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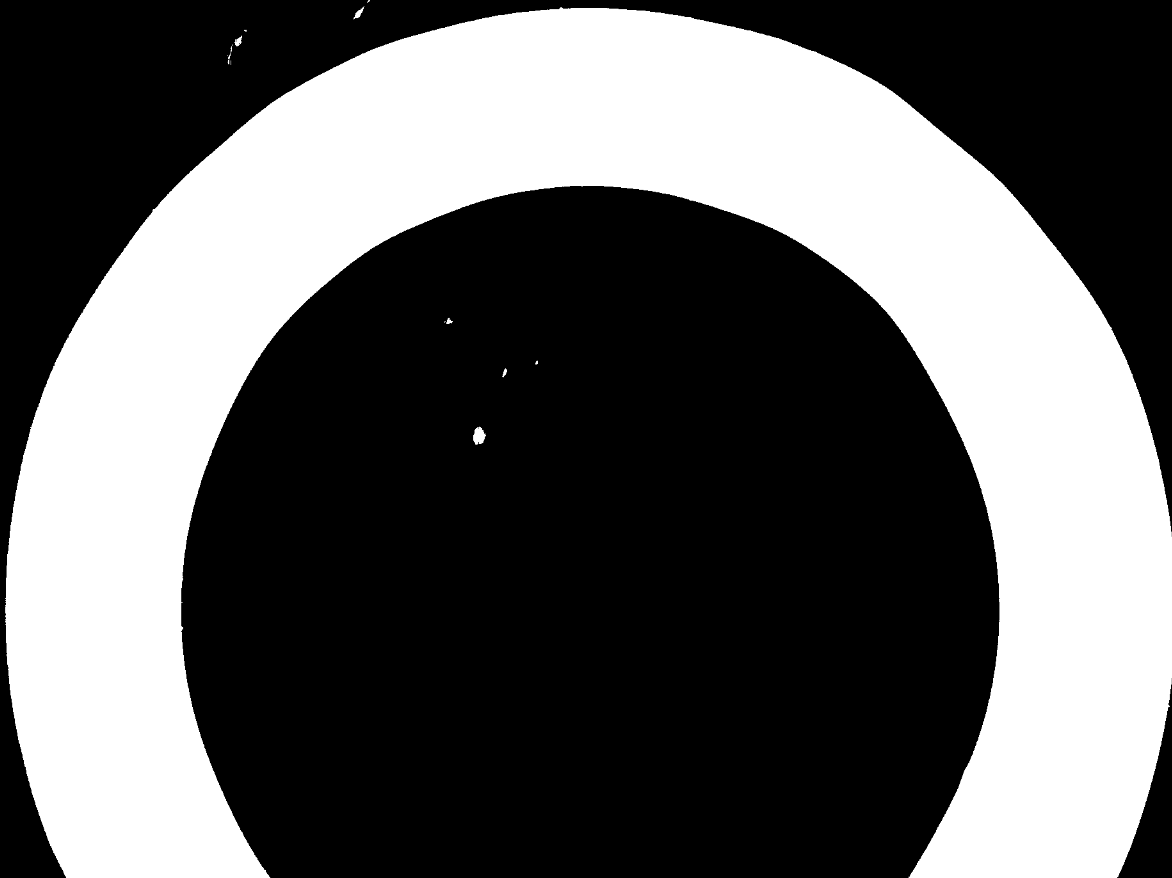

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Illustrations are following text

I. TYPIFICATION AND MODULAR CO-ORDINATION OF INDUSTRIAL BUILDINGS.

The correct design of industrial buildings is demanding the elaboration of all details in regard of their economy, technology, architecture, etc., and in addition the consideration of the economical and political aims in connection with the establishment of the industrial plant in question, together with the examination of the results of the development of the settlement. A decisive factor affecting the plan-fulfilment is given by the rate of the construction work from which the increase of the productivity of the building-industry as well as the decrease of the cost depends. These facts are compelling the architects of industrial buildings to search for all possible ways during the design process and the construction works as well. In particular during the planning of typified buildings these have to be evolved that in respect of the investment and operation the most economic industrial buildings should be erected for the national economy. The development of the methods of planning is characterized by the expansion of typification. In Hungary typification started with the typification of structures. The proper and correct structural typification has to be preceded by the modular co-ordination, by the establishment of the characteristic measurements of the industrial halls, and by normalization.

Typification and modular co-ordination means not alone the speeding-up of construction-activity. It possesses an important role in connection with the regulation of building and in the improvement of its quality. Therefore typification and modular co-ordination form an important part of the work of the architect when he is designing large scale buildings or large building complexes. In typification ways have been found for the new design methods to unify ideologically and constructionally all buildings, which have to be erected repeatedly in large number in identical resp. nearly identical form. These two methods of building activity are suitable to be used for the development of the industrialized building methods, as they are: -

(a) assisting considerably the prefabrication of constructions.

(b) abbreviating the time needed for erection work, because at the moment the decision is made regarding the erection of the building technical detail-drawings are already at the disposal of the designer.

(c) eliminating the seasonal character of building, as the constructor in possession of all the necessary drawings is able to have prefabricated all structural parts in the most convenient time whether in the prefab-plant or onsite.

(d) rendering construction-activity more economical, as in the moment decision is attained as to the site of the building all required data are at disposal regarding the public utilities, roads, railways, etc.

With the further development of the modular co-ordination, of typification and of normalization the structural elements which can be transported, should be manufactured in prefabrication-plants, instead onsite. Reinforced concrete structural elements should be mostly made in prestressed construction, while those of the heavy weight type and thus madeon-siteshould be made post-stressed. Prefabrication ofstructuralelements made of other materials - /steel, aluminium/ is performed always in their works.

When developing standard designs start should always be made from the principle that the single buildings belonging to the same industrial ensemble should be designed on base of identical technical conditions. This consideration applies inter alia to the network of the pillars, to the heights of the buildings, to the selection of the character of the supporting construction.

The unification of planning is evidently a highly important means of encreasing capacity, and the fundamental problems of typifical planning activity were already defined by the First International Conference on Standardized Planning 1957 in Berlin. One of its main subjects was the introduction of the unified modular measurement of 10 cm though the question of the large modular series of 60 - 120 - 300 - 600 cm were discussed as well. The Conference has accepted further the recommendations in regard of the unified methods of standardized planning and the unified planning terminology of standardized planning.

The member-countries of the COMECON have lent particular attention to the investments of the chemical industry stressing the necessity of the maximum standardization of the buildings for the chemical industry. On the Conference of the Chemical Industry held in 1959 in Halle the basic conditions of standardization of the buildings of the chemical industry had been accepted. Similar agreement were found necessary in regard of the general industrial halls.

Standardization and unification is as a matter of fact useful not only for similar buildings, but for different types of buildings as well, in particular concerning their structure. Thus a structural unification is desirable, which can be later used for civilian, industrial and agricultural construction work as well. No doubt this would have very great importance for the total national economy. With the unified modular system and with the building method employing the large building elements this question could be solved. The modular network of 3 x 6 and 6 x 6 m can be used in communal building too and is thus suitable for typification in this sphere as well.

The demand for typification is strong in the countries of the western hemisphere too. The about 100 experts participating on a discussion held in Washington have agreed that by employing the general principles of modular measurements better building with decreased costs can be erected. One of the participants said:-"This is the only method where the architect, the structural engineer, the constructor and the factory superintendent are thinking and speaking the same language."

Standards are promoting the industrial building methods but are influencing the requirements of the architect too, as while searching for the architectural form he is bound to the building elements manufactured by industrial processes in very large quantities to satisfy the demands which were increasing rapidly. In this way the correlation of architecture with large scale industrialization with all its inherent possibilities for creative activity was established.

The main points of view of the correct typified planning are:-

1./ industrialization of building

2./ industrial prefabrication

3./ modular co-ordination

4./ acceptance of a modular system

5./ ample selection of structures and elements

6./ onsite mechanisation of construction work

7./ saving in materials, decrease of costs, faster construction work,

8./ satisfying the requirements of architecture.

For the industrialization of building the typified structural elements, the normalized building sections are indispensable, but these have to be previously proved by scientific methods and on de facto erected experimental building. To judge the economic solution of a plan all costs of the investment of the total building should be summed up viz.: the total amount of the expenditures related to the unit of capacity of the manufacturing plants of different profiles has to be established, thus only in possession of such index-numbers the possibility will be given to reach rentability for the typified designs. If the total amount of expenditures in connection with a certain building is placed against the unit of the economic index-number the most important bases for the economics of building are correctly established.

II. UNIFICATION OF INDUSTRIAL BUILDINGS

A small country or a developing country with an industry in its initial stage generally does not have the possibility to produce large series, and in the interest of competitiveness her industry has to be flexible and mobile.

For this reason, it is required that its Industrial building should possess great adaptability (flexibility). It is a permanent endeavour of industry to improve its products. It produces new machines, raises new needs, creates new products of consumption. It follows from this that Industrial building should accommodate itself to the constant change, to technical development.

It is well-known that there is a fundamental contradiction between the lifetime of industrial buildings and the obsolescence time of the machines and production processes located in them. The lifetime of industrial buildings is approximately 50 years, whereas the modernization of technology varies between 3 and 15 years, but it shows a rapidly decreasing trend in consequence of technical development.

The new materials introduced in the individual industrial branches result in significant technological changes even if the production process retains its traditional character. Such is e.g. among the new methods of metal working, the chipless technology replacing processing by cutting or the spreading of synthetic fibres in the textile industry, the sudden advance of new surface treatment processes or the application of plastics. All these raise new requirements concerning the new or already existing buildings.

Several possibilities offer themselves to bridge the contradiction between technology and the life of buildings:

1. The present machine park is taken into consideration, and the lightest, simplest possible building is applied, which can be replaced together with the machines. In this case, the "building" actually becomes a covering, a wrapping the life of which is the same as that of the machines. An extreme example of this is the so-called machine park installed outdoors, gaining more

and more ground. Though the protection of machines against the weather /heat and water/ increases the machine costs, this solution saves the building, entirely or partially. Nevertheless the protection of the operating staff must be taken into consideration in this case too, which sets limits to the outdoor installation of machines. It also occurs, however, that the costs of the machine covering are almost as high as the building costs /e.g. semi-outdoor power plant/. Outdoor machine installation has gained ground primarily in the chemical industry.

