# NON-TECTONIC SYSTEMS: INDUSTRIAL WORKSHOPS THE "TILT-LIFT" BUILDING METHOD*

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**Abstract**

The tilt-lift building method introduces an adaptation of the non-tectonic systems for mass construction of industrial workshops. This fundamentally new building method of technological relevance for hot arid tropical areas is realized by transplantable factories and has been designed in such a way as to render it possible—interalia— to build industrial workshops in any remote area without being bound to definite spans; then, to construct very large size elements—even with unskilled workers—without requiring transportation; finally, to develop a building method in which the point precisely is to tilt and lift expressly big volumens—structural elements of 10—40 tons—without requiring any lifting equipment independent from the structure; etc. The non tectonic systems are based on the recognition that tectonics is not the only possible axiom of building and the tilt-lift building method gives a further proof that such an axiomatic change is realizable and that we may open new hitherto unknown ways of industrialization of building if we break with the axiom of tectonics.

## Introduction: Scope of the research 1971—87

At the Institute of Building Constructions and Equipments ever since 1971, many years' research work has been spent on a new coherent theoretical, technological and economic approach to mass-construction in developing countries.*** Initial research strived to elaborate the theory of construction [12] and succeeded in proving scientifically that in the age of industrialized building the axiom of tectonic—that is the simple principle of putting loadbearing

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The theme was elaborated by *M. Párkányi* and his co-workers *L. Hajdú*, *J. Barcza* and *Z. Szirmai*.

Consultants were *J. Bakondi*, *L. Garai*.

** . . . "Given the alarming deterioration in the overall conditions of shelter and basic services for over 1.000 million people in developing countries and a significant number in industrialized countries, the General Assembly of the United Nations Centre for Human Settlements (Habitat) decided that there was need to focus attention on this global problem" . . .

To do so and in order to seek solutions to the issues which are raised, *The General Assembly proclaimed 1987 as the International Year of Shelter for the Homeless.*

*** See: References.

structural elements on one another—is not the only possible axiom of building but it has a working alternative. This is how the *non-tectonic systems* arose.

Success of a series of pilot tests—the experimental non-tectonic structural unit [3], the experimental non-tectonic maisonette [4], the experimental non-tectonic hall [7], etc.—carried out 1971—74 urged us to solve essential technology problems of different adaptations of the system, therefore since 1975, research had two main lines.

The first was the original line of research concerned with the *adaptation of non-tectonic systems to low-cost housing in developing countries* [2]. It was given significant support by UNIDO which has for some time been in contact with the Hungarian experts [6]. Considering the results achieved hitherto the system was considered very promising for use in hot-arid countries (where gypsum is available) for low-cost housing, community centres, industrial workshops, rural health centres [9] and the technology to be ripe for testing under actual conditions in a developing country. Now, in the period that followed, quite a series of pilot projects, plans for low-cost housing, industrial workshops, schools etc. were elaborated for different developing countries (inter alia: Egypt, Somalia [6], Senegal, South Yemen [11], Iraq) but due to the well-known—mainly political-economic—circumstances, none of them could be realized up to this time, most unfortunately.

The other line of research was devoted to the *making of an appropriate technology*, that is to calling into being building methods of technological relevance for hot arid tropical areas [14] capable of satisfying a system of determined requirements possibly most favourably in a given space and in a given time.

Since the non-tectonic systems are not bound to a particular building method—the same building, namely, can be realized in many different ways depending on the simultaneous consideration of all social, technical, economic, geographic, zonal, functional, architectural etc. factors—consequently quite a series of building methods can be at the builder's disposal to ensure the most favourable solution. This is how at last *the seven basic methods of non-tectonic building: the in-situ, the lifting, the box-unit, the box-frame unit, the closed cellular the lift-cell and the tilt-lift building methods* became elaborated.

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Having finished elaboration of the seven basic methods of non-tectonic building, in 1985 we started on a new phase of research, again on two main lines.

The first line devoted to the *further development of non-tectonic systems to curved structures* basically aims at elaborating the outline of methodology. For this purpose the work is designed to include the making of architectural (design) variations on the fundamental stereometric forms of the non-tectonic curved structures; the elaboration of structural (manufacture) variations on the industrialized forms of producing domes and vaults and finally, the working out of technological (assembly) variations and combinations on building methods of technological relevance for hot arid tropical areas.

The other line of research was inserted into our programme on the request of the Ad hoc IYSH Committee for the purpose of elaborating our scientific *contribution to the IYSH Research Action Area* (covering the field of "identifying and testing low-cost techniques for construction and upgrading of community services, especially those using local materials and skills"). To do so, we decided to *restate main results of our research into non-tectonic systems* in five subsequent studies, as follows:

1. *An illustrated report of the open, lightweight silicate-based building systems* [13]. In this abundantly illustrated report we aimed at giving a dense account of our research work which led us to the fundamental recognition that tectonics is not the only possible axiom of building and prove that the axiomatic change is realizable and that we may open new, hitherto unknown ways of industrialization of building;

2. *Building methods of technological relevance for hot arid tropical areas* [14]. In this study we first introduce the theoretical outline of technological irreversibility and then two fundamentally new building methods particularly fit for hot arid countries are expounded in detail. Both technologies—*the box-frame unit building method and the closed cellular building method*—are concerned with *low-cost housing*, introduce adaptations of the non-tectonic systems for solving different problems of mass-housing in developing countries and have been designed in such a way as to give optimum solution for the social-sociological, technical-economic, climate geographic, architectural-constructional requirements prevalent today in the P.D.R. of Yemen;

3. *Communal buildings: the lift-cell building method*, and

4. *Industrial workshops: the tilt-lift building method.* In these separate studies two further non-tectonic building methods of technological relevance for hot arid tropical areas are expounded in detail. Both technologies exemplify a further development of the system to solving problems of mass-construction of communal buildings and industrial workshops, respectively;

5. *Organization of an open system industrialization of building in hot arid tropical areas.* In this article finally, we introduce our propositions for an organization of building activities in developing countries and expound some technological and economic aspects of changing the structure of building industry in hot arid countries.

Our present study is the *fourth* in the series of articles to introduce the non-tectonic systems.

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## Section 1

## Adaptation of non-tectonic systems to industrial buildings

### Introduction. Short description of non-tectonic systems and technological relevance

The themes—*non-tectonic systems* and *technological relevance*—have already been treated in detail in the series of articles devoted to introducing main results of our research in the Periodica* therefore, here only short descriptions will be given to remind the Reader.

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*The non-tectonic systems are open, lightweight, silicate-based building systems founded on the Gutenberg principled fragmentation.*

In the non-tectonic systems, building is *complementary operation*, that is, a process in which we combine the *factory-production of surface elements with some kind of technology of pouring in of concrete either in the factory or on the building site*, whereby we produce structural units (in the factory) or call into being the structures themselves (on the building site).

*In the non-tectonic building method the final product (that is the building) is realized in such a specific building process where additivity (that is the axiom of building) is founded on the simultaneous non-loadbearing (non-tectonic) capacity and temporary or incidental instability of semantically meaningless (Gutenberg-principled) surface elements. In this building method the immediate product of manufacture is not the load-bearing structure but its surface and therefore alignment of surface elements of vertical and horizontal structures does not lead to immediately load-supporting—load-transferring (that is: tectonic) junctions between these surface elements.*

*

In the industrialized building *technological relevance* is defined as an immanent (inherent) quality of manufactured structural systems by means of which these building—structural—technological systems can most favourably satisfy a system of concretely determined requirements in a concretely determined particular case.

The system of requirements of industrialized building, however, is extremely composite and complex not only because quite a series of technological, economical and social constituents have to be taken into consideration but

* See: References 13, 14.

first of all, because this system of requirements keeps constantly changing in space and in time. *A technology satisfying a system of determined requirements possibly most favourably in a given space and in a given time inevitably loses its validity—its relevance—if applied at another time or in another place.*

*The degree of technological relevance in the industrialized building reaches its maximum in the non-tectonic systems.* The combinatorial qualities of these systems, namely, offer almost unlimited possibilities for adaptation to requirements varying in space and in time and actually it is this circumstance which also renders it possible for the system to create a series of products ranging from *individually manufactured individual products through individual products produced by mass-production methods up to mass-products produced by mass-production methods.*

The fact that in the non-tectonic systems technological relevance reaches a maximum degree is of crucial importance from building industrialization point of view because it makes something possible that we could never realize in the mechanization-principled technologies, that is an equally *optimum solution of building tasks characterized by the most different levels of quantity or quality.*

Finally, it seems particularly expedient here to mention a technical-economic consideration definitely pertinent to this theme in support of our conviction, that *the real domain of the adaptation of non-tectonic systems is mass-housing, or rather, mass-construction in developing countries.* The consideration goes as follows:

Whilst in developed countries the specific cost of building constructions, or rather the specific cost of the primary loadbearing structures—that is to say: that specific part of the building cost where the silicate-based, lightweight, non-tectonic systems may save a particularly considerable sum of money—does not amount to more than approximately 10—20% of the total building cost, in developing countries exactly the opposite is relevant: *in developing countries, namely, the building cost of the primary loadbearing structures in low-cost housing may reach even 80—90% of the total building cost!*

## General description of the tilt-lift building method

The tilt-lift building method spells *adaptation of non-tectonic systems to industrial buildings.*

From the point of view of principle of construction the building method is *a special combination of the in-situ, lifting and box-frame unit building methods complemented with a tilting operation*, as we shall see.

The building method is characterized by a high level relevance, that is, *a high degree of technological relevance with geographic-zonal validity* and as such it is most advantageously applicable to conditions in developing countries particularly in hot arid tropical or subtropical areas and it can be realized exclusively in *transplantable factories*. The structures called into being by this building method are always composed of two materials; gypsum and reinforced concrete.

In the tilt-lift building method we manufacture on a *low degree of readiness.*

*In the factory*—more accurately: in the transplantable factory—we only produce Gutenberg-principled non-tectonic surface elements, that is to say: *profiled gypsum surface elements for pillar box-frames and beam box-frames; plane gypsum surface elements for floors and profiled gypsum surface elements (stripes) for beams.*

*On the building site* each operation of the creation of the loadbearing structure is based on the additivity of surface elements, as follows:

*The pillar box-frame* — this large box-unit of parameter size in two directions — is constructed in such a way that first we assemble the non-tectonic profiled gypsum surface elements in the situation prior to tilting, that is to say, we call into being the loadbearing structure in the situation preceding the operation of tilting, and then, we tilt the pillar box-frame around a fixed point into vertical position and conclude the operation by creating homogeneous junction;

*The beam box-frame* — again a large box-unit of parameter size in two directions — arises in such a way that first we assemble the non-tectonic profiled gypsum surface elements underneath the final in-situ position, that is to say, we call into being the loadbearing structure in the situation preceding the operation of lifting, and then, we lift the beam box-frame into in-situ position and conclude the operation by creating heterogeneous junction.

*The floors* are constructed in such a way that first we preassemble on the zero level the non-tectonic profiled gypsum surface elements into beam elements (that is: tectonic, linear r.c. structural elements) and then we locate the beam elements and the surface of floor elements of pillar-zones underneath in-situ position, whereas those of the intermediate zones in in-situ position and conclude the operation with concreting the floors of pillar-zones underneath in-situ position, prior to lifting, whereas those of the intermediate zones in in-situ position, after lifting.

## Variability of the tilt-lift building method

Amongst the non-tectonic systems the variability of the tilt-lift building method is of medium degree, because on the one hand, the freedom of planning is increased, since the sizes and increments of the elements and components — including their thicknesses as well — can be selected within very broad limits and since the relative span-indifference of the beam box-frames keeps the span — the most important parameter of industrial building — theoretically open; on the other hand, however, the degree of freedom of planning is decreased, since the relative height-indifference of the pillar box-frames must be brought in harmony with the spans, and since the building, in the last analysis, can only have an odd number of zones (pillar-zones + intermediate zones).

