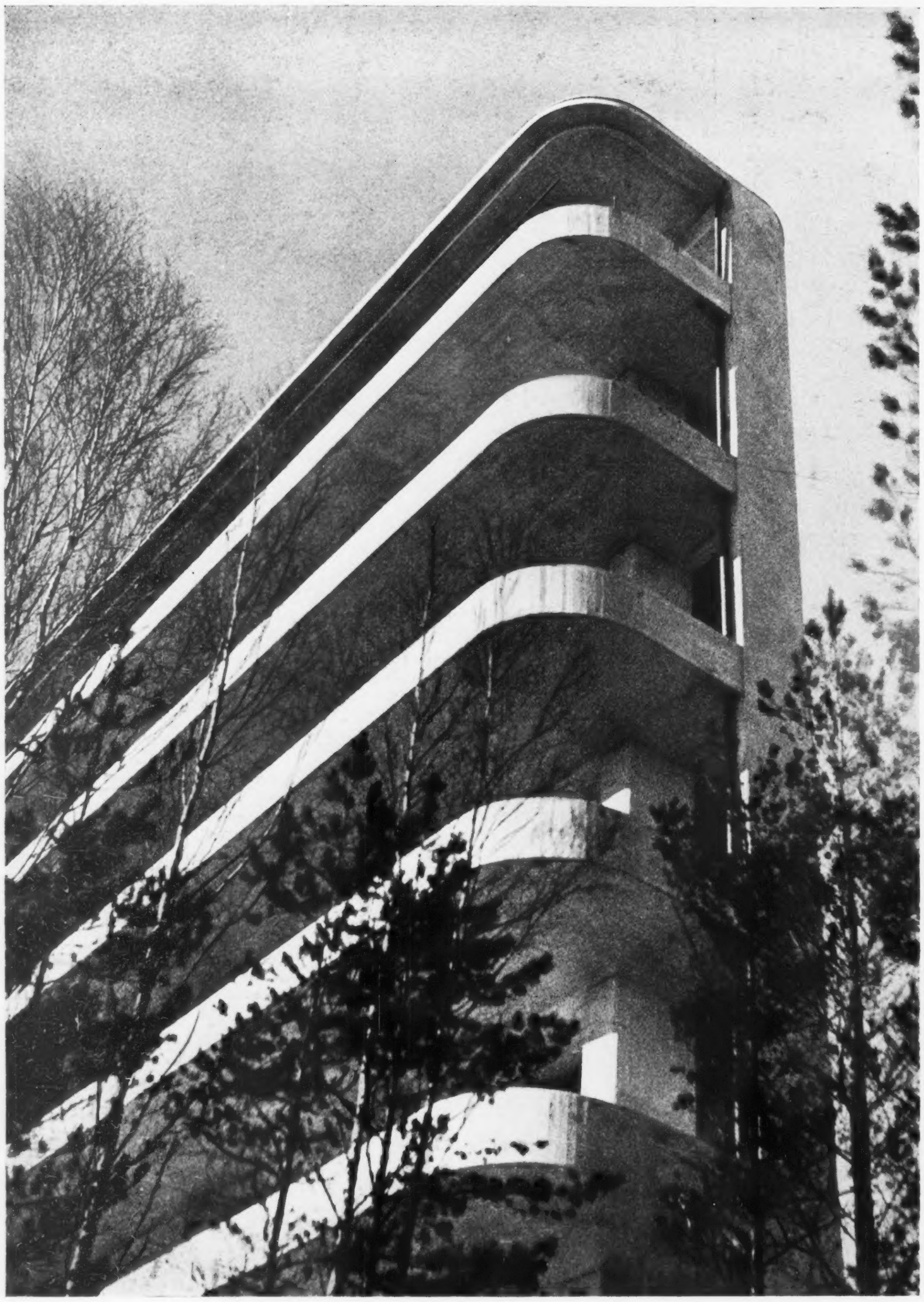
of reinforced concrete to purely formal ends, is no more than a clever *tour de force*. The same architect designed the "dismountable" steel church which was shown at the "Pressa" Exhibition at Cologne, and has since been re-erected at Essen. Paul Tauran's Sainte Thérèse de l'Enfant Jésu at Elizabethville, outside Paris, proves that it is only too easy to prostitute concrete to the itch for barbarous eccentricity. In A. Bosslet and K. Lochner's PARISH CHURCH AT LUDWIGSHAFEN (**105**) concrete has been used in a somewhat more traditional, though still quite logical, spirit. Another outstanding example is Herkommer's "Frauenfriedenskirche" at Frankfort-on-Main, with which Martin Weber's CHURCH OF THE HOLY CROSS in the same city (**99**), (**100**), (**101**) and (**102**) has considerable decorative affinities—particularly in its rather Neo-Byzantine interior decoration. Externally his church bears some resemblance to Karl Moser's St. Anthony's, at Basle. The only English church built in concrete—that is, in which concrete is used otherwise than as a cheap substitute for stone—is Raymond Erith and Hilda Mason's St. Andrew's, Felixstowe: a brave experiment that has the merit of combining structural sincerity with a genuinely English feeling. Unfortunately the interior has been irreparably ruined by its furnishings. The new Church of Christ the King, at Cork, in Ireland, designed by the American architect J. R. Boyd-Barrett, is revolutionary both in design and plan, its breadth being greater than its length.



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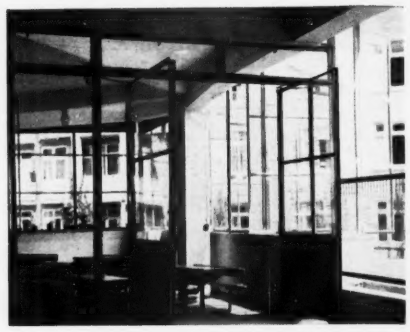

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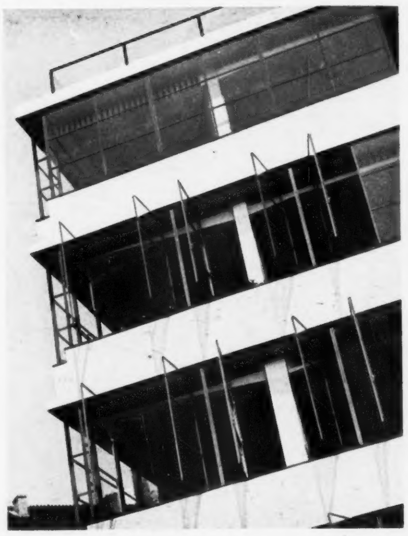

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C A N T I L E V E R I N G   E F F E C T S

One of the most spectacular forms in reinforced concrete is the slab-beam or cantilever, as used in balconies, flat overhanging roofs, grand-stands, station canopies, hotel marquises, bandstands, theatre galleries, outside staircases, and, to a less this-looks-all-wrong-and-damned-dangerous-into-the-bargain extent, in splaying out the receptacles of coal-bunkers and water-towers from their supporting trestles. What usually worries us about the optics of cantilevering far more than its apparent absence of compensating support is its very real absence of compensating symmetry. Corbusier delights in exploiting this system asymmetrically in a way which almost justifies that scathing condemnation of dialectically-ideological Russian architects when outraged in their Marxian-structural sincerity : "Engineering Romanticism."

(108) and **(112)** illustrate different aspects of the continuous tiers of cantilevered balconies in the solarium of Alvar Aalto's huge PAIMIO SANATORIUM, FINLAND just after the shuttering was struck. To praise this building would be impertinence. The same principle is embodied in Bohuslav Fuchs's

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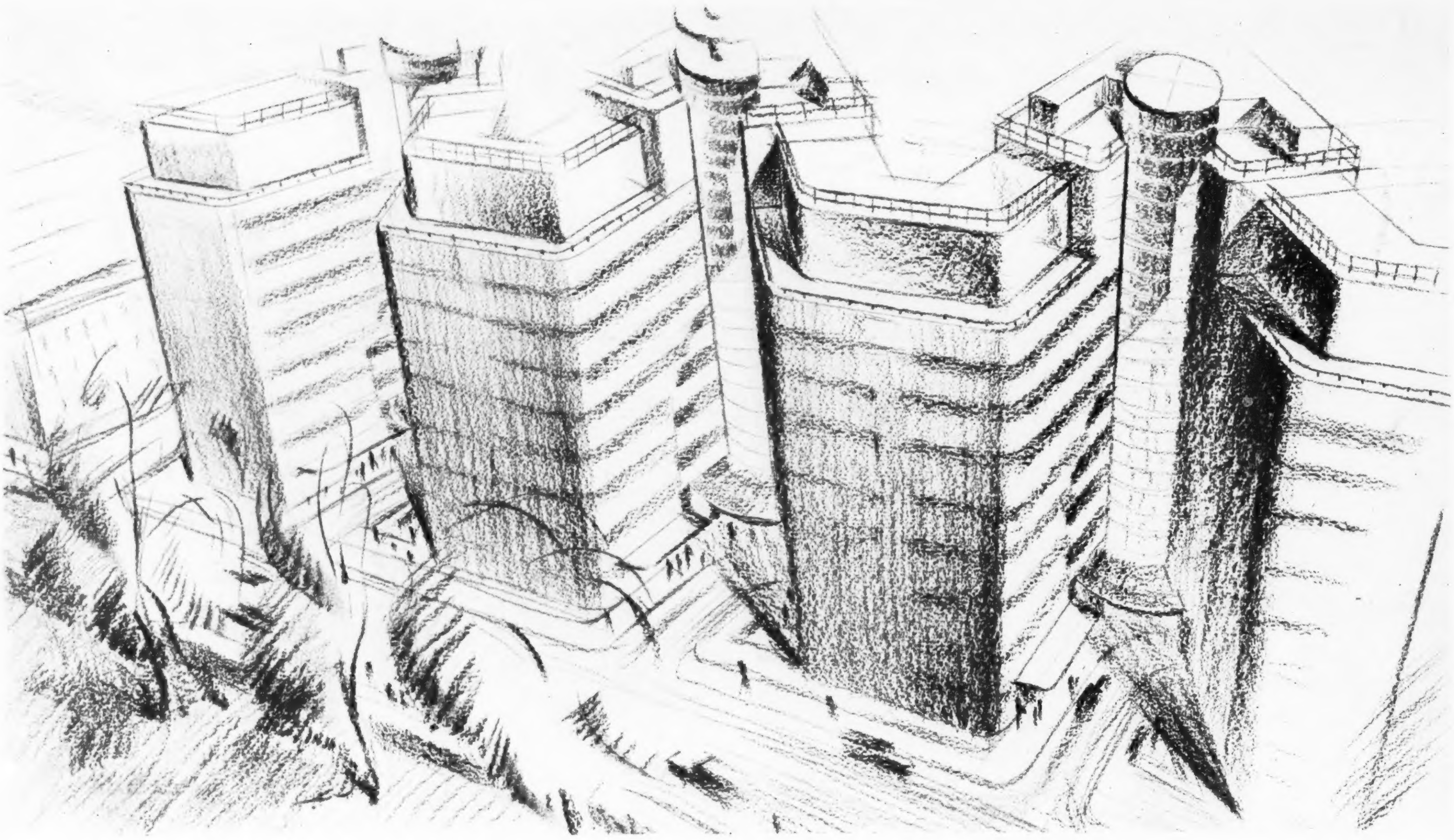
PROFESSIONAL SCHOOL FOR WOMEN, Brünn, Czechoslovakia (**113**), where all the upper stories of the two buildings linked by the covered corridor in the middle of the photograph are cantilevered out over their ground floors. (**114**) is the rear elevation of the ÅBO PRINTING WORKS of a Finnish daily paper, the "Turun Sanomat." This all-concrete building, which is finished in white cement stucco, was also designed by Alvar Aalto: a young architect who is one of the ablest and most audacious exponents of new forms in concrete. (**110**) shows the exterior, and (**109**) and (**111**) interior views, of J. Duiker's OPEN-AIR SCHOOL IN THE CLIOSTRAAT, AMSTERDAM, one of the "purest" examples of functionalist architecture in Holland. In (**110**) the arms of the branching beams sustained by the main stanchions can be seen gracefully thinned away, floor by floor, like the reefed mainyards of a sailing ship.



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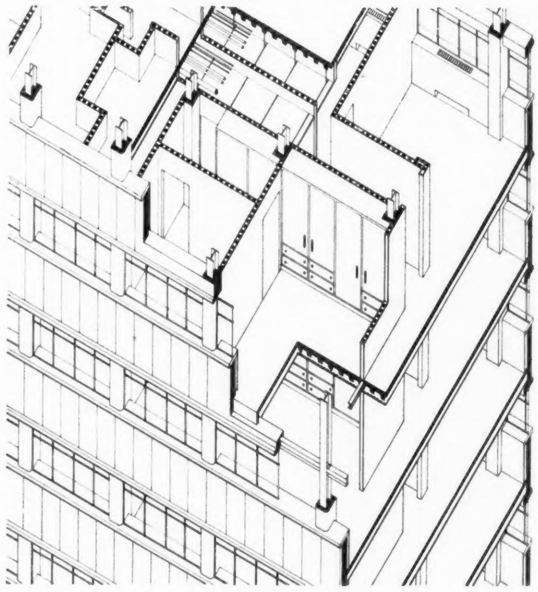

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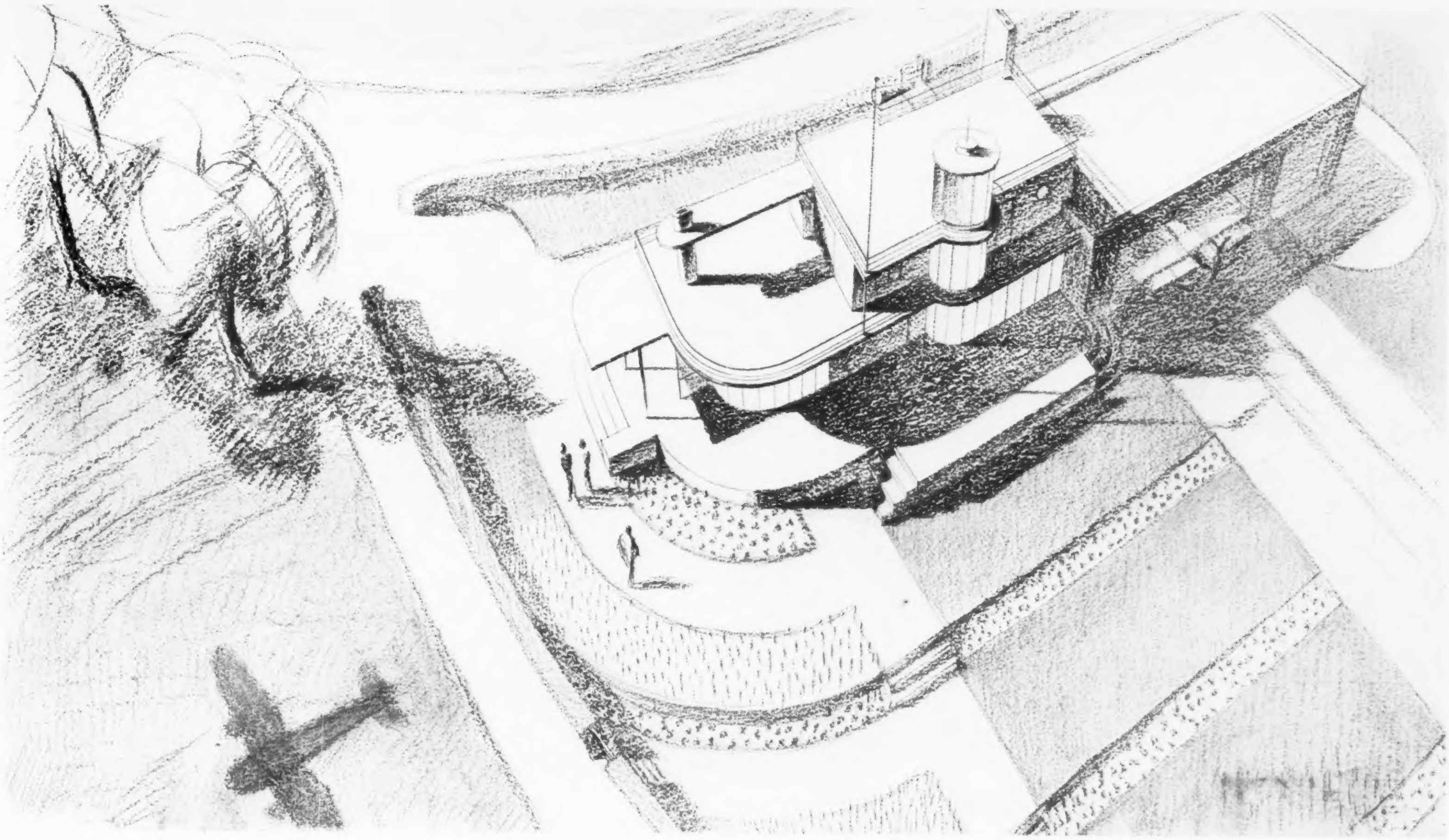
(115) and (116) HYDE PARK COURT, KNIGHTSBRIDGE, LONDON, Raymond McGrath, *architect*. A block of 105 flats ranging from one to four bedrooms each. The plan is a triple-V taking advantage of light and air on all the frontages. The block contains six passenger and six service lifts, a swimming pool with plenum ventilation, gymnasia, squash racquets courts and garage accommodation for 40 cars. The construction is steel frame with tee-beam floors and suspended ceiling enabling all pipes to be carried parallel to the run of the floors and free from the floor construction into ducts provided in the corridors. These ducts connect with vertical pipe shafts specially designed for facility of access.



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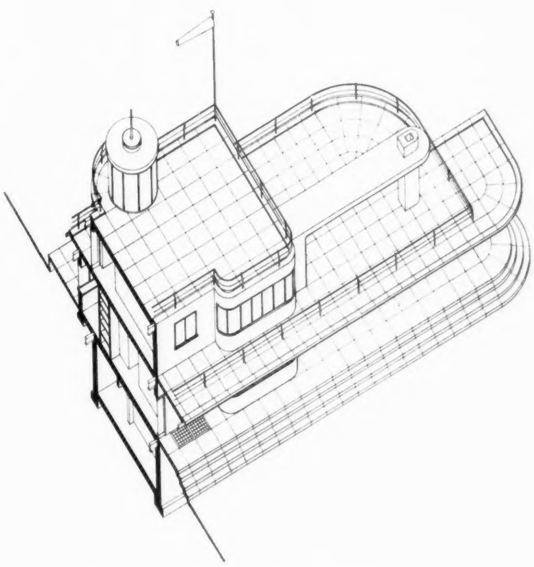

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(**117**) and (**118**) RUDDER BAR, a house and hangar on Hanworth Aerodrome, for the Hon. Mrs. Victor Bruce. Raymond McGrath, *architect*. A steel-frame house on the edge of the aerodrome with attached hangar and garage for two cars. The external walls are cavity construction, floors hollow tile with suspended ceilings, internal walls pumice concrete blocks fibre boarded, with air spaces to ensure efficient insulation and sound absorption. The circular iron stair which carries above the roof as an observation tower and beacon, is encased with glass. In its construction and planning the house expresses air-mindedness in architecture.

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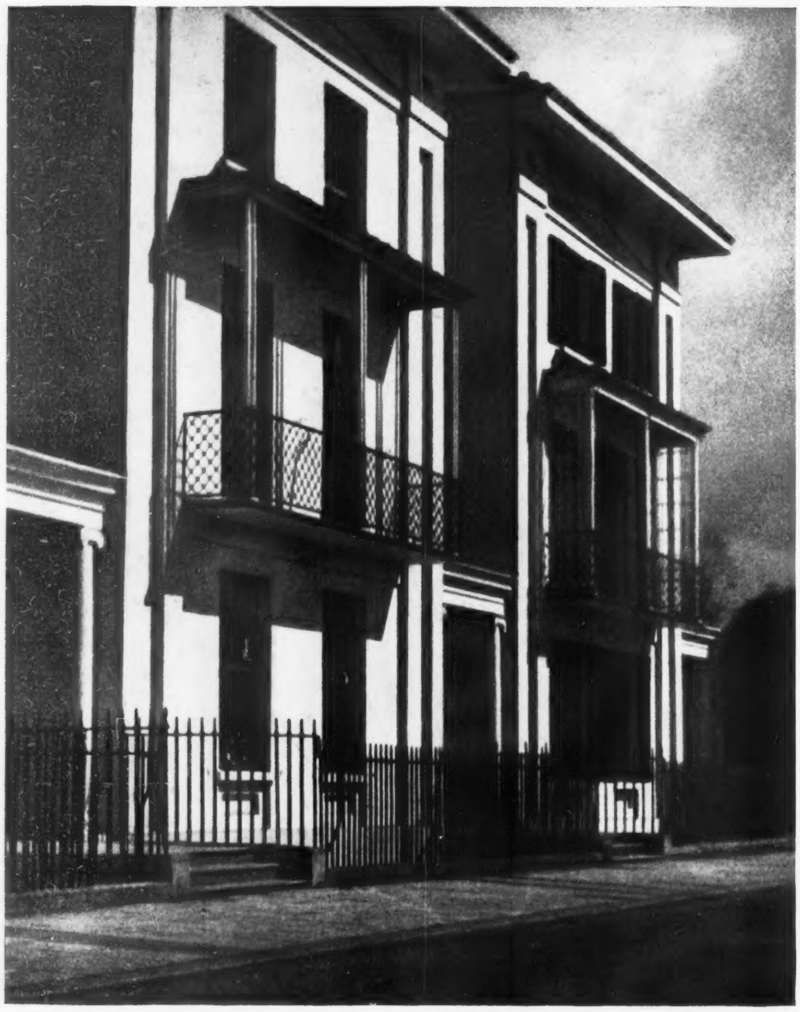

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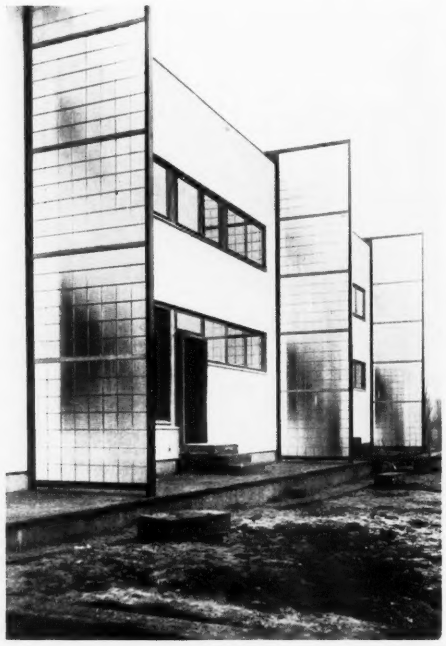

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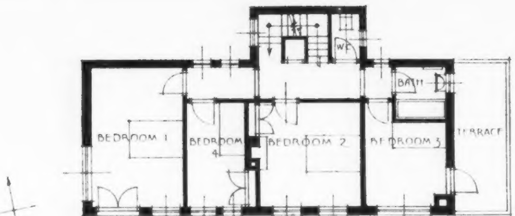

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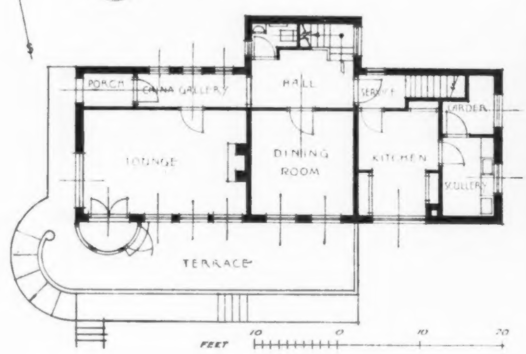

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A COMPARISON IN THE CLASSIC TRADITION

(119) PENNSYLVANIA PARK, EXETER.—A row of buildings of late Hanoverian date commanding what was once a fine prospect over hills. Almost all unnecessary decoration has been eliminated, the panelled pilasters emphasize the vertical construction lines behind the stucco, and the tall, perfectly proportioned windows are designed to admit as much prospect as possible ; by their disposition they reveal at once the plan and purpose of each house. The entrance porches between each residence are not a vulgar attempt at being different, but they display a civic-minded desire to conform with one another and produce an harmonious whole. The same civic-mindedness inspired the architects of **(120)** the SUBURBAN DWELLING HOUSES IN GERMANY where the houses are separated by steel and glass partitions. In these houses and in **(121–123)** WHITE WALLS, TORQUAY (William Walter Wood, *architect*), the same logic which prompted the Hanoverian architect of Pennsylvania Park, Exeter, to show his vertical lines of construction in the exterior window openings, prompted the German and contemporary English architects to emphasize the re-inforced concrete cantilever construction of their houses with horizontal windows. This is the true Classicism : " White Walls," Torquay, looks on a fine prospect to the South and the main rooms have windows looking over it, as the plan indicates, either on the first floor or ground floor. Such honest expression of construction and logical planning show that the English Hanoverian and the International contemporary architects both follow the Classic tradition.

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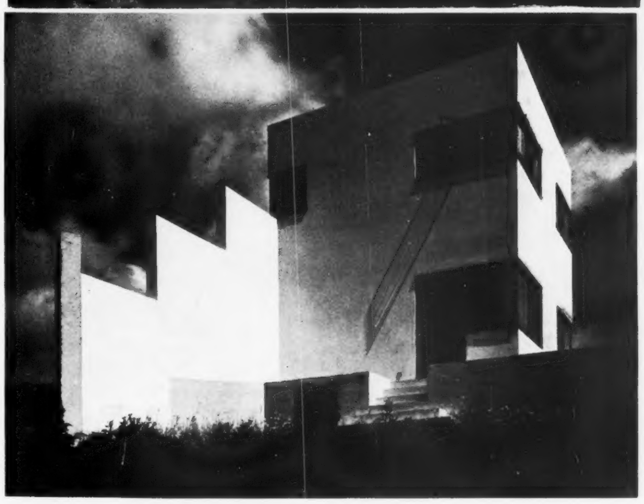

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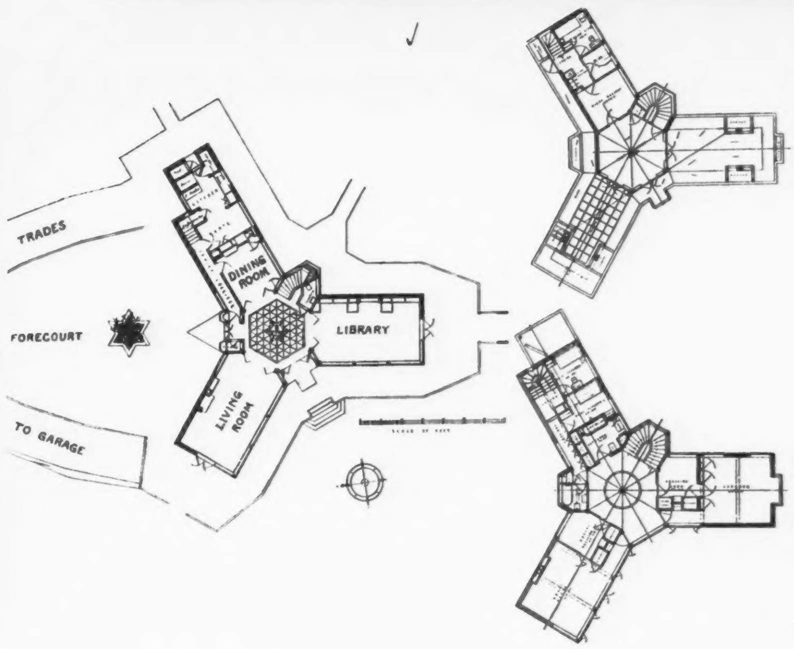

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STRAIGHT LINES AND STRAIGHT THINKING

HIGH AND OVER, AMERSHAM, BUCKINGHAMSHIRE, Amyas Connell, *architect.* Although this house may not fit in with the local use of brick and tile in Buckinghamshire, the straight lines of the cantilever reinforced concrete construction in the house, and the long terraced garden walls, have been designed to merge with the lines of the chalk hills behind and around it. Since it is a twentieth-century building it is designed with the object of getting as much sunlight and as many fine views as possible. For this reason it is far more logical than the " Elizabethan " bijou residences that are being built elsewhere in the district. The Elizabethans did not require views from hills, nor sunlight. We do. **(124)** A south-west view. **(125)** Looking down-hill from the south-east. **(126)** The Lodge and the beginning of the Garden Wall. **(127)** In the distance is the north Elevation of the house and in the foreground the water tower with a fives court abutting on to it. **(128)** The plan shows how every room has three outside walls each pierced with windows. The whole house is of cantilever construction in reinforced concrete so that the horizontal lines are not a " jazz modern " affectation but a logical outcome.

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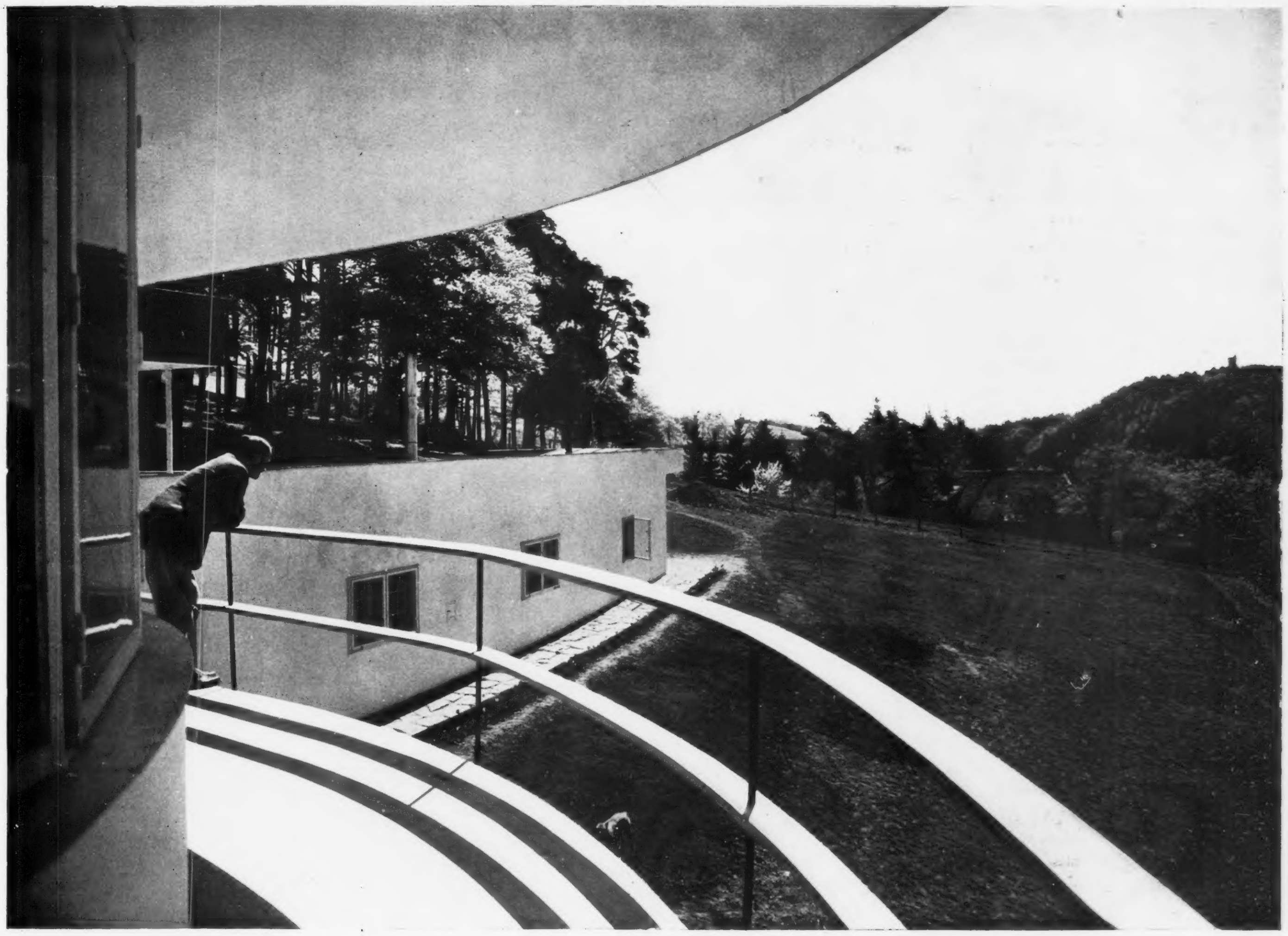
ROOF GARDENS AND TERRACES

As Le Corbusier pointed out several years ago the logical acceptance of the properties of steel and concrete set us free from that romantic and awkward makeshift, the gabled roof. The cult of open-air gymnastics and sun-bathing make the flat roof an invaluable resource for the householder as well as a practical structural simplification. In crowded city areas it allows the multiplication of private gardens.