2. The disassembly of the wrapping or even the building and its repeated application are also conceivable, though this will probably become general in, a wider field only with the popularization of plastic structures. Such is e.g. the Buckminster-Fuller system, which consists of polyester derivative space-delimiting structures stretched on built-up metal structures, or the inflatable balloon space-delimitations for the purpose of storage, where the rigidity of the tent is ensured by the small overpressure of the internal space.

After all, the building covering of wrapping character is economical only under the following conditions:

(a) Identical obsolescence time of the covering and the technology,

(b) assembled building method, repeated applicability;

(c) the reduction of the order of magnitude of the weight of the covering compared to that of the current structures;

(d) the perfect following of the technology.

It appears from these conditions that the building method will be applicable only in certain partial fields for the foreseeable time.

3. The other solution is the so-called flexible, multi-purpose industrial building. What does the idea of the flexible plant mean? The building, independently of its momentary function, should be designed in a manner to be suitable for several types of the production processes. By the selection of the structures, by the farsighted design of the sanitary engineering services it is possible to ensure the convertibility of the plant without a considerable reconstruction of the building.

The multi-purpose plant, contrary to the construction of wrapping character is constructed not for a short time, with the application of materials and structures known today it can be easily converted.

Which are the criteria of the multi purpose industrial building?

The spans should be selected optimally, as large as possible within the limits of the possibilities offered by the structure.

From the point of view of material consumption and building cost, the application of larger spans, up to 30 m - at least when related to the entire investment - is relatively not significant.

The larger column grid /the desire of the technologist is the plant without columns/ facilitates not only the freer development and possible rearrangement of the technology, but it means direct area and volume savings as well. In most cases this is not appreciated, even though the columns protruding into the zone of communication and material handling require 5-10 % extra area. The cost of the larger span may be directly repaid already in the construction costs.

The built-in production surface should be contiguous, it should serve exclusively the direct production purposes of the plant. Accessory service facilities hindering rearrangement /e.g. transformer/ should not be interlocated.

Extension and development should be ensured maximally in both directions if possible. Extension should be taken into consideration not only in the layout-plans, but in the solutions of the building structures too /it is wrong e.g. to dimension the front columns for the loads of a half bay/.

Roof structure should be suitable to carry lighter transporters which cannot be installed on the floor, conduits, intermediate floor and false ceilings.

Sanitary engineering service should make possible alterations suiting the new requirements both in the conduits and in the apparati. The subsequent introduction of the entire services, e.g. the low-current networks necessary for automation, or the clad bus-bar power transmission system instead of the obsolete cable ducts should be also taken into consideration.

The life of the building, with regular maintenance, should be long.

Of course, the satisfaction of the requirements concerning the multi-purpose building increases to a certain extent, the investment costs of the plant. However, certain overdimensioning of the load-bearing structures and the design of the sanitary engineering conduits taking into account alterations and extensions, will be returned several times in time and material.

II/1. Single-storey and multi-storey buildings

A question of prime importance in the designing of the industrial building is whether it should be a single-storey, or multistorey building?

Of course, in the heavy industry, in industries operating with large material quantities and considerable weights the decision is evident, but it is all the more questionable in the light industry and in the industries serving for mass production /instrument industry, plastic production, textile industry, etc./

II/1.1 Advantages of single-storey buildings

Arguments in favour of the single-storey plant:

1. The fundamental requirement of the up-to-date industrial building: flexibility, the possibility of rearrangement are satisfied better by the single-storey hall with its unlimited dimensions /width-length/ than by the multistorey building.

2. From the point of view material handling, the single-storey solution is generally more favourable /with the exception of possible gravity operations/, - because material handling can be effected on a larger floor area, simultaneously with several transportation facilities. In the case of a multistorey arrangement, the traffic of the storey is also concentrated on a smaller floor area. In a multistorey case, the vertical handling of the material is always necessary, too. The operating and wage costs of loading into and unloading from the elevator and of manipulation are always higher than the costs of horizontal transportation. The difference, of course, is a function of the quantity of the material handled. In the case of lifts, or elevators, the possibility of a breakdown, thus possible stoppages of the material handling should be also taken into account.

3. The standardization of the single-storey plant can be solved more simply both for the entire area and for parts of buildings and structural components than that of a multi-storey plant. The halls can be constructed in a given case with identical components prefabricated in plants.

4. The less restricted ground plan and larger grid of columns of the single-storey arrangement makes the development of the technological process easier, and it results in the free arrangement of the machines, the larger span results in the saving of area. The utilization of the area improves because there is no need for stairs and elevators.

5. The useful load is practically unlimited because the load is carried by the natural soil. The greater internal height does not mean considerable extra cost, and since the dimensioning of the lower floor need not be cared for, storage height can be increased.

6. The foundation of the building is simpler and cheaper because the foundations have to be dimensioned only for the dead weight of the structure and for the snow load.

7. The single-storey building can be constructed more rapidly. Though the speeding-up of [illegible] reinforced concrete construction is also possible (self-supporting frame with rigid reinforcement, acceleration of cement setting, etc.) the construction of the single-storey hall can be started simultaneonsly on a larger surface and it can be organized better.

8. The construction of development of the plant in stages can be solved more simply and more economically. It is well-known that the vertical extension of industrial buildings is disadvantageous not only from the point of view of the construction costs - a superfluously overdimensioned supporting frame and foundation must be established already in advance -, but the roof structure must be also demolished, destroyed or lifted; and a perhaps even greater disadvantage is the production loss due to the disturbance of the plant in operation in the course of construction.

II/1.2 Advantage of multi-storey buildings.

As recognized in the foregoing, in most cases the single-storey and multistorey plants cannot be compared on the basis of exact economic indices, but only on the basis of the judgement of engineers, and it is important to listen to the arguments in favour of the multistorey solution as well. When does the multistorey arrangement come into prominence?

1. A decisive argument in favour of the multistorey building may be the restricted construction area. The plot has a significant use value primarily from the point of view of public utility supply, but from the point of view of housing, communal and manpower supply as well. Especially in the case of plant development by reconstruction, vertical extension is frequently unavoidable.

2. In those industrial branches where the weight and material quantity to be handled is not significant, e.g. pharmaceutical industry, fine mechanics, telecommunication engineering, etc., vertical material handling may be faster, less expensive, occupying less space /taking even reloading into consideration/ than the horizontal one. On the other hand, there may be bulky materials in the case of which the technology involving gravity material handling requires a multistorey arrangement /stone-breakers, lime burners, ore dressing mills, some technologies of the chemical industry, etc./.

3. It is conceivable that plants not requiring a great deal of material handling, but equipped in a high degree in the field of sanitary and technological engineering /e.g laboratories/ can be operated more economically vertically than horizontally.

4. In some cases, the minimum cooling-down and warming-up surfaces of air-conditioned plants are smaller in a high-rise building than in a single-storey building.

5. If the vertical arrangement comes into prominence, then the expedient height and number of floors are determined by the capacity of the vertical material handling equipment. It is necessary to strive for maximum utilization, in other words, if it has been necessary to decide in favour of vertical arrangement, one should not be afraid of increasing the number of stories reasonably, even up to 10-16 storeys.

In this case, superposition is determined by the economical design of the load-bearing structure and the frame of the building in addition to the capacity of the transporters.

The importance of the arguments in favour of the single-storey and multi-storey arrangement, respectively, varies in every case. It is doubtless, however, that the utilization of the area is one of the most decisive points of view.

There are cases when the single-storey and multistorey buildings can be expediently combined in accordance with the technological process. The first phases of working: cutting, machining, pickling, etc. that is, the work phase operating with heavier pieces is located in the single-storey building, - and assembly in the multistorey building.

Let us examine a few fundamental points of view of the design of the single-storey plant space - supplementing flexibility:

1. The internal height of the halls increases in spite of the fact that bridge-cranes are superseded more and more. There are several reasons for this:

(a) the higher internal space can be utilized better and more economically, the suspension tracks can be rearranged more easily. The so-called "palette" system is gaining more and more ground. In the space of the manufacturing works, intermediate work floors suspended on floor elements, or supported by the floor structure on columns, so-called "palettes" are constructed. These intermediate floors can be easily disassembled and rarranged. The area below the "palettes" is used as a production area and as a plant store. The lower surface of the "palette" floors can be used for sanitary engineering conduits. With its extraordinary flexibility, this system ensures the possibility of the modification of the current technology, but it can be applied, of course, only in halls with 6 m or larger internal height.

The "palette" character appears in another form in those halls of the chemical industry with larger internal height and a single space, where steel-structured operating and servicing platforms belong to the installations at the necessary places.

(b) Air pollution, as well as the heat generated in the hall dissipate in a larger space, thus they are specifically reduced.

(c) In summer, the heat radiation of the ceiling is less disturbing. On the other hand, heating costs increase insignificantly because the cooling surface of the higher side walls is insignificant compared to the flat roof.

/Hating-up however demands considerable extra calory/.

(d) Storage is more economical in a high hall.

(e) The extra cost of the high hall does not increase in proportion with the volume. /Nowadays specific cost of the hall is always projected to m2/.

2./ It is expedient to accommodate the conduits of sanitary engineering services in the plane of the floor structure. Thus, the uppermost space field serves for sanitary engineering purposes /heating, possibly air-conditioning, ventilation, power transmission, compressed air, lighting, etc./. As few conduits should be placed below the floor as possible - just because of the possible rearrangement.

3./ Practically natural lighting of large single-storey halls can be solved only through the roof surface, though ofter sanitary engineering fittings are restricting the application of fanglights to a great extent. In the last decade, in the majority of plants of the developed industrial countries people have been working under completely closed horizontal roofs without fanglights, under artificial lighting.

Contrary opinions are also voiced against the total artificial illumination from a psychological point of view it is not right to keep people permanently in a uniform closed environment. Every living being needs the effect of the outside world. The workers observe the morning, noon and evening light, and their behaviour and performance change accordingly. The task of medical research in the field of work-psychology is to determine how the work performed permanently in artificial light affects the human organism and performance.

Today, a generally accepted compromise solution is the supplementation of artifical illumination with window bands located on the side walls, the role of which is not the improvement of the illumination, but a psychological one: they reduce the sensation of being in a closed space.