## The surface and the box-frame as principles of construction

*The surface as principle of construction* — in general — has been dealt with in detail in our previous studies [13], therefore here it seems sufficient only to remind the Reader that the surface, actually, is a universal principle of non-tectonic building, since the non-tectonic systems break with the axiom of tectonics and substitute it for the principle of surface. This simply means that in these systems the immediate object of manufacture is not the load-bearing structure but its surface.

The principle of building with non-loadbearing surface elements, in other words: the simple principle of vertical and horizontal alignment of non-load-bearing — i.e. *non-tectonic* — *surface* elements next to one another, either in the factory or on the building site (according to a certain order, of course) and uniting them into monolithic structure (through pouring concrete into the cavities and channels arising between, within or on top of these surface elements) — this is the essence of every *non-tectonic* structure, be it done by handicraft forms of production, or by any higher level of industrialization.

*The box-frame as principle of construction* — in general — has also been analized in detail, with the box-frame unit building method [14]. It is very important to note here, however, that *in the tilt-lift building method the construction of the box-frame is modified both from manufacture and from assembly points of view:*

- from *manufacture* point of view, because in the tilt-lift building method *the pillar box-frame and the beam box-frame* — in contrastto the box-frame unit building method — *is not an immediate object of manufacture* but that of a preassembly operation on the building site, in which the *pillar* box-frames are assembled in *horizontal* position (that is in a situation preceding the operation of *tilting*), whereas the *beam* box-frames are assembled *underneath the final in-situ position* (that is in a situation preceding the operation of *lifting*);
- from *assembly* point of view, because the large-size pillar box-frames and beam box-frames realized in a process of preassembly on the building site, are threaded through each other in the process of the final assembly (more accurately: in course of the operations of tilting and lifting) consequently the structural connection to be created between them — in contrast to the box-frame unit building method — can only be a *heterogeneous junction.*

These circumstances, however, bring entirely new elements of fundamental importance into the industrial building in the tropical areas both from technical and economic points of view. The modification of the box-frame as principle of construction, namely, makes quite a number of things possible that we could never totally realize in manufactured reinforced concrete industrial workshops. Here are some examples:

— the tilt-lift building method clearly proves that the combining of monolithic structure with the additive principle of construction renders it possible *to build industrial workshops in any remote area* without being bound to definite spans;
— first because in the tilt-lift building method *the very large size elements* required for construction of industrial workshops *do not require transportation of any kind;*
— second because *the tilt-lift building method*—in course of the preassembly operations—*reduces the "envelope volume" of the primary structures to minimum* and thereby the volume of auxiliary structures required for the process of assembly can also be reduced to a possible minimum, at the same time.

Now, if in addition we take into consideration that the tilt-lift building method—in which the point precisely is to tilt and lift expressly big volumes, structural elements of 10—40 tons—*does not require any lifting equipment independent of the structure,*

then it is unambiguously verifiable that the tilt-lift building method establishes expressly *ideal* circumstances for building industrial workshops. Considering everything:

*The tilt-lift building method* — that is the special combination of the in-situ, lifting and box-frame unit building methods complemented with a tilting operation — *is founded on the simultaneous application of the surface and the box-frame as principles of construction.*

Since in this building method *manufacture* has only one immediate object (which simply means that in the transplantable factory we only produce Gutenberg-principled small size non-tectonic surface elements),

therefore *on the site* each building operation is based on the additivity of surface elements, as we have seen.

* * *

## Section 2

## The tilt-lift building method

### Design

**Introduction. A short description of the structural variations on industrial workshops.** (See: Fig. 1)

Variations on plan and in section, on:
— structural systems of one-level industrial workshops, applying the surface and the box-frame as principles of construction;
— variable spans and cantilevers;
variable heights;
variable widths of pillar — beam box-frame zones and intermediate zones;
variable r.c. shell floor-fields with ribs in one direction,
— composite primary grid systems;
monotonous secondary grid systems, with
variable grid dimensions.

**Determination of the constant and variable constituents of the structural variations.** (See: Fig. 2 and Fig. 3.)

— *spans;* distance between pillar box-frames: variable but always multiple of the chosen secondary grid unit;
— *heights:* story height, interior heights; variable but always multiple of the basic module (M = 10 cm)
— *dimensions of beam box-frames:*
*interior dimensions:* variable, but always multiple of secondary grid unit;
*exterior dimension:* equals interior dimension (variable) plus two thicknesses of "cross beams" (variable, but multiple of microcell, mc = 37,5 mm);
*distance between beam box-frames:* multiple of the secondary grid unit;
— *dimensions of pillar box-frames:*
*width;* measured in span direction: equals the chosen secondary grid unit;
*width;* measured at right angle to span: variable but always equals interior dimension of beam box-frames minus two tolerances, modular dimension;
*height;* equals storey height: variable but always multiple of the basic module (M = 10 cm);
*distance between pillar box-frames* at right angle to span: variable but always multiple of the basic module, etc.
— *thicknesses* of "walls" in beams and pillars: variable but always multiple of microcell (mc = 37,5 mm), and finally:
— *the formula of double co-ordination:* 3M = 8 mc.

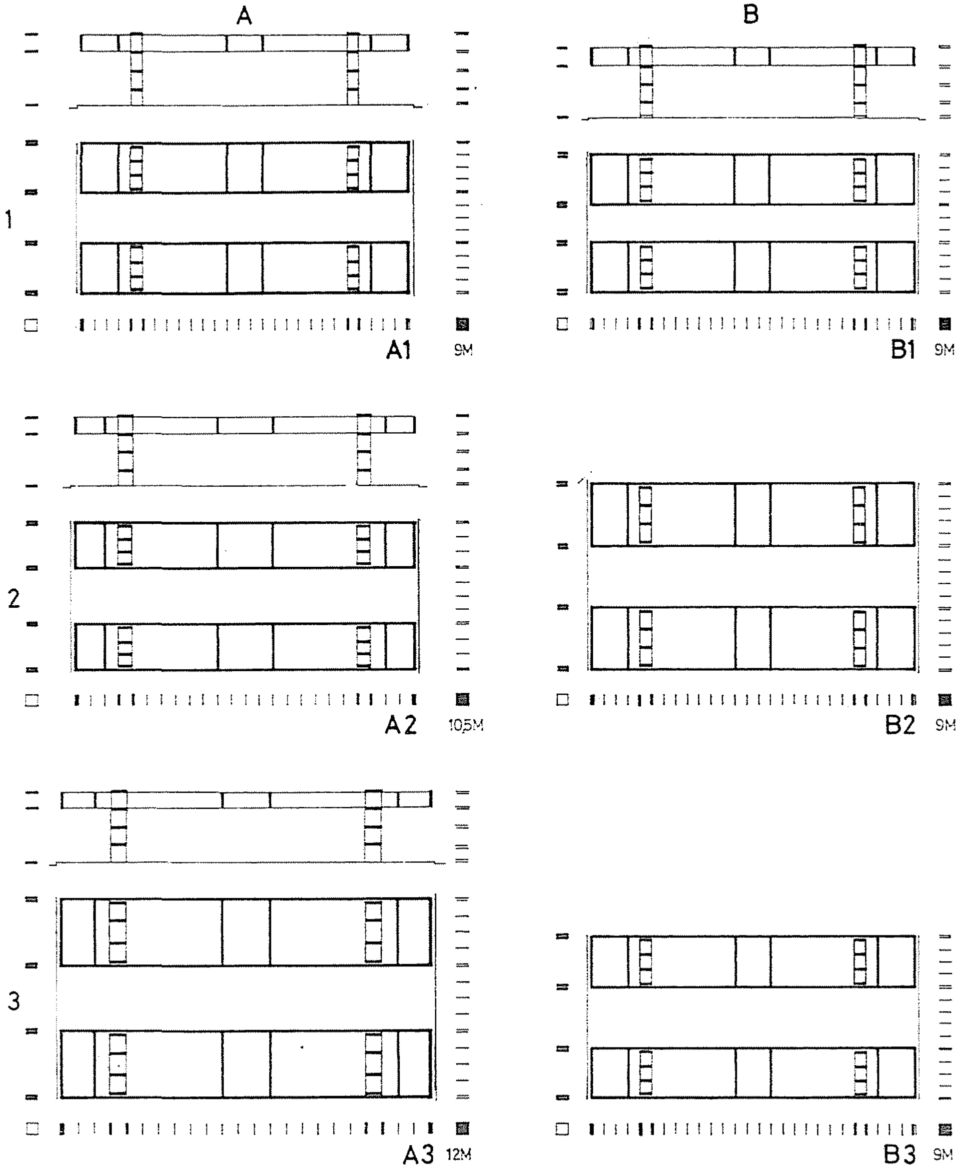


*Fig. 1. The tilt-lift building method. Structural variations on industrial workshops: the system of primary and secondary grids on plan and in section.* Nine variations have been elaborated, grouped in threes, on the 9M; 10,5M; 12M monotonous secondary grids and different spans, heights, widths of zones, cantilevers etc. and considered to prepare analysis of the constant and variable constituents. Fig. 1. shows only six of them, schematically. From points of view of manufacture and assembly selection of *Variation "A1"* seemed most expedient. In the following *the repetitive structural unit* of Variation "A1" will be analyzed exclusively

## Analysis of the repetitive structural unit of the industrial workshop

## Parameter grids and the modular increments

### The primary grid

Lines of the primary grid *on plan* are selected to determine unambiguously the location of the *pillar box-frames* and the *beam box-frames*, that is the zones of the repetitive structural units. For this purpose the unit dimension of the tertiary grid—9M—was taken constant first and then, from this unit two further dimensions were derived as follows:

— interior width of beam box-frame $4\times9M = 36M = 3{,}60m$
— distance between beam box-frames $4\times9M = 36M = 3{,}60m$

(Let us mention here between brackets that within the individual variations the unit dimensions of the monotonous tertiary grid can be variable, of course, but all further dimensions of the repetitive structural unit have to be derived from the chosen grid unit.)

The next step is the determination of the correlations between structural thicknesses and tolerances. This again is based on a constant—4mc = 1,5M—dimension:

— thickness of pillar box-frame 4mc = 1,5M = 15cm
— thickness of beam box-frame 4mc = 1,5M = 15cm
— width of tolerance-zone 4mc = 1,5M = 15cm

The above selection of sizes is very advantageous from point of view of pillars because the sum total of tolerances + thicknesses + distances between the "walls" of pillar equals 36M = 3,60m that is the distance between the beam box-frames, since:

— sum total of tolerance-zones $2\times4mc = 2\times15cm = 3M$
— sum total of structural thicknesses $4\times4mc = 4\times15cm = 6M$
— sum total of "openings" within pillar $3\times9M = 3\times90cm = 27M$

According to this the following *co-ordination dimensions* can be derived: (See also Fig. 4. and Fig. 5.)

| | |
|---|---|
| — width of pillar box-frame in span direction | 9M |
| — width of pillar box-frame at right angle to span | 27M + 6M = 33M |
| — span, distance between opposite pillar box-frames | $17\times9M = 153M$ |
| — distance between neighboring pillar box-frames | 36M + 6M = 42M |
| — cantilevers | $4\times9M + 1{,}5M = 36M + 1{,}5M = 37{,}5M$ |
| — exterior width of beam box-frame | 36M + 3M = 39M |
| — exterior length of beam box-frame | $17\times9M + 3M = 243M + 3M = 246M$ |
| — longitudinal *increment* | 42M + 33M = 75M |

From the abovesaid it follows unambiguously that the primary grid is a composite grid, the smaller grid dimension of which (9M) always determines the width of the pillars, the larger dimension (153M) designates the span. In the other direction running parallel with the span the smaller grid dimension (1,5M) determines the structural thickness, whereas the larger dimension (36M) designates the interior width of the beam box-frames. (See: Fig. 2. and Fig. 3.)