Richard J. Neutra's new SANATORIUM AT LOS ANGELES (**129**), which affords an interesting comparison with Bijvoet and Duicker's well-known sanatorium at Hilversum, is built on a terrace system adapted to falling sites that was first employed by Professor Richard Döcker in his now celebrated District Hospital at Waiblingen in Wurtemberg (1927). In each case a slope has been turned to structural advantage, with the result that though every room enjoys the maximum of light and air, the cost of construction was less than it would have been with a perfectly level site. (**130**) shows the ROOF GARDEN OF A VIENNESE HOUSE laid out by Egon Fridinger, which might be mistaken for one of the many in Paris designed by André Lurçat. (**131**) illustrates how a narrow wedge of rising ground between two roads running at different levels has been transformed by Gabriel Guevrékian into an interestingly-patterned formal garden at the Comte de Noailles's VILLA, HYÈRES.



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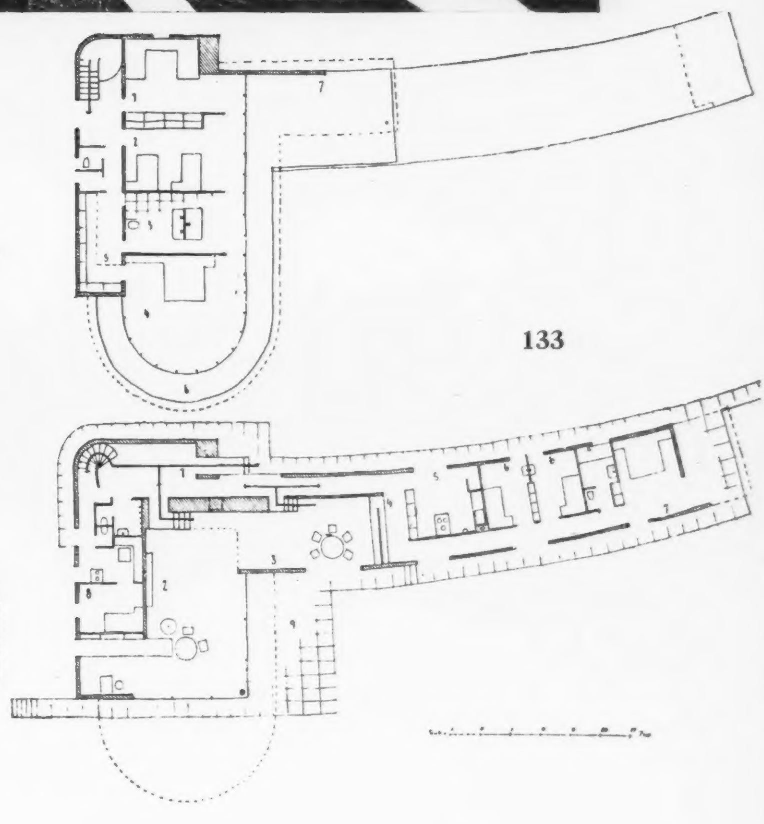

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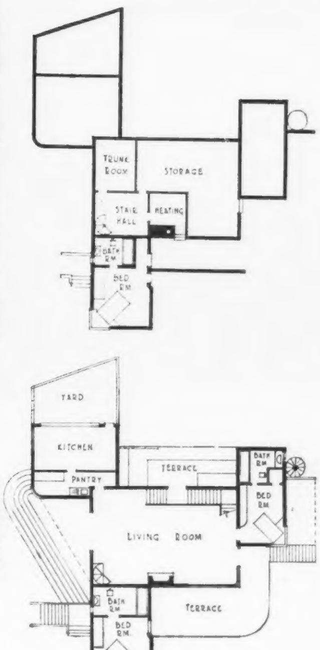

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(132) and **(133)** THE HAUS ROSENBAUER, LINZ, AUSTRIA, designed by Lois Welzenbacher. The approach to the house is through a wood, and the design and distribution of the main masses have regard to this, the long block which runs parallel with the trees being kept low so that it shall not interrupt the view. The wing, which is at right angles to the wood, has two storeys. On the first floor are the sleeping rooms, glazed entirely on the south-east side **(132)**—as are all the important apartments—and opening on to a balcony. Above the bedrooms is a roof terrace, the parapet of which gives a pleasing weight above the first-floor windows. This projecting wing acts as a defence against the wind from one side and a trap for the sun on the other. The flat roofs, floors, and great overhanging slab of the upper floor are in reinforced concrete. **(134)** and **(135)** A HOUSE AT OJAI, CALIFORNIA, designed by Howe and Leseaze.

AN ENGLISH COUNTRY HOUSE

BY SERGE CHERMAYEFF

One of two reinforced concrete houses to be constructed on a wooded site overlooking downs.

The house has been designed for a married couple with two children. The plan has been dictated by the essential requirements.

The owner's Bedroom on the ground floor, Living Room, Dining Room and Library command an uninterrupted view over the sloping ground.

The Living Room can be thrown open to the Terrace, with its suntrap corner and Swimming Pool.

The Dining Room window frames the sunsets and has a shady loggia for outdoor meals.

The Library has been isolated as far as possible to ensure minimum interruption.

The Guest Rooms on the first floor are a repetition of the owner's suite, and are self-contained, with access to roof from the large landing.

The staircase hall was designed on a generous scale to ensure the effect of spaciousness on entrance, and is lit from the east and west.

The Nurseries and Maids' Rooms form a separate wing, with the Day Nursery opening on to the roof playground with a shelter from the north.

The Garage is open to both Drive and covered Wash and has an internal communicating door.

The electric lighting plant and oil-burning heating and domestic services are situated immediately below the Garage.

Careful planning of the service quarters isolates them from the Living Rooms and Garden.

The Terrace sides of the house are fitted with sliding- and sliding folding steel windows.

The upstairs passages, the basement, housemaid's cupboard and Dining Room, in addition to windows, are lit through pavement lights.

The whole structure is a homogeneous mass. The walls of 4 in. concrete act as beams, in some cases cantilevers carrying single span hollow tile floors. The whole is insulated with building board which forms the base for plaster, plywood panelling and floor finishings. Carpet in Bedrooms, composition floors elsewhere. All cupboard fitments, etc., are on a unit system and are interchangeable.

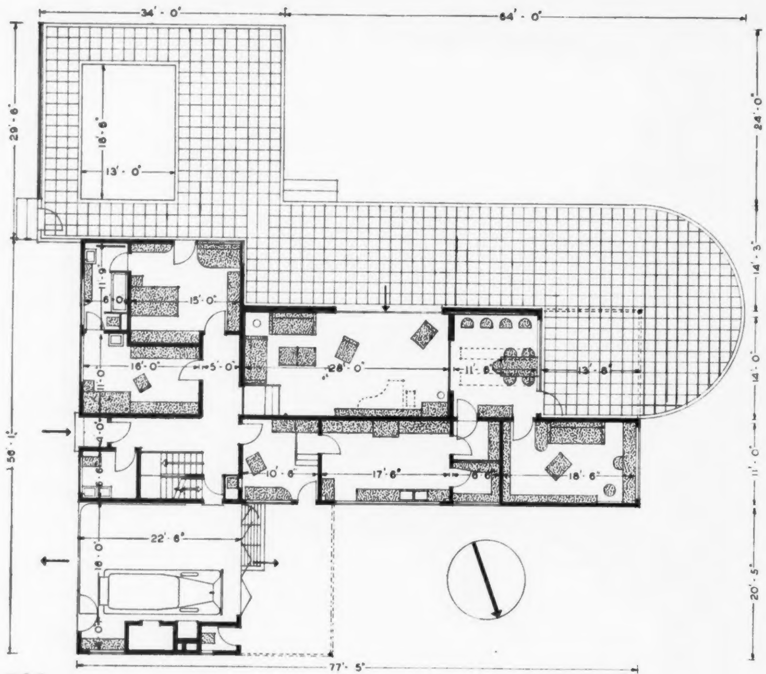
The roof playground and terrace are paved in precast slabs.

The illustrations are:—**(136)** Plan of the ground floor; **(137)** Plan of the first floor.

(138) A constructional detail. The materials indicated by numbers are as follows:—

Exterior. (1) coloured Portland cement; (2) reinforced concrete. *Ventilation.* (3) outer vent, galvanized iron; (4) inner vent, aluminium alloy. *Plaster finish.* (5) cavity; (6) insulating wall board; (7) plaster. *Floor and ceiling.* (8) plaster; (9) insulating wall board; (10) grout; (11) patent floor; (12) concrete; (13) insulating wall board; (14) linoleum or composition. *Wood finish.* (15) hardwood skirting; (16) hardwood fillet or metal 'T' set in cement; (17) plywood wall board; (18) 2 in. by 1½ in. waterproofed batten.

(139), *on the facing page*, an axonometric projection showing the internal arrangement of the house, and **(140)** *left*, the north front; **(141)** *right*, a bird's-eye view from the south-west.



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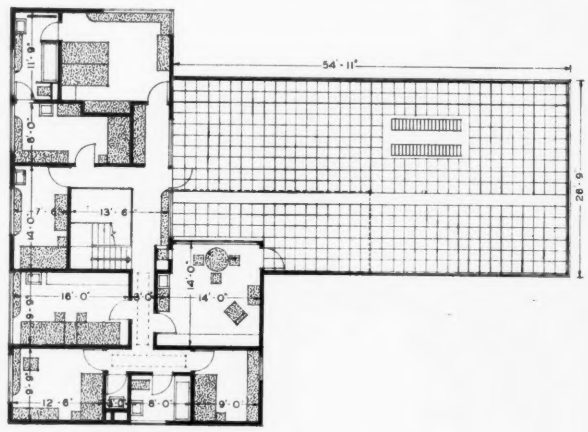

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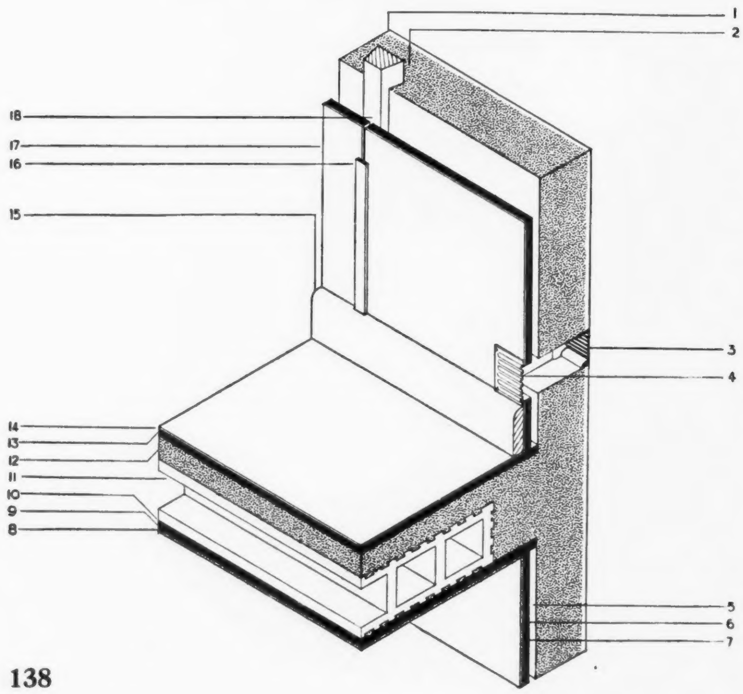

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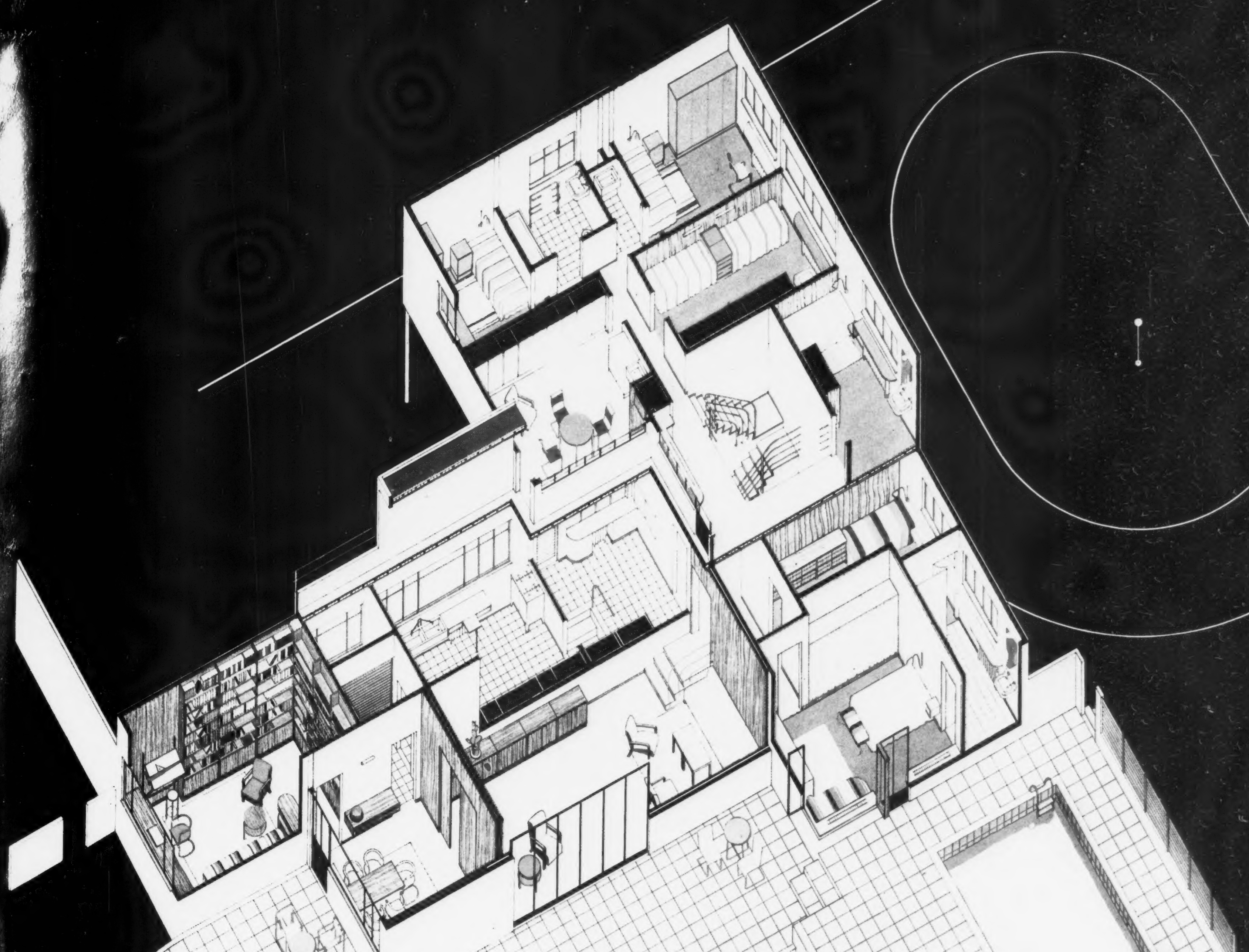

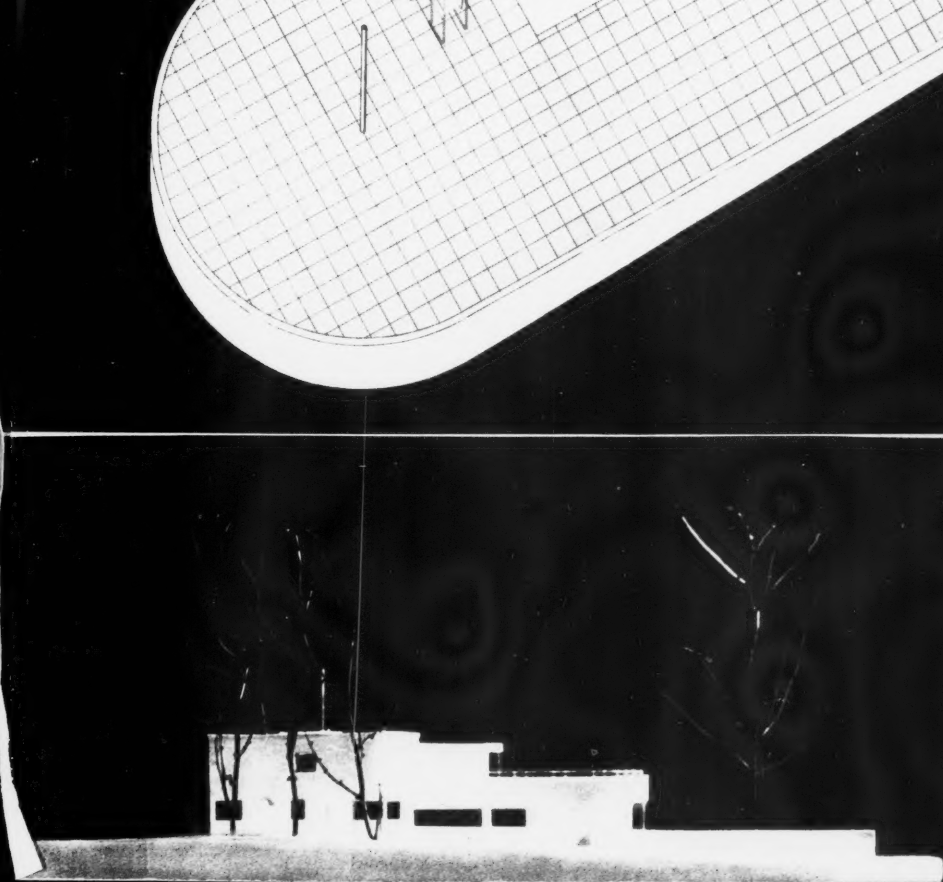

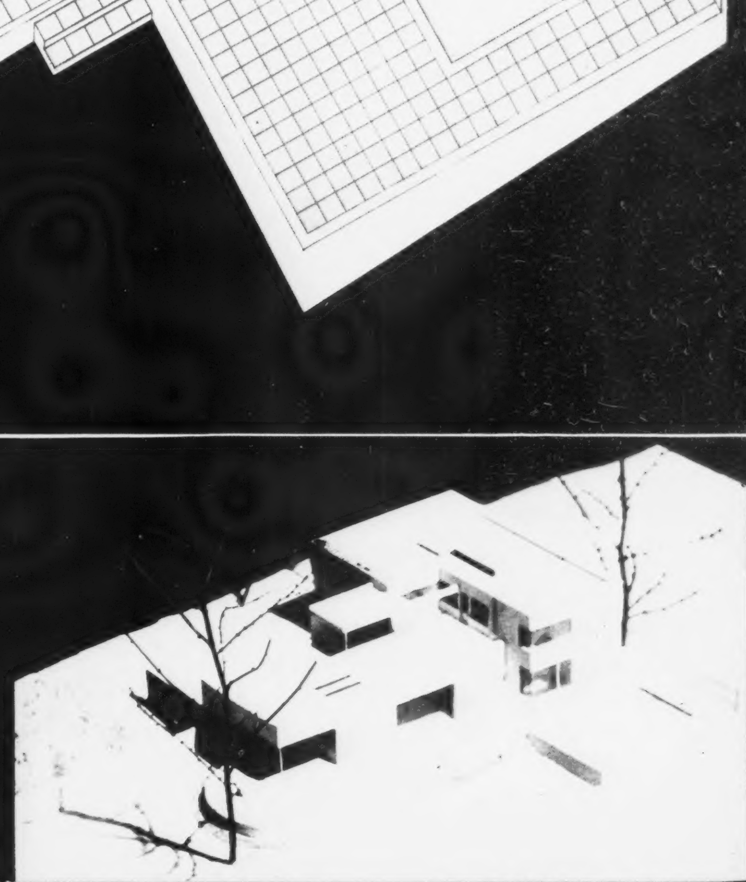

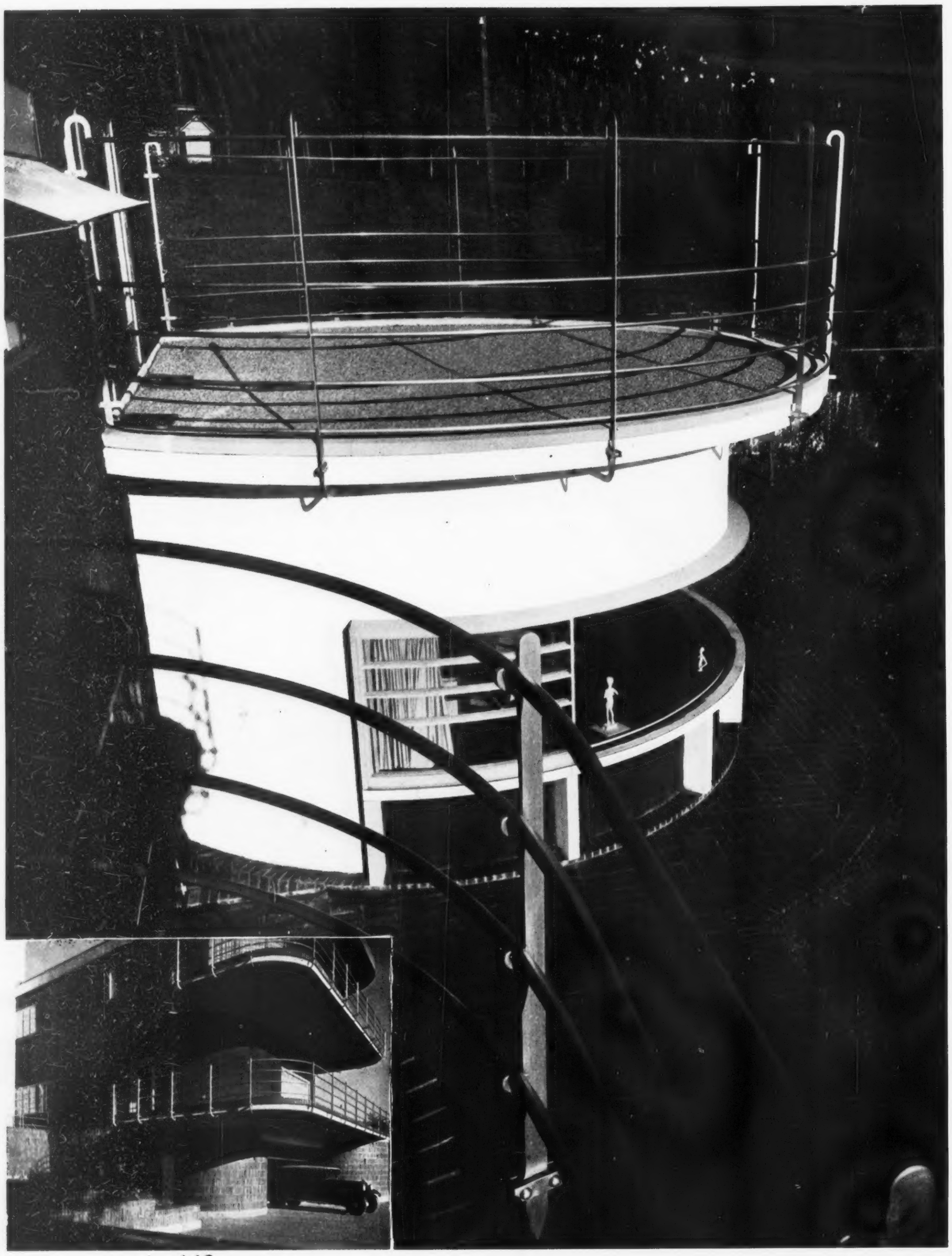

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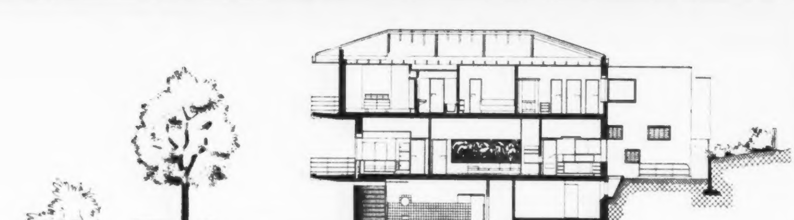

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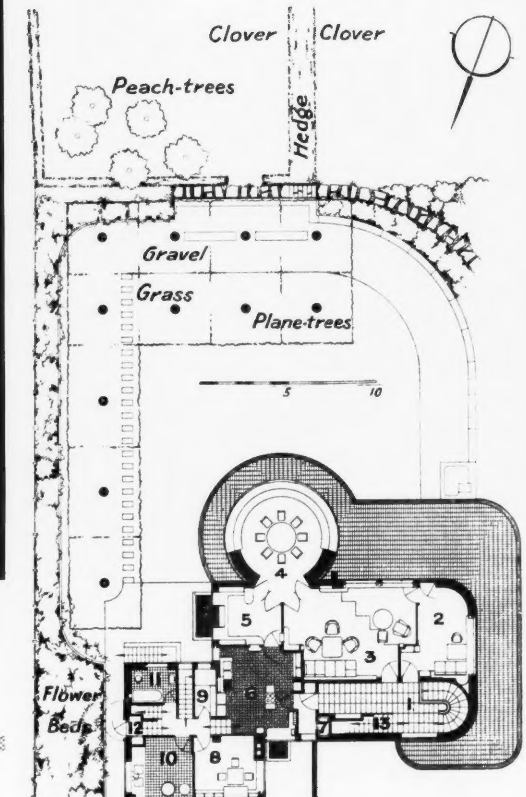

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T H E   C O N C R E T E   H O M E

(142), (143), (144), (145), reproduce two exterior views, the ground-floor plan, and a longitudinal cross-section of a concrete VILLA AT GOLDBACH, NEAR ZÜRICH, of which Otto Zollinger was the architect. In this design the two wide balconies form a repetitive motif echoed by the deep soffit of the overhanging roof. On the far side, level with the garden, is a turret-like dining-room, which has a continuous semi-circular bow-window of plate glass that slides down into the cavity wall. The roof of the dining-room is used for sun-bathing and physical exercises. The turret is rendered externally in a smooth white cement finish, and the body of the house in cherry-coloured roughcast. House and garden were planned as a single unit. The entrance is on the first floor, the garage occupying the basement.

The rooms represented by numbers on the plan are as follows: (1) hall; (2) small living-room; (3) large living-room; (4) dining-room; (5) pantry; (6) kitchen; (7) refrigerator; (8) servants'-hall; (9) store-room; (10) scullery; (11) servants'-bathroom; (12) servants'-entrance; (13) stairs to first floor.

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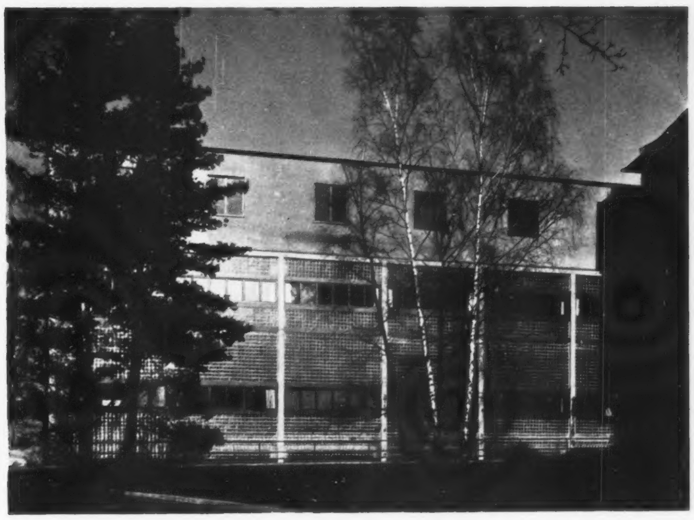

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The façade of the new "TRAUBE" CAFÉ AND RESTAURANT, BERLIN (**148**), of which Leo Nachtlicht was the architect, affords an interesting contrast with the elevations of the Röntgen-Ray Institute of the FRANKFORT-ON-MAIN GENERAL HOSPITAL (**147**) and (**149**), designed by Professor Martin Elsaesser. Both are equally forthright, yet each succeeds in expressing its function without any recourse to decorative details. The former, designed for effective display as "night architecture," is faced with opaque white glass that is illuminated from within. The latter combines large expanses of reinforced glass of the "pavement lights" type with plain cement-stucco wallage. A view of a quite legitimately "amusing" corkscrew staircase (a form peculiar to concrete) in the tropical winter-garden of the "Traube" is reproduced in (**146**).

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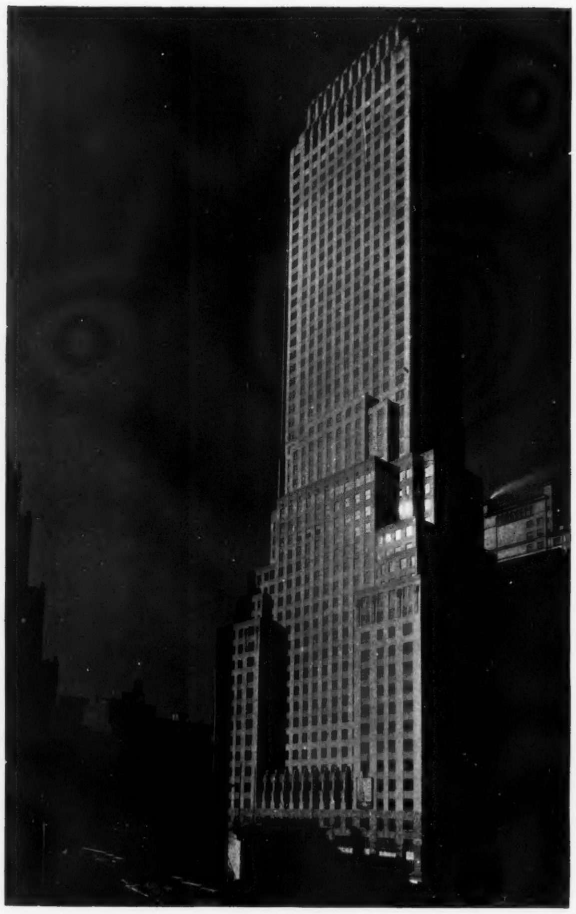


151

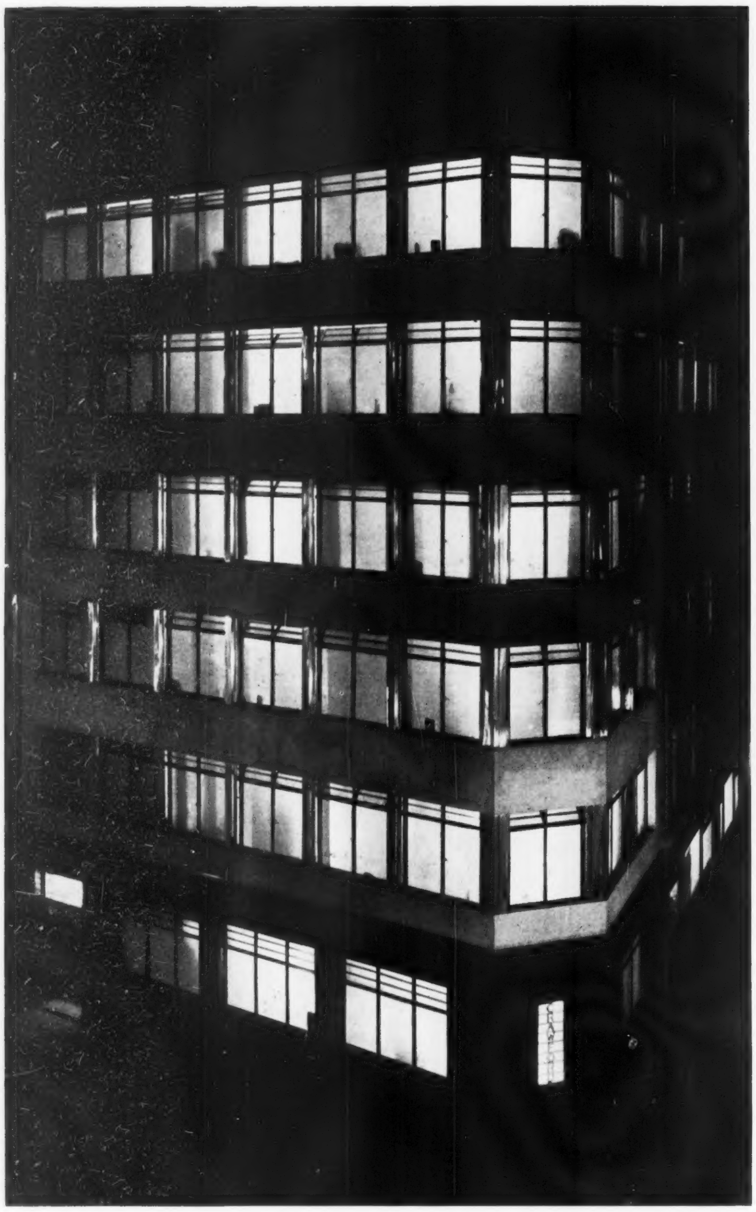
NO STEEL, NO SKYSCRAPER!