It should be established, however, without underestimating the importance of the psychological factors, that in our up-to-date plants operating in two, frequently in three shifts, artificial illumination is limited a priori only to one shift, let alone the finer work processes requiring greater illumination intensity

/500-1000 lux/ - instrument industry, telecommunication engineering, pharmaceutical works, etc. - where artificial light is indispensable even with the most up-to-date external lighting.

It is not a decisive point of view, but it is worth mentioning that according to a complex economic analysis /construction and operating costs together/, the hall without fanlights is approx. 3-5 per cent less expensive.

If, however, one still decides in favour of fanlights, two circumstances should be taken into consideration. Firstly, fanlights are permeating a larger heat quantity into the hall in the summer period, which must be removed /ventilation/. Secondly, it has been unequivocally established by our design practice that the application of glass surfaces of fanlights for ventilation - even if it appears to be obvious at the first moment - is structurally complicated, unsatisfactory and expensive. It is expedient to satisfy the lighting and ventilating functions by separate devices.

Nowadays, the plastic /polyester/ refractive skylight domes are wide-spread already.

Ventilation is done by means of deflectors, which can be supplemented with fans according to requirements, and in this way a changing perflation corresponding to the season of the year can be ensured.

III. Stages of development of the use of prefabricated elements for industrial buildings.

The following brief review discusses the solutions of supporting structures and hall coverings used in our industrial architecture in a stricter sense, according to two fundamental building types of industrial architecture: the single-storey hall and the multistorey industrial building.

In order to facilitate the judgement and understanding of the degree of the Hungarian building industry's development achieved so far, a brief reference is made to the main development stages of the period after the Second World War. This we consider particularly useful, since the position of the Hungarian building industry after the destructions of the Second World War was in many respects similar to the actual position of the building industry of many developing countries. As a consequence, several of the experiences we gathered during the past three decades could facilitate the development of those countries.

After the first three-year plan devoted to the reconstruction of war-time damages, the intensive development of the heavy industry was one of the tasks: an increased investing-building activity started in the field of industrial architecture.

III/1. Main supporting structures

This period is characterized by the fact that almost exclusively reinforced concrete was reliably available as building material. Since it would have been simply impossible to realize the needed building volume by the monolithic concrete building technology - used almost exclusively before the war -, the large-element version of on-site prefabrication, considered to be a great technical advance at that time, developed and gained ground.

The building solutions and supporting structures of this period, as technical and engineering achievements, rightly aroused the interest of foreign countries, too. With knowledge of subsequent development, it can be stated in retrospection that the supporting structures built at that time were characterized by variety, the supporting structure components, primarily the joint connections of frames built together from them, were characterized by a certain kind of cumbersomeness and complicacy - because of the effort to achieve corner stiffness and continuity, respectively.

In the meantime, among others the realization of the endeavours of dimensional coordination and standardization created the conditions of the change-over to industrial prefabrication which can be considered to be the next step of development.

Expedient prefabrication, transportability, rapid assembly, the string-type prestressing technology and the better concrete quality necessary made possible the application of lighter components of linear character both for the single-storey hall and for the mulistorey building.

Following this, besides the almost exclusive reinforced concrete material, by the improving steel situation, and due to the advantages of rapid transportation and assembly, as well as the proper appreciation of the time factor, moreover the deteriorating manpower situation, the interchangeable steel-structured equivalents of the reinforced concrete main girders were developed.

As a conclusion of this development trend, steel structures were introduced in our industrial architecture as a parallel structural solution.

With gaining ground of the more advanced lightweight structures with the appearance of the corrugated sheet components , - the former contradiction that the steel-structured main girders of the halls were loaded by heavy prefabricated components also ceased to exist.

Finally, primarily in cases of multistorey buildings , - the modernized monolithic concrete building technology also developed.

Besides the traditional structures, a branch of the development affected the construction of shell structures. In the case of the traditional monolithic technology, the scaffolding, shuttering and concreting of the shell structure involved difficulties. On the other hand, the modernized construction method results in a competitive solution for the purpose of individual requirements. The flange girders of shell components are assembled from bridge cranes moving on crane tracks mounted on prefabricated columns - as from a rolling scaffold. The panel shuttering of the shells is suspended on the constructed flange girders. In this way, craned halls covered with hyperbolic paraboloid and elliptic paraboloid shells were constructed. By the way, onsite prefabrication with large-sized components, - in its final development stage , - also reached the construction of short barrel shells, and even that of framespace delimiting structures of shell character, having a unified function.

Coming to the more detailed analysis and presentation of the traditional structural solutions of single-storey halls, it is essential from the point of view of the judgement of the present situation that the structure of our industry has shifted to a certain extent from the heavy industry towards the light industry, moreover that it is our intention to resolve the contradiction of the different obsolescence-times of the technological equipment and the building primarily by flexible buildings. On the basis of the analytic elaboration of the requirements of investors it appeared that the overwhelming majority of the technological requirements can be satisfied in a hall with a column-gird of 12 x 18 m.

Taking also into consideration, - the technical development that has taken place in the meantime halls of this size can be erected economically with supporting structures of the traditional type as well.

III/2 Covering structures

The more essential stages of development of the main supporting frames were already mentioned. In the following the stages of development of hall coverings with traditional structures will be reviewed.

The earliest period was characterized by the purlin system. Prefabricated purlins were laid on the main girders perpendicular to the main axis of the hall with 3 m axial distance, then small roof elements of various design were placed on these in rows. Thus the roof structure was built together from three different kinds of components. The size, weight, number of the individual components - main girder, purlin, small roof element - were very different. This made the selection and utilization of the hoisting machine type also difficult; the number of the joint connections of assebly was large; the three-stage construction, especially the placement of the small components was time and labour intensive, less productive.

The development of on-site prefabrication, the improvement of material qualities, the development of hoisting machines made possible the partial integration of the fragmented structural system. By the gradual development of the so-called large-span roof element - up to 12 m main girder axial distance -, it became possible to solve the bridging of space with two supporting elements, with main girders perpendicular to the hall axis and with the roof elements placed on them in rows.

This space-covering system remained at the time of the change-over to industrial production too, and the large-span roof elements were used even in the case of steel-structured main girders as well. By the proper designing of the connection, the composite action of the upper flange of the steel-structured main girder and the joining roof elements could be also solved.

IV. MAIN TRENDS IN USING PREFABRICATED ELEMENTS FOR INDUSTRIAL BUILDINGS

The industrially manufactured, multi-purpose reinforced concrete hall structure with 9x9 column grid was still of purlin character. The one with 12x18 m column grid was already made with large-span roof elements, and it had a version with steel main girder, too.

The so-called short main girder system which can be regarded as a further step forward meant a change of qualitative character in many respects compared with the previous. Because of its wide application and its further spreading to be expected in the future, it is worth investigating it more thoroughly.

IV/1 Short main girder system

It was justified to place the monolithic or even prefabricated main girder frames perpendicularly to the axis of the hall; the beam participated in taking the horizontal loads too. It was to be seen in the foregoing that the justifiable strive for simpler supporting elements and joint connections brought into prominence the main versions of fixed columns and free beams, respectively two-hinged columns and beams. Here the horizontal loads cause a moment only on the columns, the beam only transmits and distributes the load. If composite action is ensured, the roof panel system as a plate rigid in its plane is also suitable for this, mainly in the case of halls without crane, making up a great part of the requirements. Thus, the main girder having a lattice construction often required by the span, became superfluous, although of considerable height was placed perpendicularly to the axis of the hall.

The manufacture of the earlier large-span roof element, - either on insitu concrete core, or in industrial steel template, - was not simple on account of the coffered design. Roof elements with considerably larger span can be manufactured by omitting the cross ribbing, by using a simpler cross-section and by prestressing.

The greater length /span/ makes it possible to place the main girder carrying the total load of the floor section in the direction of the axial distence of the smaller column and to place the roof elements otherwise carrying a smaller load in rows perpendicular to the axis of the hall, with an arrangement turned

90° relative to the former systems. /Figure 1./.

IV/2. Reduction of structural height

In consequence of the cross-girder character, of smaller loads and limited deflections of the roof elements due to stressing, their structural height is small compared to the main girder height of the previous arrangement. In the new arrangement, the useful /m_1/ internal height of the hall is determined by the lower edge of the roof element. The stressed main girder with a smaller span may be also a beam with smaller height and generally with a solid web. The weights to be hoisted become equalized. Though the free height of the opening /m3/ will be less between the adjacent halls, in the case of halls with controlled nave this generally does not disturb the technology. In the case of halls with cranes, the free height of the opening /m2/ between the naves is limited anyway by the crane girder running significantly lower /Figure 2./.

Thus, in the short main girder system, - mainly in the case of lower halls without crane - the ratio of the useful volume has significantly improved. Though it is doubtless that the increase of the height of the hall does not increase the investment costs in direct proportion, the reduction of the volume has an economically favourable effect - in respect of the limiting walls, heating, ventilation alike.

Moreover, an advantage which can be evaluated only qualitatively, but which is not to be underestimated is the clean, clearly arranged, grandiose internal appearance of the halls constructed in this way, more favourable aesthetically, too.

The prototype of the short main girder system used in Hungary and outlined above was applied for the first time at the Hódmezővásárhely Hardware Factory. On the basis of the favourable experiences, the Ministry of Building and Urban Development ordered its standardization.

IV/3. Manufacturing technology

The TT-section components constituting an essential element of the 12x18 m hall are manufactured on a concrete prestressing bench lined with steel plate, by string stressing /Figure 3./. The two-support, two-cantilever plate solution supported by the two ribs makes possible 2,40 m width still favourable from the point of view of transportation. The short main girder versions are also prefabricated and stressed. The component weights are balenced, being about 10 Mp. By constant development, by widening the product range, the building enterprise in charge strives for the developm nt of complex hall systems Figure 4./. Multistorey and combined building types can be also constructed from the product range available at present.

Ribbed upright panels are also manufactured for the purpose of external limiting wells, thus the basically three different kinds of limiting walls, the horizontal panel, section-glass glazed and upright panel type solutions provide a satisfactory choice. Figure 5/.

From the point of view of the simplification of the structural system, the securing of expansion movements by neoprene underlays was significant. In this way, the inconvenience of column doubling aside the dilatation joints could be avoided Figure 6/.

The fundamental advantage of the solution is that it represents a purely reinforced concrete structural system made of uniform material.

To satisfy the less frequently occurring, but still realistic 24 m span requirement, a T-section roof element otherwise manufactured on the basis of principles similar to the FT roof element is also available /Figure 7/.