Lines of the primary grid *on plan* establish exclusively *face-line* reference: the pillar box-frames fit on these lines with their long-sides, whereas the beam box-frames with their interior and exterior wall-planes.

Lines of the primary grid *in section* are used for determining the following planes: the zero level (0,00m); the lower level of beam box-frames (+3,90m); the upper level of beam box-frames (+5,10m). Thus, the lines of the primary grid in section again establish a *face-line* reference, which practically means that all the horizontal border-planes of the pillar box-frames and beam box-frames and the ribbed r.c. shell floors coincide with these lines.

It is important to note here that in the tilt-lift building method the location of pillar box-frames has to be elaborated to situations *prior to and after tilting*. (See: Fig. 4 and Fig. 5.) The most important thing here is the designation of the *axis of rotation*, this is always done when constructing the auxiliary structures. (See also: Fig. 17. and Fig. 18.)

### The secondary grid

Lines of the secondary grid *on plan* determine the axis of the intermediate cross-beams of the *beam* box-frames with a *centre-line* reference and in such a way that they always coincide with the lines of the 9M monotonous grid. Periodicity in our case is 27M + 81M + 27M + + 81M + 27M, whereas in case of *pillar* box-frames, the lines of the secondary grid always designate the planes of the pillar-walls with a *face-line*. Periodicity here in the horizontal direction goes as follows: 1,5M + 9M + 1,5M + 9M + 1,5M + 9M + 1,5M; whereas in the vertical direction: 10,5M + 1,5M + 12M + 1,5M + 12M + 1,5M + 12M + 1,5M. This, the secondary grid is also a composite grid.

### The tertiary grid

Lines of the tertiary grid *on plan* create a 36M×9M, or, 36M×4,5M *monotonous* grid. The 9M gridlines determine the edges of the surface elements of the beam box-frame, whereas the 4,5M gridlines designate on the one hand the centre-lines of the linear structural elements (beams), on the other hand the leading rods of the reinforcement within the beam box-frames.

The horizontal lines of the tertiary grid *in section* designate the profiles of the surface-of-beam elements with the following periodicity: 1,5M + 9M + 1,5M.

### Basic grids and the submodular increments

(module grid: M = 10cm; micro-grid: mc = 37,5cm; the formula of double co-ordination: 3M = 8mc have already been treated many times)

* * *

**Basic structural thicknesses**

in case of beam box-frames: (See: Fig. 7a; 7b.)

| | |
|---|---|
| — width of beam element | 4mc = 150mm |
| — thickness of r.c. shell within beam in the middle | 2mc = 75mm |
| — thickness of r.c. shell in the upper and lower zones | 2,5mc = 94mm |
| — thickness of gypsum surface element in the middle | mc = 37,5mm |
| — thickness of gypsum surface element at profiles | 0,75mc = 28mm |

In case of pillar box-frames: (See: Figs 8; 9; 11)

| | |
|---|---|
| — thickness of wall in pillar | 4mc = 150mm |
| — thickness of r.c. shell within pillar in the middle | 2mc = 75mm |
| — thickness of r.c. shell within pillar at ribs | 2,5mc = 94mm |
| — thickness of gypsum surface element in the middle | mc = 37,5mm |
| — thickness of gypsum surface element at profiles | 0,75mc = 28mm |

in case of beams (linear structural elements) (See: Fig. 10.)
(See: Fig. 10.)

| | |
|---|---|
| — thickness of beam | 2,5mc = 94mm |
| — thickness of r.c. shell within beam in the middle | mc = 37,5mm |
| — thickness of r.c. shell in the upper and lower zones | 1,5mc = 56mm |
| — thickness of gypsum surface element in the middle | mc = 37,5mm |
| — thickness of gypsum surface element at profiles | 0,75mc = 28mm |

in case of floors (See: Fig. 10.)

| | |
|---|---|
| — thickness of floor | 1,5mc = 56mm |
| — thickness of gypsum surface-of-floor element | 0,75mc = 28mm |
| — thickness of frozen r.c. shell within floor | 0,75mc = 28mm |

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The figures on the pages to follow illustrate the abore-said.

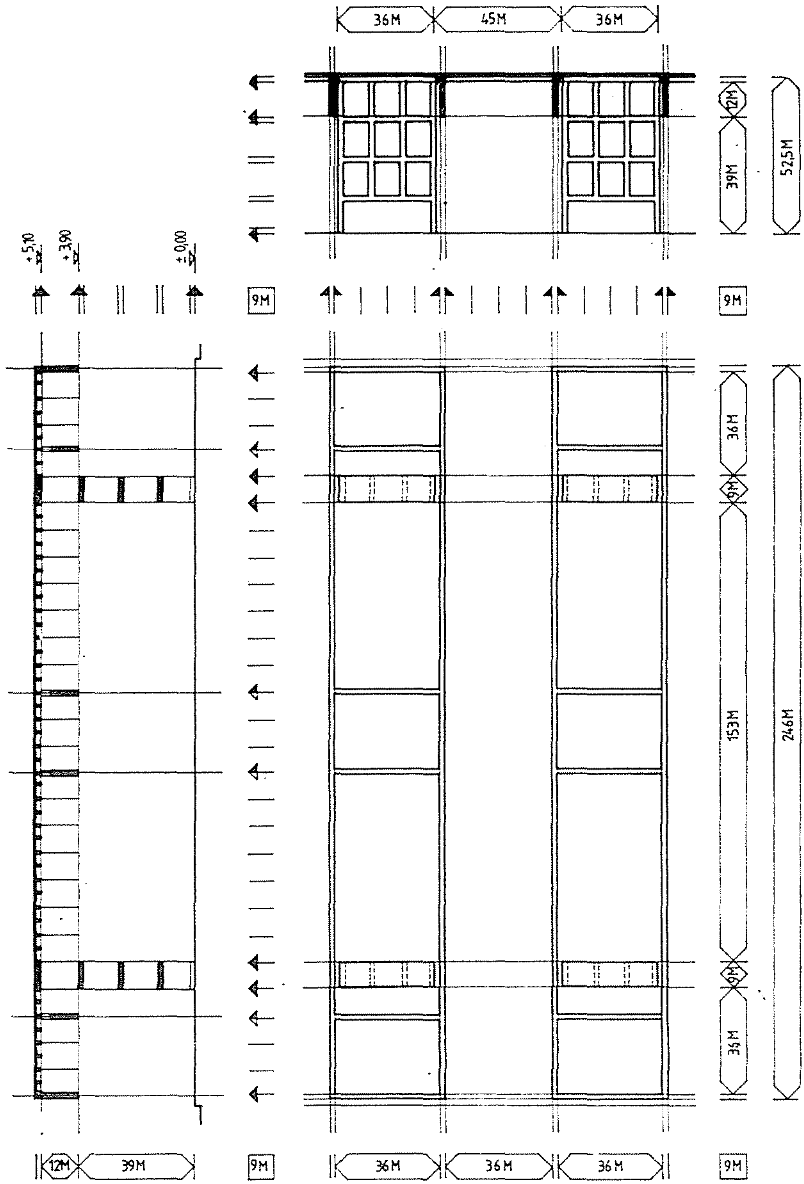


*Fig. 2. The tilt-lift building method. The repetitive structural unit of the indsutrial workshop: the system of primary and secondary grids on plan and in section. (The final situation.)* The decomposition of the structure: The location of the pillar box-frames and beam box-frames in the system of grids on plan and in section. The primary grid and the secondary grid: basic grids of the repetitive structural unit

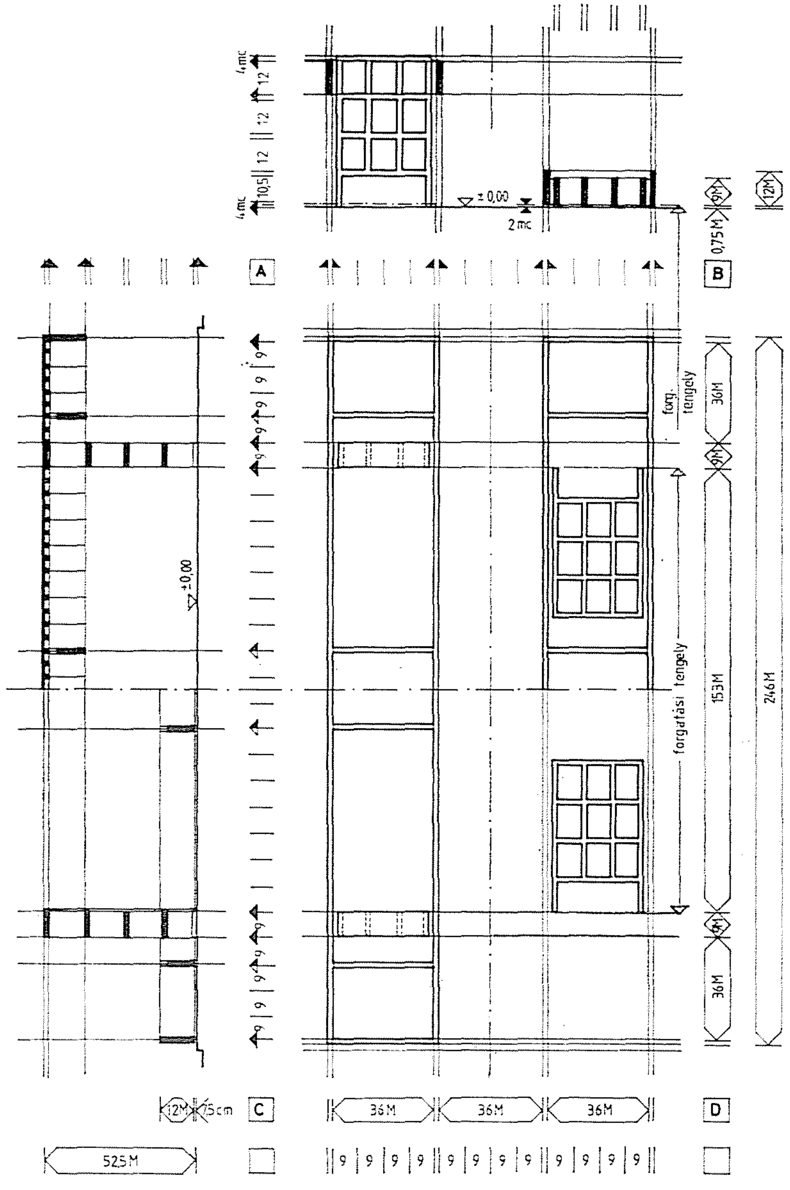


*Fig. 3. The tilt-lift building method. The repetitive structural unit of the industrial workshop: the system of primary and secondary grids on plan and in section. (Situation prior to and after tilting and lifting.)* The decomposition of the structure: Locations of the pillar box-frames and beam box-frames: A. Cross-section after tilting and lifting; B. Cross-section prior to tilting; C. Plan after tilting; D. Plan prior to tilting; E. Longitudinal section prior to and after tilting and lifting