The American contribution to the progress of steel conjures up immediately a conglomeration of towering peaks of public and commercial buildings. Here steel holds unchallenged sway, for "no steel, no skyscraper" is a truism, with reinforced concrete at a practical limitation of 20 storeys and an economical limitation of 12 storeys in height. It is strange, however, that in spite of much progress few efforts have equalled in quality the some 20 years old Woolworth building. (**150**) gives a view of the 30 storey GRAYBAR BUILDING, NEW YORK, taken from the much higher Chrysler building opposite. The resulting increase of light and air produced by "zoning" set backs is exemplified by comparison of the shadows cast by the building on the left with that of the zoned masses. (**151**) A night view of the CHANIN

152

153

BUILDING, NEW YORK, by Messrs. Sloane & Robertson. Here the set backs are not so predominant, but the simplicity and dignity of the mass is somewhat marred by the fussiness, half way up. (**152**) The strong verticality of NO. 500 FIFTH AVENUE, NEW YORK, by Messrs. Shreve Lamb & Harmon, who were also responsible for the Empire State Building, is obtained by forcing the central portion, which if functionally truthful should house nothing but the elevators immediately behind the slits. Here again the weakness in the mass lies in the petty set backs immediately above street face level. (**153**) A new form of skyscraper in the grand manner? No! This seemingly splendid verticality of glass and steel is none other than an unfamiliar bird's-eye view of the roof of our old friend VICTORIA STATION, LONDON.



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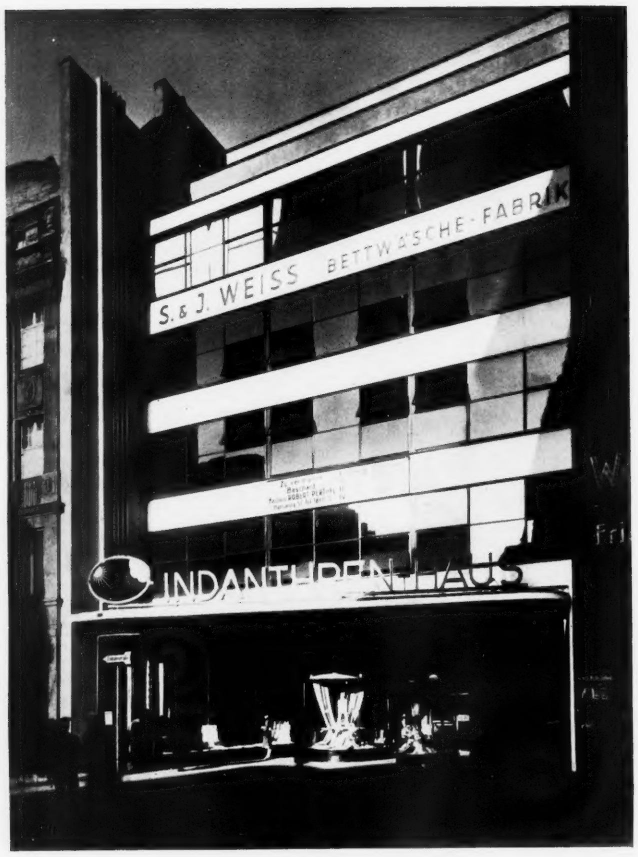

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S H E L L   A N D   S T R U C T U R E

The significance of figures 154–165 is that the finished appearance of a large modern store, hotel, or block of offices makes it impossible to tell whether steel-framed or reinforced-concrete construction was adopted. As walls no longer support anything, the result is that glass is used as the predominant facing material in each. **(154)**, **(157)** and **(163)** are concrete buildings; the rest are steel-framed. Yet nobody who had not helped to design or construct these buildings, or actually watched their construction, could be sure whether the first three were not steel-framed, and the remainder reinforced-concrete structures.

(154) CRAWFORD'S OFFICES IN HOLBORN, designed by Frederick Etchells is finished with ordinary cement-stucco—except on the ground floor, which is faced with black Belgian granite. The mullions between the windows are cased in rustless steel. **(155)** and **(157)**, the INDANTHRENHAUS, COLOGNE, designed by Riphahn

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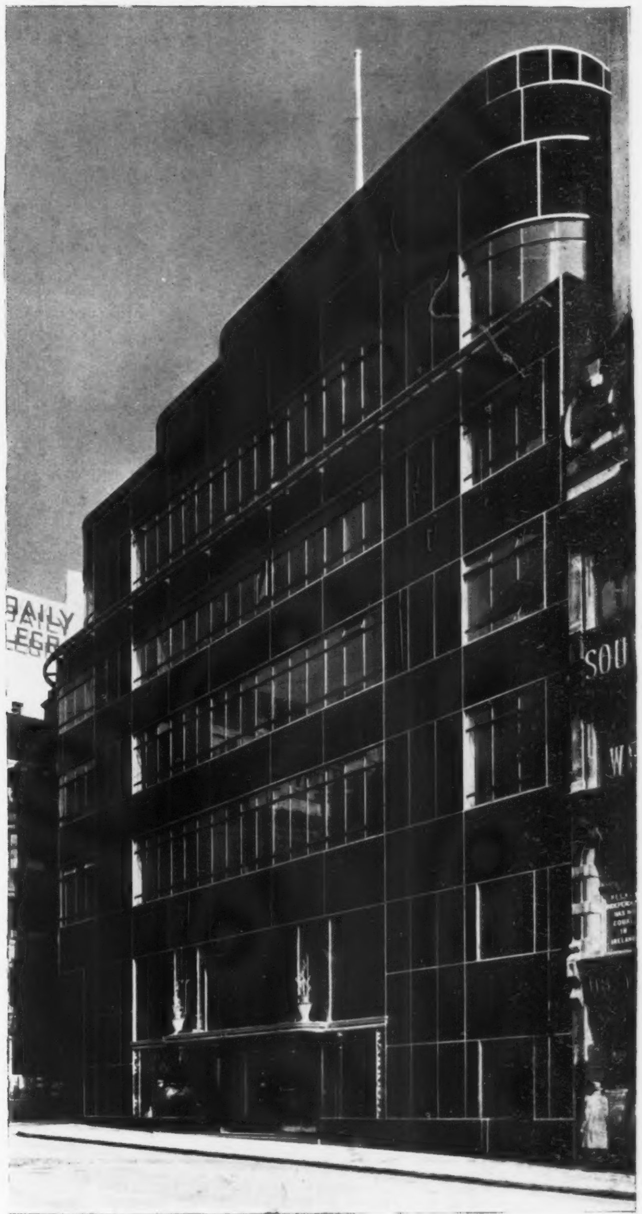

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and Grod, and the NEW DAILY EXPRESS OFFICES in Fleet Street, designed by Ellis and Clarke *in association with* Sir Owen Williams, are faced with slabs of opal-white and black glass respectively. (**164**) The DORCHESTER HOTEL, W. Curtis Green, *in association with* Sir Owen Williams, is faced with thin biscuit-coloured tiles made of powdered Botticino marble and white Portland cement. (**156**), (**159**), (**158**)—(**160**) is another view of (**158**) nearing completion—and (**162**) which show (*a*) EISENLOHR AND PFENNING'S BREUNINGER STORE, STUTTGART; (*b*) A CINEMA AND OFFICE BUILDING IN THE SAME CITY; (*c*) Professor Fahrenkamp's SHELL BUILDING IN BERLIN; and (*d*) Eric-h Mendelsohn's COLUMBUS BUILDING, also in Berlin, are all faced between floors with thin slabs of Cannstadt travertine, laid like tiling without visible bonds. The second of these, which was erected at the rate of six days a floor, bears a marked resemblance to Eric-h

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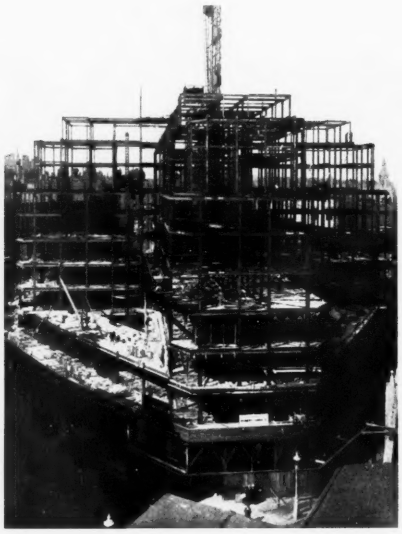

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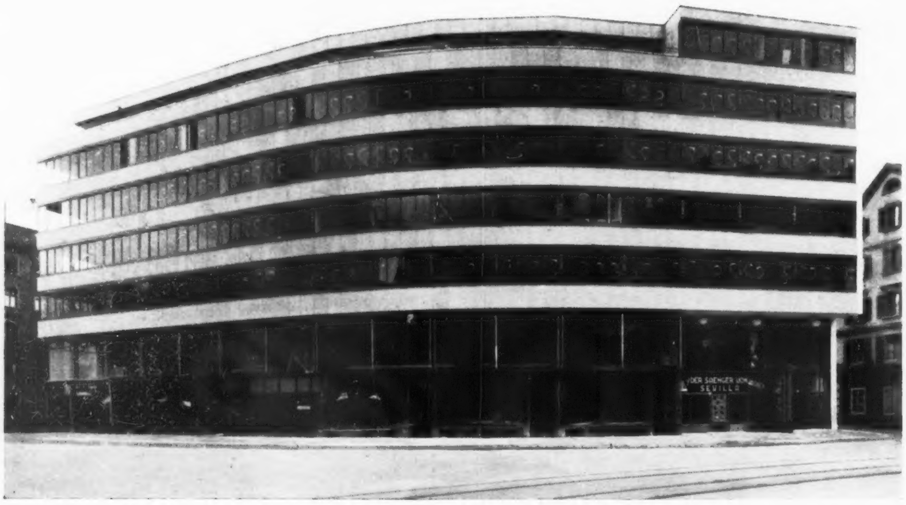

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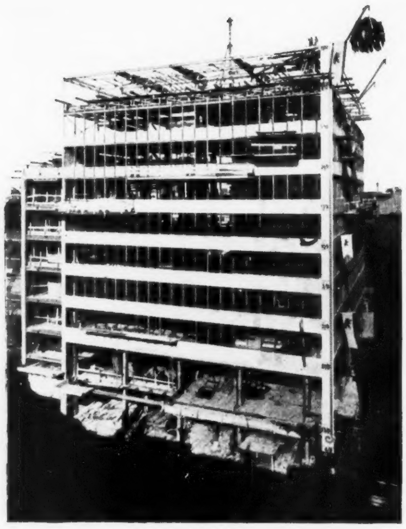

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Mendelsohn's Schocken Store at Chemnitz: a building that has actually a reinforced-concrete framework.

(165) The Eastern extension of BUSH HOUSE in the Strand, London, designed by Helmle and Corbett, is encased with blocks of stone in an attempt to achieve a "modern" note by a wholesale simplification of ordinary "traditional" detail. As a result, it falls rather lamely between the two stools of American pseudo-classicism and European functionalism: a criticism that also applies to some extent to the Dorchester Hotel.

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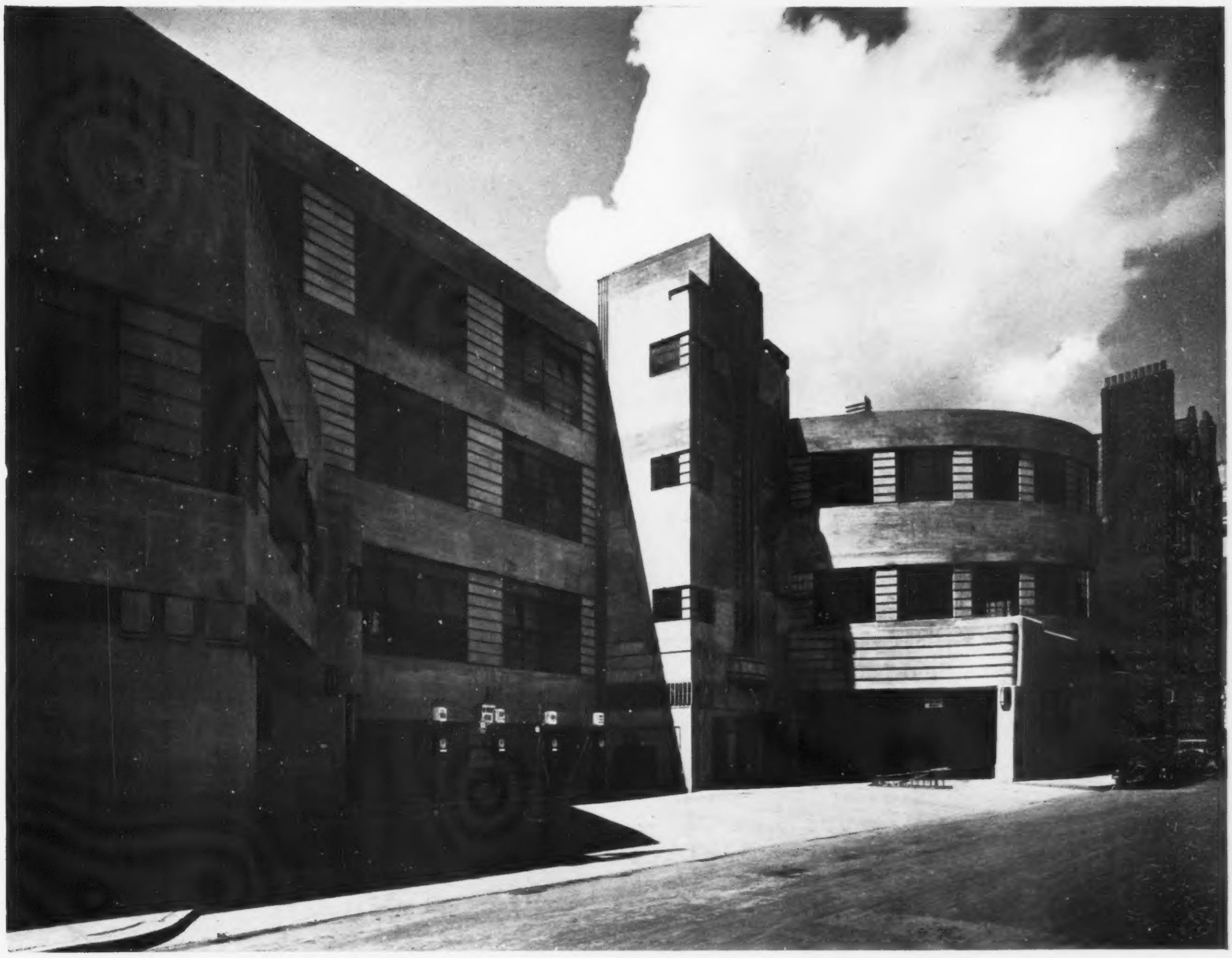

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(163) The DAIMLER HIRE BUILDING in Herbrand Street, London, designed by Wallis Gilbert & Partners, is, like **(154)**, an example of ordinary cement rendering on a concrete structure. Being a garage, the need for almost continuous window openings (which is common to all the other buildings on these four pages) did not arise.

(161) The UNDERGROUND BUILDING, London, Adams, Holden and Pearson, *architects*, which, like **(165)**, is faced with Portland stone, and **(162)**, are examples of English and German record jobs in steel-frame construction. The latter was erected in just two months !

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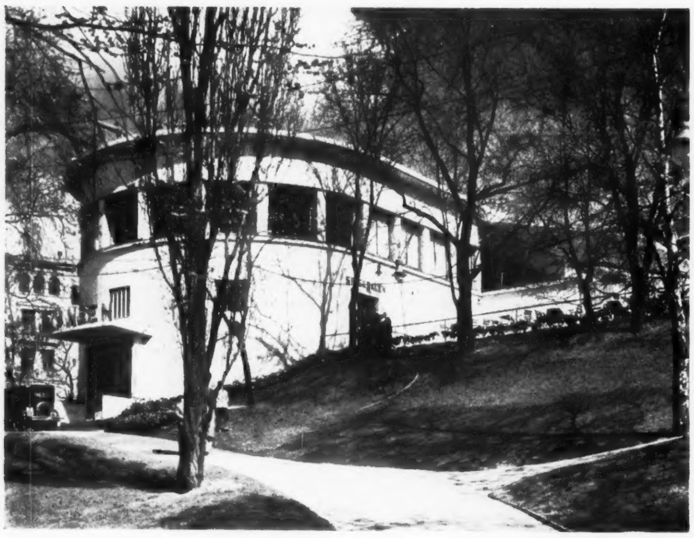

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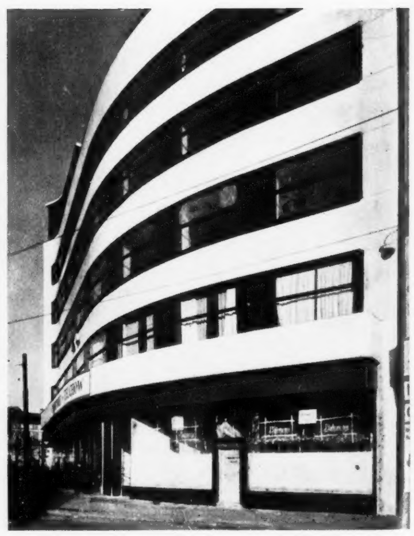

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THREE CONTRASTS IN HORIZONTALISM

Verticalism is the natural expression of steel-frame construction, horizontalism of reinforced concrete: a statement that obviously implies the limitations of all generalizations. **(166)** (reproduced by courtesy of the Swiss Postal Administration) shows the fine new SIHL GENERAL POST OFFICE, ZÜRICH, which was designed by the architects Gebrüder Bräm *in conjunction with* the engineer Robert Maillart. In this very long façade the adoption of standardized six-pane vertical windows helps to counteract what might otherwise have been an exaggerated horizontal effect. On the ground and first floors the surface of the concrete has been exposed by bush-hammering, while in the upper stories it was rendered in white stucco. The charming little bow-fronted building reproduced by courtesy of the *Norsk Cementforening* in **(167)** is L. Bacher's "SKANSEN" RESTAURANT, OSLO—another good example of a concrete structure with a dead white cement finish. The elliptically-fronted TELTCHOWHAUS IN THE POTSDAMERPLATZ, BERLIN **(168)**, which was designed by Gebrüder Luckhardt and Alfons Anker, is a steel-framed building faced with continuous sheets of virtolite—milk-white between the floors, and dark blue between the standardized longitudinal casements.

169

SMELTING ORE

A BATTERY OF FIVE-YEAR-PLAN BLAST-FURNACES AT THE DJERJINSKY IRONWORKS, KAMENSKI, IN THE UKRAINE. The basic slag of a Thomas furnace can be used either as raw material for artificial Portland cement, or, if fairly rich in phosphor content, as the basis of a synthetic fertilizer. The resourcefulness of German chemists in discovering a process by which the highly phosphoric " Minette " slag of the Lorraine ironfields could be converted into an agricultural manure initiated the second phase of industrialism : the recovery of valuable by-products from " waste."

170

(170) A Crystal Palace where there are no blinds to pull down. The new bridge at J. A. Brinkman & J. C. van der Vlugt's VAN NELLE FACTORY AT ROTTERDAM, connecting the packing rooms with the main building. The bridge contains a mechanical conveyor, recently added in order to obviate the noise caused by the circulation of trollies. This great glass-walled factory, in the framework of which steel girders and reinforced-concrete cantilevering are combined, is one of the most majestic monuments of our age. No modern-minded man or woman can stand before it and remain insensible to its transparent beauty.

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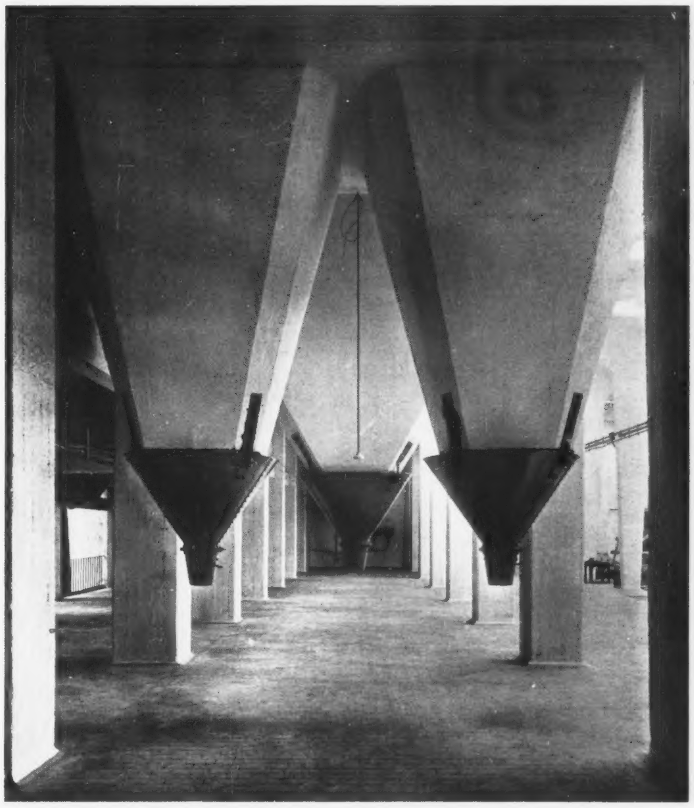

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CONCRETE SHAPES AND CONCRETE SHADOWS

(174) and **(175)**, two typical industrial landscapes in the Ruhr—a complex of MECHANICAL CONVEYORS AT THE ERNESTINE PIT, STOPPENBERG, and the MAIN COAL-BUNKER OF THE BRUCHSTRASSE PIT AT LANGENDREHER—are reproduced by courtesy of " Hochtief " A.G., Essen. **(172)** is the WOOD-PULP SILO AT THE TOPPILA CELLULOSE FACTORY (a British concern) in the Arctic Zone of Finland, designed by Alvar Aalto. **(171)** shows the OUTLET VALVES OF THE SILOS OF A SUGAR REFINERY AT TANGERMÜNDE (1922). The pendulous forms of these gigantic funnels irresistibly suggest the appearance of a mechanical cow stalled ready for its synthetic milking—which, in point of fact, presents some analogy to the process of extracting sugar from beetroots. Coal-bunkers, silos, water-towers, the bell-shaped cooling-towers of thermal power-stations, and monolithic factory chimneys and lighthouses are all embodiments of the tower form in concrete ; while the Perrets' "*Tour d'Orientation*" at Grenoble (1925) and the belfry of the new " *Hôtel de Ville* " at Lille exemplify towers *qua* towers. Skyscrapers have been built with reinforced-concrete skeletons (the Petroleum Building at Oklahoma is an example), but they merely reproduce the same beam-and-post sequences of box-frames which have long been standardized in fabricated steel. Up to 10 or 12 stories concrete can hold its own with steel, but thereafter the advantages of the latter in point of speed and cost of construction become overwhelming.

(173), a still from one of Jaromir Funke's films, gives A BIRD'S-EYE GLIMPSE OF THE WORLD OF HOUSE-TOPS, purged of sham turrets and " fancy " roofs, and proves how far more exciting it will be to look down from the sky when concrete buildings become more general. From the photographic point of view it is interesting to see how attractively the sun shades the blacks, greys, and whites of the sharp lines and flush surfaces of this hard, clean material.

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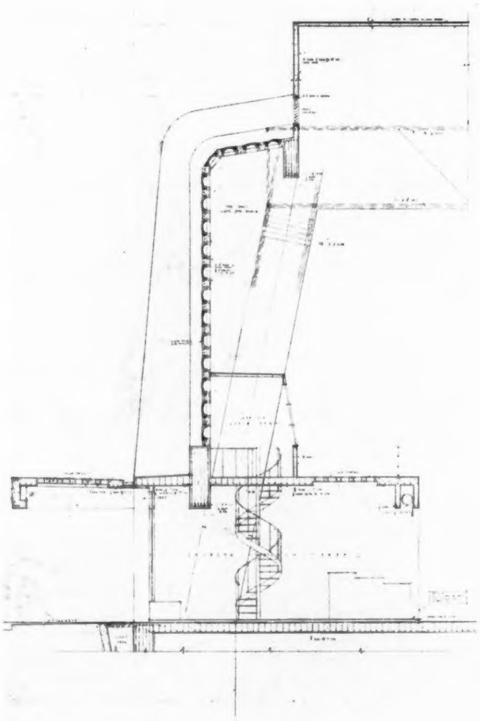

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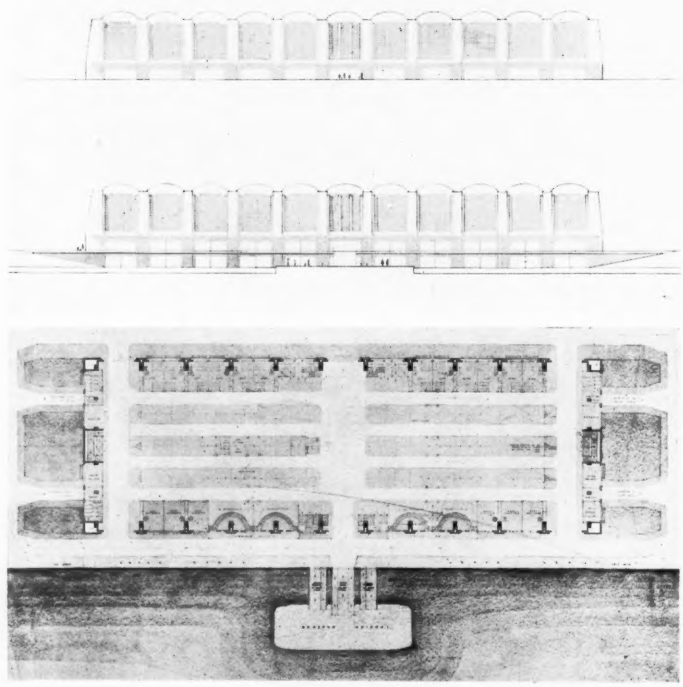

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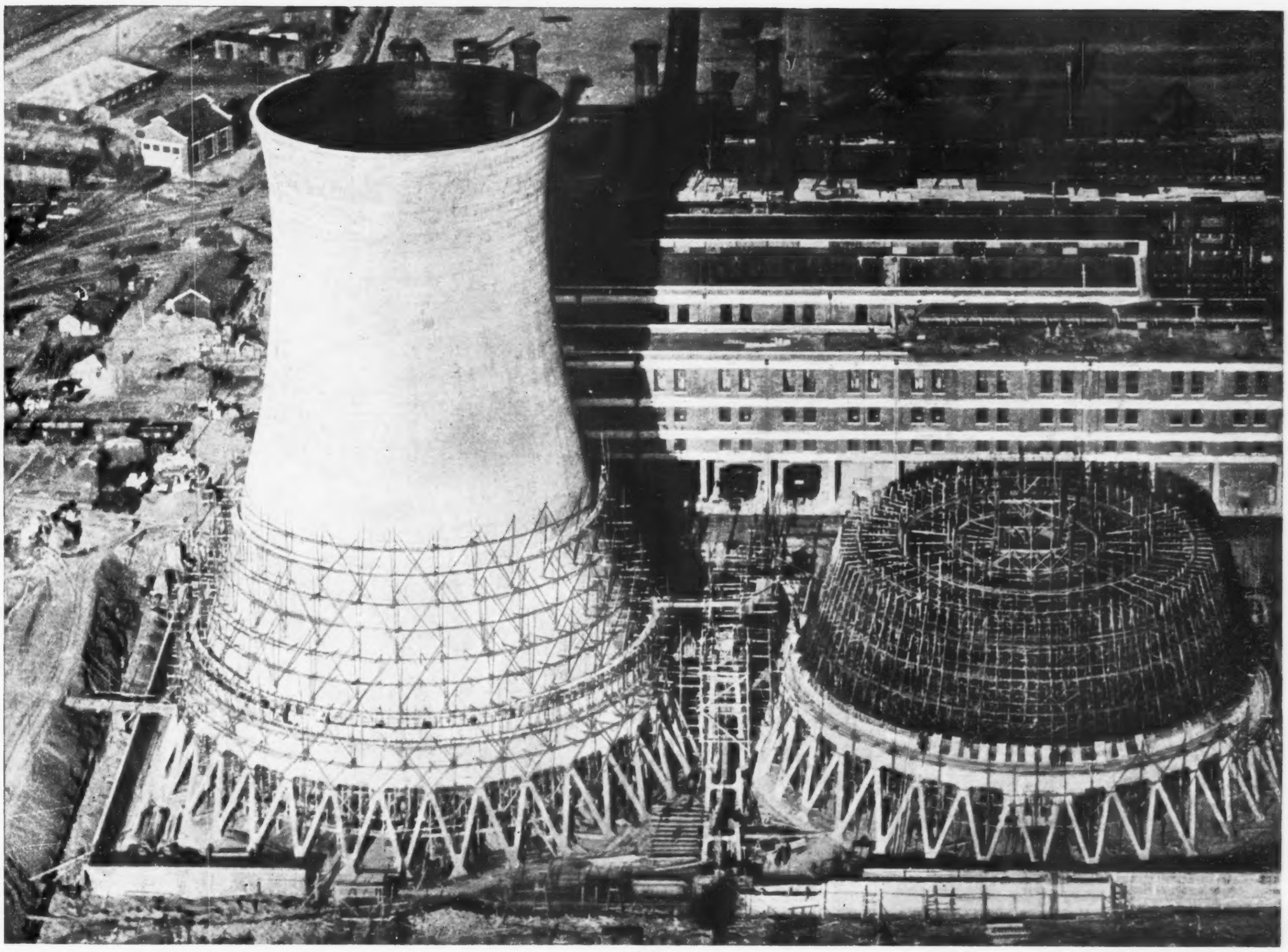
(176-179) A REINFORCED CONCRETE FISHMARKET, *architect* and *structural engineer*, Walter Goodesmith. The construction consists of a series of 11 barrel reinforced concrete shell roofs on the Zeiss Dywidag principle, 3 in. thick at the crown and 4 in. thick at the springing, with pumice concrete filling and triangulated double nets (top and bottom) of reinforcement made of extruded steel sections, and the whole covered by layers of tarred paper. Deep horizontal tie-beams at the springing form the top members of rigid concrete frames with sloping legs, thus increasing the virtual span of the roof. The wall infilling between frames is of reinforced concrete beams and mullions with cast glass slabs specially shaped to counteract expansion and contraction, on the "G" system. Space is available in the legs of frames for full accommodation of all mechanical equipment and services.