In the foregoing the short main girder system was derived from the integration requirement of the traditional, differentiated supporting structure system. The system can be derived also from the surface structure performing the space-delimiting and load-bearing function alike, thus having an integrated role.

In case that extensive, bent r.c. shell surfaces are made with monolithic technology, the difficulties of scaffolding, shuttering and concreting come increasingly into prominence. Even if an up-to-date monolithic process is applied - moving scaffold, sliding formwork, welded steel net, guniting concreting process - they are suitable rather to satisfy only the individual requirements exceeding the standard ones.

In the case of standard requirements, with in-situ or industrial prefabricatio - asserting the structural advantages and possibilities offered only partially and limited only to the function of a roof element. - as well as combined with traditional structure /column, beam/ they can be used to advantage, and ultimately they also result in the short main girder system.

IV/4. Various cross sections for roof elements

The economic efficiency of the short main girder system is influenced primarily by the solution of the roof elements. The usual cross-sectional forms are shown /Figure 8/. In the case of the spans in question - from the point of view of the supporting structure - most of the cross-sections are suitable with the minimum plate thickness necessary because of the construction technology. In the selection rather the expediency of manufacture is authoritative. Components consisting of flat plates are more advantageous than the components having a curvilinear cross-section from several points of view. According to investigations the trapezoidal cross-section, the wave line and the T-section girders are also showing favourable grades of efficiency from the point of view of the degree of merit of the individual cross-sectional forms - the moment capacity related to the dead weight. The disadvantage of the somewhat lower degree of merit due to the T-section form may be compensated by advantages originating from the simplicity of construction and the freer alignment of the stressing wires.

IV/5. Multistorey buildings.

Concerning the multistorey industrial buildings, it can be established that their frequency is less than that of single-storey halls. Apart from the arguments mentioned in the first part of the paper, the desirable flexible design of the multistorey building is also more difficult because the fundamental conditions of this, the large continuous footing area, the large axial distance of the columns possibly in both directions ensuring the possibility of extension, are a priori more circumstantial.

In addition to the former disadvantages of functional character, the multistorey buildings are more complex from a structural point of view as well. The precondition of industrial production, to ensure the large product number and the standardization of the structures, respectively, are difficult also because the number of parameters and accordingly the number of the variation possibilities is high.

Besides the parameters of the span, main structure axial distance and internal height of the single-storey building, the number of floors and the useful loading of the intermediate floors are other variables. Since some columns of the multistorey buildings carry the load of all the floors above them, taking the number of floors and the useful floor load into consideration in a broad-minded and unified manner plus the usual overdimensioning, they have significant economic disadvantages too.

All these account for the fact that in the case of multistorey buildings the range of the well-proved, repeatedly applied structural systems is poorer.

Turning to the more detailed analysis, the versions of the intermediate floors applicable in multistorey industrial buildings are greatly reduced by the span requirement and by the useful load of the floor, moreover by the fact that an efficien heat and sound insulation between the floors is generally not a requirement. Because of the permanent load-useful load ratio, continuity and, in the case of plates, two-way load-bearing is desirable.

The bottom-ribbed reinforced concrete floor was the classical floor solution of the older industrial buildings. On account of the relatively freely selectable plate thickness, rib spacing distance, the action on the field moment as a T-section and the continuous arrangement, its structural [illegible] could also be favourable.

Its economic disadvantage was the significant gross thickness of the floor structure, which may make up a considerable percentage of the cubic space in store with limited storage height, e.g. in platform-type granaries.

It was a technological, functional disadvantage that the air-space formed between the ribs can be ventilated only with difficulty, moreover the sagging ribs make natural aeration and natural illumination difficult.

In the period of in-situ prefabrication, the intermediate floors of the multistorey buildings were also solved by coffered floor components placed between the principal beams. Because of concentrated loads the plates of these were considerably thicker, and because of the moving wheel loads generally a load-distributing in-situ concreted layer ensuring the composite action of the floor componets placed in rows was also needed.

Where other advantages also contribute to the existing advantages of flat plate roofs - small floor thickness, proper aeration, proper natural lighting- such as e.g. the simple fixing of the heat-insulating layers of multistorey cold storages -, these have gained ground. The prefabricated version of the mushroon construction is cumbersome, therefore it is generally made with monolithic technology.

IV/6. Modernized monolithic processes

The latest period in this field is characterized by the tooling for the modernized monolithic processes. By the introduced UTINOR, SCANFORM, etc, systems, generally plate floors flat on the top and on the bottom, without mushroom and with concealed mushroom, respectively, are constructed. The appearance of the zinc-sprayed trapezoidal corrugated sheet- because of its relatively dense support requirement - brings floor solutions with ribs at the bottom into prominence again for multistorey buildings.

IV/7. Principles of subdivision

If the framework is made from assembled components, primarily the principles of the subdivision and assembly of the structure should be clarified. Several possibilities offer themselves - because of the the high degree of statical indeterminacy - for the subdivision of the multistorey, multilegged frame model. A fundamental requirement is the relatively few number of different components: the expedient utilization of the hoisting machine justifies similar component weights if possible.

IV/8. Contradictory requirements

The statical requirements and those of building technology are contradictory in many cases. The points of view of structures - taking the loads of the multistorey building into consideration - require assembly from larger, rigid units. For the places of the joint connections of assembly - in view of their reduced load-bearing capacity - the places around the zero moment points offer themselves.

Both of the above points of view contradict the requirement of simple manufacture, transportation and assembly, which can be achieved best in the case of linear components, columns, beams.

For the relatively high buildings with wide tracts hoisting machines with great hoisting height and great handling radius are necessary. This often restricts the hoisting weight. The smaller component weight - the fragmentation of the structure - contradicts not only to the statical requirement, but to the requirement of the productivity of the building technology as well, similarly to the building technological requirement of the few number of joining places - because of its labour and time intensity , - however, the meeting of a large number of components in one joint connection, - especially in the case of prefabricated reinforced concrete, - should be avoided on account of the difficulty of reliable solution.

IV/9. Compromise solution

The final solution will be a compromise between contradictory requirements. Figure 9 shows the schemes of the constructed versions. The column-beam version and the solution using continuous columns and hinged beam connection manufactured monolithic are the most frequent ones.

In the case of steel-structured frames, transportation, lifting-in, temporary fixing and assembly are already simplified by the smaller component weight and by the bolted connection having a temporary, or supplementary function as well. The structural requirement of corner stiffness the steel-structured frames applied at places with reduced stress, asserting on-site fitting, and the continous monolithic reinforced concrete two-way slabs supported along the edge of the floor, and concreted on the formwork suspended on the steel frame are shown in Figure 10.

IV/10. Composite structures

In the case of a steel supporting structure, the application of the composite supporting structure would be obvious theoretically and justifiable from the point of view of the supporting structure. The steel-structured frame dimensioned only for the dead weight of the structure for the weight of the wet concrete and the assembly load, can be rapidly erected, and besides this, it also ensures dimensional accuracy in advance. Pouring of concrete can be done in the formwork fixed on the frame. After setting the frame already works as a composite structure for additional loads. Concreting solves at the same time the fire protection of the steel structure too.

The sprading of the construction of composite frames is hindered primarily by the higher organizational scheduling and time requirement of the two different types of work: - steel structure and reinforced concrete work.

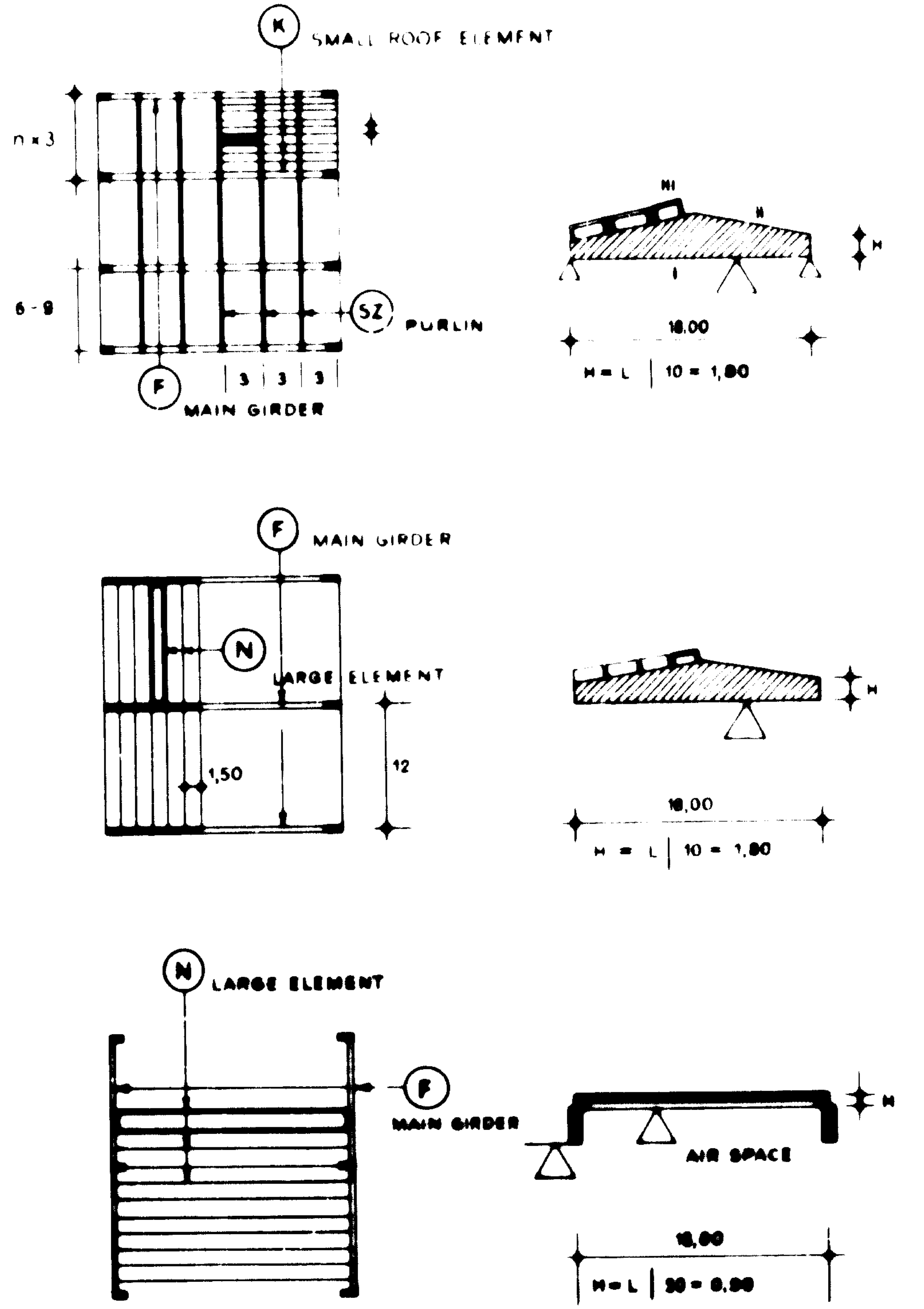

Figure I: Arrangement schemes of the roof floor of a hall: purlin, long and short main girder systems