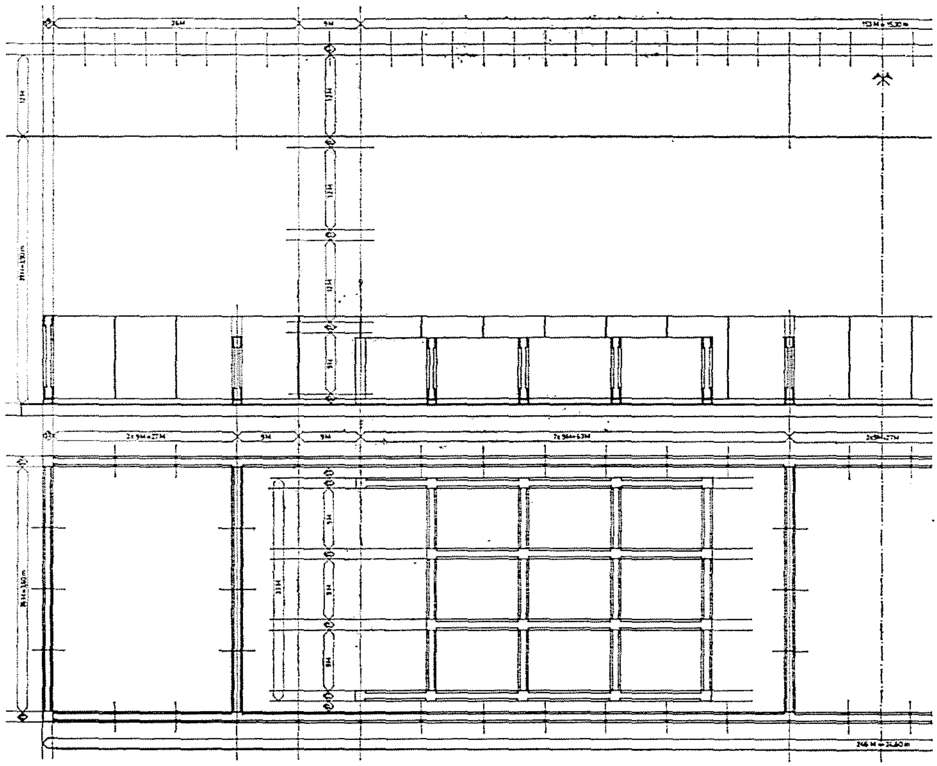

*Fig. 4. The tilt-lift building method. Analysis of the repetitive structural unit. Detail: The location of the pillar box-frame and beam box-frame in the system of primary and secondary grids on plan and in section in the situation prior to tilting and lifting.* Designation of the axis of rotation. Consignation of the profiled gypsum surface-of-pillar and surface-of-elements. The tertiary grid: basic grid of the surface elements

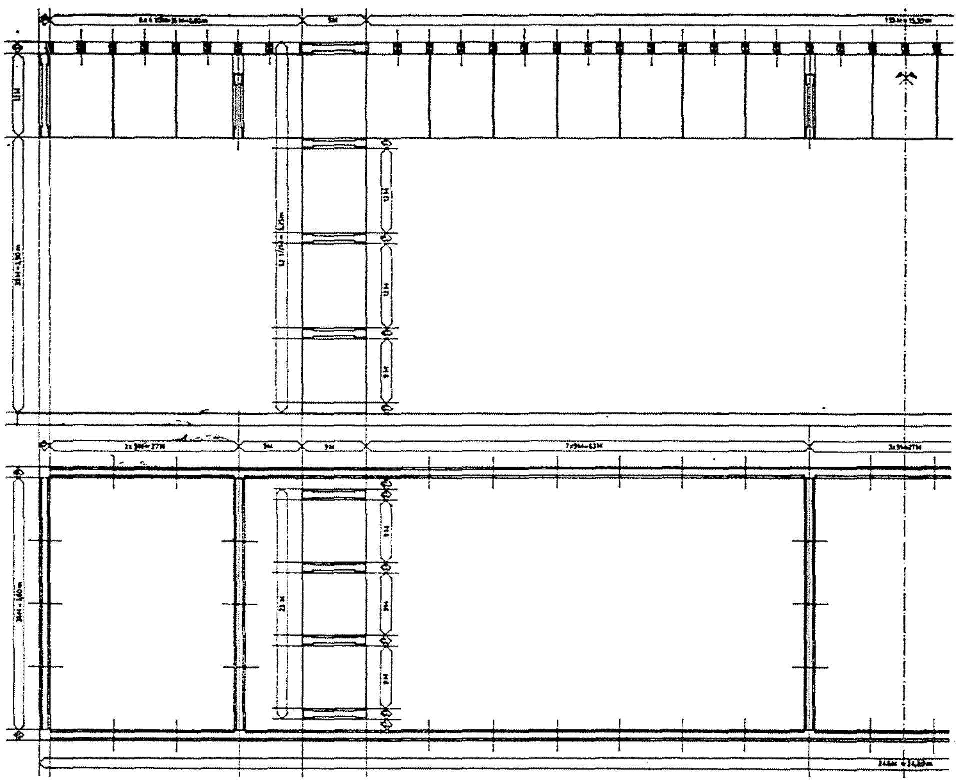

*Fig. 5. The tilt-lift building method. Analysis of the repetitive structural unit. Detail: the location of the pillar box-frame and beam box-frame in the system of primary and secondary grids on plan and in section in the situation after tilting and lifting.* The profiled gypsum surface elements in the system of grids in their final in-situ position. Designation of the points of heterogeneous junctions. The superposition of modular and submodular grids

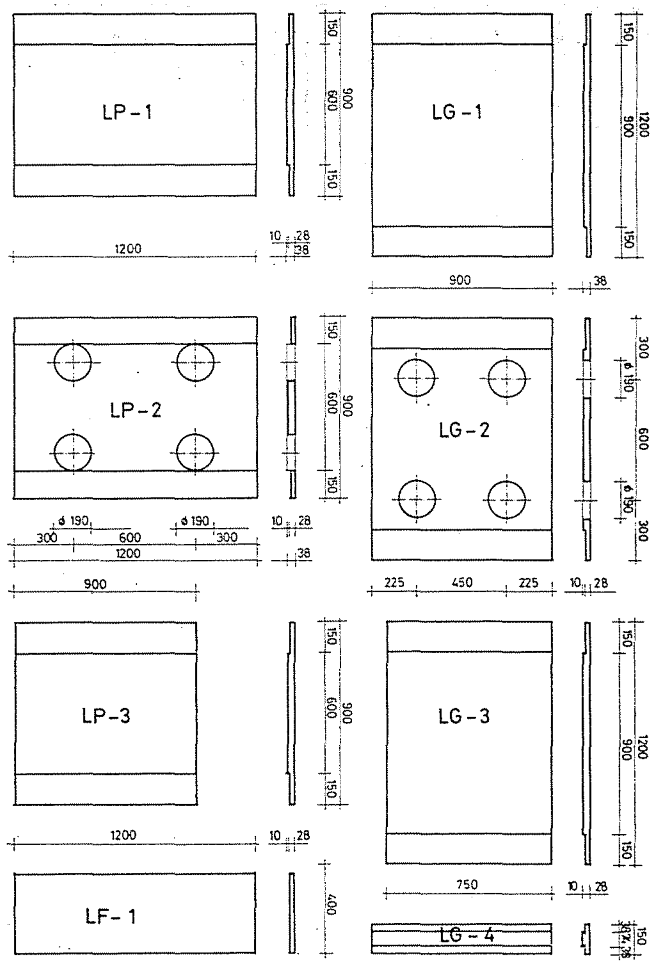


*Fig. 6. The tilt-lift building method. Basic non-tectonic elements.* Profiled gypsum surface elements for pillar box-frames (LP-1—4); beam box-frames (LG-1—3) and beams (LG-4) and plane gypsum surface element for floors (LF-1). The tertiary grid: basic grid of the surface elements

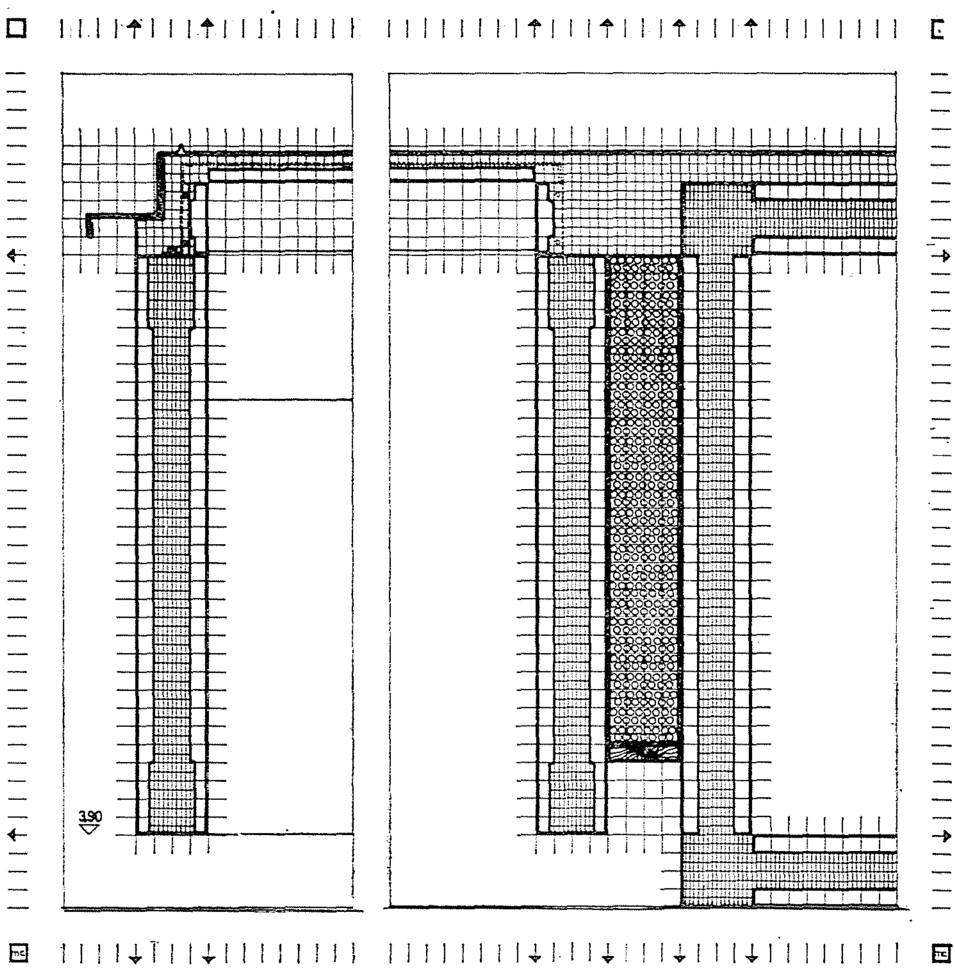


*Fig. 7a. The tilt-lift building method. The repetitive structural unit; microgrid details. Vertical section at right angle to span through butt-end of the industrial workshop*
*Fig. 7b. Vertical section at right angle to span in the middle line of pillar, through beam box-frame and ribbed r.c. shell floor*