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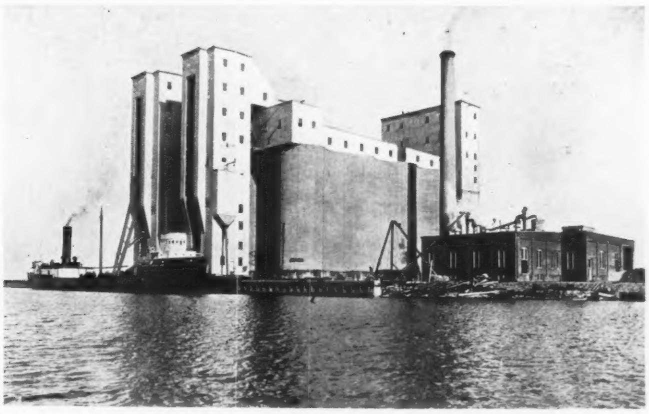

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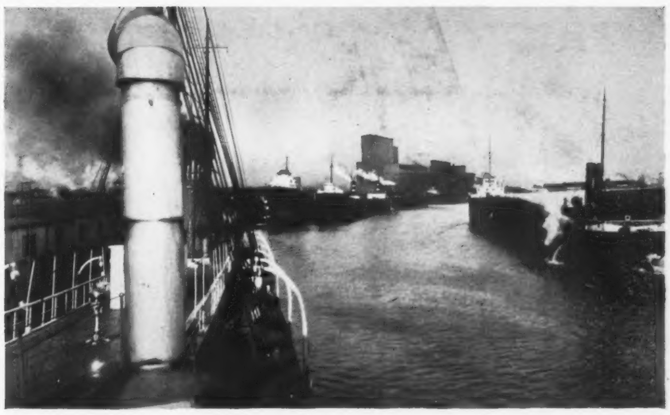

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M O D E R N   M O N O L I T H S

Power stations and grain elevators, or silos, are built in the tower form. These unadorned, enormous buildings rise up above the horizontal lines of merchant ships and goods yards and locomotives, memorials to industrialism much as the monoliths of Stonehenge or Avebury rise out of the smooth levels of the downs as memorials to a hazy past. The designers of cooling towers (an explanation of which appears on page 227) and silos are as anonymous as the architects of Stonehenge. This anonymity makes even more impressive the generous proportions and towering strength of the constructions. They show, at their best, the dignity and size of industrial architecture and proclaim the majesty and terror of industrialism.

The illustrations on this page are (**180**) the ELECTRICAL POWER STATION AT WATER ORTON, Hams Hall, near Birmingham (reproduced from *Modern Architecture* by permission of "The Studio"). (**181**) a GRAIN ELEVATOR AT PORT McNICOLL, Canada, the property of the Canadian Pacific Company. (**182**) is a SHIPPING SCENE AT FORT WILLIAM, Canada. Grain elevators, the modern temples of Canada, are, appropriately, the focal

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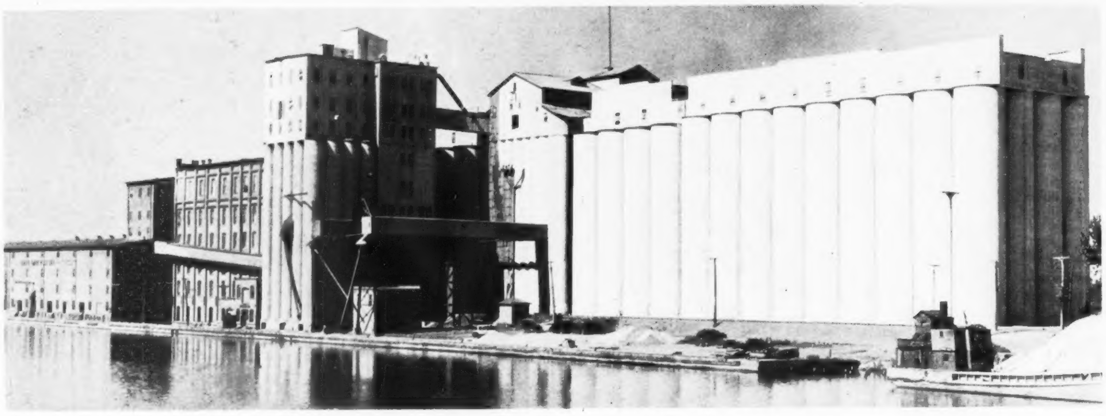

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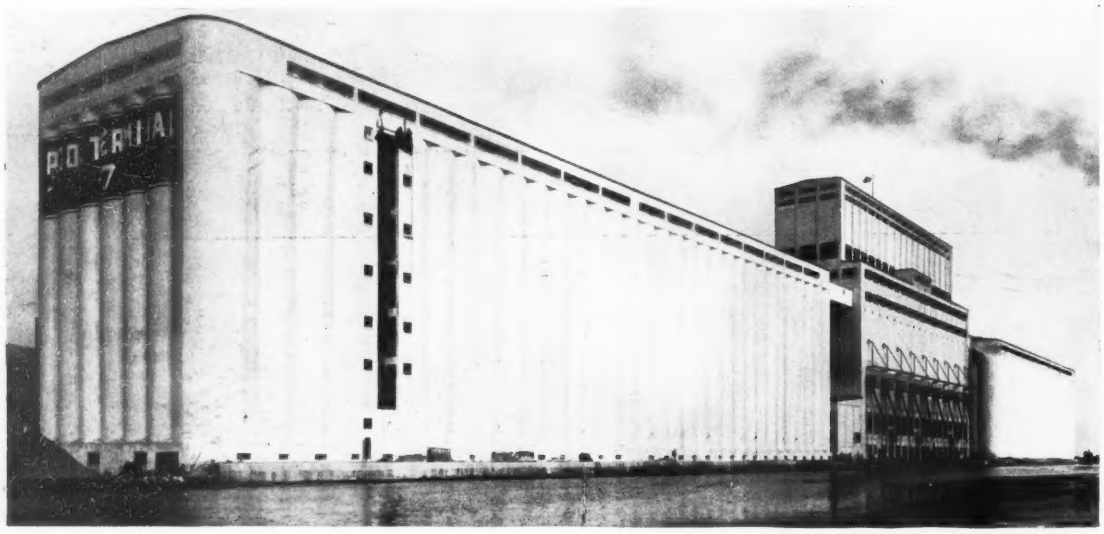

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points of communications. Waterways, railways and roads lead to them from the wheat growing plains. The three large railways of Canada converge on Fort William and Port Arthur, situated at the west end of Lake Superior. Thence grain ships sail for all parts of the world.

(183) a view of VICTORIA BASIN, PORT OF QUEBEC, shows the huge grain elevator with the conveyor galleries running along the top. The low somewhat ramshackle buildings round the Basin cause this silo, one of the largest in the world, to stand out in contrast by reason of its vertical lines. The reinforced concrete cylinders containing the grain which is carried along the galleries resting on them, resemble the columns of a Greek or Roman temple with the gallery as architecture. **(184)** is OGILVIE'S SILOS AT FORT WILLIAM, Ontario, while **(185)** is the NEW TERMINAL ELEVATOR OF THE CANADIAN WHEAT POOL, ONTARIO. The familiar remark " but I could not go to Canada—there is no ancient building, no architecture " is characteristic of the architect who is only to be moved by

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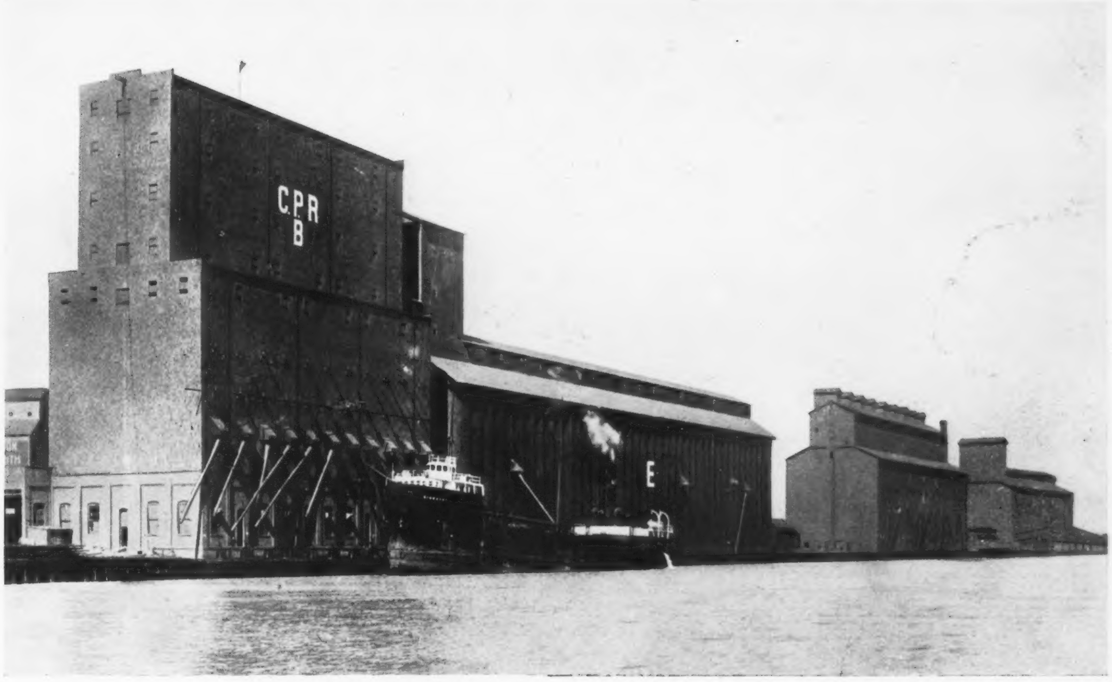

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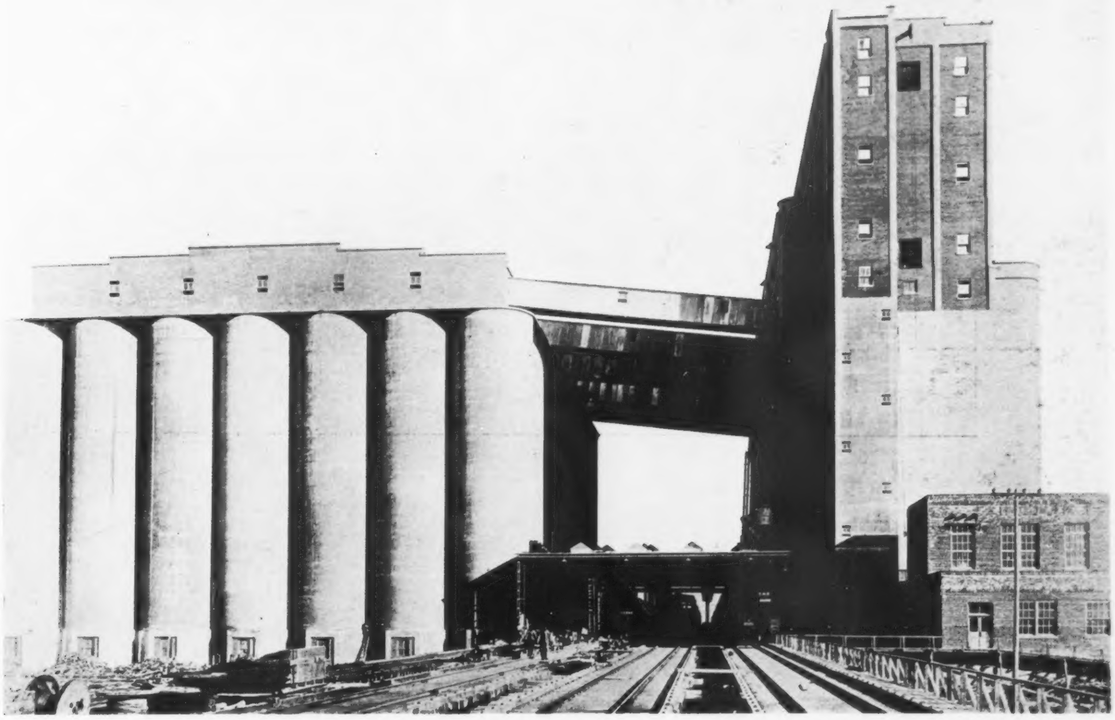

antiquarianism. In Ontario he can find structures as solid as the nave of a Norman cathedral, as imposing as a classical temple.

The impressiveness of their trade—the elevator at Port Arthur is capable of holding 325,000 bushels of wheat—is equalled by the impressiveness of the size of the silos. Nor are they lacking in proportion; difficulties in raising the grain more than a certain height have prevented any attempts at a skyscraper effect and have kept the cylinders squat but not ungainly. For this reason a distant view of a silo is reminiscent of a Doric temple. Yet analogies become superfluous, for the strength and size of the buildings may be estimated by comparing the fair-size grain ship in (**186**) and the goods trucks in the shed in (**187**) with the buildings alongside them. This is the new Empire architecture. (**186**) is the CANADIAN PACIFIC ELEVATOR AT FORT WILLIAM. (**187**) is the DOMINION GOVERNMENT ELEVATOR AT PORT ARTHUR.

A future archæologist will probably explain that some ruined silo he has succeeded

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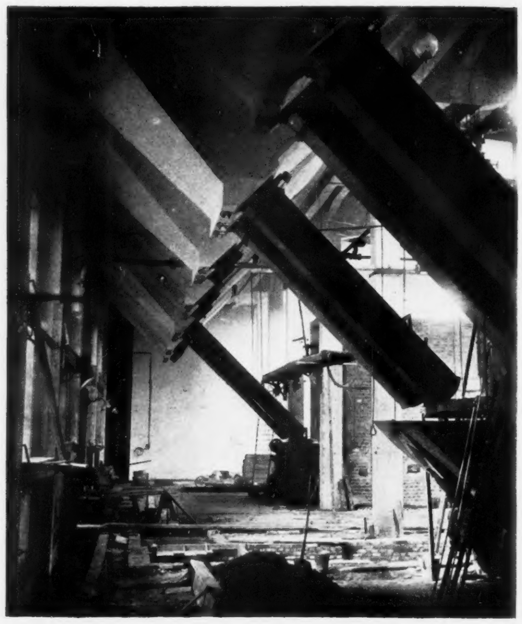

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in dating " circa 1925 " was a monolithic monument of undoubtedly phallic type erected to the memory of Joseph Monier, reputed by tradition to have been the first man to reinforce concrete with steel. Silos are simply large cylindrical containers for the storage of grain, etc., and Monier's first rude potter's-thumb moulding of cement round iron mesh was also a container : a small garden tub to hold earth in which a (if you like symbolically) growing tree could be planted. Certainly the shapes of the earliest silos in the grain-ports of the Great Lakes—for the silo originated in America—were crude enough, but they contained the genesis of an architectural expression which has been magnificently realized by European engineers. The Quai d'Arenc silo in Marseilles, the largest in Europe, which forms an almost classical colonnade on the harbour front, is a fine example ; but there are plenty of others.

(**192**) shows a flood-lit view of a CEMENT SILO IN ARGENTINA : a monolith every whit as impressive and monumental as an Egyptian pyramid by moonlight. Here pure form expresses pure function, and achieves pure beauty. A coal-bunker is

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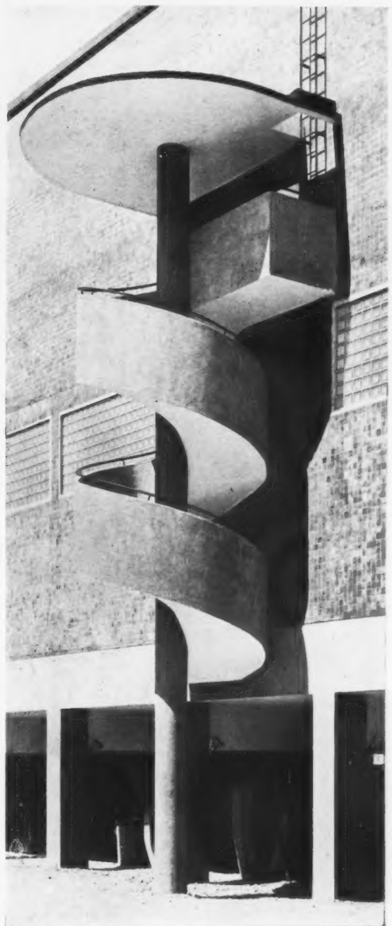

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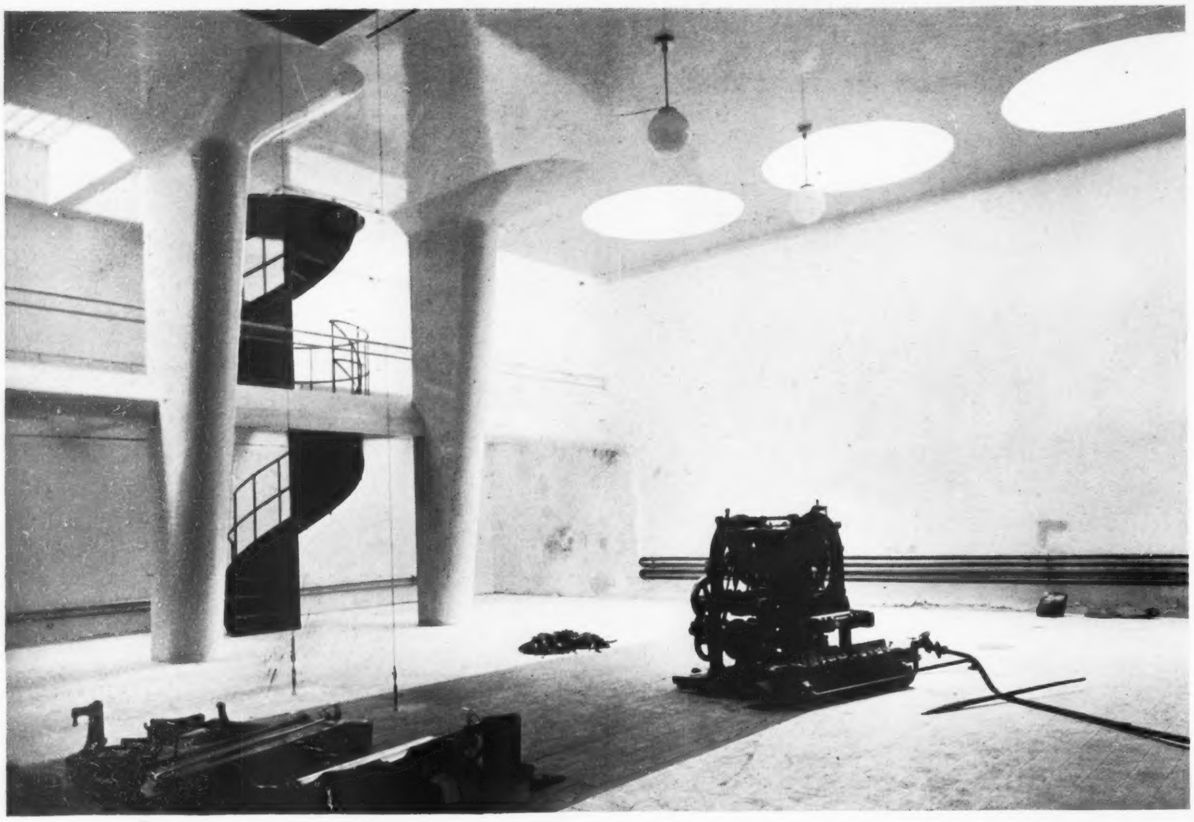
simply a specialized form of fuel silo. **(189)** is a " close up " of the DISCHARGING VENTS OF THE COAL-BUNKERS AT A WEAVING MILL AT FORCHHEIM IN GERMANY. **(188)** is a photograph of the INTERIOR OF A COOLING-TOWER AT THE DIOSGYÖR STEELWORKS IN HUNGARY taken during construction. **(190)** and **(191)** are examples of concrete construction in waterworks. The latter shows the circular catacombs of the MERIDEN RESERVOIR, COVENTRY, with only part of the vast cistern as yet roofed in; the former an access gallery in RESERVOIR NO. 3 AT THE NUREMBERG WATERWORKS.

(193) is a CANOPIED OUTSIDE STAIRCASE of intriguing spiral design that affords connection between two floors of the Permanent Exhibition Buildings at Brünn in Czechoslovakia, of which Bohuslav Fuchs was the architect.

(188) is reproduced by courtesy of Wayss & Freytag, A.G. of Frankfort-on-Main; **(189)** and **(190)** by courtesy of Bauunternehmung Dyckerhoff & Widmann, A.G. of Wiesbaden-Biebrich; and **(192)** by courtesy of Christiani & Nielsen, of Copenhagen.



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MUSHROOM-SLAB CONSTRUCTION

Mushroom slabs enable the floors of a structure to be cantilevered out from supporting points standing some distance behind the exterior walls indirectly sustained by them : an effect which, when the ground floor is recessed back from the façade, or left unenclosed, is apt to make us feel the design is top-heavy. As beams can be dispensed with altogether, this method is ideal for warehouses and multi-floored factories on account of its lightness and cheapness. A characteristic of these buildings is that though the pillars are superimposed on one another floor by floor, they decreas progressively in girth from cellar to attic. When finely handled, as in Rober Maillart's Federal Granary at Altdorf, in Switzerland, long columned vistas resul that are as austerely beautiful as the interior of any Greek temple. The slabs are firml united to round, square, hexagonal, octagonal, or twelve-sided columns by fan-shape reinforcement ; though certain designers prefer to eliminate visible slabs altogethe

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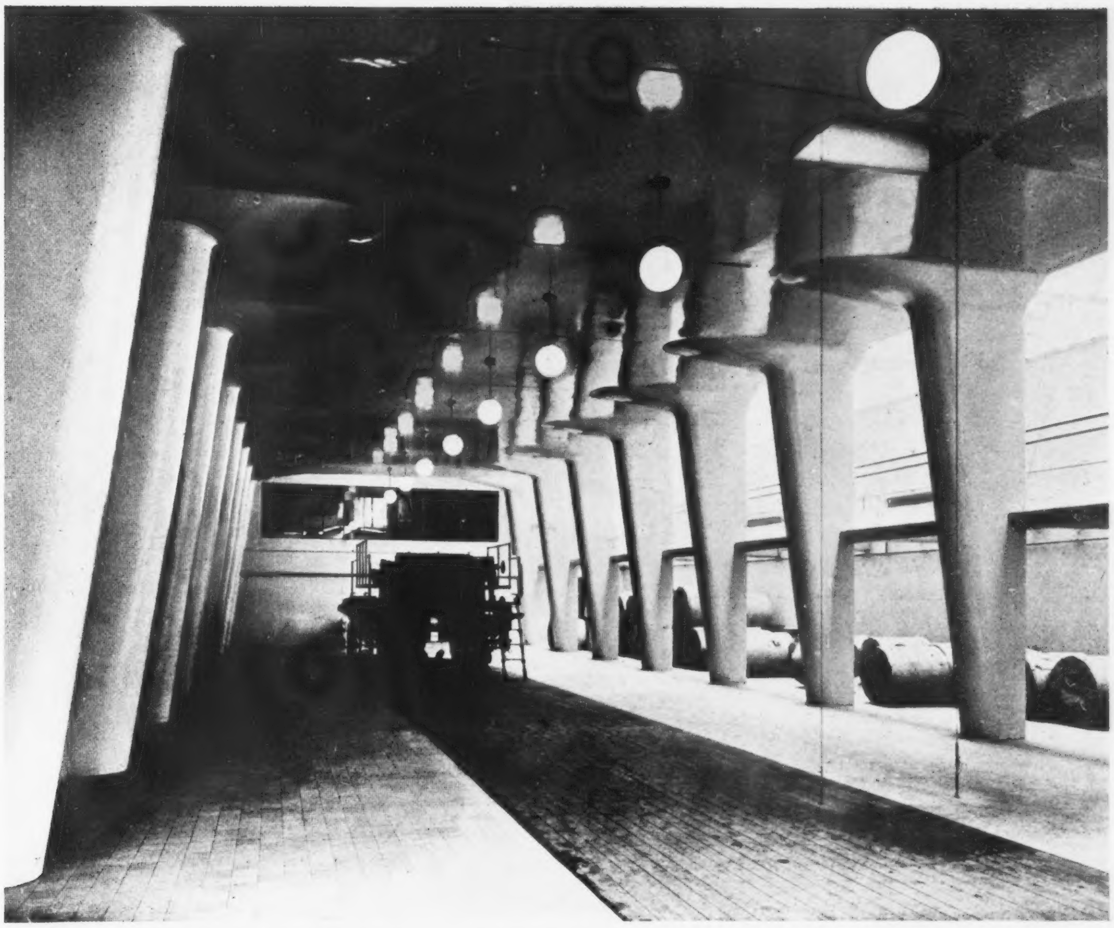

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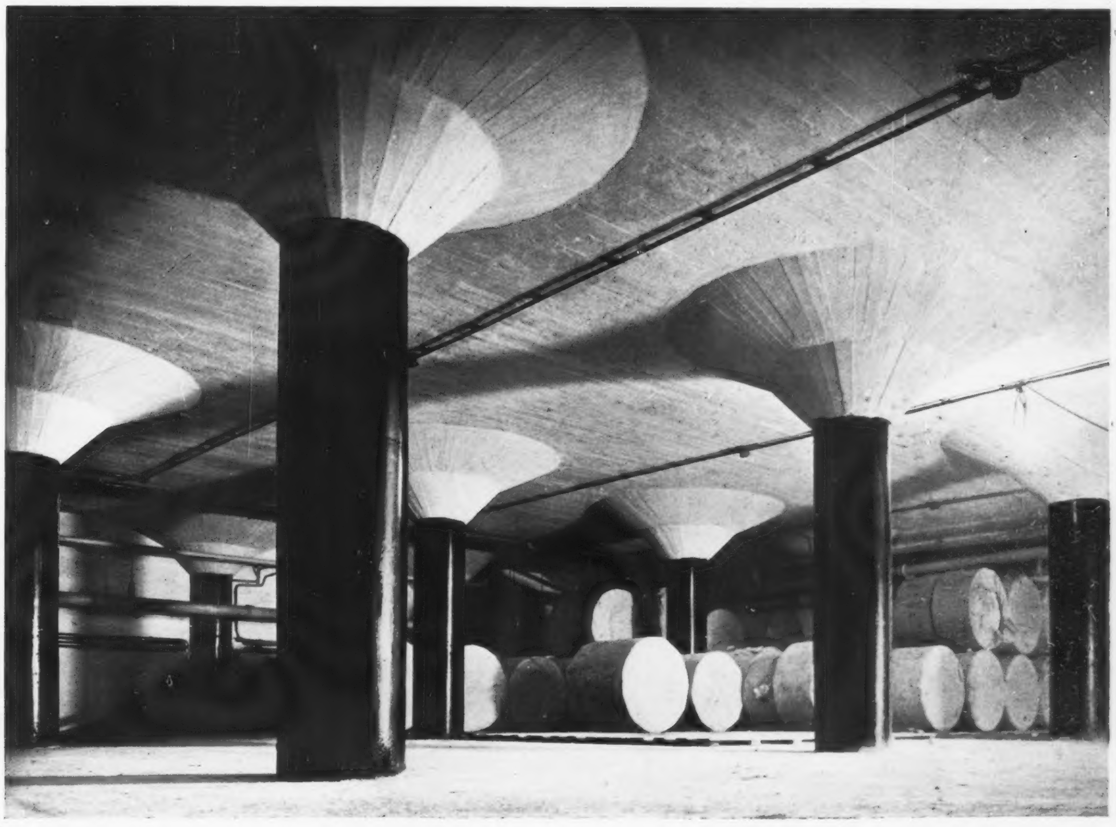

as unnecessary complications entailing an unnecessary multiplication of surfaces.

Sir Owen Williams's revolutionary design for a new Waterloo Bridge substitutes a single row of cylindrical mushroom-headed pillars for piers and cut-waters of the conventional type. He has used the same type of construction in the new BOOTS FACTORY AT BEESTON, NOTTINGHAM (195). The photograph, which illustrates what will ultimately be only a third of the main frontage, reveals tiers of fungoid forms rising shadowily behind their glass screens. **(194)** and **(196)** show two views of the Linotype Room at the "TURUN SANOMAT" BUILDING, ÅBO, FINLAND, designed by Alvar Aalto. These slanting peg-top stanchions are examples of what is known as "dropped" slab support. In **(197)**, the paper storage cellars of the same building, ordinary mushroom-slab construction is employed, the shafts of the columns being finished in black cellulose enamel.

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R E P E T I T I V E   R H Y T H M S

(198) shows the workshop and the double-tiered bridge connecting it with the Students' Hostel at yet another "Crystal Palace": the "BAUHAUS" AT DESSAU, of which Walter Gropius—perhaps the most extreme of the German functionalists—was the architect. Gropius, like Mendelsohn, was the pupil of Peter Behrens, whose steel, concrete, and glass "*Turbinenhalle*" at the A.E.G. Works in Berlin (1909) was the prototype of all modern factory buildings. **(199)**, a striated cubic design finished in alternating bands of scarlet and white cement stucco, is a RICE MILL AT THE NEW POLISH PORT OF GDYNIA, on the Baltic. **(200)**, the new SWISS NATIONAL LIBRARY AT BERNE, embodies an asymmetrical juxtaposition of vertical and horizontal fenestration. In the main building the wallage prevails over the windows. In the annexe the position is reversed.