SZ = Purlin, F = Main girder, N = Large element

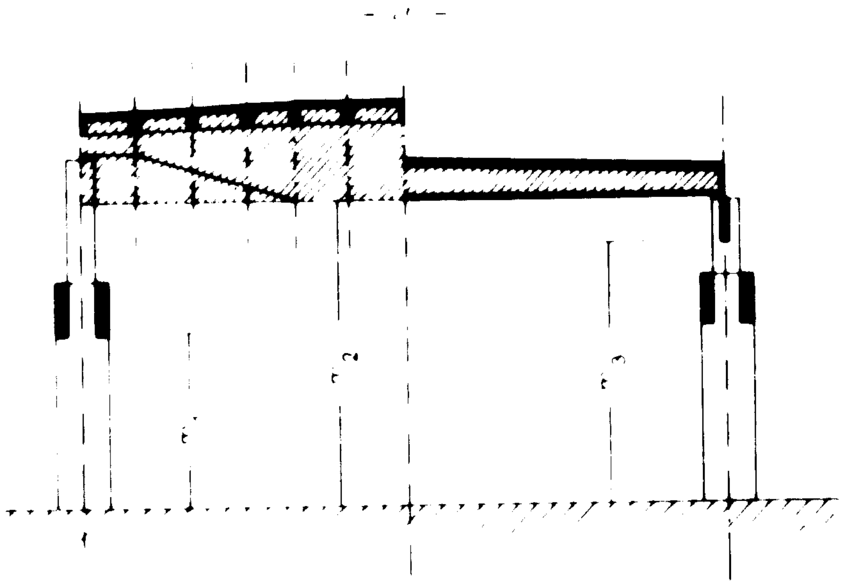

Figure II. The development of the excess air space of long and short main girder halls.

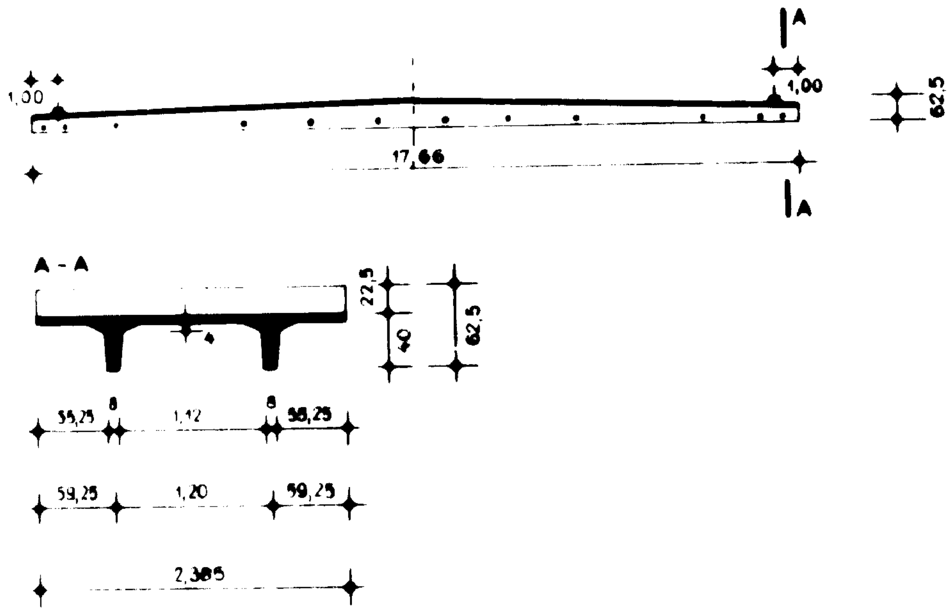

Figure III: TT roof element used for the 18 m span halls

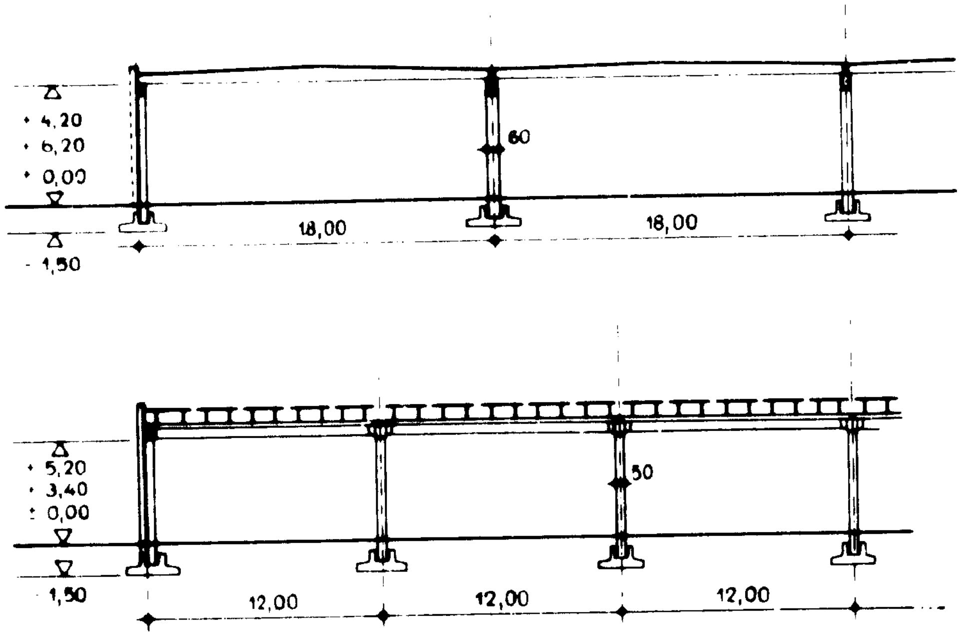

Figure IV: **Standardized, short main girder hall system with 12x18 m column grid. Cross-section and longitudinal section.**

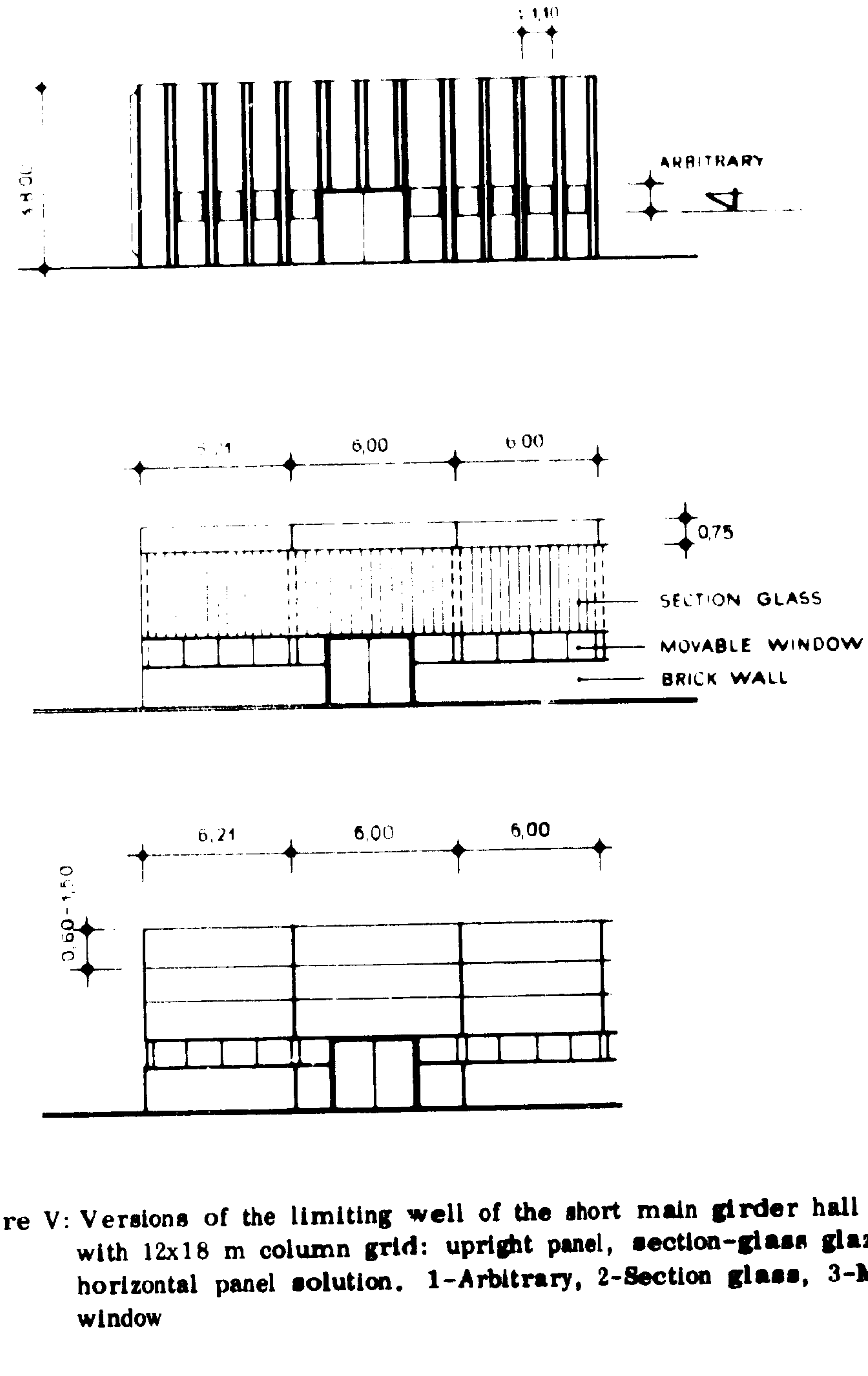

Figure V: Versions of the limiting well of the short main girder hall system with 12x18 m column grid: upright panel, section-glass glazed and horizontal panel solution. 1-Arbitrary, 2-Section glass, 3-Movable window