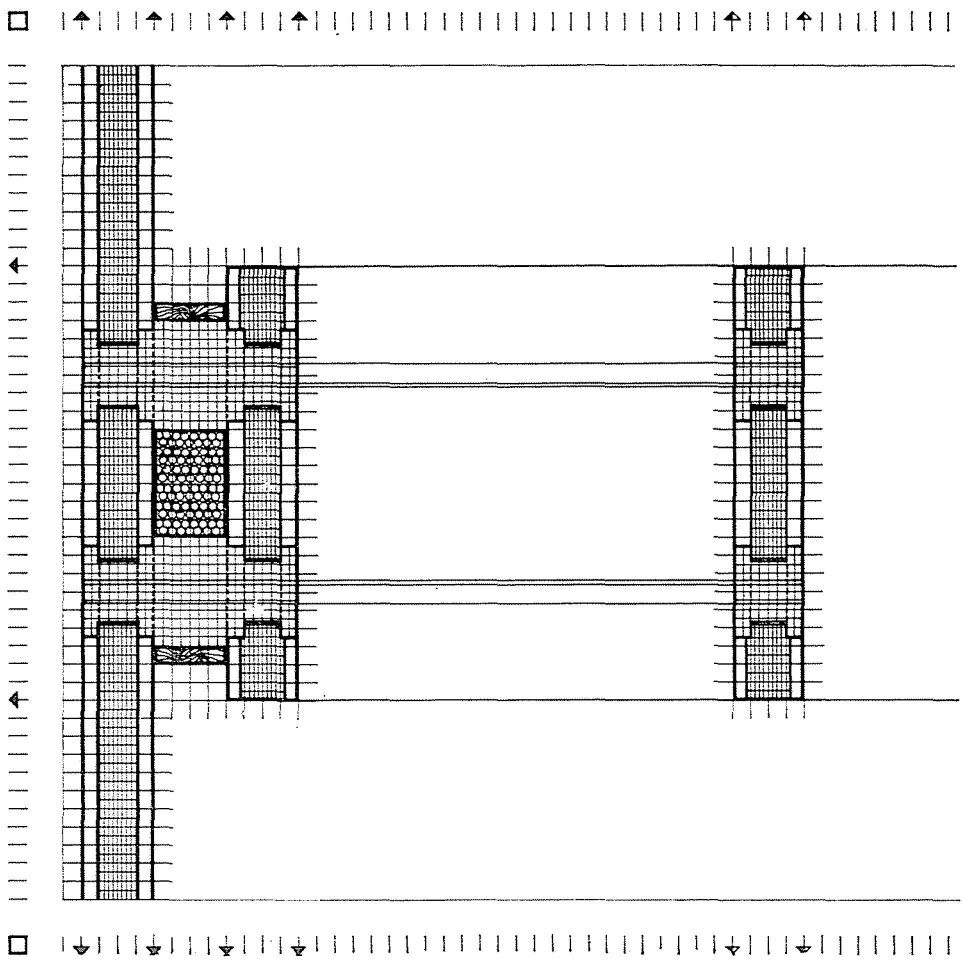

*Fig. 8. The tilt-lift building method. The repetitive structural unit; microgrid details. Horizontal section through the heterogeneous junction between pillar box-frame and beam box-frame; location of junction in the system of the micro-grid, on plan*

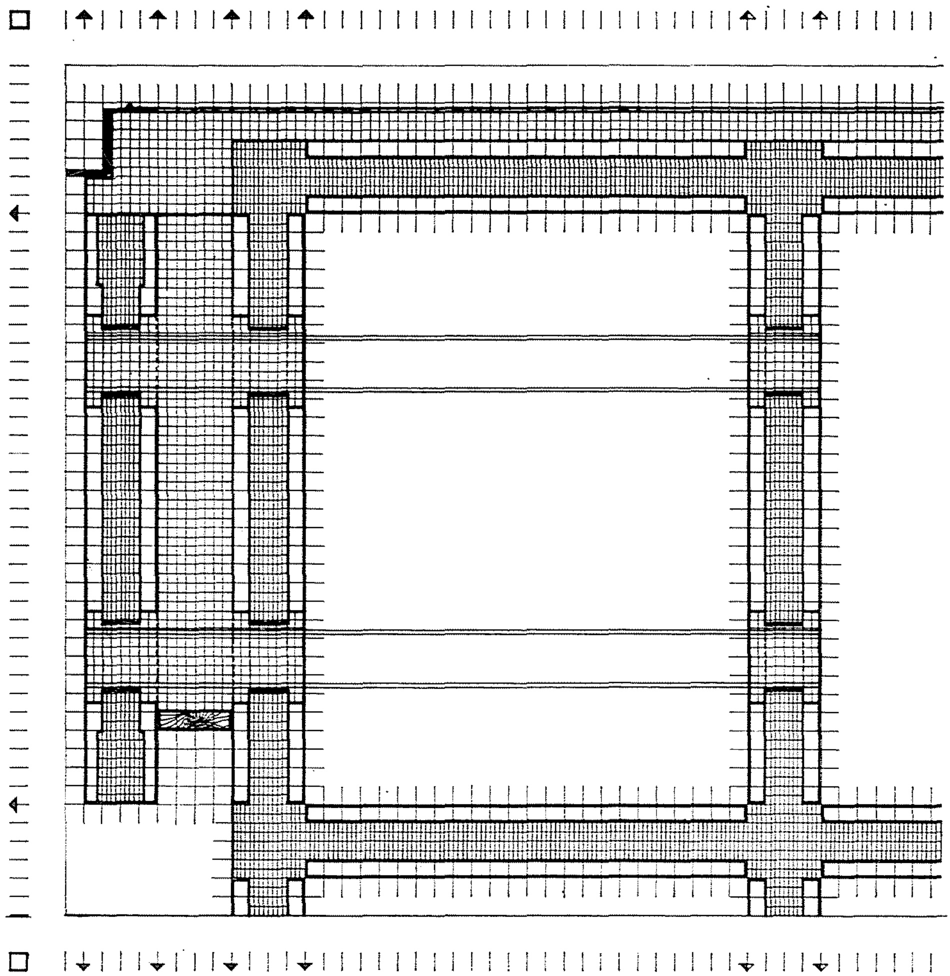

*Fig. 9. The tilt-lift building method. The repetitive structural unit; microgrid details. Vertical section through the heterogeneous junction between pillar box-frame and beam box-frame; location of junction in the system of the micro-grid, in section*

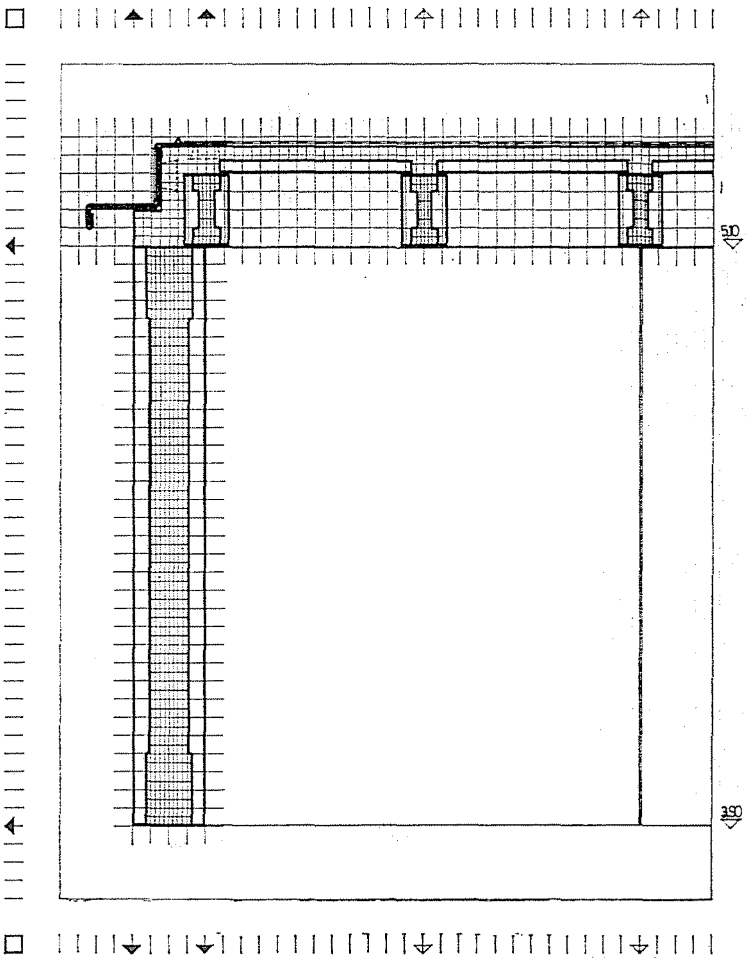


*Fig. 10. The tilt-lift building method. The repetitive structural unit; microgrid details. Vertical section in span direction through butt-end of beam box-frame and through ribbed r.c. shell floor. Location of the beam elements in the system of grids, in section*

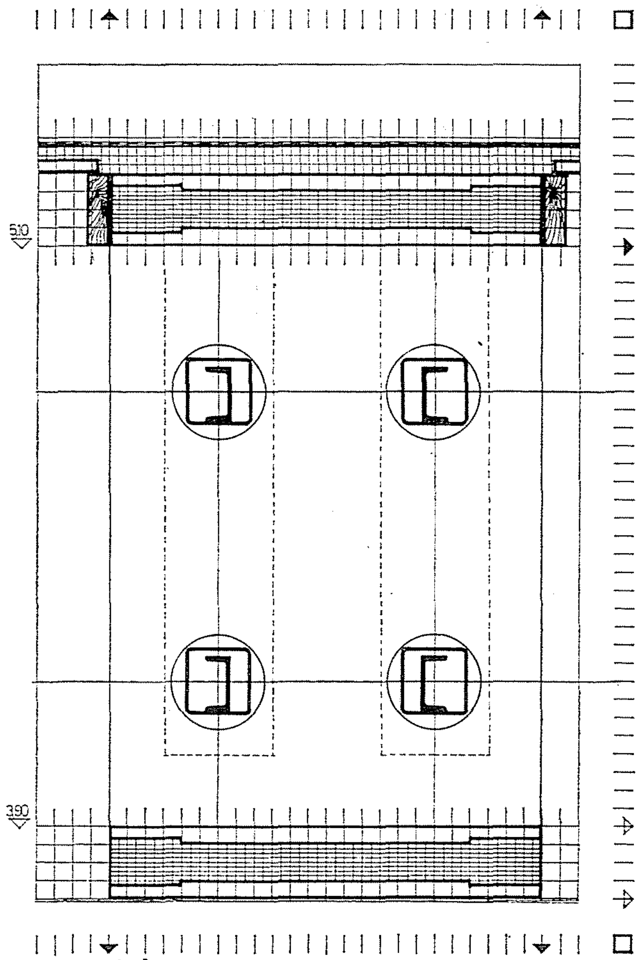


*Fig. 11. The tilt-lift building method. The repetitive structural unit; microgrid details. Vertical section in span direction through the diaphragms of pillar box-frame and the heterogeneous junctions. Location of the heterogeneous junctions in the system of micro-grid, in section*