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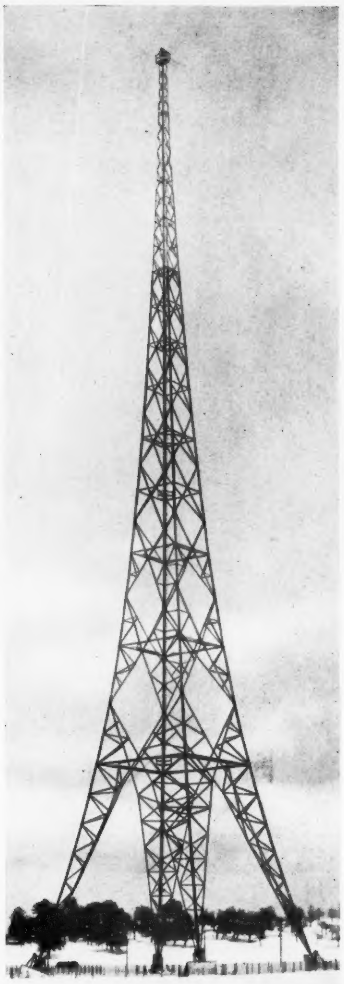

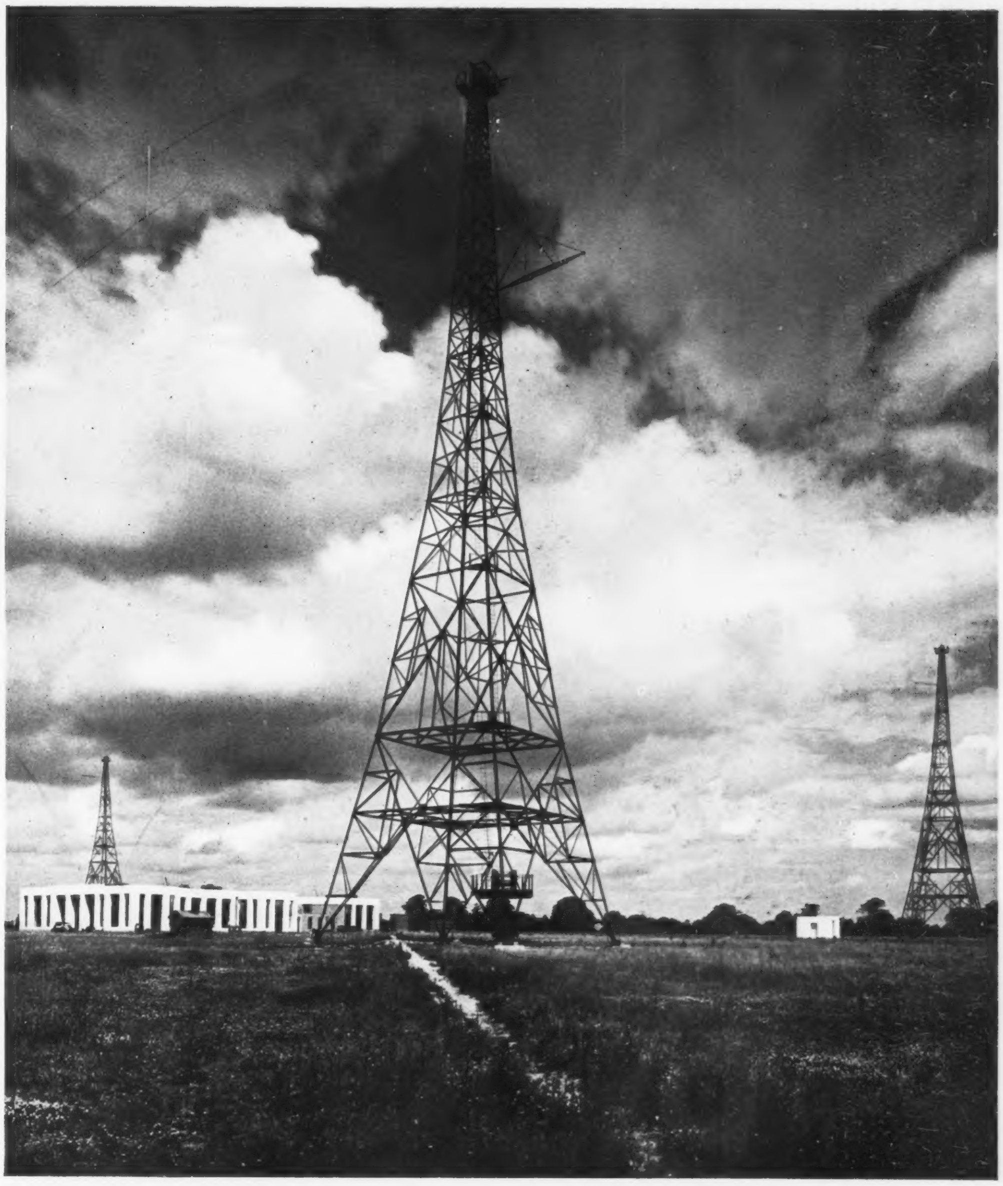

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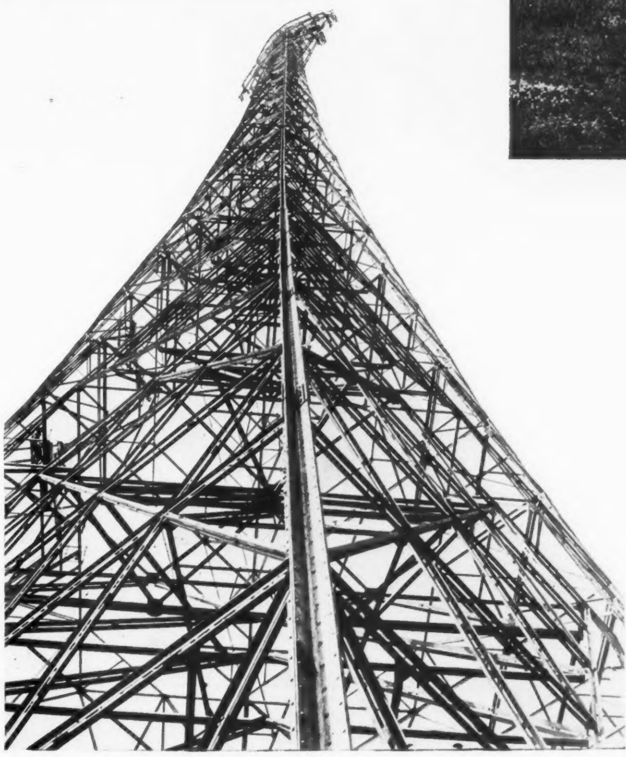

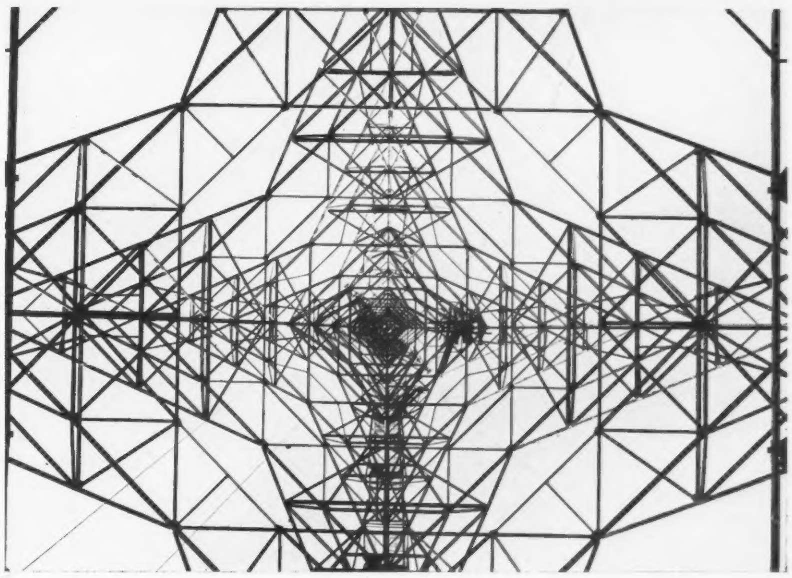

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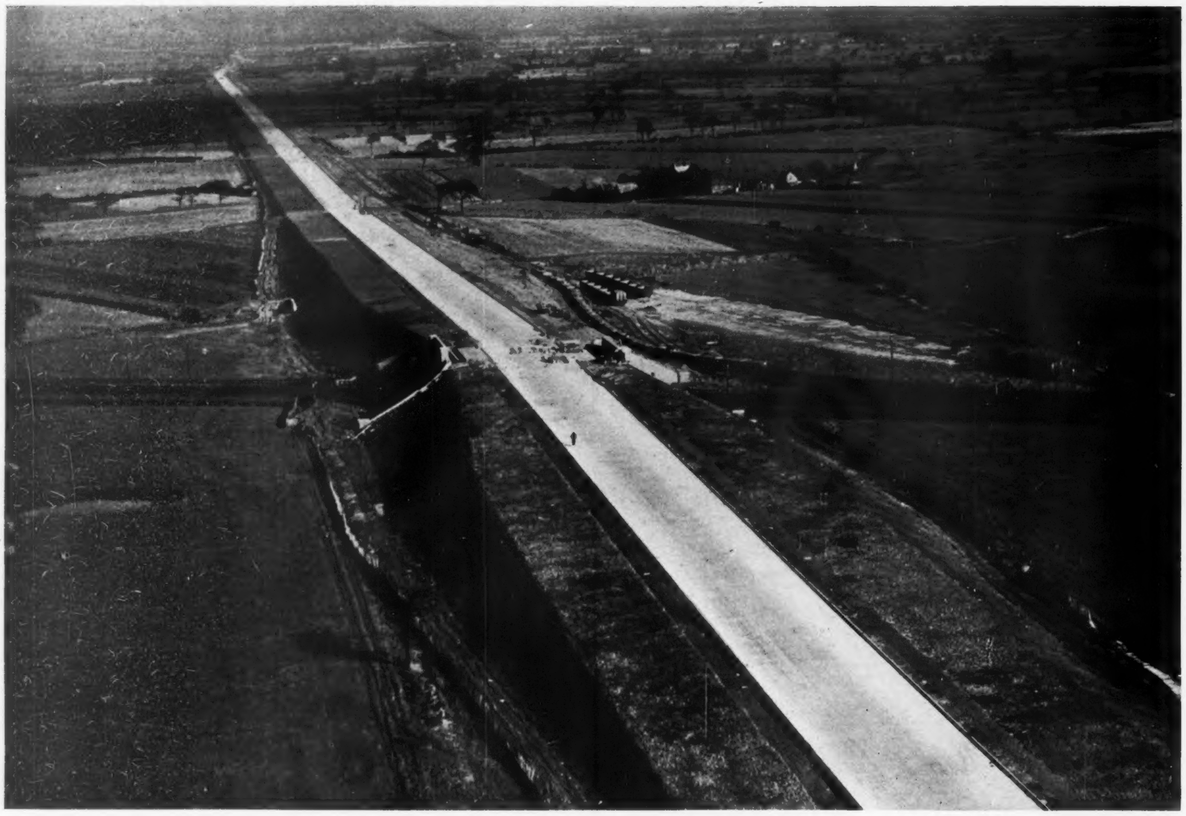
S T E E L   I N   H I G H   P L A C E S

Radio Antennæ-Towers at (**201**) the SCHWEIZERISCHER LANDESSENDER, BEROMÜNSTER, and (**202**) the BROOKMAN'S PARK LONDON REGIONAL STATION of the B.B.C. In both cases the towers, which can withstand wind pressures of hundreds of miles an hour, are anchored to "pin-point" foundation-sockets. (**202**), being more complicated, is a rather coarser design than (**201**): a fragile interlacing rhythm of the purest formal beauty, patterned with the knife-edge metrical delicacy of Alcaic scansion. (**203**) and (**204**) are exterior and interior worm's-eye views of the DAGENHAM PYLON at the Thames Crossing of the "Grid," connecting the Essex and Kent primary circuits. These twin towers, which are incidentally the tallest examples in the world, have a height of 487 ft.; and cover a base area of 120 square feet. As a warning to aircraft, each is illuminated at night by a 1,200 c.p. beacon at its apex, and groups of crosses on three sides of its framework placed at heights of 365 and 175 ft. above the ground: a total of 19,000 c.p. The interval between the two towers is 1,000 ft., in the middle of which the cables dip down to 220 ft. above the stream. (**204**), which, like (**203**), is reproduced by courtesy of *The Times*, would make an ideal frontispiece to Dr. Erasmus Darwin's famous treatise on "The Loves of the Triangles."



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THE DIAGONAL OF MODERN TRANSPORT

Throughout the intervening centuries the lesson of the Roman roads—roads drawn straight as a die over hill and dale between military stations that were geographical symbols of a co-ordinated civilization—had been forgotten. Napoleon, the only autocrat to remember it, scarring the face of Europe with his *routes militaires*, could hurl battalions along metalled highways, and conquer by command of lateral communications while his adversaries floundered in the muddy ruts of meandering mediæval byways. Then came industry with its imperative need for rapid distribution. The railway, born of this need, restored the Roman diagonal in England. The modern arterial road, which is now superseding it, drives straight through physical obstacles with the same majestic ruthlessness. Pneumatic tyres demand surfaces smooth as glass, easy gradients, curves of wide radius. Without the technical perfection of reinforced-concrete highways, the generalization and mass-production of the motor-car would have been impossible.

(**205**)—which is reproduced by courtesy of the Twisteel Reinforcement Company—is an aerial view of the NEW EAST LANCASHIRE ARTERIAL ROAD, between Liverpool and Manchester, crossing a railway line on an embankment as it furrows through the passive landscape.

(**207**) is a photograph (reproduced by courtesy of " Hochtief," A.G., Essen) of the 35 metres high Pylon No. 2 on the PREDIGTSTUHL PASSENGER CABLEWAY, which runs up the Lattengebirge near Garmisch-Partenkirchen in Bavaria, taken just after it was unshuttered.

(**206**) which is reproduced by courtesy of Wayss & Freytag, A.G., Frankfort-on-Main, is described on page 240.

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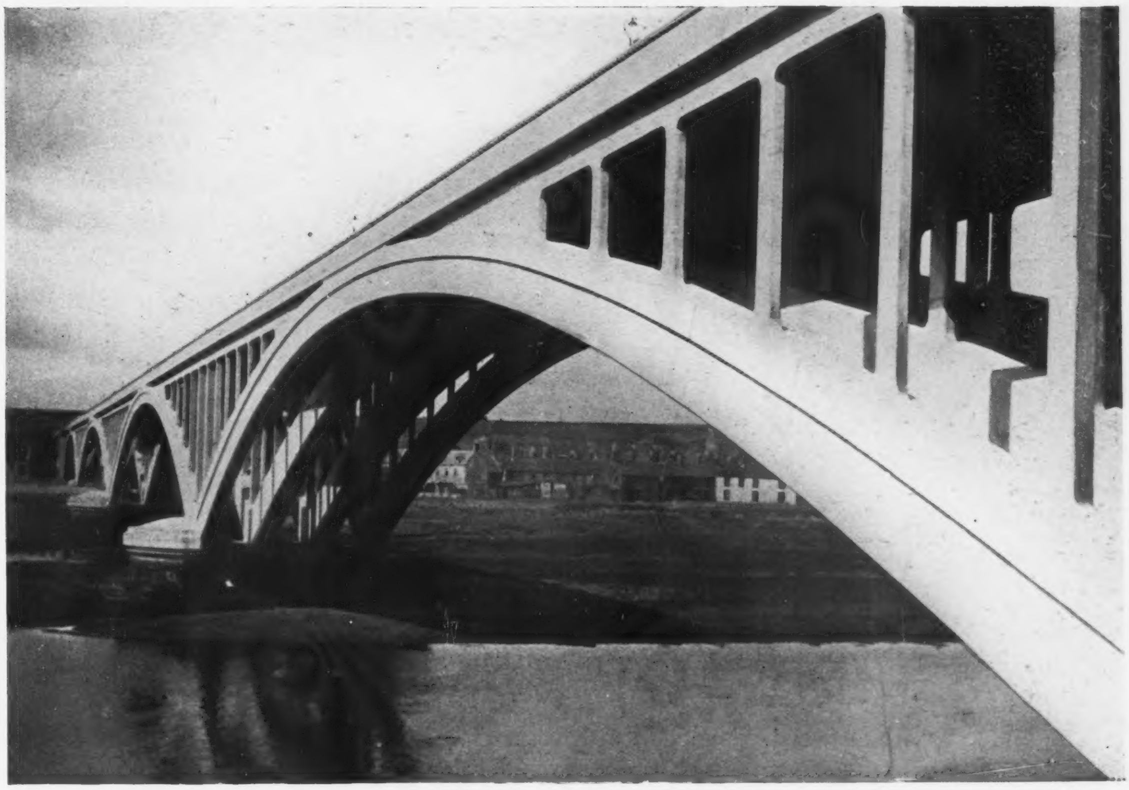

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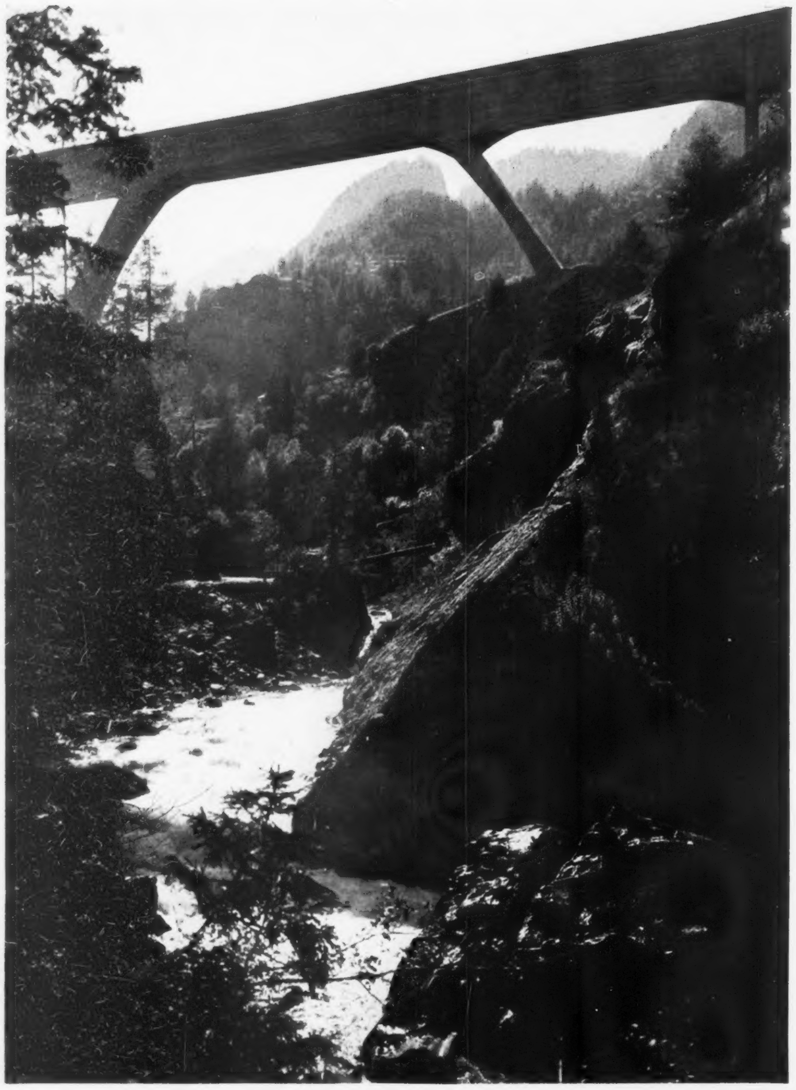
THE BRIDGE IN CONCRETE

The cost of keeping a large steel bridge like the Forth Bridge, or the bridge over the St. Lawrence at Montreal, in proper condition is enormous. A permanent staff of painters has to be employed, and the work never ceases. By the time one span is finished it is time to start on the next. A constant watch has also to be kept for rivets working loose. Concrete requires no periodic maintenance or repair, and can be left almost entirely uncared for indefinitely.

Flat-arch bridges in concrete, which are only suitable for spans up to about 20 or (at most) 30 metres, are exemplified by Mr. Maxwell Ayrton's Lea Valley Viaduct, Emperger's Alt-Schadow Bridge near Berlin, the fine four-span bridge at Eichstadt; and in an even purer, though by no means typical, form by Robert Maillart's CHÂTELARD AQUEDUCT (**213**). Elliptical arched bridges, which constitute the largest class, include the widest spans yet built in concrete. The longest of all (or rather the three longest, for here the chord of each measures 186·5 metres) is in Freyssinet's magnificent triple-arched Pont Albert Louppe over an arm of the landlocked harbour of Brest, near Plougastel. The Plougastel (or, as it is sometimes called, Elorn) Bridge, which was opened in October 1930, consists of three huge hollow ribs supporting a double platform for road and (ultimately) railway. As a result of the experience gained at Plougastel, M. Freyssinet has announced that he is ready to build a single-span tubular concrete bridge of 1,500–2,000 ft.—or with good rock foundations of 3,270 ft. (which is 1,620 ft. longer than the Sydney Bridge)—anywhere in the world tomorrow; though he considers the probable ultimate span-limit for a bridge of this type should be somewhere between 4,900 and 6,000 ft. He maintains that as the cost of one ton of concrete is hardly a fifth of a ton of fabricated steel, an arched concrete bridge of such a span would cost about half as much as a steel suspension bridge of the American type; and that since the use of reinforced concrete produces a saving of 6 lbs. per ft. run, the weight span for span would also be about half.

Among other notable arch bridges are the ECHELSBACH BRIDGE over the River Ammer in Bavaria (**220**)—built on the Melan system without centering—which, with a clear span of 182 metres, is the third longest ever built in concrete; the



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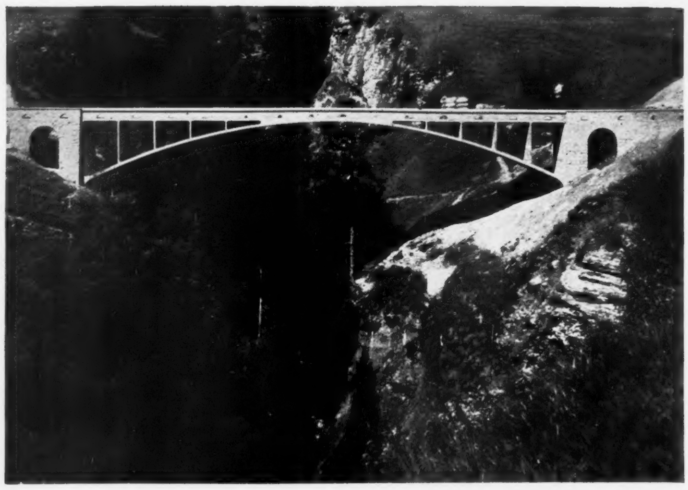

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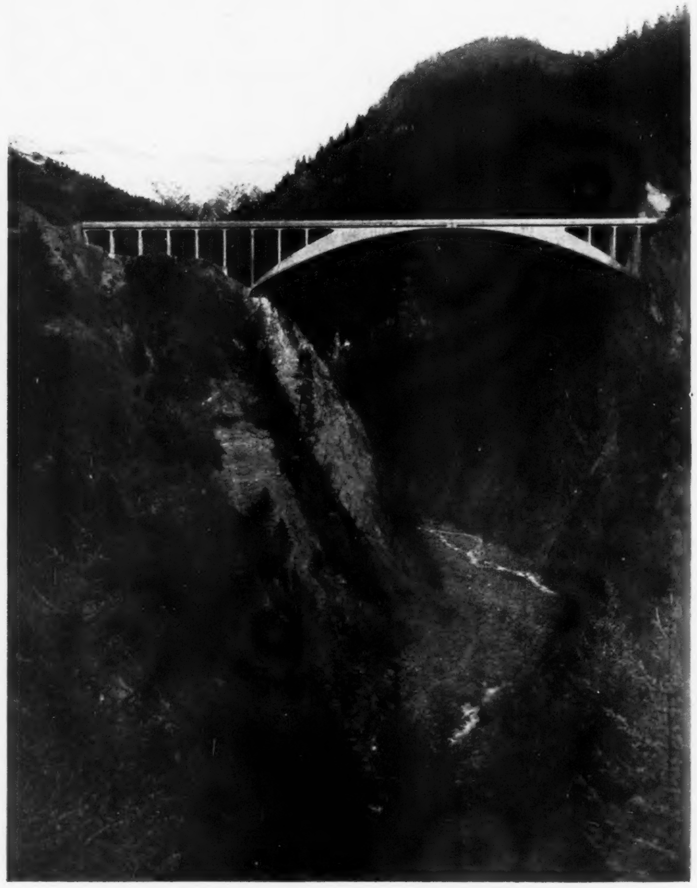

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elegant Hundewilertobelbrücke in Appenzell, Switzerland, of 105 metres; the Langwieserbrücke of 100 metres span on the Chur-Arosa Railway in the Engadine; the triple-span Skurubron over a channel of the Saltsjön near Stockholm; and the five-spanned Pont de Pérolles in the Canton of Fribourg. The outstanding example in Great Britain is the ROYAL TWEED BRIDGE AT BERWICK (**210**), designed by L. G. Mouchel & Partners, which has four spans, 361½, 285, 248 and 167 ft. in length respectively. This bridge has a falling gradient from the Scottish to the English side. In the view reproduced the illusion of distance is increased owing to the fact that the photograph was taken from the side of the longest span. Concrete arch bridges (which have been likened to the lithe leanness of leopards in full spring) are much more graceful than stone ones because they contain much less material, and yet preserve all the essential characteristics of lithic form. The flattened and elongated elliptical arch adopted in the ERNST-WALZ-BRÜCKE AT HEIDELBERG (**206**) page 238, the bridge over the Loire at Cosne, and the Josef-Strüber-Brücke at Golling, in the Tyrol, are of undeniable beauty judged by any æsthetic canons.

The longest arched span in mass concrete (which has certain advantages over reinforced in particular sites and circumstances, quite apart from being cheaper) is that of the Pont de Caille, or Viaduc des Usses (1925), in Haute Savoie, where the arc's chord is 140 metres in length.

Three of the most graceful single-span arched bridges ever built in concrete are (**215**) THE VALTSCHIELBACHBRÜCKE (1925) of 43·20 metres span; (**216**) THE SALGINATOBELBRÜCKE (1930), with a span of 90 metres attenuated to only 20 cms. thickness at the crown of the arch; and (**221**)—which was swept away by an avalanche in 1927—the original 51 metres span "skate-blade" that vaulted the Upper Rhine at Tavanasa (1905). All three were designed by Robert Maillart,

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and all three are in the Swiss Canton of Graubünden. The " hump-backed " arched bridge is a much lighter and cheaper type to build. (**209**) is the FORSTWERDER FOOT-BRIDGE in a park at Halle, Germany; and (**214**) a BRIDLE-TRACK BRIDGE of 170 feet clear span over the river Fnjoska, near Skogar, in Iceland (1907). The CRUBENMORE BRIDGE in the Highlands of Scotland (**219**), designed by Maxwell Ayrton in conjunction with Sir Owen Williams, K.B.E., is an interesting geometric design that blends admirably with its desolate surroundings. (**217**) and (**218**) are underviews—the former of the Echelsbach Bridge, showing the transverse compartmenting of the arch between the two hollow ribs; and the latter of the LECH BRIDGE at Hochzoll: a much flatter-arched structure of 84·40 metres span supported on four solid ribs.

The " bowstring," which has been extensively adopted in France (i.e. the triple-span PONT DE PESEUX) (**212**) and Sweden—as in the BRIDGE ACROSS THE KLARA RIVER (**211**), with its three spans of 70 metres—for wider openings owing to its lightness and cheapness, is typified by Emperger's Hindenburgbrücke at Breslau, and a railway bridge of 64·5 metres span crossing the River Saar at Völklingen. Actually the longest concrete " bowstring " in the world is still Henri Lossier's Pont Lucien Saint (1926) over the Oued Mellègue in Tunisia, with its clear span of 92 metres. A very interesting highway bridge of the suspended type, which is not a bowstring at all, has recently been finished at MONTROSE in Scotland (**208**). This particular design of Sir Owen Williams rather invites the ignorant criticism of " looking like steel done into concrete."

(**217**) and (**220**) are reproduced by courtesy of " Hochtief." A.G., Essen; (**209**) by courtesy of Bauunternehmung Dyckerhoff and Widmann. A.G., Wiesbaden-Biebrich; (**206**) and (**218**) by courtesy of Wayss and Freytag. A.G., Frankfort-on-Main; and (**211**), (**212**) and (**214**) by courtesy of Christiani and Nielsen, Copenhagen.

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THE BRIDGE IN STEEL

It is not always too generally realized that the principles on which bridge construction is based—principles that by the last quarter of the previous century had become synonymous with the triumph of steel over space—are identical with those inherent in ordinary building. Only the scale differs. The function of a bridge is to span the interval between two points that need to be connected: a function performed by every flooring girder that unites a pair of parallel stanchions. For this purpose steel beams and arches, and steel cantilevering are all employed; just as they are in the balconies of theatres and cinemas, and in the amphitheatres of stadiums and velodromes.

It was characteristic of English conservatism that up till 1877 the Board of Trade prohibited the use of mild steel for bridges. Sir Benjamin Baker's Forth Bridge (1889), with its triple 1,710 ft. cantilever spans, still remains the most notable British achievement in bridge-building; though, unlike its contemporary, the Eiffel Tower, the details of the design had constantly to be modified on the spot. The nickel-steel Quebec Bridge largely reproduces the form, though not the structural design, of the Forth Bridge; the main difference being that it is cantilevered between two long diamond-shaped lattice-work piers instead of three hexagonal ones; and that these support a single intermediate (1,800 ft.) suspension span. Here there is an apparent increase in massiveness accompanied by a very real loss of beauty—perhaps because the tops of the piers are pointed instead of being flattened (which in the Forth Bridge helps to emphasize the otherwise not too conspicuous function of a continuous platform).

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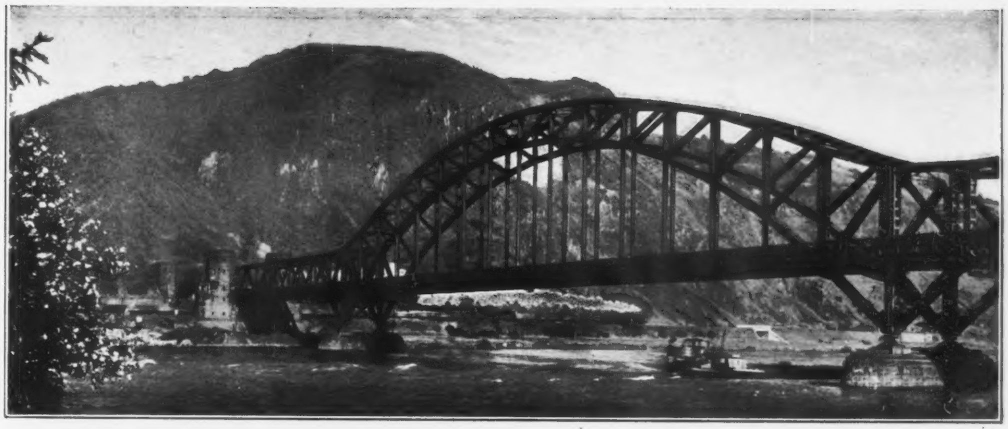

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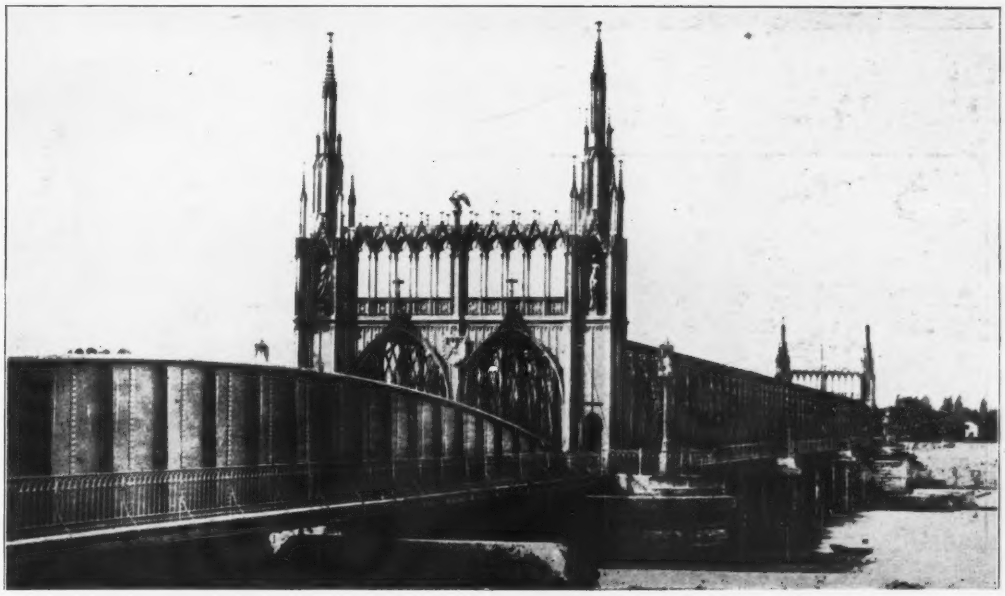

Between the Forth Bridge and the Sydney Bridge opened this year, the most interesting major British design was the 500 ft., single-span Victoria Falls Bridge: which is really a repetition of the very fine, but rather shorter, Hof Gastein Bridge in Austria.

American conditions have favoured the suspension bridge, in which the theoretical limit of length is said to be about 7,000 ft. Major American examples of this type are the Brooklyn Bridge, 1,595 ft. long (1883), the Williamsburg, a few feet longer (1904), and the Manhattan (1909), 1,470 ft. long; all in New York. The 50,000,000 dollar bridge now under construction between Fort Lee and Fort Washington in New York to the designs of O. N. Ammann has a span of 3,500 ft. It is being monumentally "architecturalized" in masonry by Cass Gilbert.