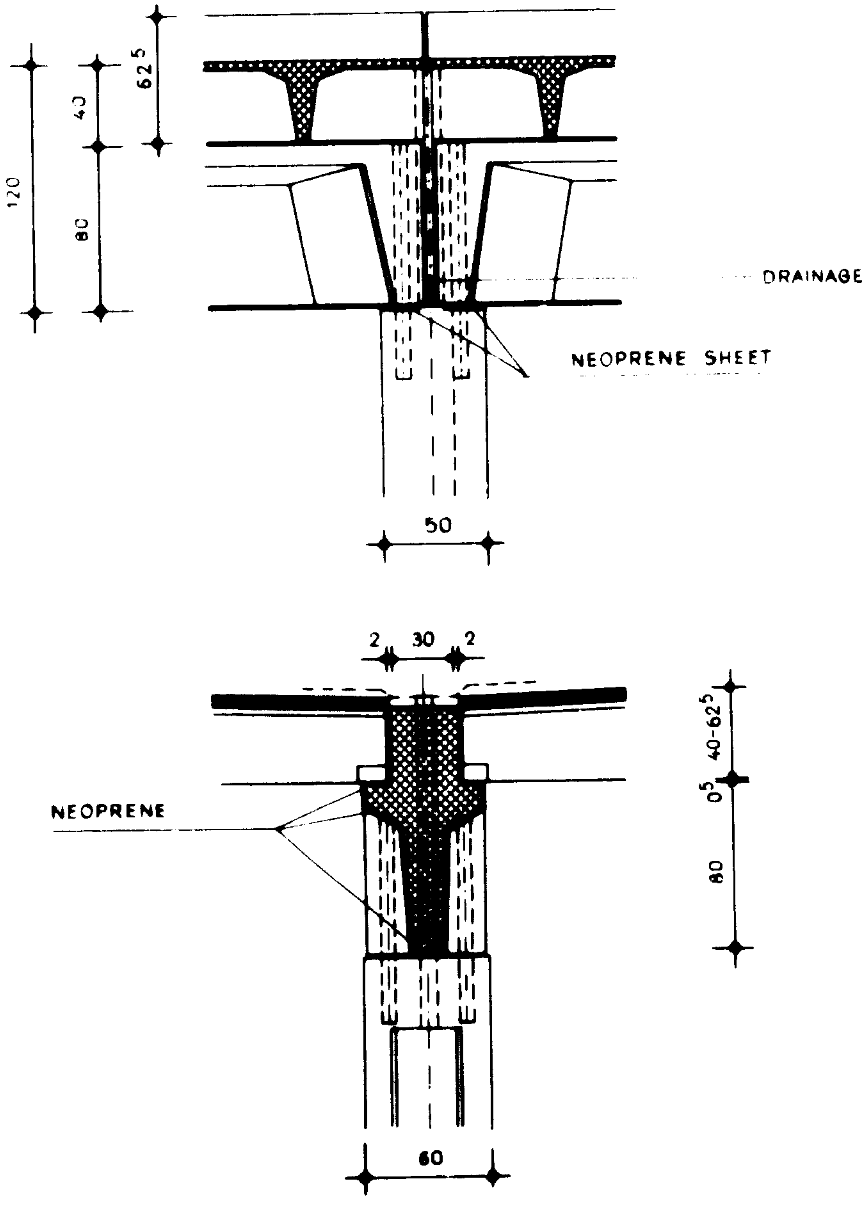

Figure VI: Joint connections of the short main girder hall with 12x18 m column grid.