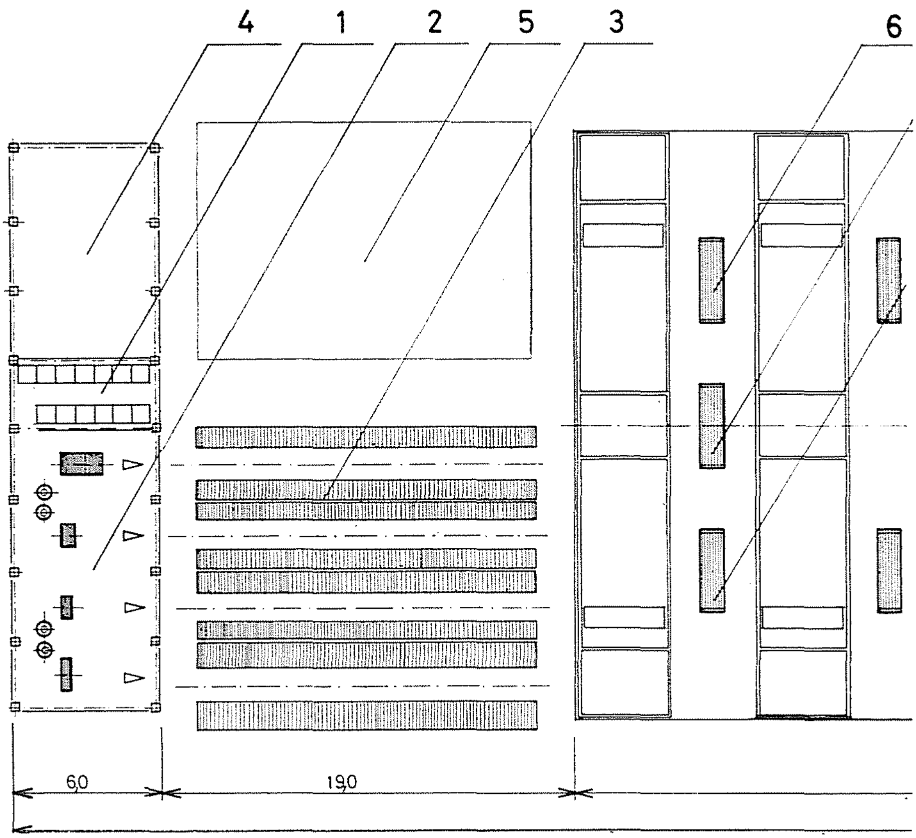


*Fig. 12a*

## Manufacture

*Layout plan of the transplantable factory located next to the building site for producing the elements and components of the industrial workshop to be realized*

The layout plan of the transplantable factory is shown by Fig. 12a and 12b. The technology elaborated is only concerned with the production of the primary structures necessary for realization of the industrial workshop. The factory itself is composed of the following units:

1. Place for storing gypsum and gypsum feeder;
2. Covered shed for manufacturing non-tectonic profiled gypsum surface elements for pillar box-frames, beam box-frames and beams, and plane gypsum surface elements for floors; (See also: Fig. 13.)
3. Place for dense-storing of the different profiled and plane gypsum surface elements on storing stands;
4. Fenced open-air place for ranging and preparing reinforcements;

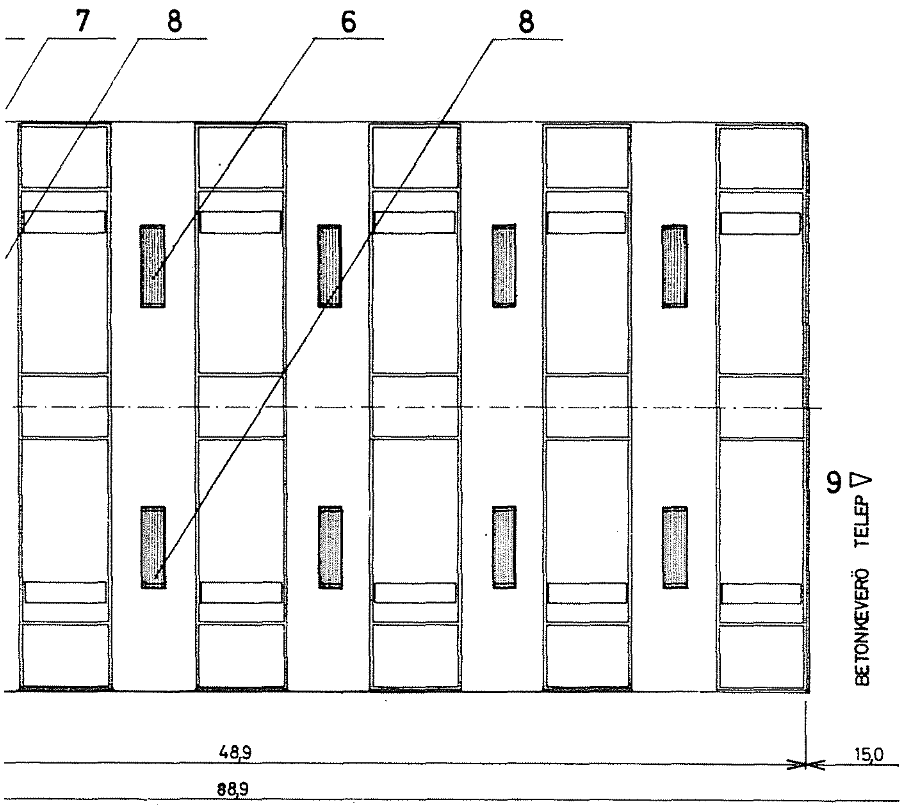


*Fig. 12b*

5. Fenced open-air place for manufacturing and storing reinforcements, jointing points etc., and for storing auxiliary structures;
6. Fifty-unit multi-level stacks for open-air manufacture and storing of linear structural elements (beams) in groups on stack-plate (producing ten units by row in five rows above one another); for beam elements to be located in the pillar-zone underneath in-situ position;
7. Fifty-unit multi-level stacks for open-air manufacture and storing of linear structural elements (beams) in the same way as aforesaid; for beam elements to be located in the last pillar zone underneath in-situ position;
8. Fifty-unit multi-level stacks for open-air manufacture and storing of linear structural elements (beams) in groups in the same aforesaid way; for beam elements to be located in the intermediate zones between pillars in in-situ position;
9. Concrete factory (storage for aggregates, storage for cement, concrete mixer, etc.)

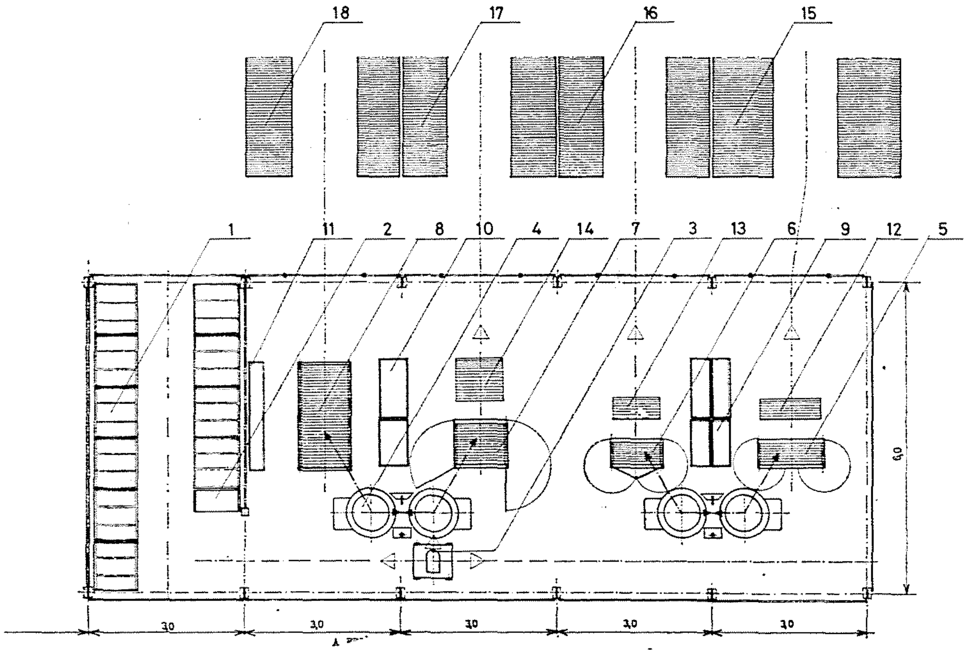


*Fig. 13. Layout plan of the covered shed for producing non-tectonic profiled gypsum surface elements for pillar box-frames, beam box-frames and beams and plane gypsum surface elements for floors.* Index: 1. Storage of gypsum in sacks, on storing boards; 2. Place for opening sacks and calibration of gypsum for battery casting; 3. Feed-tank rolling on rubber wheels; 4. 2 pcs of 250 l. gypsum mixer with pump; 5. Ten-unit battery casting apparatus for manufacturing profiled gypsum surface elements for beam box-frames; 6. Ten-unit casting battery apparatus for manufacturing profiled gypsum surface elements for pillar box-frames; 7. Twenty-unit casting battery apparatus for producing plane gypsum surface elements for floors; 8. 66-unit apparatus for producing profiled gypsum surface elements for beams; 9. Storing shelf and cleaning table for preparing the alternating partitions of battery 5. and 6.; 10. Storing shelf and cleaning table for preparing the alternating partitions of battery 7.; 11. Storing shelf and cleaning table for preparing the alternating partitions of battery 8.; 12. Carriage for transporting the profiled gypsum surface elements of beam box-frames to place of storing; 13. Carriage for transporting the profiled gypsum surface elements of pillar box-frames to place of storing; 14. Carriage for transporting the plane surface-of-floor elements to place of storing; 15. Storage of surface elements of beam box-frames; 16. Storage of plane gypsum surface-of-floor elements

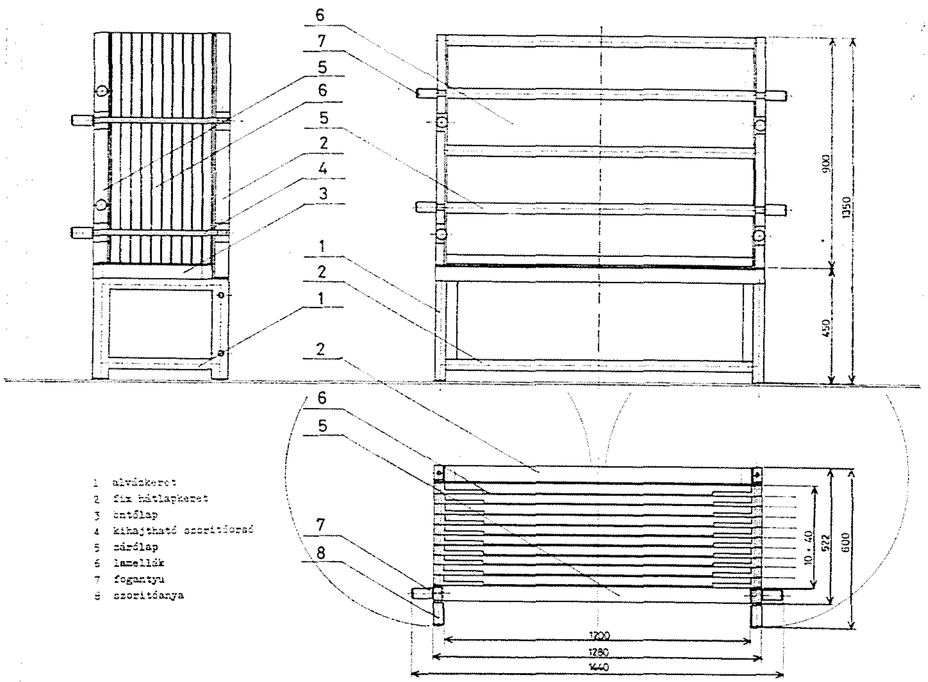


*Fig. 14. Casting battery apparatus*

## Manufacturing apparatuses and processes of manufacture

1. *Apparatus for manufacturing non-tectonic gypsum surface elements:*

*Ten-unit casting battery: apparatus for manufacturing profiled gypsum surface elements for beam box-frames*

The casting battery is actually a mould constructed of linear bars and plates, closed by pressure. In the tilt-lift building method it seemed most expedient to apply separate apparatuses for producing the different elements. The casting battery shown by Fig. 14. introduces an apparatus used for manufacturing profiled gypsum surface elements for beam box-frames. It is composed of the following parts:
1. Basic frame; 2. Back frame fixed to basic frame; 3. Pouring plate fixed to basic frame; 4. Pressing spindle turned out sideways jointed to back frame; 5. Closing plate; 6. Partitions (lamellae): stainless steel plates provided with fixed vynil forming and closing inlay elements; 7. Handle jointed to closing plate; 8. Pressing screw.