Other important American bridges include the supremely ugly, cantilever-type Queensborough Bridge in New York; the Poughkeepsie Bridge, 2,260 ft. in overall length, over the River Hudson (1889–1904), of reverse cantilever construction; the silicon-steel Bear Mountain Bridge, likewise over the River Hudson, with a length of 1,632 ft.; the Carquinez Strait Bridge at San Francisco (1927), with a 1,100 ft. cantilever span; and the high-carbon steel Hell Gate Bridge in New York, which has a "bowstring" span of 977 ft. The last of these (like the Kill van Kull Bridge, also in New York, which repeats Hell Gate in all essentials), a very fine design as far as the steelwork is concerned, has two towers 95 ft. high at each approach that contain 3,000,000 cubic ft. of masonry and do just nothing at all. In Dorman Long's silicon-steel SYDNEY BRIDGE, which with a clear span of 1,650 ft. is the longest "bow-

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string" yet built **(222)** and **(224)**—the former showing the platform during the finishing stages, and the latter an air-view taken before the four granite pylons had risen high enough to mask the beauty of the chord—Sir John Burnet and Partners have followed this American precedent. Their granite pylons are indeed immense (and therefore, of course, proportionately "imposing"), but above the springing of the arch they impair the unity of a clean structural design by piling up "æsthetic" dead weight on the heroic scale. The effect of these particular "embellishments" on natural form and symmetry can be seen by comparing the three last-named bridges with the three "bowstrings" over the Rhine built by the *Reichsbahn*; the Hindenburg brücke at Rüdesheim (1915), with two spans of 169·40 metres, THE BRIDGE NEAR REMAGEN **(223)**, and that at Engers, which have single spans of 156·20 and 188 metres respectively (1918). In each the beauty of the arc's descending parabola, as it curves slightly outwards to meet and merge in the horizontal girders of the platform, is left unobscured. It is hardly necessary to add that all three sites combine unique historic and natural "amenities" such as neither America nor Australia can hope to rival; and that German public opinion is very much alive to the necessity of safeguarding them.

(225) and **(227)**, THE KEHL BRIDGE AT STRASSBURG and THE HOHENZOLLERNBRÜCKE AT COLOGNE, offer amusing contrasts in architectural "historicism" on the Rhine. The first, opened in 1861, was designed with cast-iron Gothic portals to "harmonize with the style of Strassburg Cathedral"; the latter, inaugurated in 1910, is guarded by ponderous equestrian statues and massive sally-

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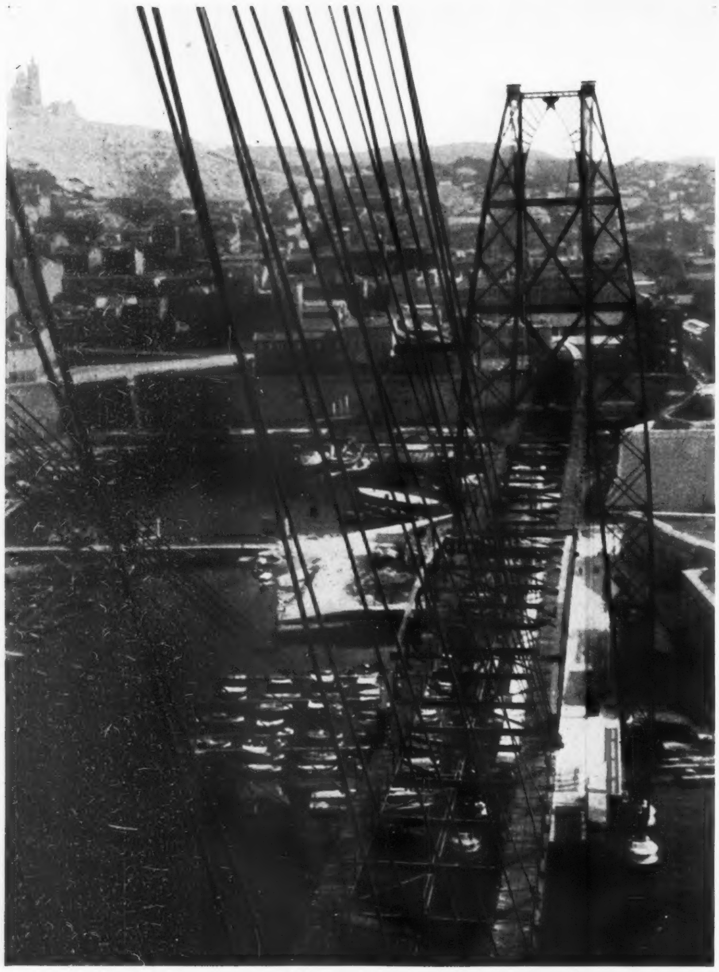
ports of pseudo-Romanesque masonry in the very personal taste of the ex-Emperor William II. But if Cologne has to suffer from the presence of a monstrous *Kaiserzeit* hybrid, it can in compensation boast the loveliest metal bridge in the whole world—one of the purest and most fluid forms ever expressed by iron. American designers could learn a good deal from this all-steel COLOGNE-MÜLHEIM SUSPENSION BRIDGE (**226**) and (**229**)—designed by Professors Abel and Kapsch in conjunction with the Harkort Gesellschaft of Duisburg—which, with a clear span of 315 metres (1,033 ft.), happens to be the longest in Europe (1929). Its design brusquely refuses all commerce with masonry or metal decoration, but the rivets are finely massed in great concentric swathes to emphasize nodal points of the construction. The result is a far surer and more dynamic formalization of power in tension than in the 1,750 ft. span, 36,000,000 dollars, silicon-steel Camden Bridge at Philadelphia over the Delaware River, of which Paul Cret was the associated architect. Great skill has been shown in simplifying the entrance arches to their lowest possible terms—not as abstract forms, but as forms essentially native to fabricated steel: plain rectangular beams supported by octagonal stanchions. The cables slung over the peaks of these crossbars seem balanced on their points. They have no land anchorages as their pull is taken up by the stiffened platform-girders to which they are attached.

The interesting through-truss RAILWAY BRIDGE OVER THE RIVER RUR near Düren (1930), illustrated in (**228**), which was designed by Dr. Tils, is constructed of equilateral grooved girders forming an enclosed triangular framework. With a middle span of 377 ft., the KADITZBRÜCKE OVER THE ELBE at



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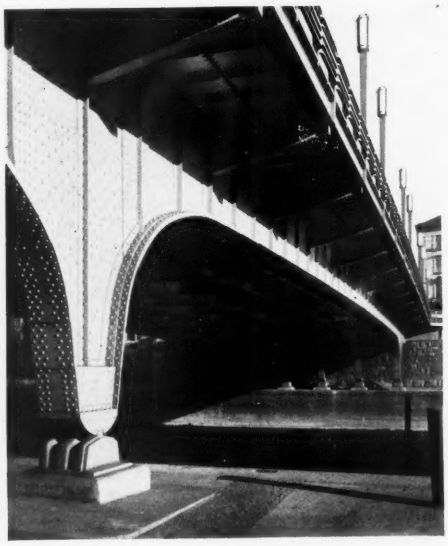

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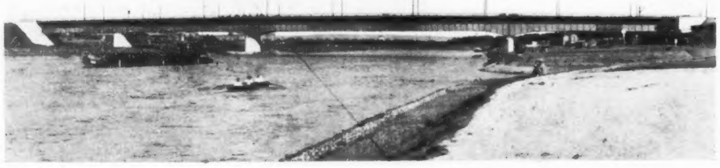

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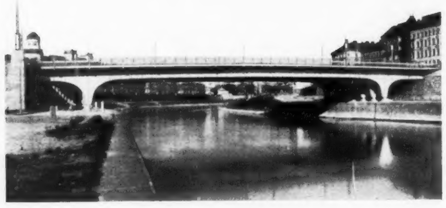

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Dresden (**231**) has the longest span of any plate-girder bridge yet built. (**234**), THE AUGARTENBRÜCKE OVER THE DANUBE CANAL in Vienna, of 90 metres span, designed by the Waagner Biro, is also of the plate-girder type. (**233**), an UNDER-VIEW OF THE SAME BRIDGE, shows the seven parallel flattened ribs; and details of a pier and the grouping of the rivet-heads. In this supremely elegant bridge the articulation of the frame supports visibly lightens the structure, and makes "legible" the manner in which the platform load is transmitted to the foundations. The simple treatment of the brackets carrying the pavements, and the clean, unfussy metal balustrading, are among the many praiseworthy details of one of the most "finished" designs in which the newest high-tensile steels have so far been employed.

The oldest example of the Transporter Bridge, a variety of the suspension bridge which is really an aerial ferry plying between two lofty steel towers, is that at Rouen (1899). In 1905, Arnodin, its designer, built the better-known "PONT-TRANS BORDEUR" OF MARSEILLES (**230**)—(**232**) shows details of one of its slender supporting pylons, the suspending cables, and a perilous access-staircase—and subsequently others at Nantes, and Bordeaux, which is the longest of all. English examples exist at Runcorn, Middlesbrough and Newport (Mon). There are several kinds of bridges with lifting, opening, or revolving spans, the commonest being the Schertzer rolling type.

(**223**) and (**225**) are reproduced by courtesy of the German *Reichsbahn*.

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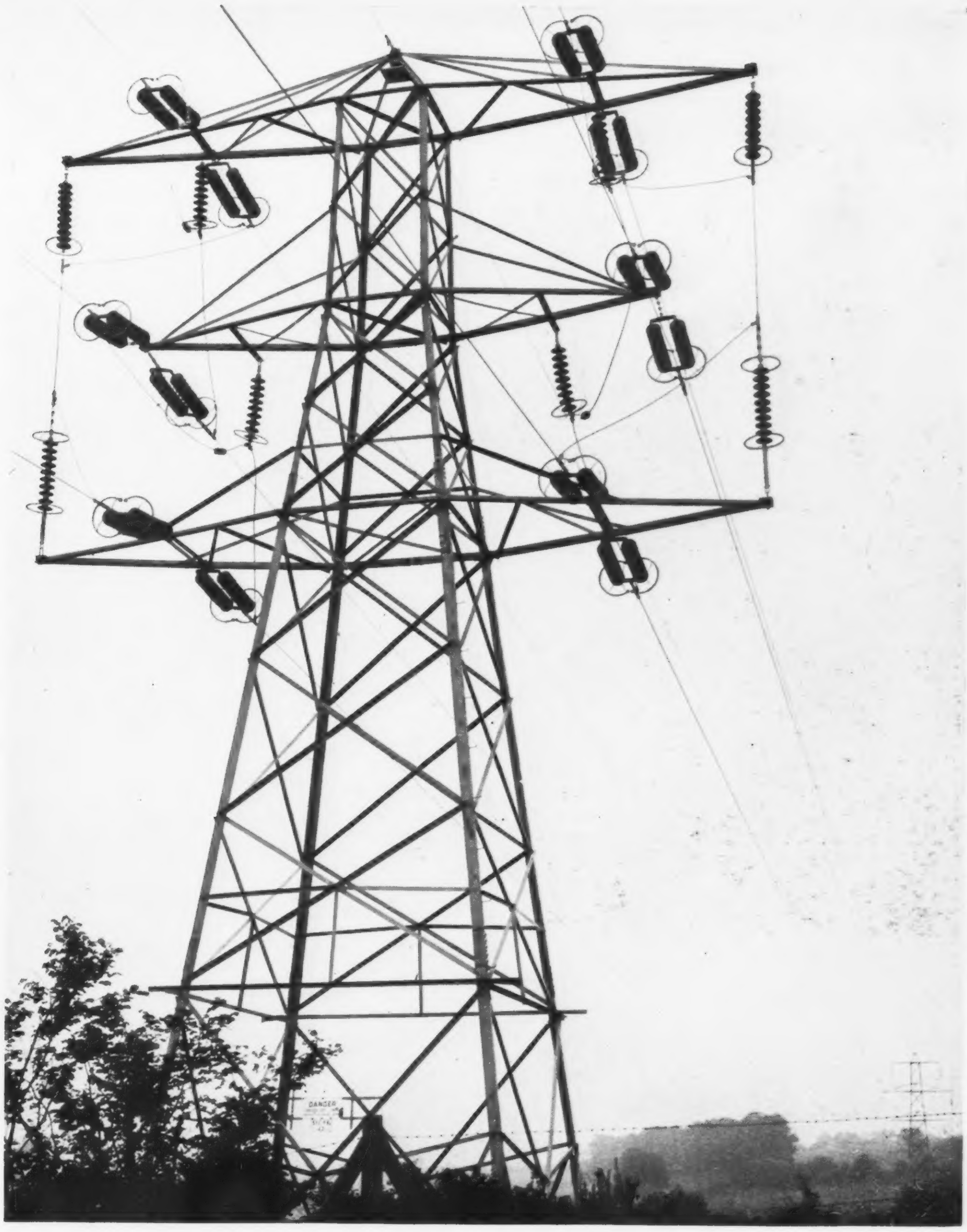

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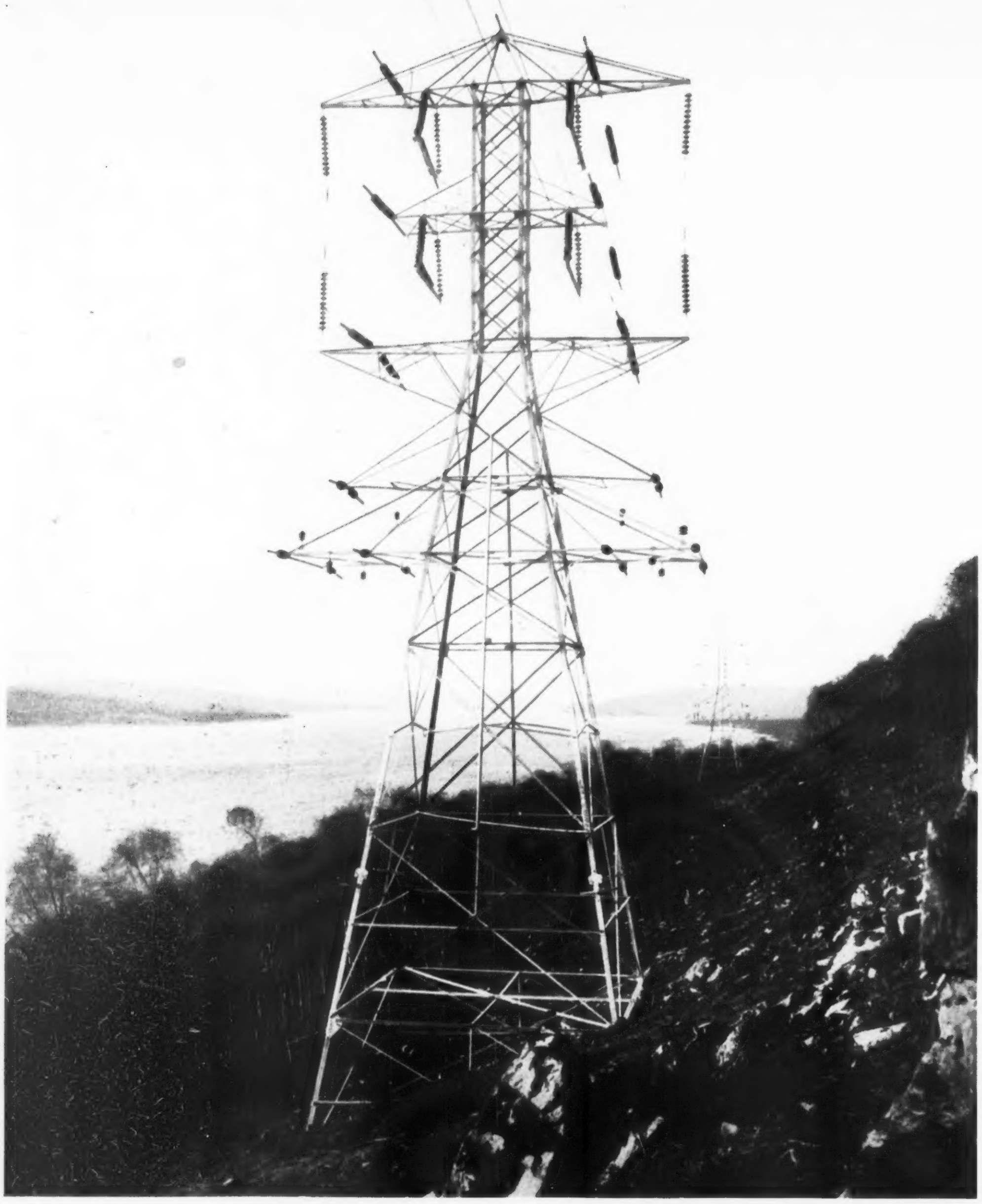
POWER TRANSMISSION—STEEL

BUILT-UP LATTICE-STEEL PYLONS. So little in modern England which is seemly can claim to be the expression of our age that the forthcoming completion of the vast spider's web of the national " Grid " ought to be celebrated as an event of outstanding " artistic " importance. The tranquil charm of the English landscape has been notably enhanced by the files of high-stepping pylons which, as Euclid says, " project " their enigmatic flight across coppiced and meadowed shires (to say nothing of building estates), treading delicately as disembodied Agags. That the advent of these stately steel ghosts has aroused the frenzied antagonism of Squire Splutter, Canon Athanasius, Admiral Roar, General Bellow, and the Society for the Compulsory Half-Timbering of Outer-Suburban Villas is proof that they have



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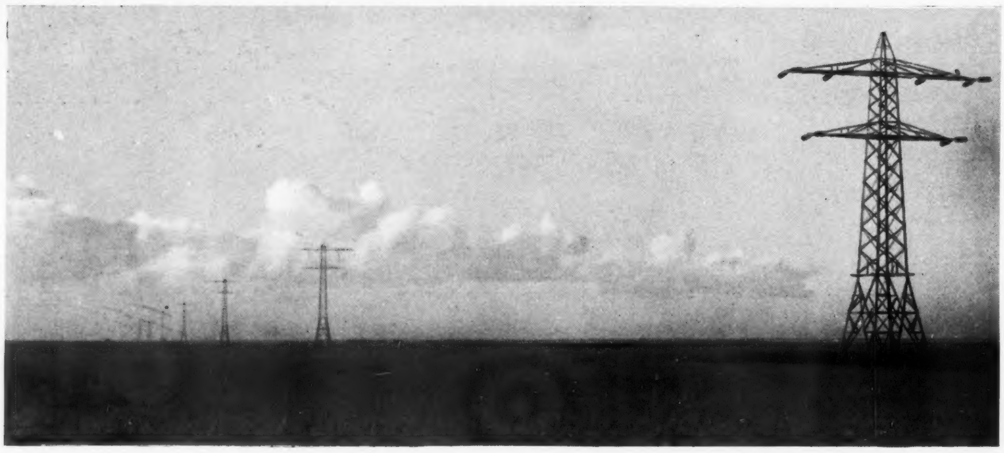

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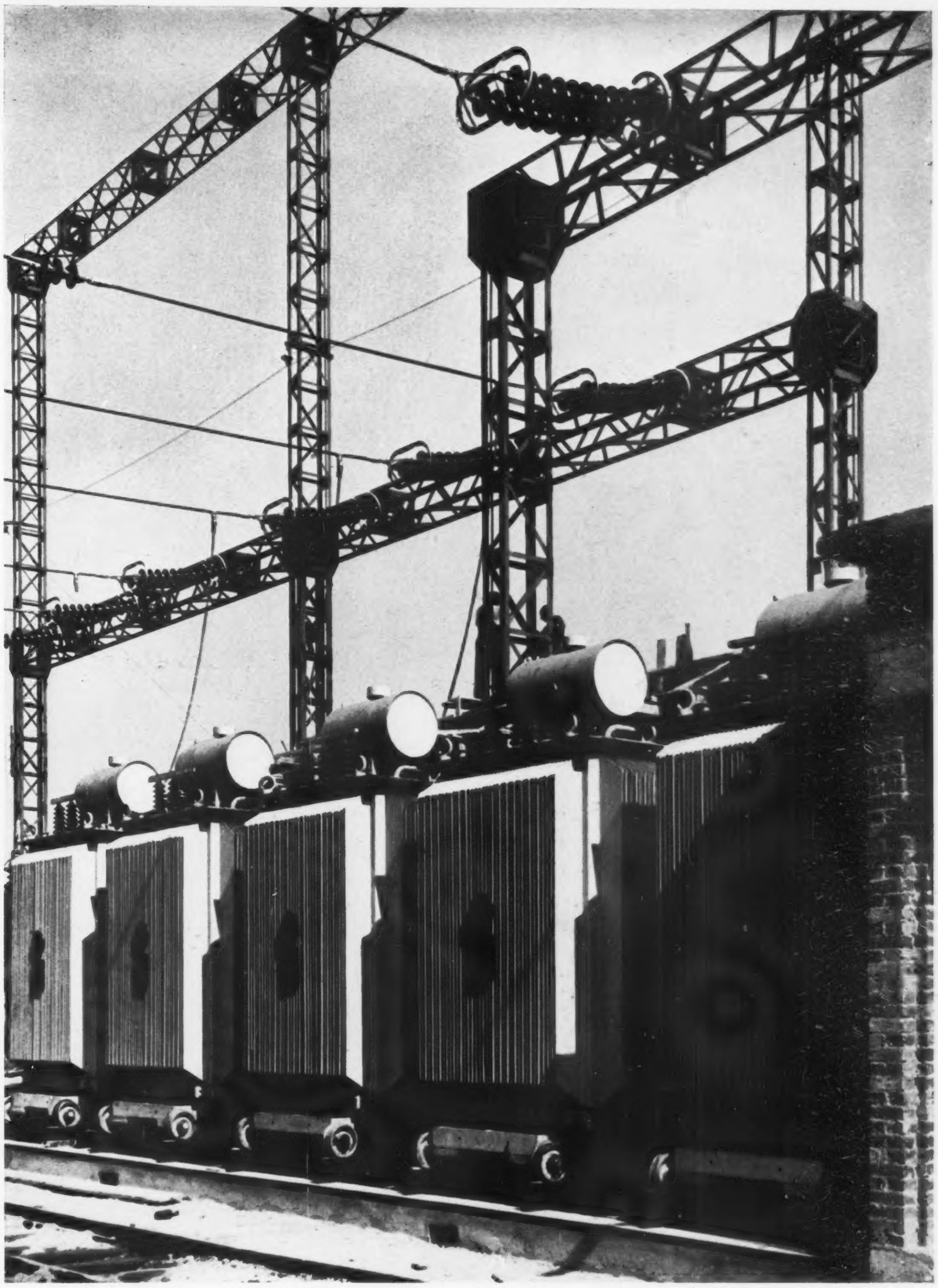
stimulated the imagination of youth. There is nationality in pylons as in everything else. The models adopted in France, Germany and other countries are often quite different to our own.

(**236**) and (**238**) are examples of BRITISH STANDARD TRANSPOSITION TOWERS on the main transmission lines of the South-East England area and the Grampians Electricity Corporation of Scotland respectively. The latter carries two 33 KV feeders in addition to its two 132 KV primary circuits. (**237**) is a view of the 33 KV LINE OF THE FURUKAWA ELECTRIC COMPANY OF JAPAN crossing the sea among the Amakusa Isles. In (**239**) a 66 KV CIRCUIT OF THE PALESTINE ELECTRIC CORPORATION is seen striding away across the Jordan Plain "into the shadowy realm of the fourth dimension." The anchor tower in the foreground of the latter is of a



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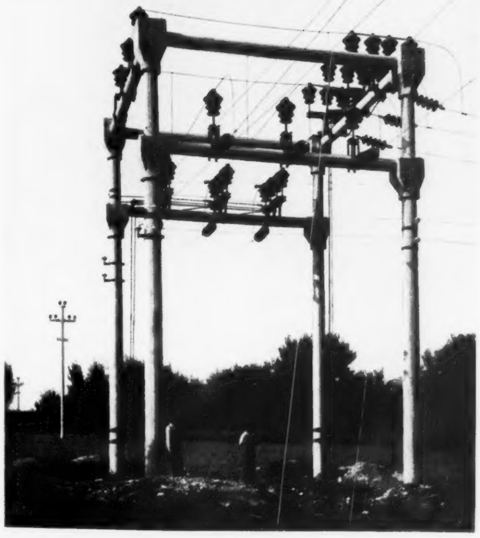

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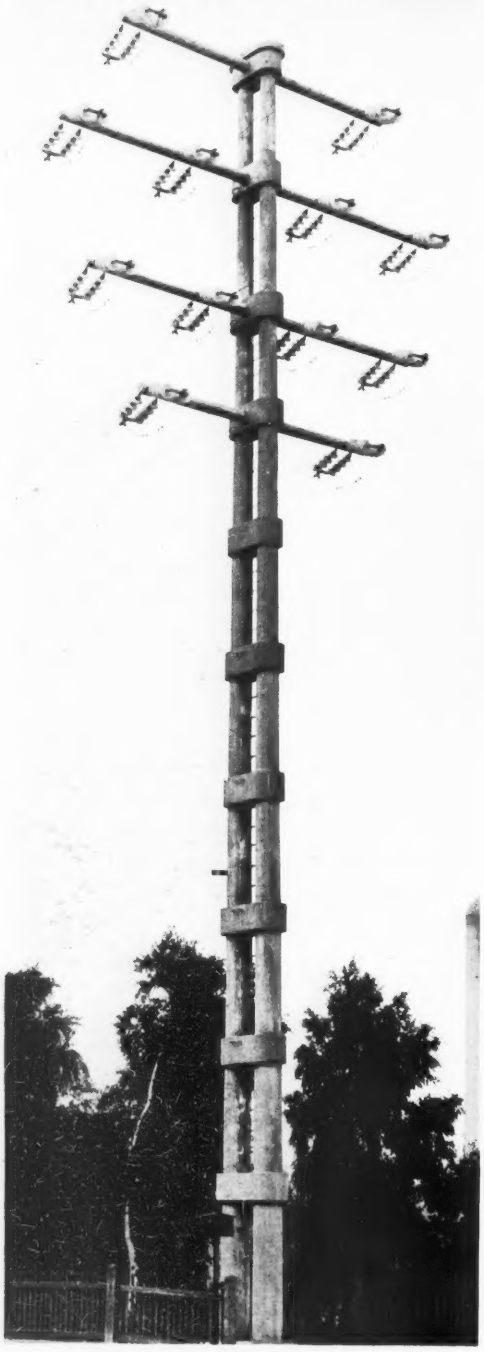
much more elegantly nautical design than the full-rigged materializations of dimly-remembered "advanced" propositions in geometry which sling out their furlong lengths of steel-cored aluminium cables athwart the saddle of the South Downs. **(235)** shows a lattice gantry at THE UPPER END OF A 1,700 FT. SPAN ON THE BOLIVIAN POWER COMPANY'S 66 KV TRANSMISSION LINE among the everlasting snows of the Andes. **(241)** and **(240)** contrast the forms of A STEEL-FRAMED, OPEN-AIR TRANSFORMER STATION of the Rheinisch-Westfälisches Elektrizitätswerk and a REINFORCED-CONCRETE DISCONNECTING-SWITCH on a 40,000 volts line in Northern Italy. Both make a brave display of those curious Japanese-artichoke-like insulators which seem to have become standardized shapes in all countries. **(235–239)** inclusive are reproduced by courtesy of the British Aluminium Company, Ltd.; and **(241)** from *Eisen und Stahl* by courtesy of the Verlag Hermann Reckendorff, Berlin.



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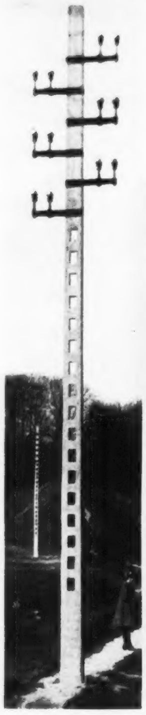

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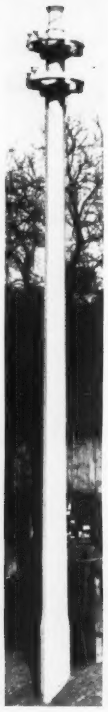

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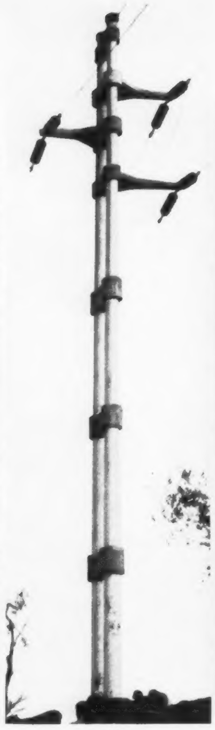

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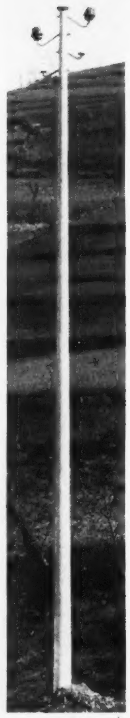

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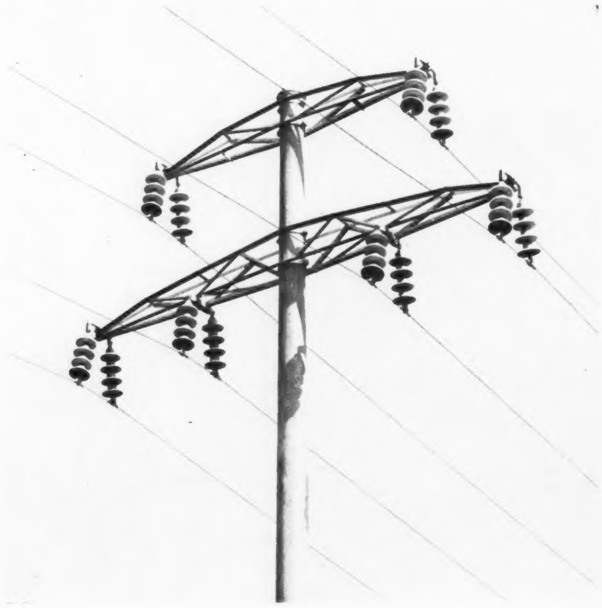

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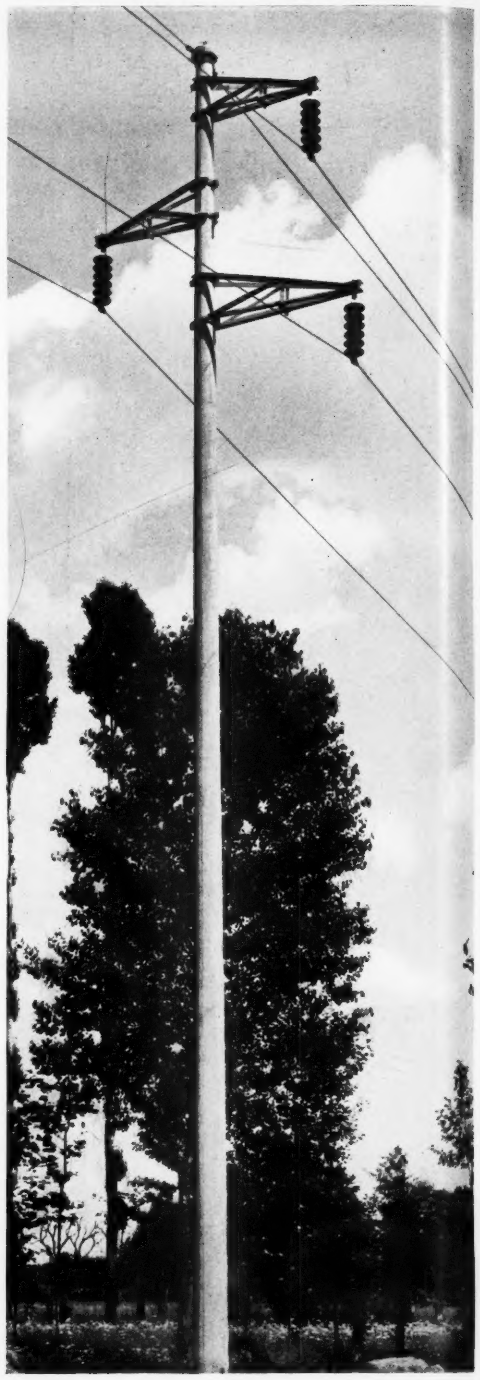

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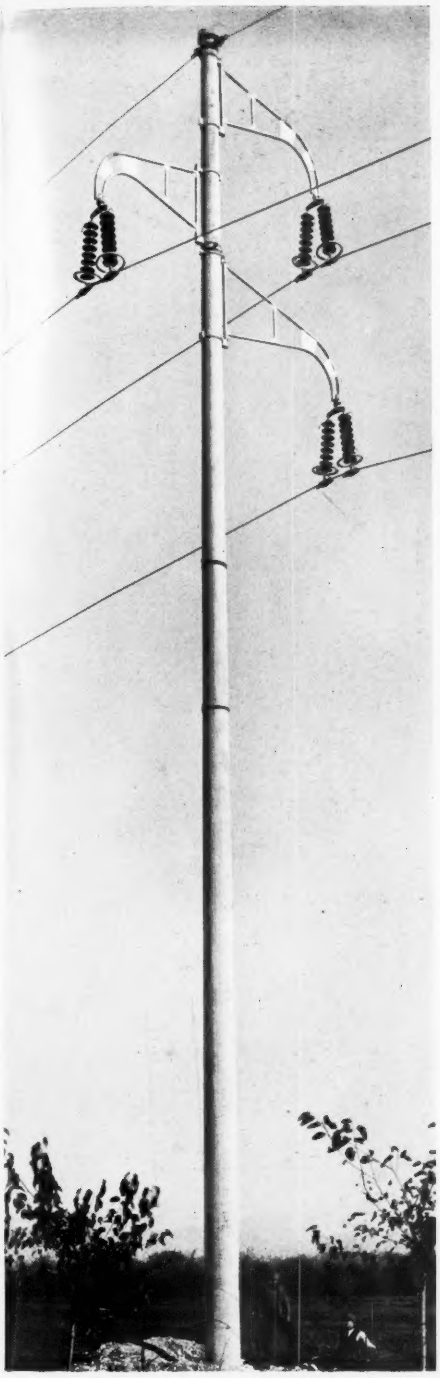
P O W E R   T R A N S M I S S I O N — C O N C R E T E

Precasting is a form of mass-production which, though still comparatively in its infancy as an industry over here, has attained a very wide development on the Continent. Today the utilization of precast concrete includes the manufacture of piles, lighting-standards, electric-transmission-masts, tram-poles and signposts (most of which are cast hollow by a centrifugal process—the Vianini process being probably the most widely adopted); besides pit-props, gates, fencing, milestones, seats, window-cills, steps, balustrading, gravestones, kerbing, paving-slabs, flooring-beams, sewer-piping, telephone-ducts, standardized wall-sections, etc. In many of these applications mechanical vibration is employed. Some types of piles are cast in helical moulds, and driven home like screws in wood by rotary action; others have their points exploded into onion-shaped bulbs when the required depth is reached so as to obtain a still surer hold in soft ground.