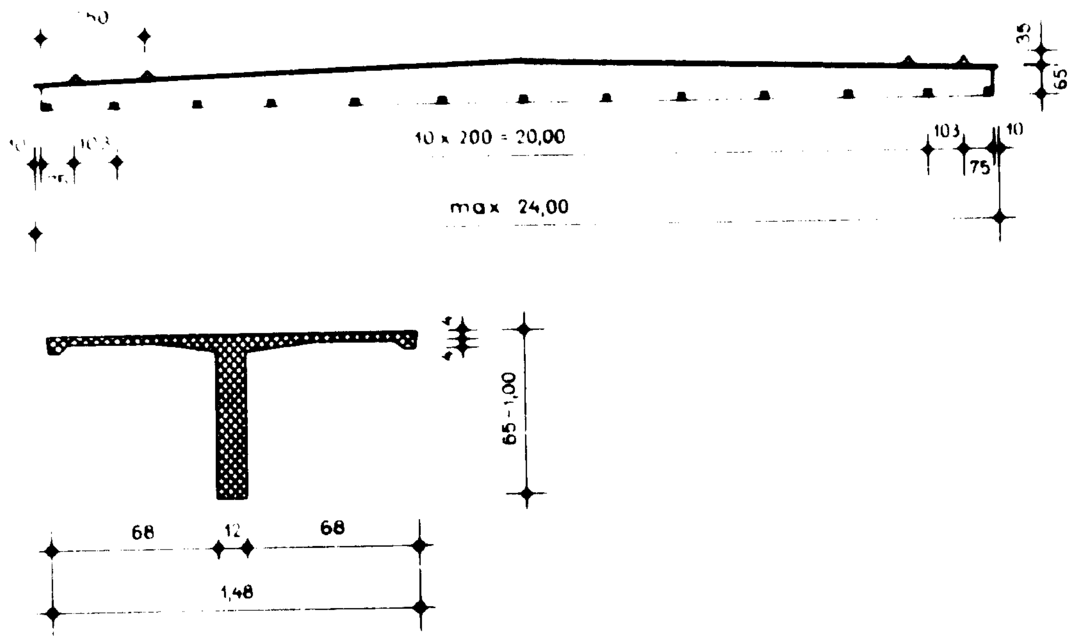

Figure VII: The T roof element designed for the hall with 24 m span

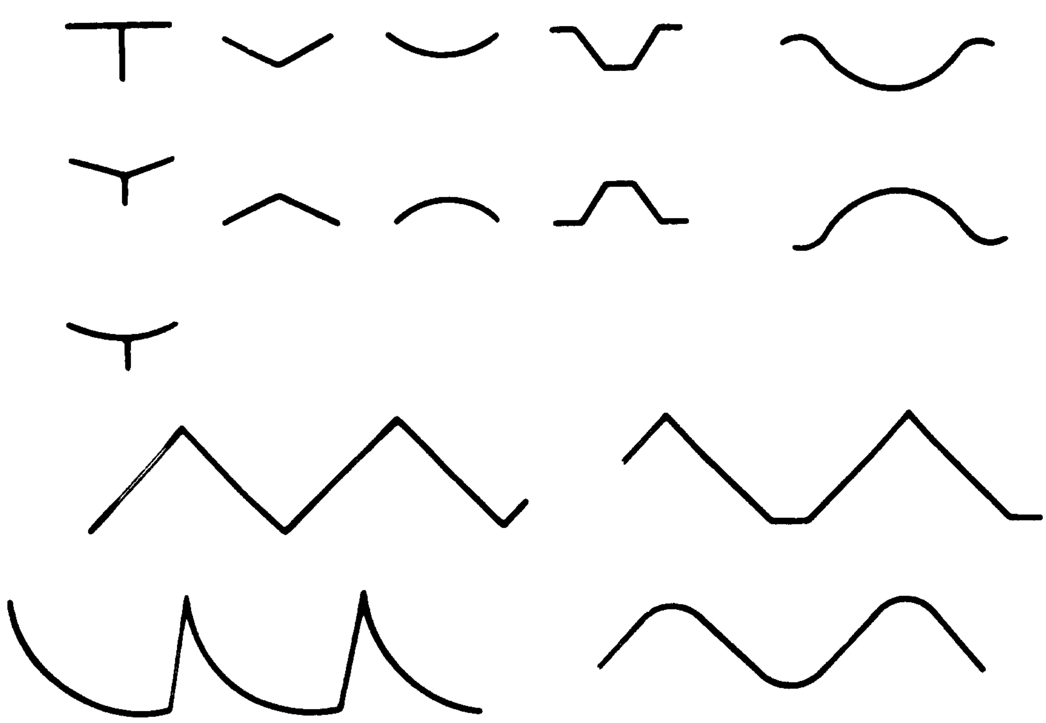

Figure VIII: Versions of roof element cross-sections

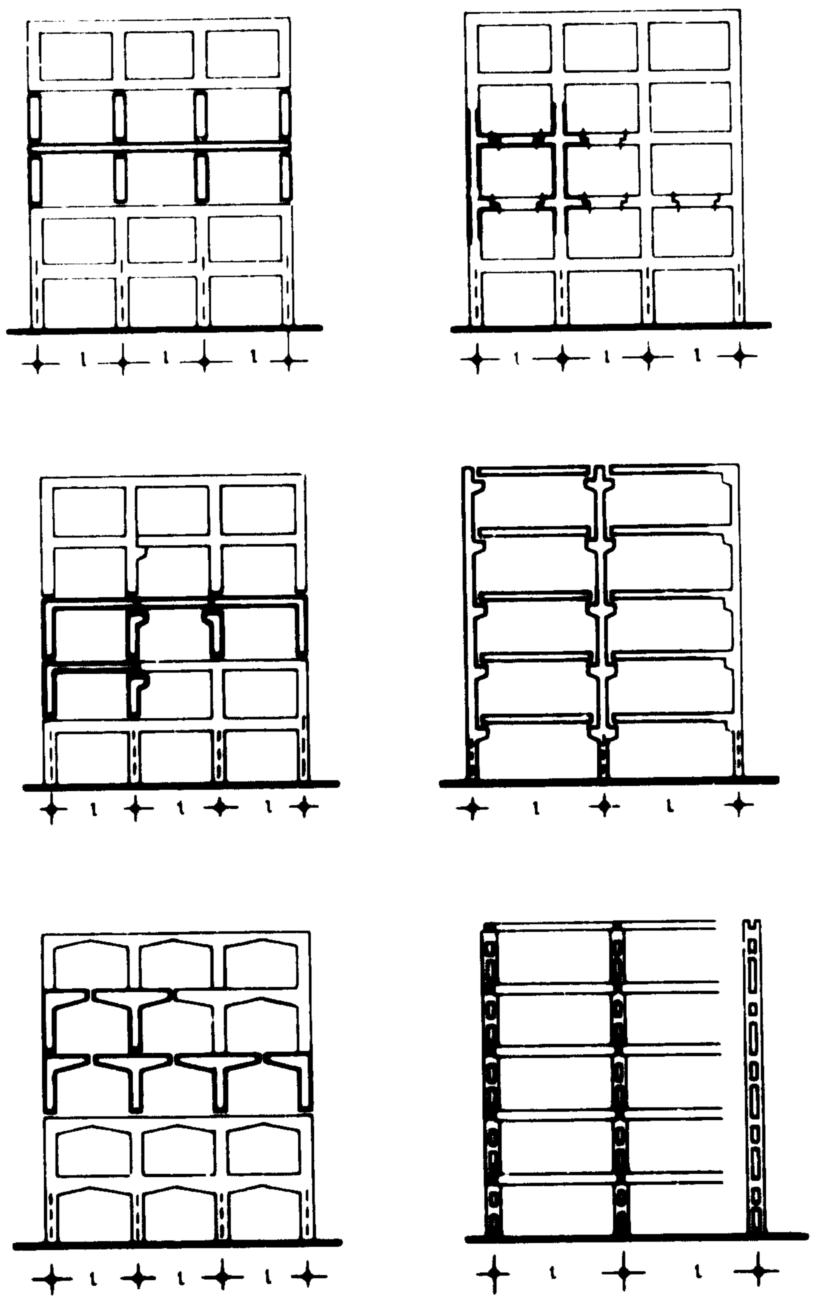

Figure IX: Versions of multistorey frameworks built together from prefabricated concrete components: column-beam: beam connected at zero point of T column moment: two-legged, two-hinged frame - connected beam: through columns - connected beam: T columns with hinged joint in the span centre; through Vierendel columns - string type longitudinal beam.

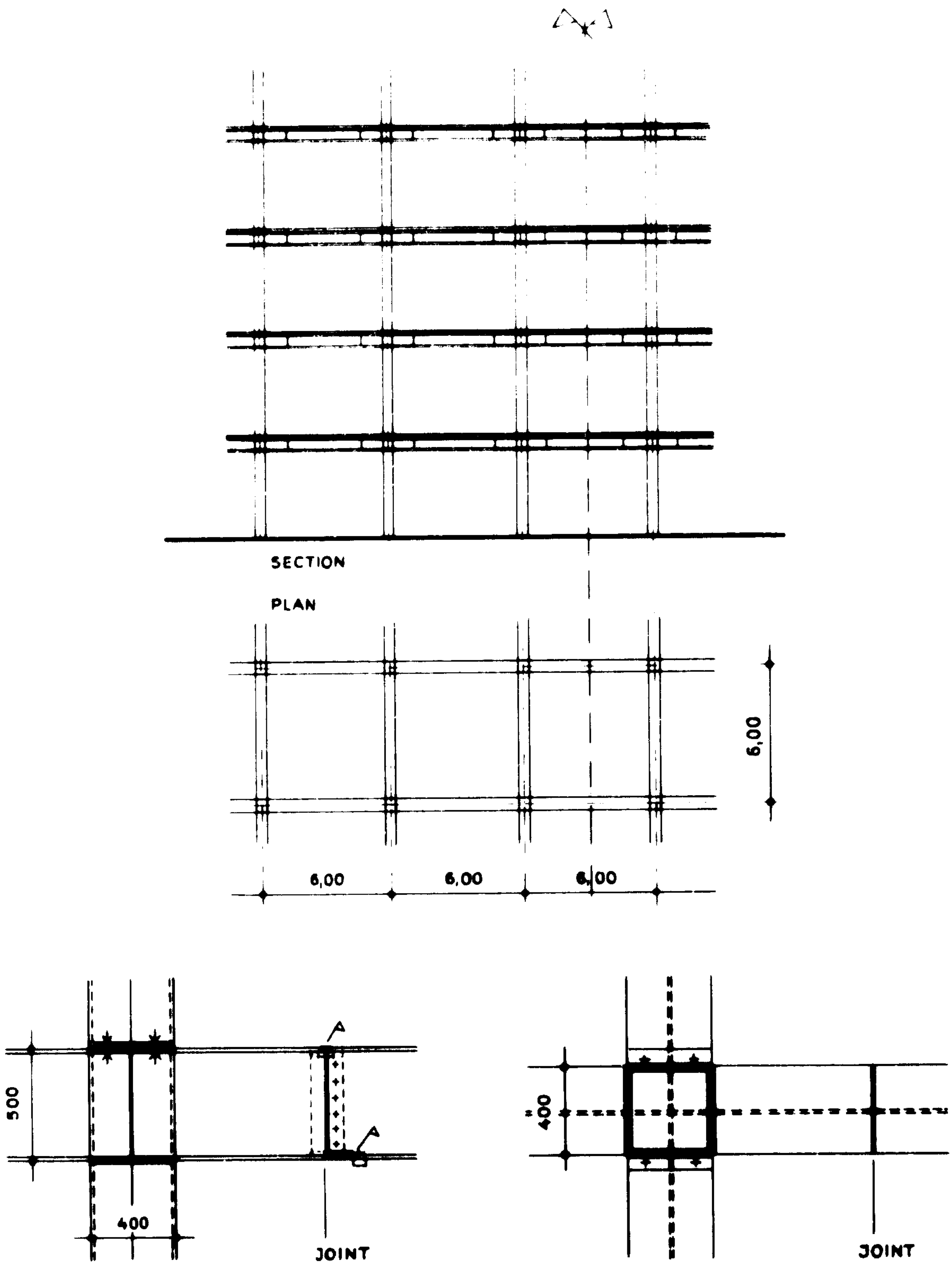

Figure X: Multi-storey steel frame, with joints at moment-zero points. Column joints hinged welded on spot after screwed fixing.