Removal of the elements in this case is a manual operation. The elements removed are transported in containers to the storing place where they are "loosely" stored on storing stands, the necessary minimum spacing between elements is assured by fastening clips. When transporting the elements to the building site again containers are used.

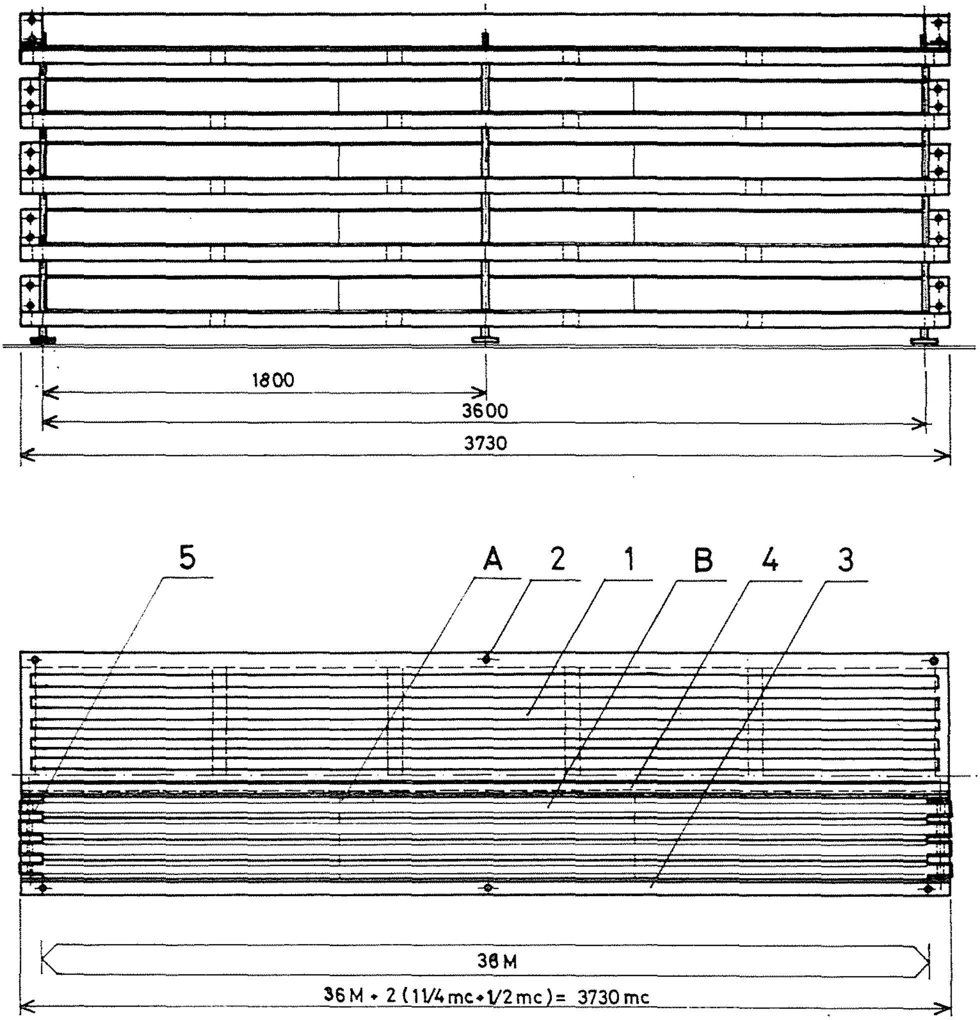


*Fig. 15a. Multi-level stack: apparatus for manufacturing beam elements. Plan and longitudinal section*

The process of manufacture involves the following *technological cycles:*
—assembly: placing the partitions and the closing plate; turning in the spindles and closing the mould by pressure—pouring in of gypsum—hardening—turning out the spindles, taking off the closing plate—removal of the last lamella from the element—removal of the last element from the lamella next to the last, etc.—putting the elements on the carriage and transporting to the place of storing.

The complete technological cycle takes 45 minutes. 10 castings per day were calculated. Number of workers at battery: 2 men; gypsum mixing and feeding: 3 men; cleaning: 2 men; transportation, storing: 2 men.

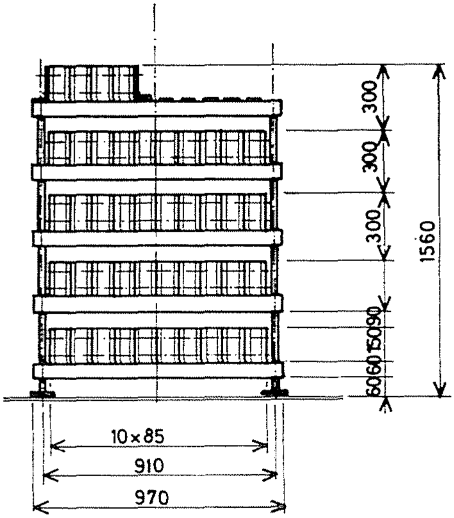


*Fig. 15b. Multi-level stack: cross-section*

2. *Apparatus for manufacturing beam elements:*

*Fifty-unit multi-level stack for manufacturing linear r.c. shell structural elements (beams) in groups*

The multi-level stack for manufacturing tectonic beam elements composed of two materials (gypsum + reinforced concrete) is a two-functional apparatus serving both for manufacture and storing. In our case on one stack plate, that is on one level we produce 10 elements one by one and then, this operation is repeated five times above one another, on separate stack plates. As a result of this process a multi-level stack contains all beam elements necessary for a pillar-zone, or, an intermediate zone. The multi-level stack—shown by Fig. 15a. and Fig. 15b.—is composed of the following parts:
1. Stack plate for producing 10 tectonic beam elements: a two-functional pouring board used for manufacturing and storing; a rigid plane frame constructed of linear steel U-profiles, stiffened with ribs, covered with a steel plate supplied with steel stripes for determining the location of the surface-of-beam elements; with 3—3 welded in steel tubes on the long sides or ensuring the jointing of legs; with 10—10 welded in jointing points with internal threads on the narrow sides for positioning and fixing of the closing profiles used for casing the butt-ends of beam land for exact positioning of reinforcement. 2. Legs, lengthened in each row; 3. The starting; longitudinal profile led by the "needles" of the legs; 4. The periodically transplantable internal longitudinal profile led by the steel stripes fixed to the pouring board; 5. Closing profile A. Profiled gypsum surface-of-beam element; B. Frozen reinforced concrete shell.

The process of manufacture of the linear structural (beam) elements composed of two materials (gypsum + reinforced concrete) involves the following *technological cycles:*
— location of the stack plate on the starting legs—location of the starting longitudinal profile: threading of the L-shaped profile through the needles of the starting legs—location of the transplantable internal longitudinal profile through adjusting it to the second steel stripe — fixing the closing profiles to the periodic jointing points on the narrow sides of stack plate — location of the lower clips at butt-ends for determining the lower position of reinforcement, adjusting its vertical position with upper clips at the ends—location of profiled gypsum

surface-of-beam elements using clips for temporary fixing—pouring in of concrete. (This series of operation is repeated 10 times on one stack plate, and then: the process goes on, as follows:) — location of the lengthening legs—location of the second stack-plate on the lengthening legs — manufacture of beam elements, as above.

The complete technological cycle of one 10-unit stack-plate takes 4 hours; two stack plates are completed daily by a four-man brigade, this means that two 5-level stacks are produced weekly.

The closing profiles at butt-ends can be removed after every second row, whereas the longitudinal profiles are regained after each row. The removing and location of beam is a manual operation.

*

## Assembly

### The sequence of operations on the building site

The process of assembly in the tilt-lift building method is shown in Fig. 16a and Fig. 16b. The axonometric drawings always represent the operations completed. In the text to follow all necessary working processes are enumerated in due order:

1. *Creating the zero level of co-ordination*

The object of this technological cycle actually is on the one hand to determine the exact zero level, that is to create a smooth concrete basic surface extending all over the building and on the other hand to prepare the calyxes of the pillars, that is to assure precise homogeneous structural junctions for the pillar box-frames. These operations always proceed from the unprecise towards the precise, as we shall see. The whole technological cycle is preceded by the making of the traditional strip-foundation at right angle to span under the zone of pillar box-frames, the operation is started with soil preparation and finished by the making of the strip-foundation, whereby we actually build out an unprecise basic level.

The very cycle of creating the zero level of co-ordination is composed of four subsequent phases:

— *first phase; the making of precise zero level under the "legs" of the pillar box-frames:* location of levellable auxiliary structures (composed of longitudinal and cross U-profiles) at right angle to the span for determining on the one hand the exact $\pm 0{,}0$ level of pillar zones, on the other hand for casing the concrete on the perimeters; location of the positioning bridge (composed again of longitudinal and cross U-profiles) in the span direction and jointing it from above to the U-profiles running at right angle to the span for determining on the one hand the exact place and shape of the calyxes by means of the steel casing form suspended from its bars and on the other hand for

exact positioning of the anchoring rods (to which, later on, the tilting bridges will be fixed); location of the regainable timber boards for casing the concrete of the foundation blocks under the "legs" of the pillar box-frames; concreting;
— *second phase; completing the zero level in the zones of the pillar box-frames:* removing of the timber boards casing the foundation blocks from the outside; removing of the positioning bridge together with the attached, suspended steel forming box used for casing the calyxes from inside; removing the cross U-profiles used for spacing the longitudinal U-profiles running at right angle to the span; concreting the zero level between the foundation blocks first under the pillar box-frame and then between the neighboring pillar box-frames; smoothing off of the upper surface using for this purpose the upper flanges of the longitudinal U-profiles and the concrete upper plane of the foundation blocks as leading "etalon" levels;
— *third phase; the making of the zero level between the zones of the pillar box-frames:* removal of the longitudinal U-profiles; the making of the zero level between the zones of the pillar box-frames in sections, using for this purpose the finished concrete zero level of the pillar zones as leading "etalon" planes;
— *fourth phase; the making of the precise zero level on the perimeters* (in the zones underneath the cantilevers and at the butt-ends of the building): location of levellable longitudinal U-profiles at the perimeters; concreting, finishing the creation of the zero level using for this purpose the concrete upper level of the pillar zones, the finished upper surface between the pillar zones and the upper flanges of the U-profiles as leading "etalon" levels.