CENTRIFUGALLY-CAST REINFORCED-CONCRETE MASTS, spaced 260 metres apart, have been adopted for the Società Idroelettrica Piemonte's 220,000 volts Cardano-Cislago primary circuit on account of their economy in space and material compared to lattice-steel pylons—which cover much wider base areas, besides requiring 6-7 cubic metres of mass concrete for their foundations. These gantry masts are of the cross-bar, or goal-post, type, which has been extensively adopted for the 120,000 volts primary circuits of the Royal Swedish Waterfalls Board. They stand 19 metres high (two metres being embedded in the ground), weigh 6 tons, and taper from 57 cms. diameter at the base to 33 cms. at the summit. 220 KV is, of course, a very much higher voltage than is used anywhere in England. It is, therefore, instructive to recall a recent utterance of the Chairman of the Central Electricity Board to the effect that reinforced-concrete masts were not "practical" alternatives to steel pylons for circuits carrying as high voltages as our British 132 KV "Grid."

(**245**), (**247**), (**248**), (**249**) and (**254**)—which, like (**246**), (**240**) on page 249, and



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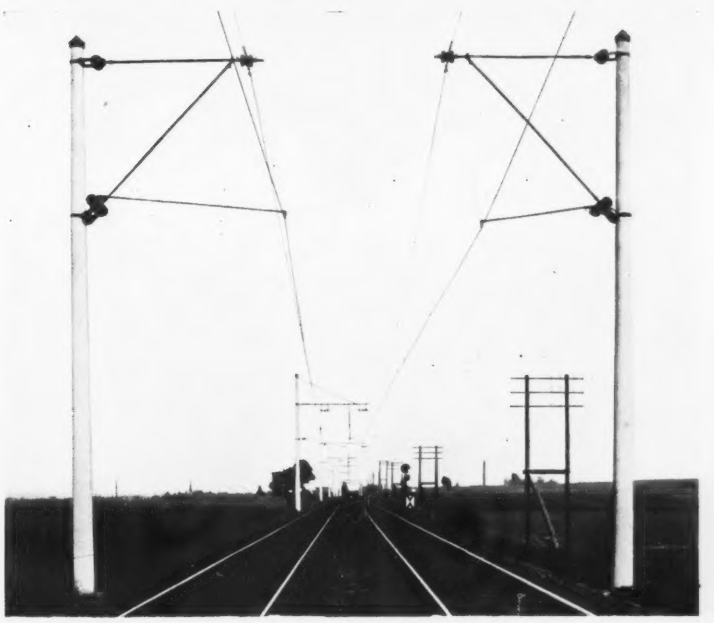

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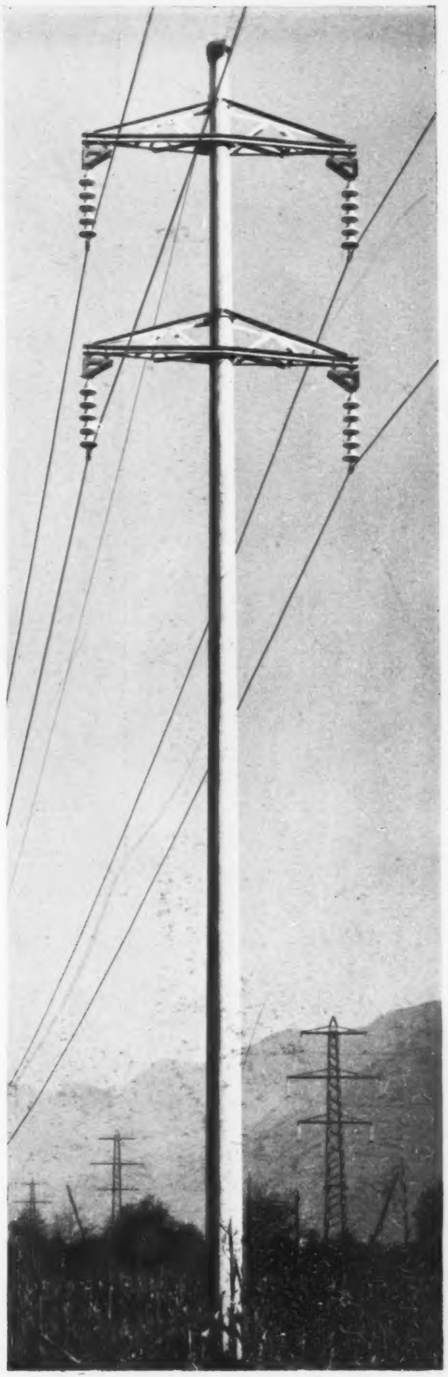

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(260) and **(262)** on page 252, are reproduced by courtesy of the Società Cementi Armati Centrifugati of Trento—illustrate some of the most recent Italian models of transmission masts. **(245)**, the only one with monolithic instead of steel brackets, is a double-anchor-pole on THE 60,000 VOLTS ROME-CIVITAVECCHIA CIRCUIT. The others, in numerical order, show standard masts of the following high-tension lines: MANTUA-MONTICHIARI, 70,000 VOLTS; NOVARA-VERCELLI, 50,000 VOLTS; MOLINE-MARGHERA, in the Province of Venezia, 120,000 VOLTS; BATTIGGIO-DOMODOSSOLA, 60,000 VOLTS. In the background of the last can be seen a file of primary circuit steel pylons from which this secondary line of concrete masts "leads off."

(242), **(250)** and **(252)**—which, like **(251)** and **(253)**, are reproduced by courtesy of Bauunternehmung Dyckerhoff and Widmann, A.G., Wiesbaden-Biebrich—show QUADRUPLE-, TRIPLE-, AND DOUBLE-TIER CENTRE-BRACKET MASTS OF THE 60 KV GRÖBA-WEIDA ELECTRICITY SUPPLY AREA IN THURINGIA. In each case the insulator-brackets are monolithic. The first is a double junction pole carrying both 15 and 60 KV lines. These masts are spaced 190 metres apart. **(243)** and **(244)**—reproduced by courtesy of Wayss and Freytag. A.G., Frankfort-on-Main, and Carstanjen & Cie, Duisburger Cementwarenfabrik, Duisburg, —are TWO TYPES OF TERTIARY-LINE-MASTS AT KIEL AND BOCHUM—the former a rectangular-section, solid fretted pole with "step" iron brackets, and the latter an octagonally-fluted junction-pole with steel ring-brackets. **(246)** is A TELEPHONE POLE OF THE GENOA-MILAN HIGH-TENSION CIRCUIT.

(251) and **(253)** are examples of the use of CONCRETE POLES in electric traction ON THE MERSEBURG DISTRICT TRAMWAYS and THE LAUBAN-SCHLAUROTH SECTION OF THE GERMAN *REICHSBAHN'S* MAIN LINE IN SILESIA respectively. The first shows direct-current span-wire construction, the second three-phase catenary suspension.

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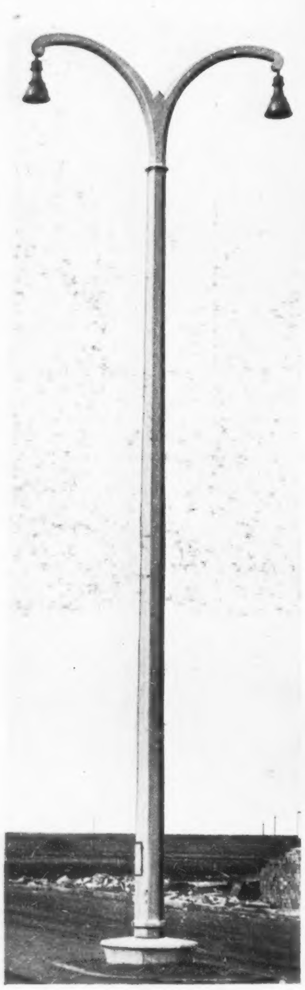

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L A M P - P O S T S

The illustrations on this page offer an interesting contrast between contemporary designs typical of home and abroad. **(256)** shows an ornamental group of weldless, tubular-steel lamp-posts manufactured by a leading firm in Birmingham. The others are foreign models. With the exception of **(261)**—a charming cast-iron example from Prague—all the others are made of centrifugally-cast, hollow-cored reinforced concrete : a material which is rapidly superseding cast-iron and tubular-steel on the Continent because it is cheaper and does not need painting. The simple, and often very elegant, early English cast-iron types of lamp-posts for gas-lighting are still the best and most forthright we can boast. Our electric-light standards are with few exceptions (the original City of Westminster model to be found in Piccadilly—not the costly and pretentious pseudo-classical " decorative " type just erected in Piccadilly Circus—being about the most notable) deplorably " fussy " when not blatantly vulgar. Paris has, perhaps, the most lamentably over-decorated lamp-posts of any city ; but the Parisian suburb of Boulogne-sur-Seine recently adopted a very good low-standing model, which would be better still without its bronze finish. Another fine design is the lofty square mast built up of narrow rectangular steel plates, riveted together so that the rivet-heads form an ascending pattern, to be seen in the main streets of Hanover.

(255) (257) and **(258)**—which are reproduced by courtesy of Carstanjen & Cie., the Duisburger Cementwarenfabrik, Duisburg—illustrate a fluted type of ELECTRIC LIGHT STANDARD AT HAMBURG, 5 metres high ; a ROUND-SECTION STANDARD, with triple wrought-iron lighting brackets and an electric-clock, IN THE DELL-PLATZ AT DUISBURG, which stands 10 metres high ; and a double-headed, lyre-shaped octagonal-section standard, 6 metres in height, at WESTERLAND STATION IN THE ISLAND OF SYLT. **(260)** shows a triple branched all-concrete standard standing on the PONTE DRUSO AT BOLZANO : a good design somewhat spoilt by a gratuitously " classical " base.

(259) is a very slender model with a reddish-brown concrete shaft, crowned by a graceful circle of iron hung with nine " P.H." lamps, that was specially designed for the STOCKHOLM EXHIBITION OF 1930 ; and **(262)** a powerful FLOOD-LIGHT AND REFLECTOR OF THE PIACENZA-BETTOLE ELECTRIC RAIL-WAY, mounted on a tall concrete pole for illuminating a marshalling-yard.

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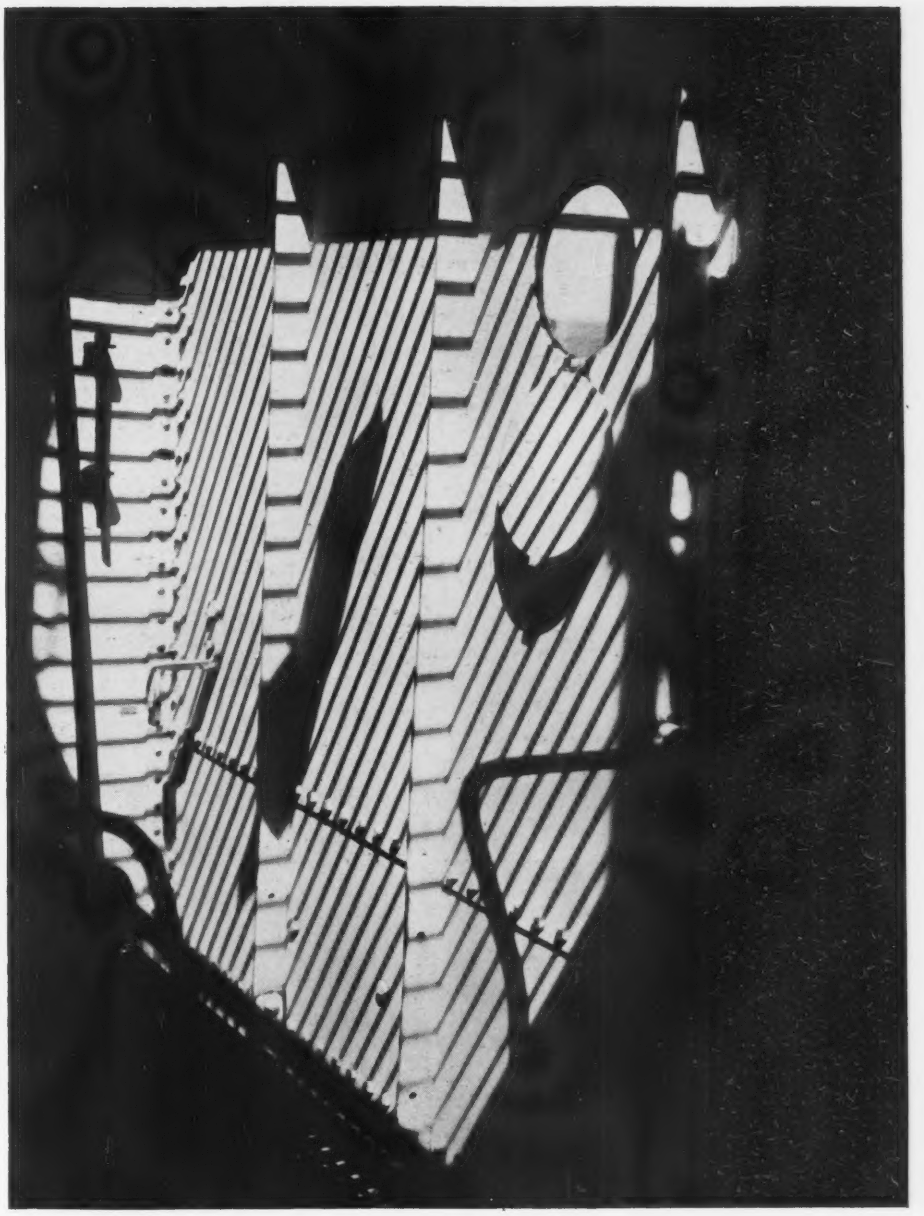

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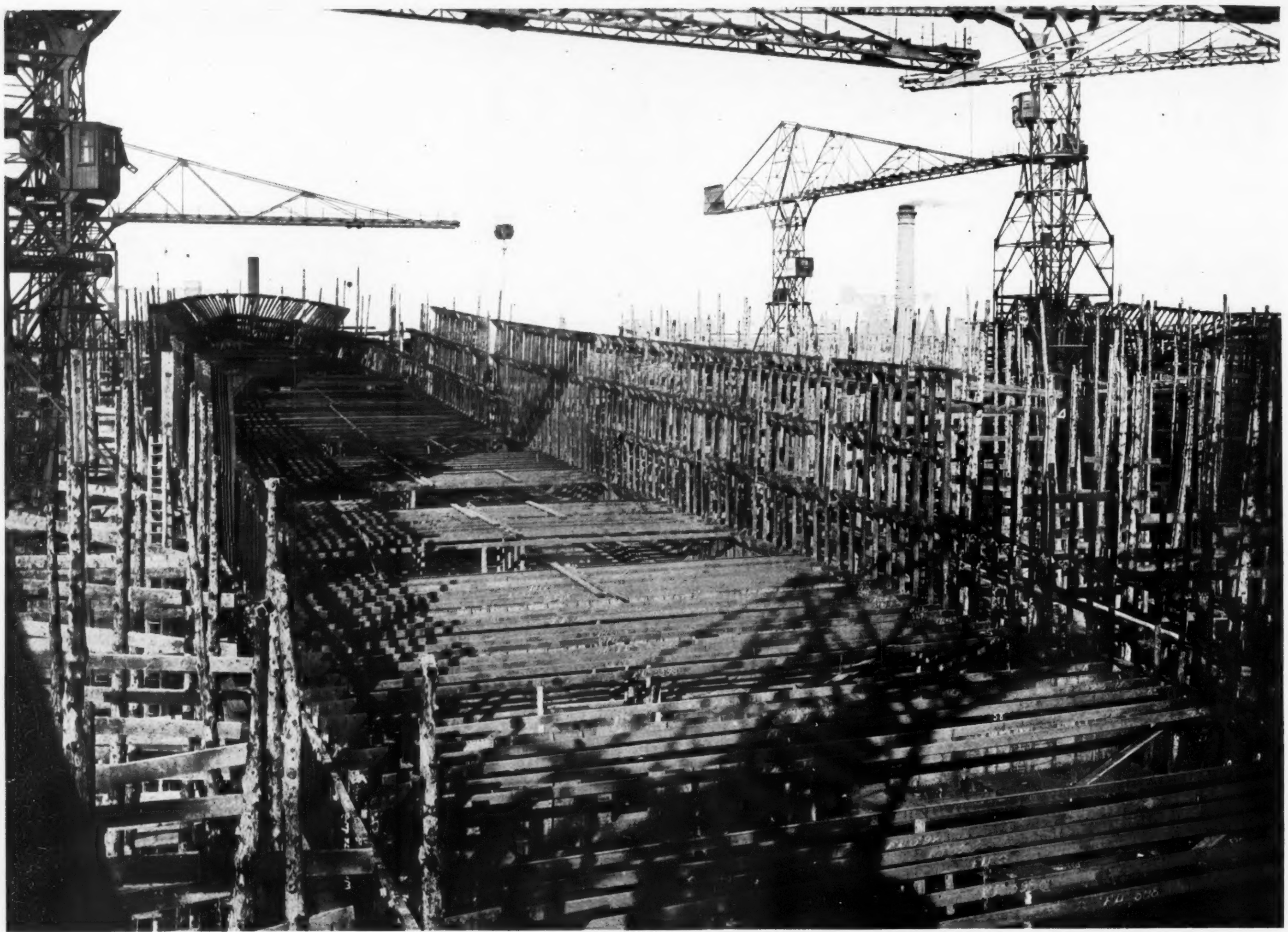
SHIPS

Helmuth Meyer's study of light and shade—a puzzle picture until the port-hole has been found and brought into relation with the steel ladder—was taken in the STOKEHOLD OF A GREAT LINER (**265**). The shadow lines flickering on the bulkhead are a recognized photogenetic metaphor for imprisonment. They suggest the toil of sweating Lascars ceaselessly shovelling coal into the steel maw of the roaring boiler-furnaces, deep down in the bowels of the ship. And they also tell us something of the mystery of far-off lands—the interplay of tropical sunshine and metallic-looking foliage, the rippling stripes of a prowling tiger. The whole romance of the steel ship's gradual conquest of ever greater speed is resumed in this delicately-patterned still. One by one it evokes the successive forms identified with hull and superstructure, from Fulton's experimental steamer to the stream-lined *Bremen*. A procession of ships of all types and all nations steams past the mind's eye: Paddle-boats, from the gracefully bell-funnelled early packets and Brunel's prodigious *Great Eastern* to the *London Eagle*, and the powerful modern type of barge-tug that fights its way upstream against the Rhine's headlong current: Liners, Channel steamers, tankers, colliers, freighters, tramps, dredgers,



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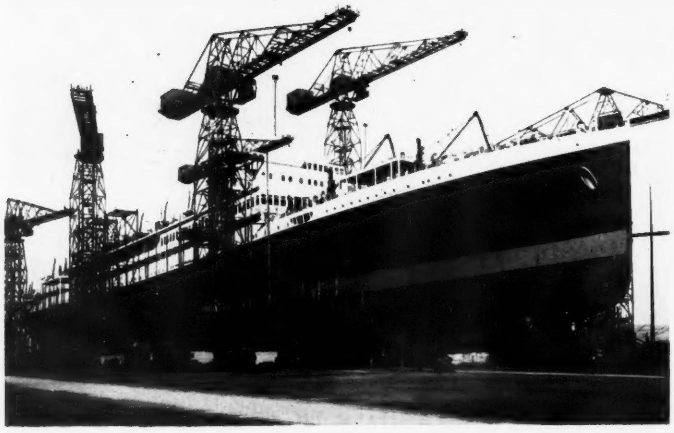

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trawlers, whalers, pinnaces, launches, troop-ships, salvage-boats, ocean-going tenders, cable-ships, train-ferries, floating-docks. Funnels vary in shape and number. Tonnage soars continuously. Decks are multiplied. The paddle is superseded by the propeller; reciprocating engines by geared turbines, turbo-electric drive, or Diesel motors. Following the mercantile marine come the warships: Battleships from the first monitors and turret-ships—the ill-fated *Captain* and *Victoria*—now with low freeboards, now with high; the strange-looking French *cuirassés* of the eighteen-nineties with their immense rams, bulging keels and embattled fighting-tops; the staid old *Royal Sovereigns*, the neat *Majestics*, the portly *King Edwards*, the tripod-masted *Dreadnoughts*, and the German "pocket-battleship" of only 10,000 tons that has made the framers of the Versailles Treaty and armament experts look rather foolish; Cruisers of all classes, armoured, protected, or unarmoured, with great battle-cruisers like the lovely, battle-scarred *Tiger*, the *Queen Elizabeth*, and the colossal *Hood* bringing up the rear; and behind them again, sloops, scouts, destroyers, flotilla-leaders, river-gunboats, aircraft-carriers, with decks as flat as dining-room tables, and funnels at one side; submarines and their suckling mother-ships. Since the war the French have begun to wrest our old supremacy in warship design from us. Their new cruisers embody the loveliest shapes, and can steam at speeds of over 40 knots an hour.

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In (**272**)—reproduced by courtesy of *The Times*—H.M.S. NELSON (43,000 tons, 23 knots speed, main armament nine 16 in. guns in triple barbettes) is seen passing the *Rodney* off Polenso—sister-ships which are probably the last great battleships that will ever be built.

The ship is built *with* steel as well as *of* steel. (**263**) and (**264**) are views of SOVIET SHIPBUILDING YARDS AT LENINGRAD: the first shows an open slipway surrounded by its pallisade of gibbet-like electric derricks; the second, a pair of berths totally enclosed with a massive " ridge-and-furrow " roof of steel and glass. (**266**) depicts the turbine Orient liner ORAMA (20,000 tons, 20 knots speed) on the stocks during the framing stage, with the deck beams already fitted. (**268**) is a photograph of the R.M.S.P. motor liner ALCANTARA (22,181 tons, 18 knots speed) a few days before she was launched; and (**267**) a " close up " of her cruiser stern, showing one of the propeller tunnels, and the fin-shaped rudder, taken when the vessel was in dry dock. (**270**), (**271**) and (**269**) are details of different parts of the oil-burning Norddeutscher-Lloyd EUROPA (49,746 tons, 28 knots speed), the sister-ship of the *Bremen*, which holds the blue ribbon of the Atlantic: a liner that does not have to blush for one single piece of " period " decoration, or furniture " in keeping with it," from bow to stern. The first shows the look-out of the captain's-bridge, the second one end of the navigating-bridge, and the third a searchlight-platform.

We have grown familiar with concrete as a material for enclosing water, or holding

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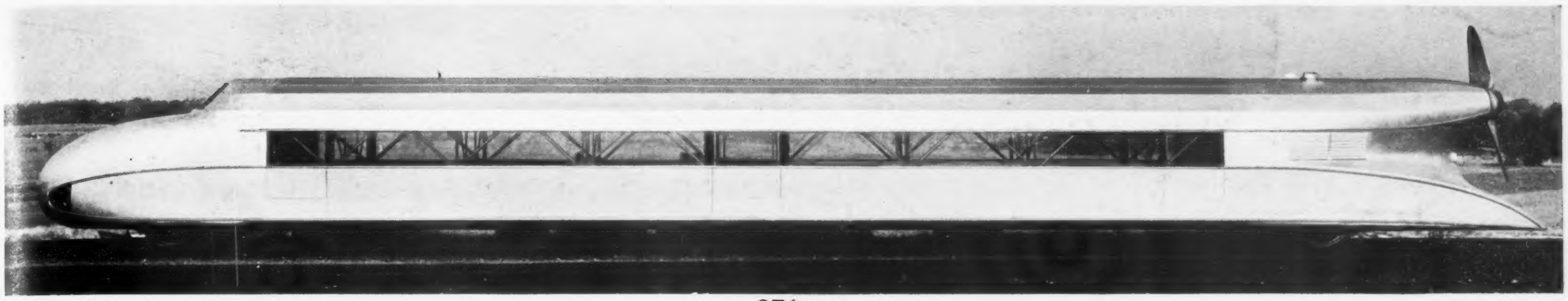
it at bay—barrages damming valley mouths to create artificial lakes for the supply of drinking water, or to provide pipe-line " drops " of hundreds of feet for the generation of electricity ; docks, moles, weirs and sluices—but concrete as a material for the construction of forms designed to *float* still seems a contradiction in terms. Every schoolboy knows that a hollow shell of iron will ride on water, but he is hardly prepared to find that hollow stone does the same. Yet concrete caissons for bridge-piers are frequently moulded some way from the site in which they are required, and then towed into position and sunk in the river bed. **(274)**—reproduced by courtesy of Bauunternehmung Dyckerhoff and Widmann, A.G., Wiesbaden-Biebrich—shows A CONCRETE BARGE UNDER CONSTRUCTION IN A YARD AT NEUSS, on the Rhine ; and another by its side completed and ready to take the water. **(273)** and **(275)**—reproduced by courtesy of *Cement och Betong*—are illustrations of THE SWEDISH RACING YACHT " YG " at her moorings, and under full sail near Stockholm. The hull of this yacht, which carries 40 square metres spread of canvas, is built entirely of concrete, only 8–10 millimetres thick.



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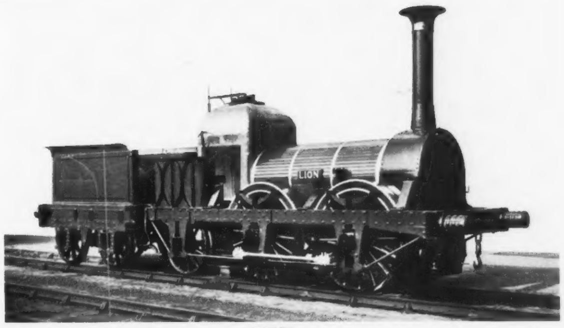

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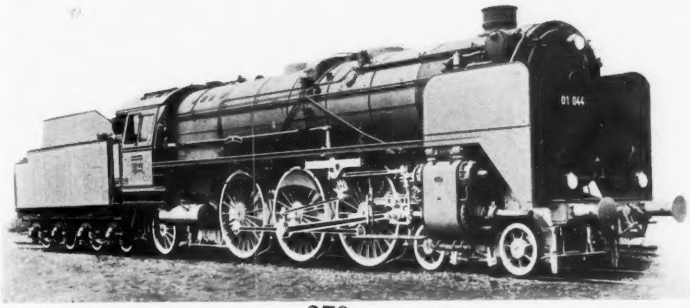

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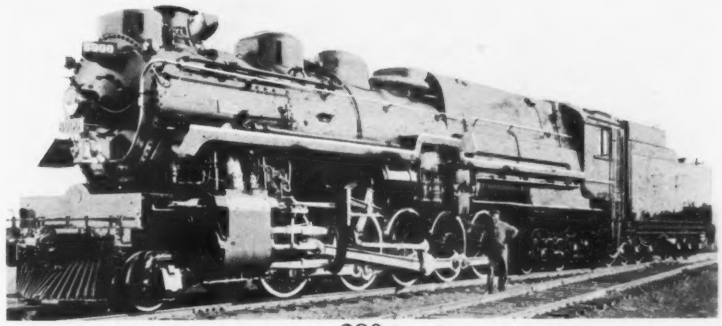

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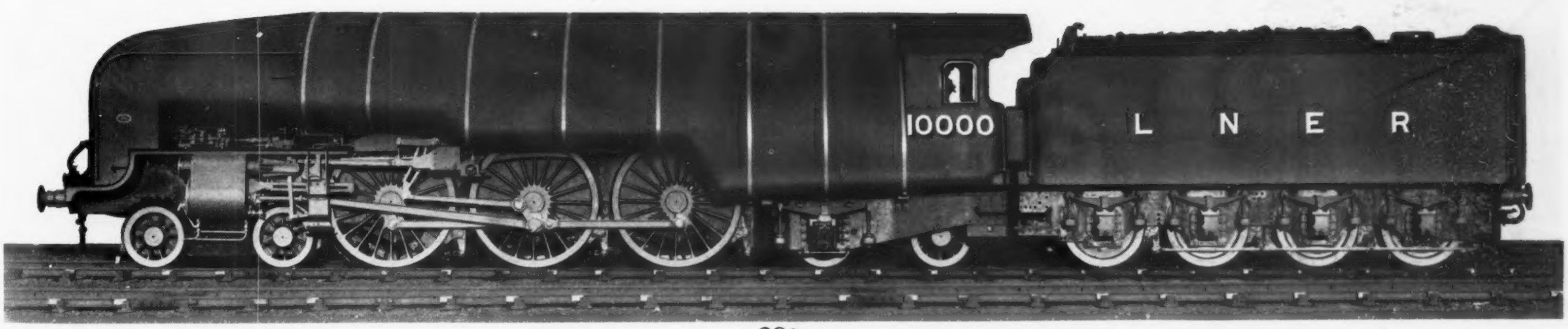

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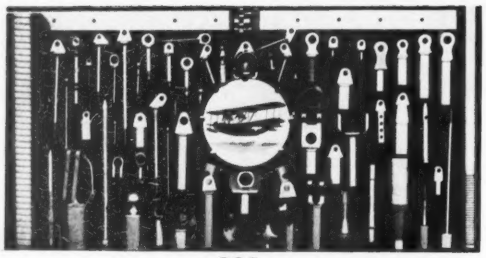
L O C O M O T I V E S

Great Britain has always produced the simplest and most elegant types of locomotive, the United States the most awkward and cumbersome-looking, and the Continent the most perversely complicated. There have been many British locomotive superintendents whose names deserve to be ranked with those of our best architects: Crampton, Stirling, Gooch, Stroudley, Drummond, Pickersgill, Johnstone, Dean, Raven, Aspinall, Billing, Wordsley, Churchward, Ivatt, Holden, Robinson, Collett, Maunsel; and, above all, J. F. McIntosh of the old Caledonian Railway, the fellow-Glaswegian and contemporary of C. R. McIntosh, who designed the immortal 2–4–0 McAlister Class. From the outset our designers treated the locomotive as the trunk of a body in which the organs should be tidily enclosed as far as possible, while their Continental colleagues deliberately extruded its viscera along the boiler-barrel, or festooned them between the frames. We led the world in the stream-lining of locomotives (of which Mr. Gresley's 4–6–4 NO. 10,000 OF THE L.N.E.R. (**281**) is only the latest embodiment), and today foreign practice (exemplified in (**279**), a standard 2.C.1 CLASS " PACIFIC " OF THE GERMAN *REICHSBAHN*, fitted with smoke-deflector screens) is reverting to what has always been the guiding principle of English design: clean, smooth lines, with a minimum of surface detail. The most recent embodiments of this typical "Englishry" in steel are the various "standardized" classes of locomotives designed for the Indian Government Railways. (**277**) and (**278**) show virtually a hundred years evolution of British locomotive design. The first is STEPHENSON'S 0–4–2 " LION," built for the old LIVERPOOL AND MANCHESTER RAILWAY in 1838; the second a three-cylinder 4–6–0 " ROYAL SCOT " CLASS EXPRESS LOCOMOTIVE OF THE LONDON, MIDLAND AND SCOTTISH RAILWAY—the clumsily-named system in which the original Liverpool and Manchester, its successor the London and North Western, and many other once proudly independent railways have been merged—built in 1930 to the designs of Sir Henry Fowler. The " Lion " has a Regency distinction; the " Royal Scot " is just spoilt by a funnel too narrow for the proportions of the boiler-barrel. (**280**) illustrates a 2–10–4 TYPE LOCOMOTIVE OF THE CANADIAN PACIFIC RAILWAY: a typical American design, which, with its tender, weighs no less than 392½ tons. (**276**) is the so-called " ZEPPELIN ON WHEELS ": a stream-lined propeller-driven rail-car, fitted with an internal combustion engine, capable of 182 kilometres an hour, recently adopted by the *Reichsbahn* for its " lightning " Berlin–Hamburg non-stop service.