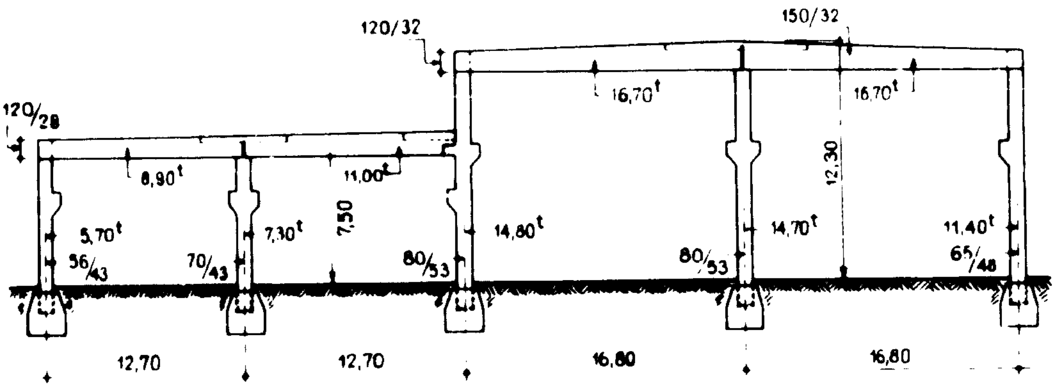

Figure XI: Ganz shipyard (1948) cross section

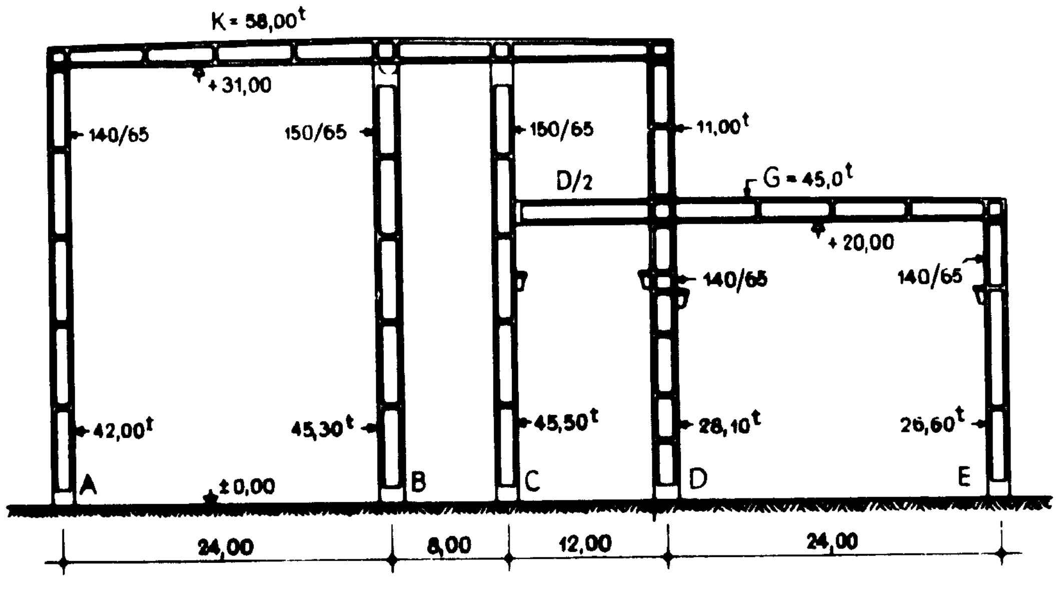

Figure XII: Inota power plant boyler house

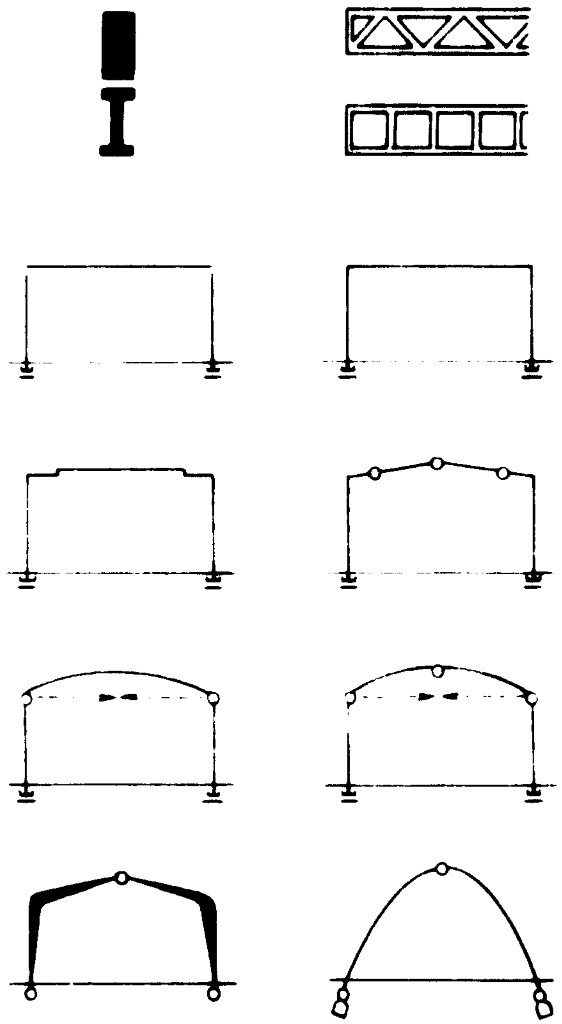

Figure XIII: **Prefabricated one-bay hall systems**

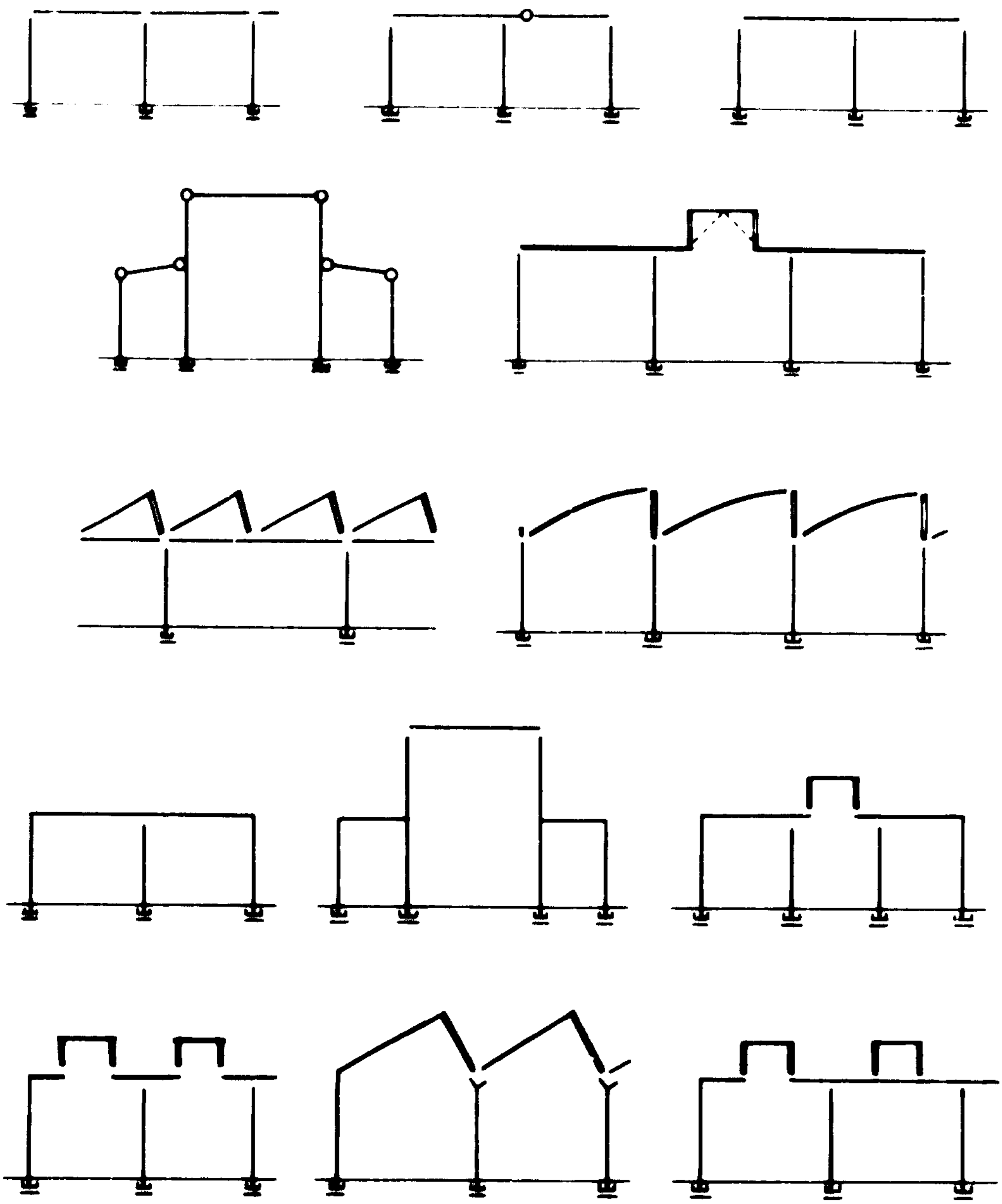

Figure XIV: Prefabricated multi-bay hall systems

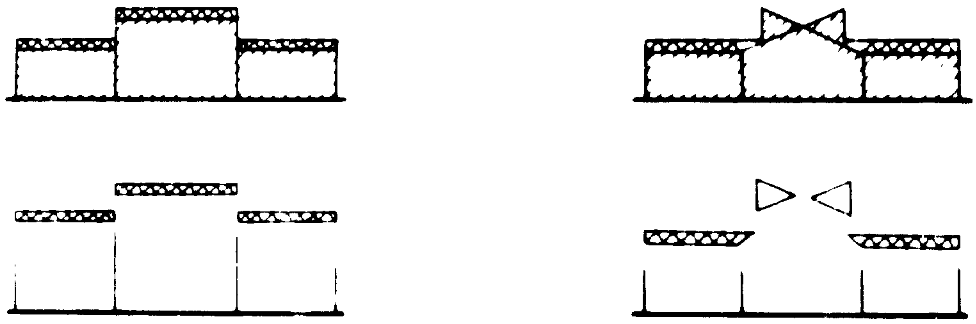

Figure XV: Prefabricated three-bay hall systems

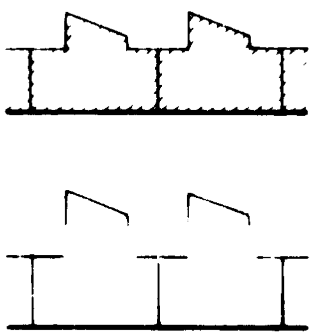

Figure XVI: Prefabricated multi-bay hall system

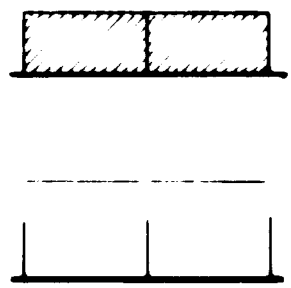

Figure XVII: Prefabricated two-bay hall system

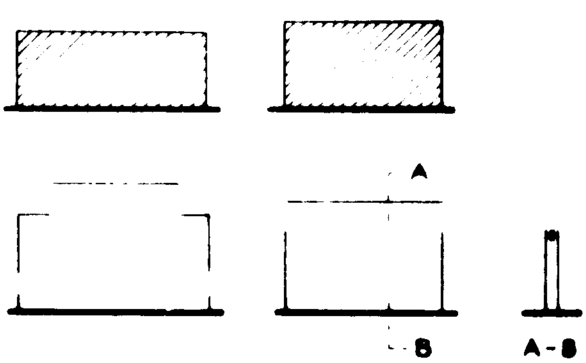

Figure XVIII: Prefabricated one-bay halls

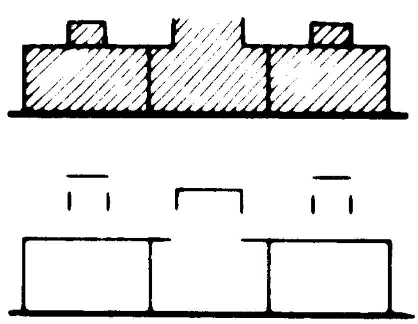

Figure XIX: Prefabricated multi-bay halls

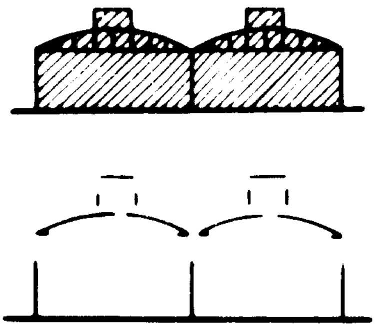

Figure XX: Prefabricated arched multi-bay halls

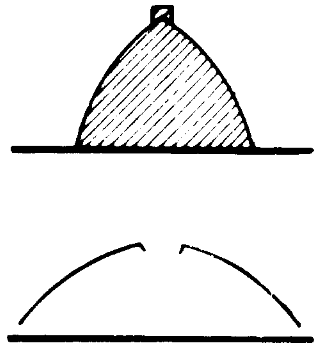

Figure XXI: Prefabricated threehinged arched halls

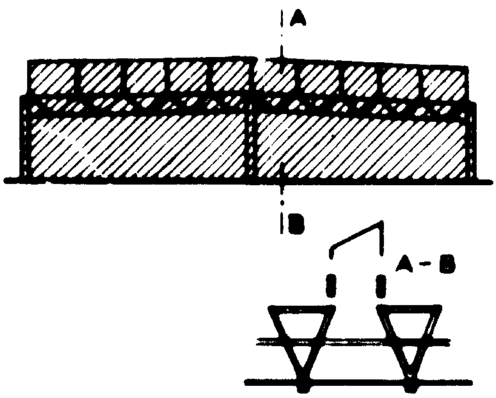

Figure XXII: Continuous trussed beam, inclined columns

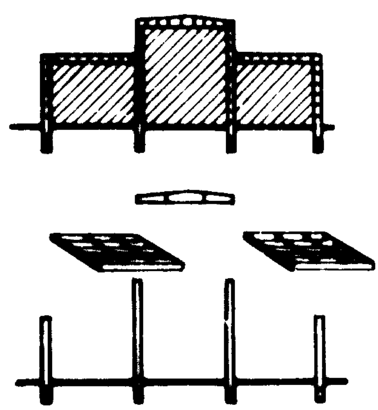

Figure XXIII: Prefabricated three-bay hall with beam-grid

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