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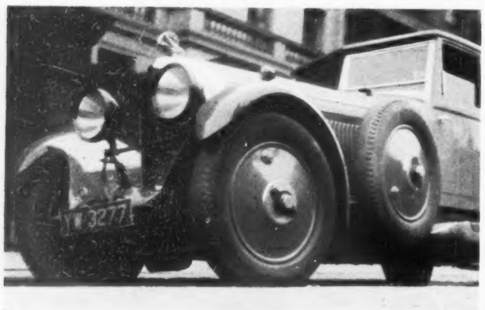

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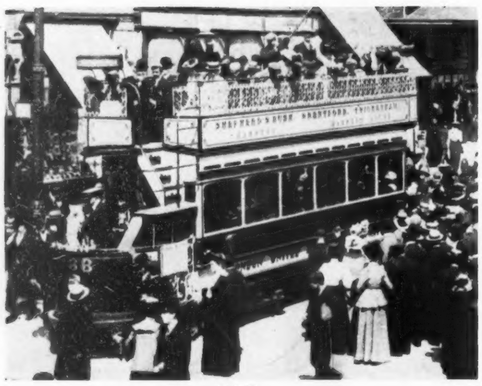

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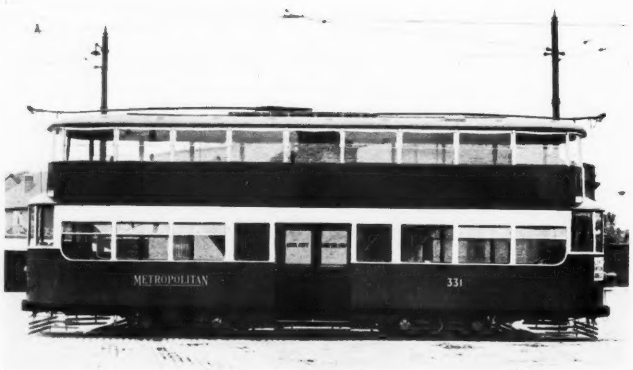

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MISCELLANEOUS TYPES OF TRANSPORT

The next form of mechanical transport to appear after the railway borrowed its flanged rigidity. Werner von Siemens was the pioneer of the electric tramway. Soon every town of even moderate importance was cat's-cradled with grooved tram-lines and trolley wires. Henceforth work and sleep could lie miles apart. "Leisure" was born. England was the only country that did not adopt the single-deck car. Time has proved that England was right in clinging to the double-decker, for today double-deck motor-bus services can be found in nearly all the world's big cities. **(285)** and **(286)**—which are reproduced by courtesy of the "Underground"—illustrate A QUARTER OF A CENTURY'S PROGRESS IN TRAMCAR DESIGN. The first shows one of the original timber-bodied, double bogie, vestibuled cars with which the London United Tramways opened their system; the second, the 1930 all-steel, stream-lined model, with covered-in top deck, transverse seats, and central entrance and staircases, which is now running on the same routes. It will be noticed that the former is virtually identical in type with the horse- and cable-cars it superseded. Very fine steel single-deck trams, which have tapered ends, and arm-chairs and tables, have recently been introduced at Dresden and Frankfort-on-Main.

After the electric tramway came the internal-combustion engine and the renaissance of the road. The earliest types of motor car (De Dion, Panhard, Wolseley, etc.) were closely modelled on wooden horse-drawn vehicles (the dog-cart, pony-trap, waggonette), just as the first railway carriages were simply stage coaches mounted on flanged wheels. In proportion as these prototypes were departed from increased strength and decreased weight resulted. Curiously enough the most momentous change to come about was also the slowest: the widening and lowering of the wheel-base. Stream-lining followed as a matter of course.

In the history of motor-car design practically all the laurels fall to the French. As they say "*la ligne exprime la marque*." Ford forgot, or ignored, this simple fact. Ultimately he had to spend millions of dollars in remodelling his plant to remedy the mistake of trying to perpetuate a spidery auto-buggey in a world of stream-lined motor-cars.

(283), a head-on view of THE LATEST MODEL OF THE BENTLEY CAR, provides a typical example of English "line" in motor engineering. With the increasing congestion of our streets by more mobile traffic, tramways are giving place to motor-buses and trackless-trolley vehicles. The latter form of public transport, which is much the cheapest, is probably more widely developed in this country than any other. It insures complete flexibility of movement, saves the cost of relaying worn-out tramway tracks, and allows the old overhead equipment to be used as before. **(284)** shows a metal-bodied, six-wheeled, pneumatic-tyred "SUNBEAM-METROVIC" TROLLEY BUS operated by Wolverhampton Corporation.

The aeroplane was the natural child of the motor car, for the type of propulsion embodied in the one made possible the realization of the other. **(287)** is ONE OF THE IMPERIAL AIRWAY'S FLYING BOATS, employed on the Mediterranean "ferry" section of their Anglo-Indian and Anglo-African services, which has fuselage and wings built entirely of special alloy-steels. It is propelled by four 550 h.p. engines, which maintain a cruising speed of 100 miles an hour, and can attain a maximum speed of 130 m.p.h. There is accommodation for fifteen passengers, a crew of four, and several tons of mail. **(282)** shows a collection of the various STAINLESS STEEL PARTS AND FITTINGS used in the construction of a VICKERS "SUPERMARINE" HYDROPLANE.

MARGINALIA

THE THAMES TUNNEL

In the last issue of the REVIEW a water-colour drawing of the Thames Tunnel was reproduced as a coloured frontispiece. There is no reference to its artist in the contemporary Royal Academy Catalogues, but a useful suggestion comes from Mr. Dudley Harbron. He writes: "The water colour drawing you have reproduced is possibly by Augustus Pugin the Elder. He was a friend and fellow-countryman of Sir Mark Isambard Brunel (both were born in the same year, in the same district of France), and he worked with the engineer on several projects. Further, the prospective vista is not unlike some of his known drawings. You will notice that the intersection of the vault is shown by a white line. The elder Pugin separated some of his shades so. It is possible to make the drawing with the colours solely used by Pugin Senior, namely, indigo, light red and yellow ochre. Moreover the figures seem to have been added, as was Pugin's habit. The only doubt I have is that the drawing is rather 'strong'—still, I think this is due to the subject. Pugin was sensitive to the character of buildings."

IT'S NOT THE CLOTHES THAT MAKE THE GENTLEMAN

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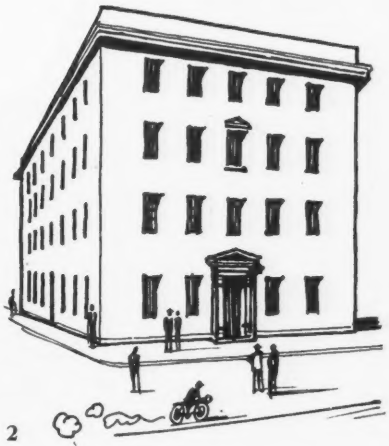
Whether you prefer the Classic style . . .



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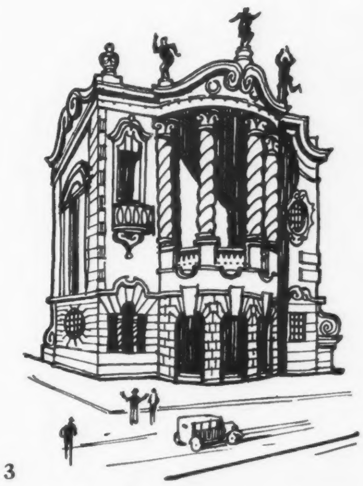
in its more severe . . .



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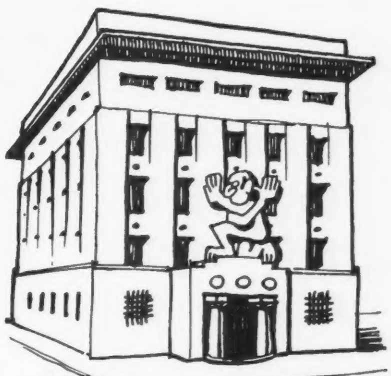
or perhaps its exuberant form . . .



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or whether you think this sort of thing . . .

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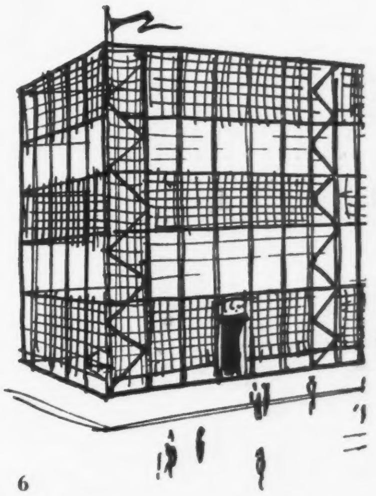

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or hold strong views about the essential rightness of this . . .

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or even though your tastes may be really catholic . . . . .

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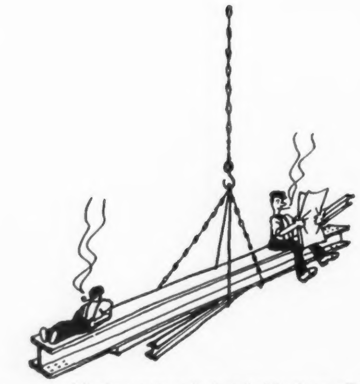

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. . . it's the steelwork that holds them all up.
From a Pamphlet published by the British Steelwork Association.

A COMPETITION

DESIGNS FOR HOUSES PROMOTING THE ARTISTIC USE OF CEMENT

The Cement Marketing Company are offering a first prize of 30 gns. and a second prize of 15 gns. for designs for each of the following types of houses.

Type (*a*)—A terrace, three-bedroom house costing £500 to build, suitable for a scheme of 48 houses in terraces of six.
Type (*b*)—Semi-detached three-bedroom house costing £600 to build.
Type (*c*)—Semi-detached four-bedroom house costing £850 to build.
Type (*d*)—Detached four-bedroom house with garage either incorporated or detached costing £1,000 to build.

Photograph by F. R. Yerbury

—THE MONKEY STAIRCASE

The Monkey House at Copenhagen. Prof. Edvard Thomsen, *Architect.*

THE HUMAN STAIRCASE—

The Rathaus at Rüstringen, Germany. Fritz Höger, *Architect.*

The object of the competition is to show the possibilities for the use of cement in external and internal treatment.

The Competition is open to anyone resident in the British Isles practising as an Architect and/or Surveyor whether as Principal or Assistant. Two or more such competitors may work in collaboration.

The Assessors are Messrs. Louis de Soissons, Howard Robertson and P. D. Hepworth.

All entries must be delivered to the Publicity Department, Cement Marketing Company, Limited, Portland House, Tothill Street, London, S.W.1, not later than 12 noon on Saturday, December 3rd, 1932. From this address fuller information of the conditions of the Competition may be obtained.

(**288**) The frame of the BREUNINGER STORE, STUTTGART, is faced with thin slabs of yellow travertine. The semi-circular staircase bays are of steel and glass. *Architects:* Eisenlohr and Pfennig.

The Facing of Steel and Concrete Buildings

By F. R. S. Yorke

THE two structural methods by which the enclosing of a unit of space may be effected are the frame and the pierced wall. The frame fell into disuse when timber ceased to be regarded as a structural material, but the pierced wall, though generally employed, limits planning: support must be practically continuous, and fenestration relatively limited.

Modern conditions, the complexity of the modern plan, the reduction of available areas of space for reasons of economy, the demand for increased areas of glazing, and the advent of steel and concrete, suggest a return to frame construction. Essential supporting members are reduced to occasional slender piers, and the plan becomes free and open. Partitions are non-supporting, and their arrangement is governed only by actual space requirements; windows are placed at will.

I am indebted to the Cement Marketing Company for the photographs reproduced in illustrations (289), (290), (291), (293), (294) *and* (296).

STEEL and concrete, the structural materials, are often faced with brick or stone to produce pseudo-brick or pseudo-stone façades. There is, however, a dawning realization of the absurdity of facing one constructional medium with another, and recently the materials have been considered with intelligence and afforded some opportunity to evolve an expression of their own. But, having been impeded for half a century, true building in concrete and steel is as yet in its infancy.

There are possibilities for the use of certain stones and granites as purely facing materials, applied, not in imitation of masonry construction, but in thin slabs, held in position by metal cramps. In England Portland stone and black granite, and in Southern Germany travertine, have been used in this fashion.

The two materials may present somewhat different problems as regards surface finish, for in the case of concrete the outer face is often an integral part of the structural material, whilst structural steel must as a rule be encased in some sort of shell. However, it may be argued that exposed steel tends to corrode, and needs to be painted at frequent intervals, that we are forced to encase it in concrete, for fireproofing purposes, and that the problems of cover therefore become, in most respects, identical.

The tendency of the material to expand and contract owing to "settling," changes in temperature, or changes in the moisture content of the atmosphere, presents the major difficulty which must be met in solid reinforced concrete work. A wall of any size should be designed in such a manner that sections of it can act independently, so that their movements will not affect neighbouring parts.

The monolithic nature of concrete is often over stressed, and there appears to be no reason why a greater number of expansion joints should not be employed as an integral part of the design, provided the stability of the individual units be unaffected. As an alternative the material may be induced to crack along selected lines by introducing grooves to reduce the sectional area at definite places. Reinforcement will then give the material sufficient tensile strength to enable it to resist the tendency to crack elsewhere.

Reinforced concrete is comparatively heavy and is particularly difficult to demolish, so, although it may be admirable for the frame, it is questionable whether it is a suitable material for the screen walls and partitions, which in modern work are regarded as flexible.

Pumice concrete, made with pozzuolanic or other volcanic lava, saves a great deal of dead weight in non-supporting elements, such as roofing, or wall-infilling, with a very slight loss of strength. Moreover, its surface can be easily drilled, or cut away, thereby overcoming what is admittedly the greatest drawback of concrete, the difficulty and expense of altering it, or making apertures in it, once set. Whereas ordinary concrete has relatively poor heat-conserving properties, a 13 cm. thick pumice-concrete wall will retain heat to the same extent as a brick wall 39 cms. thick. By a special process of aeration pumice concrete can be made to set in a honeycomb formation, which still further reduces weight.

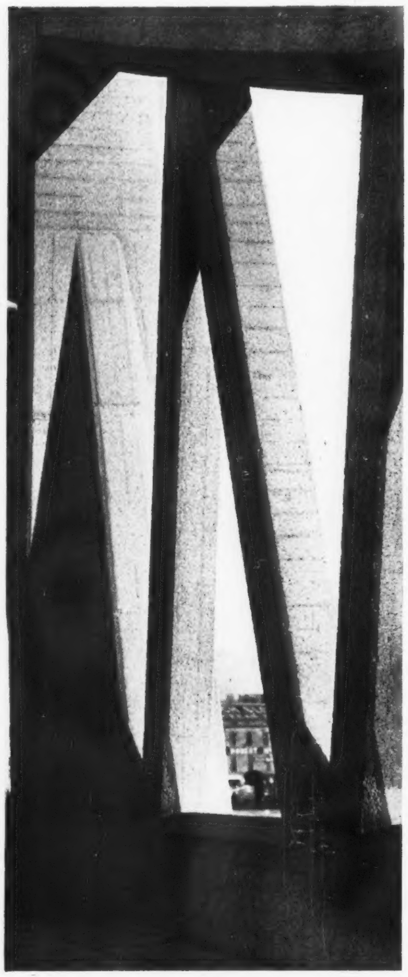
A house recently built in England has a reinforced concrete frame with 4½ in. brick filling, rendered externally in cement, coated with waterproof paint, and backed by a cavity, and 3½ in. breeze concrete blocks, plastered internally.

Similar frames are employed on the Continent, and the infilling, between 30 cms. square piers, consists of hollow breeze blocks, 60 cms. by 30 cms. by 30 cms. laid horizontally, cement rendered externally and plastered on the inner face.

The nature of the material is such that design must depend to a great extent upon proportion, aided by colour—not necessarily synthetic colouring—and texture, but never by imitation stone jointing, or ornament and semi-constructional motif: cornices, keystones, and so on, borrowed from traditional work, and belonging fundamentally to block masonry structures, not to a plastic material. Concrete has suffered much from being regarded as a cheap substitute for stone.

We can learn little from the past in the matter of external expression. The Romans used concrete only in compression, without steel reinforcement, and the massive parts resulting from such restricted usage gave to their structures the proportions of masonry. The design of reinforced concrete building today is essentially an expression of lightness of structure.

Concrete has been used for some time in constructional work, foundations, columns, floors, roofs and staircases, but it is only comparatively recently that it has been employed for external wall-construction, and even now it is rarely that we employ it on the surface and allow it to be seen; probably because, unless the surface receives some special treatment, the material is unsightly.



(**289**) A detail of the MONTROSE BRIDGE which shows that careful form work can produce a soft and agreeable surface pattern.
Engineer: Sir Owen Williams.

Unless board marks are to be visible, special consideration must be paid to the preparation of the shuttering.

Work has been done in which the board marks are allowed to give a texture to the surface. A satisfactory example of such treatment occurs at the Church of St. Anthony at Basle, by Karl Moser, where the concrete, which has a pleasant buff colour, is left direct from the shuttering, both externally and inside the building.

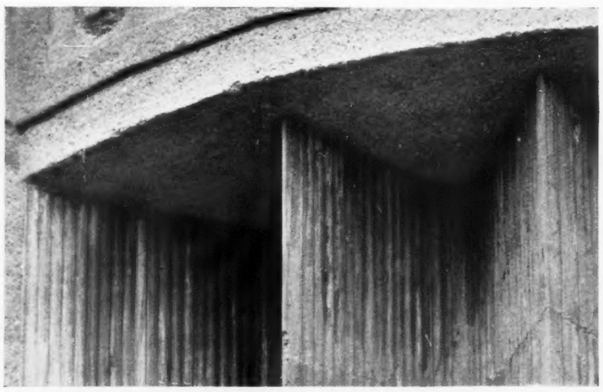
Sir Owen Williams, for the Montrose Bridge (**208**) and (**289**), employed throughout the work strips of timber arranged horizontally or vertically in the framework of the mould.

If it is not intended that the joints and board marks shall be unduly apparent, and the surface is to receive no special treatment after the shutter boards are removed, then these boards should be selected for uniformity of grain, wrought, tongued and grooved, or wrought and thicknessed, i.e., brought to an even thickness. Alternatively, plywood or some special form of thin grainless wood should be employed as a lining for the shuttering.

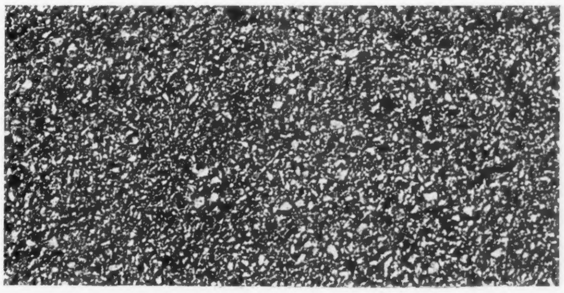
The use of reeded and moulded form boards will eliminate to some extent the reproduction of the grain and knots of the timber, and the "pour joints," which are due to a slight difference in colour of successive mixes, or laitance, scum, etc., at the form-board joint.

Air bubbles between the form-boards and the concrete face are sometimes eliminated by vibrating the shuttering with a mechanical ram. This method is reputed to be more efficient than rodding in obtaining a dense concrete between the reinforcing rods.

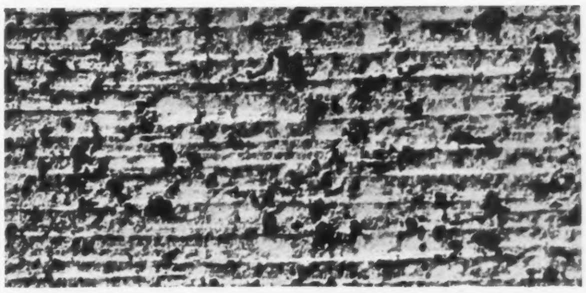
Although cement constitutes only one-fourth or one-fifth of the bulk of concrete, it is principally cement that is seen on an untreated surface, for when concrete sets the weight of the aggregate squeezes the surplus cement against the sides of the mould and, where ordinary Portland cement is used, a plain unrelieved greenish-grey finish leaves much to be desired from the æsthetic point of view. When new it is cold and unsympathetic, and it does not mellow with age. It is subject to crazing, and in weathering takes on a cheap and unfinished appearance, tending to give a false impression of poor execution.



(**290**) A typical example of the appearance of a CONCRETE SURFACE for which ordinary timber planks were used as shuttering. (Notice the irregularity of the lap-joint, where the cement skin has flaked off.) (**291**) A typical example of the appearance of a CONCRETE SURFACE for which a grainless wood was used as shuttering. (The lap-joint is clean and sharply defined, with the cement skin intact.) (**292**) A detail of one of the PYLONS ON THE LEA VALLEY VIADUCT illustrating the use of moulded and reeded form boards. The aggregate is flint gravel; the whole of the surface except the corrugations is bush hammered.
Architect: Maxwell Ayrton.



(**293**) An aggregate of finely crushed GRANITE exposed by scrubbing, after damping with a solution of hydrochloric acid.



(**294**) An aggregate of COLOURED MARBLE, exposed by "boasting," tooled to give a semi-reeded surface finish.

This "fatty" face is of no practical value and may be removed without detriment to the structural value of the concrete, to expose the aggregate, thereby giving texture and colour to the surface.

Liquids having a retarding action on the setting of the cement with which they come in contact are obtainable. The liquid is painted on the shuttering before the concrete is placed, and the retarding action is confined to the surface cement, the body of the concrete being unaffected. This method is usually employed with the object of exposing the aggregate to produce a good key for rendering.

Alternative methods of producing a surface to which rendering will adhere are by hacking—where there are no panel heating pipes—or by rubber sheeting, with a grooved surface, laid on the shuttering. This method is being employed at the Bank of England and appears to be very effective.

It is generally understood that a rendering, being richer in cement than the concrete to which it is applied, tends to "draw" together to produce a cracked and crazed surface. This, it is contended, may be overcome by casting the reinforced wall and its facing at the same time, a process effected by means of a movable shutter plate between the two concretes, which are deposited at the same rate, the work being carried upward in short lifts so that proper rodding can be done, and a dense finish ensured. The facing is actually a concrete, not too "fat," and may be cast in a 1½ in. to 2 in. thickness of white cement with a white or coloured aggregate.

However, it has been shown that crazing is not entirely due to shrinkage in "drying out," but that it is largely caused by a chemical change in the composition of the external skin. This aspect of the rendering problem is discussed on page lxviii.

When it is possible to get at the surface whilst the concrete is still "green"—say within 24 hours after pouring—the face may be scrubbed with an ordinary brush and the aggregate exposed. As a rule, however, the shuttering is not removed for some time, and in such cases no surface treatment should be attempted until the concrete is thoroughly set, when it can be bush hammered, i.e. hammered with a tool the face of which has broad-based teeth; and the surface cut away until the aggregate is exposed. The roughened surface which results is slightly absorbent and has splendid weathering qualities. The concrete must be quite hard before such a treatment is attempted, otherwise pieces of the aggregate will be dislodged, and a ragged surface produced. Tooling will give a similar effect, but usually at greater expense.

Excellent results can be obtained by the use, as aggregates, of coloured granites, marbles, serpentines, gravels or stones, employed in conjunction with white or coloured cements. The natural colours thus produced lend to the hammered or chiselled surface a liveliness and quality that cannot be produced by synthetic colouring alone.

Coloured concrete and rendering, in which the colour is obtained by the addition of pigments to the cement rather than from the nature of the aggregate, presents as a rule a drab and monotonous appearance, especially where it is used for very large surfaces. It has been used extensively for the external walls of large tenement buildings on the Continent without great success.

Such synthetic colours, used with a white cement, should be subordinate to the aggregate, which should itself govern the choice of tint.

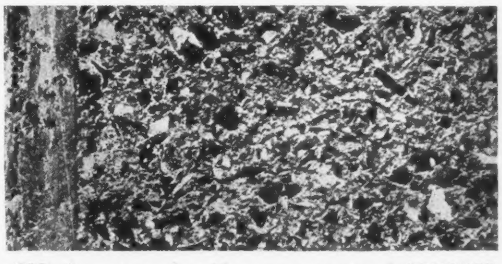
In order to economize in the cost of materials, reconstructed stones, marbles, etc., are usually made with a special mix for the surface only, and with ordinary gravel concrete for the core or backing. The core should be placed before the face has set in the mould in order to secure a good bond and to avoid any tendency for the face to peel off owing to its richer mix having a different rate of expansion and contraction from the backing. In fact, this face, which is about ¾ in. to 1½ in. thick, should be an integral part of the mass, and not an applied veneer.

The finished surface may be tooled, rubbed or polished by the ordinary methods employed for finishing natural stone.

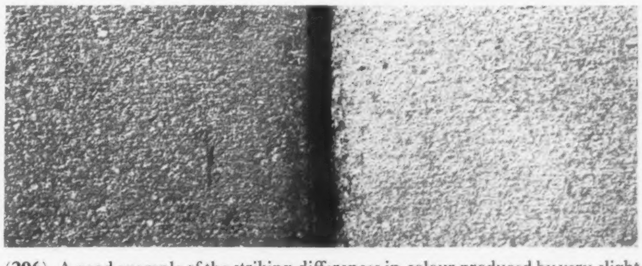
* * *

The unadorned steel frame is a beautiful thing; it has a modern scale; but almost invariably as the skeleton is clothed the beauty and the scale depart.

The architect, careless of the real purpose of the new material, sees in the steel frame a medium which enables him to perform feats impossible in solid stone, and as a consequence our buildings have pillars and arches which not only support nothing, but, such is the skill of the modern designer, are themselves supported, at considerable expense, whilst contributing nothing to the stability or efficiency of the structure, and imposing additional load upon the steel; and the completed building, whether it be in the classic, or in the modernistic blanc-mange mould style, is not lovely: it has nothing in common with the traditional apart from its ornament, and it is not related to the modern conception of life or structure.



(**295**) Concrete made with an aggregate of CRUSHED FLINTS. The surface is bush hammered. The edge is exactly as it emerged from the form.



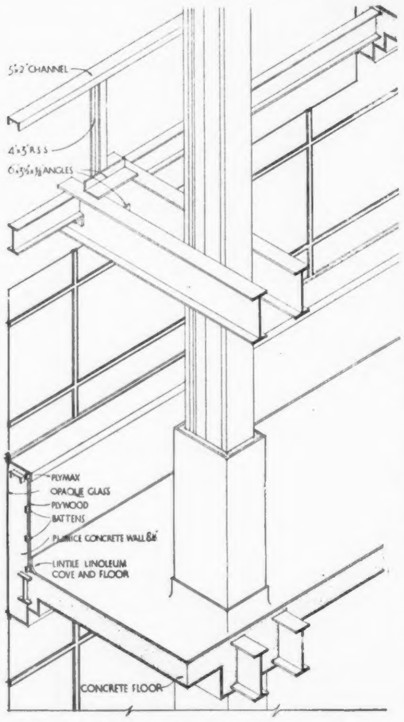
(**296**) A good example of the striking differences in colour produced by very slight variations in mix: TWO CONCRETE SURFACES divided by a mortar joint, embodying different ratios of the same aggregate, which have been wire-brushed in a horizontal sense.

Whilst we persist in adopting a traditional scale for modern buildings, which are big and without precedent, no matter what decorative motif we employ, we fail to achieve the expression of bigness, and our buildings look like overgrown small ones. We have only to compare the façades of the Selfridge's Store or the *Daily Telegraph* building with the *Daily Express* building (157), each structure equally without precedent in purpose, in order to realize the truth of this.

From contemporary design one derives the impression that there is little appreciation of the fact that, in a steel-frame building, the stanchions do all the actual supporting work, and the wall is merely a filling ; a protection from the elements, heat, cold, rain, wind and so on ; and to admit, or exclude, the light. The outer skin may be of glass, aluminium alloy, or slabs of some impervious material: with a backing that will give thermal and sound insulation in little thickness.

As the walls do not support the loads, they need have no more strength than is required to resist accidental shocks and wind pressure. Yet generally speaking the wall is so designed that it appears capable of supporting the whole of the load, unaided by the frame.

(**298**) The MAIN RESTAURANT AT THE 1930 STOCKHOLM EXHIBITION is built in steel, glass and Vitriolite. It is rather noisy by reason of the fact that all its surfaces are reflectors. *Architect*: E. G. Asplund.



(**297**) ISOMETRIC DIAGRAM showing the construction of a building 150 ft. 0 in. high with 8½ in. walls cantilevered from the steel frame. *Architect*. Joseph Emberton.

Building regulations are responsible to some extent for the perpetuation of obsolete methods of wall construction, but the New Code of Practice makes certain modifications. If constructed of solid brickwork, concrete, or hollow blocks, "panel walls" need be only 9 in. thick through the full height of the building, provided they are so divided by steelwork that the maximum dimension of a panel does not exceed 13 ft. If the wall be in reinforced concrete the thickness may be reduced to 4 in. Cavity walls having two 4½ in. walls, spaced not more than 3 in. apart, are now permitted, but walls faced with terra-cotta, faience or stone, backed with bricks or hollow blocks, must be 13 in. thick, so there appears little excuse for this method of clothing the steel.

Flame cutting and welding; processes recently developed by mechanical engineers, are likely to become important factors in the design of steel-framed structures of the future. Flame cutting gives the engineer a similar power over steel to that which saws and drills give the carpenter over wood. Welding permits connections without rivets and gusset plates.

The application of the cantilever principle to steel and reinforced concrete structures makes possible the provision of windows of infinite length, uninterrupted by vertical supports.

The diagram (297) shows a section through a building 150 ft. high. The screen wall, which consists of 8½ in. pumice concrete faced externally with opaque glass, and internally with plywood fixed to battens, is cantilevered from the frame.

The cantilevered concrete walls of the *Daily Express* building are faced with ⅝ in. thick toughened black plate glass, bedded on lead and held in position by strips of aluminium alloy that are screwed to lugs which project from the walls.

The walls of Asplund's Restaurant at the 1930 Stockholm Exhibition (298) and those of the curved staircase bays, and the bridge at the Breuninger Store, in Stuttgart (288) and (299), are of clear plate glass and steel.

We see that when the modern function of the wall is fully appreciated by the architect, there is something of a revolution in the design of the façade.

(**299**) The TWO-STORIED BRIDGE linking two blocks of the Breuninger Store, Stuttgart, is in steel and glass. *Architects*: Eisenlohr and Pfennig.