2. *Assembly of pillar box-frames and beam box-frames on the zero level in the situation prior to tilting and lifting*

With this technological cycle the operations above zero level are started. In the tilt-lift building method, more accurately: in the process of assembly of the tilt-lift building method the periodically organizable minimal cycle is composed of three units, that is, two pillar-beam units plus an intermediate unit. This was reasonably selected and therefore in the following, each analysed operation represents an operation periodically organized in these three units.

a. *Assembly of pillar box-frames on the zero level in the situation prior to tilting.* The elementary technological cycle is composed of the following operations:
— designation of the axis of rotation; jointing of the cradles to the heterogeneous anchoring points embedded into foundation; location of the tilting bridge—used in this operation as an etalon for the assembly of the steel auxiliary structures—and pushing out the end-tenons;
— assembly of auxiliary structures for erecting pillar box-frames on the zero level, starting the assembly with the U-profile to be threaded into the end-

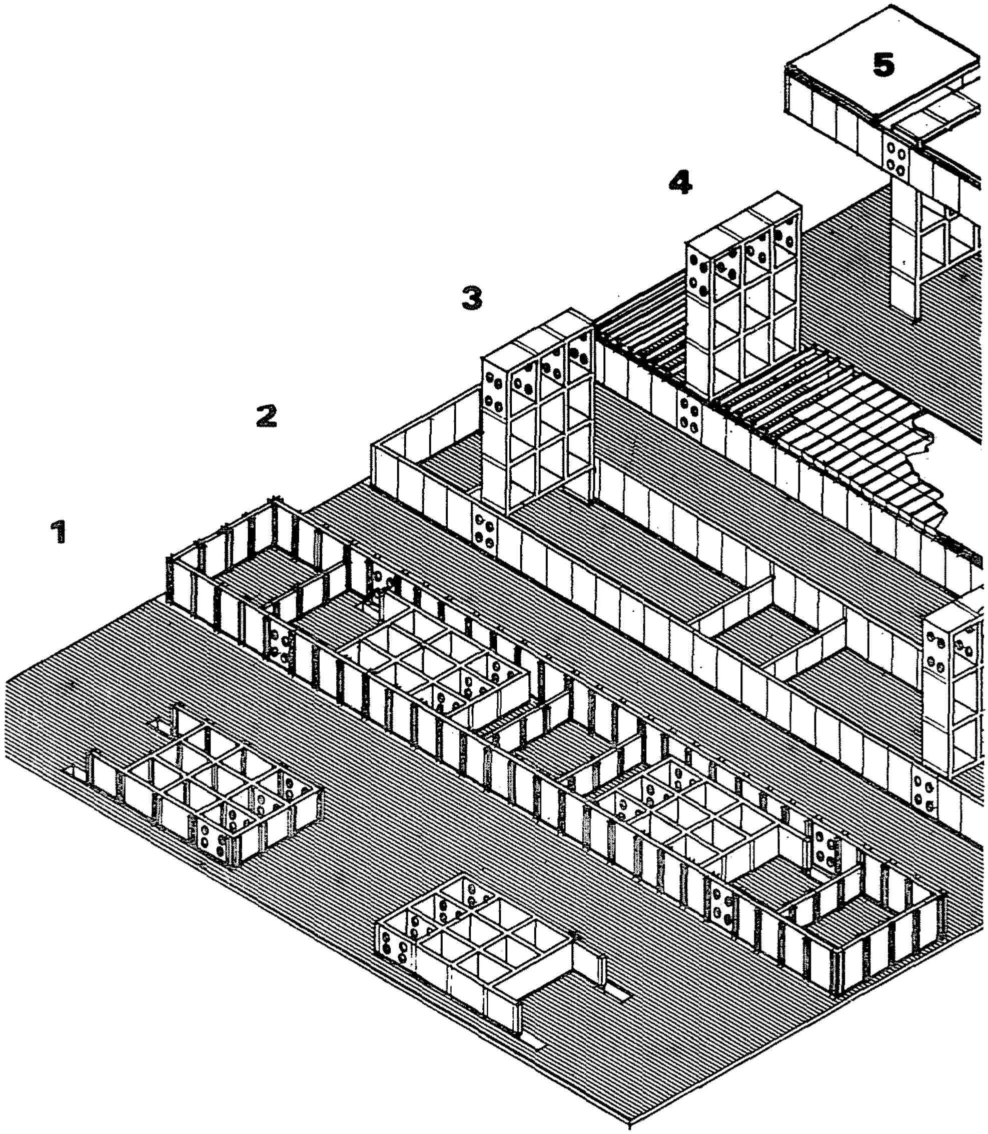


*Fig. 16a. The tilt-lift building method. Assembly; basic technological cycles:* 1. Creating the zero-level of co-ordination; assembly of pillar box-frames in the situation prior to tilting; 2. Assembly of beam box-frame underneath in-situ position; 3. Tilting pillar box-frames into vertical position

tenons pushed out from the tilting bridge, assembly is completed by the location of the "ears" composed of steel L and U profiles;

— removal of the tilting bridge and the cradles and transplanting them into the next pillar-beam unit;

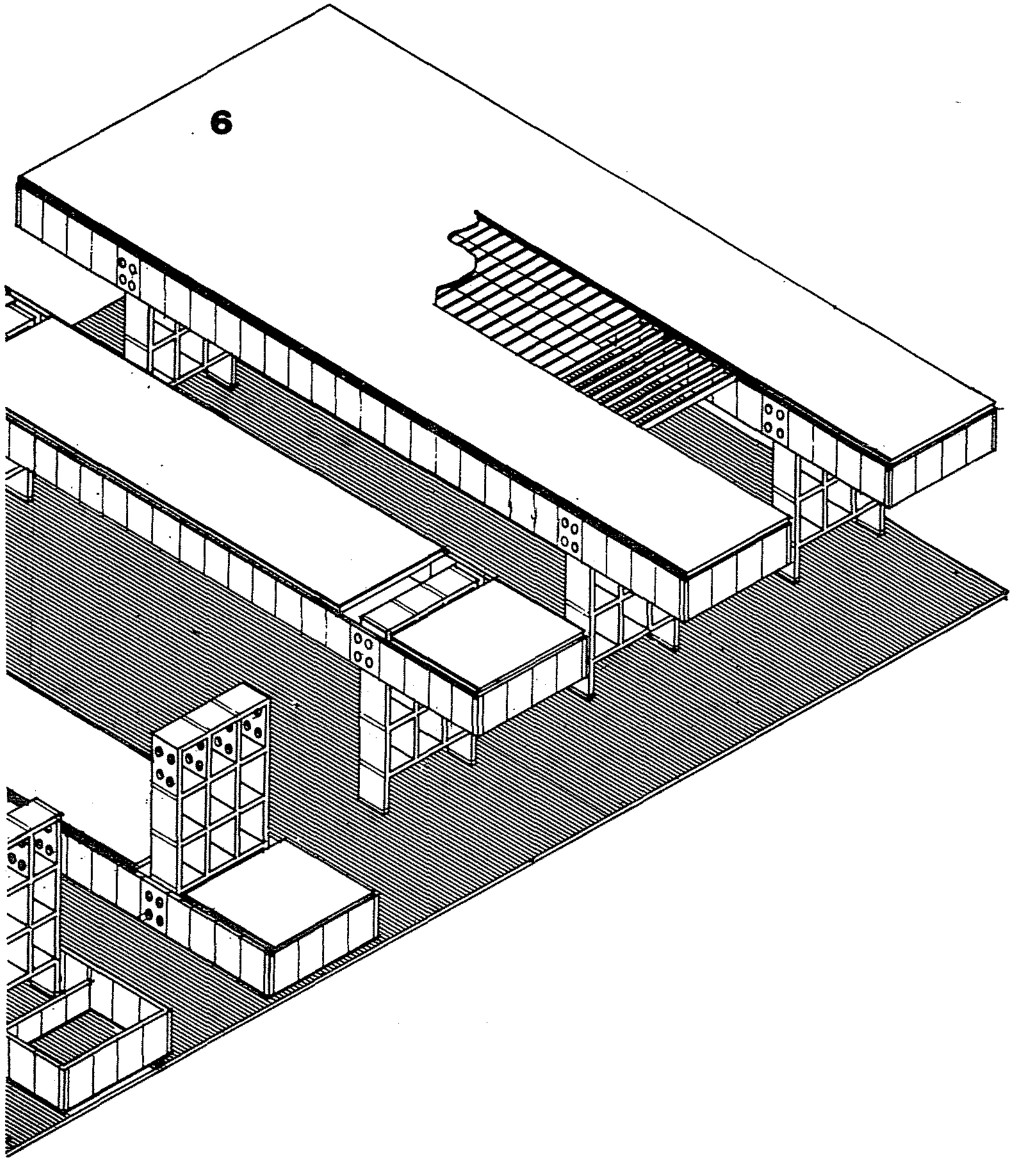


*Fig. 16b. The tilt-lift building method. Assembly; basic technological cycles:* 4. Assembly of the ribbed r.c. shell floor underneath in-situ position; 5. Lifting beam box-frame—rigidified with the ribbed r.c. shell floor—into in-situ position; 6. Assembly of the ribbed r.c. shell floor in in-situ position

— location of reinforcement of pillar box-frame; screwing the leading rods to the periodic jointing points fixed to U-profiles of the auxiliary structure; making of the two-directional stack-reinforcement; location of the shear-reinforcement; location of the heterogeneous jointing points;

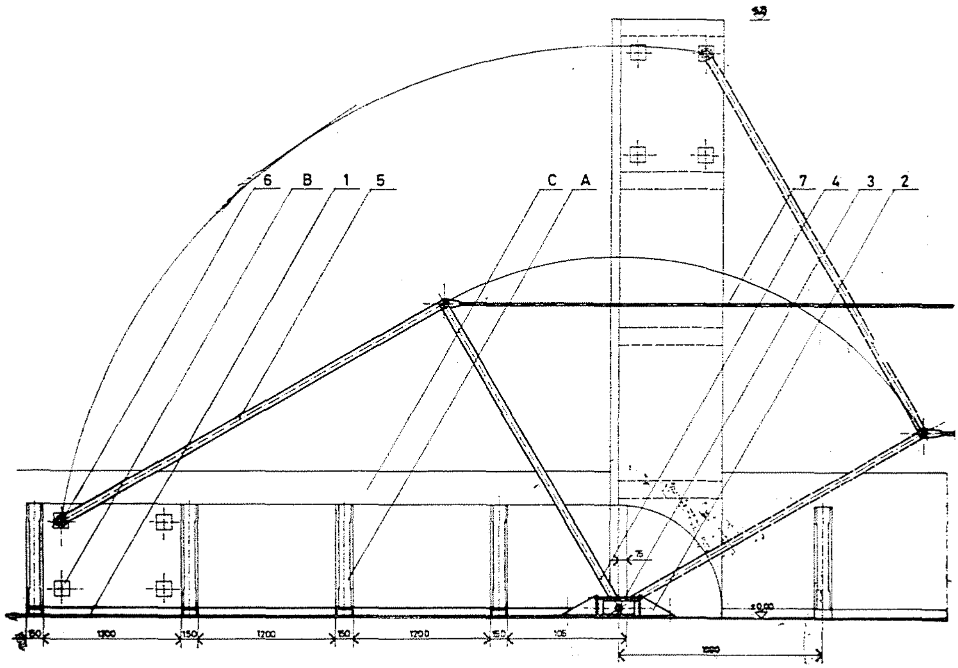


*Fig. 17. Apparatuses and auxiliary tools for tilting pillar box-frames: the tilting bridge and the tilting frame. Vertical section in span direction through pillar box-frame.* A. The pillar box-frame, situation prior to tilting; B. Heterogeneous jointing points built into the pillar; C. The beam box-frame, situation prior to lifting; 1. Auxiliary structure for erecting pillar box-frames; 2. The cradle fixed to the heterogeneous jointing points embedded into foundation; 3. The tilting bridge fixed in the cradles and jointed to the auxiliary structure with the pushed in end-tenons; 4. The tilting frame jointed to the end-tenons of tilting bridge; 5. Pulling rod jointed to the tilting frame; 6. Jointing point for connecting the pulling rod with the pillar box-frame; 7. Pulling rope driven by crab, jointed to the tilting frame

— location of surface elements;
— concreting of the pillar box-frame;
— removing the ears of the auxiliary structure.

b. *Assembly of beam box-frames on the zero level underneath in-situ position*
— assembly of auxiliary structures for erecting beam box-frames on the zero level starting with the U-profiles underneath the longitudinal beams ensuring a proper spacing by means of etalons from the respective of the auxiliary structures of the pillar box-frames, assembly is completed by the location of the "ears" composed of steel L and U-profiles;
— location of reinforcement of beam box-frame: screwing the leading rods to the periodic jointing points fixed to the U-profiles of the auxiliary structures; the making of the two-directional stack-reinforcement; location of shear reinforcement; location of the heterogeneous jointing points;
— location of surface elements;
— concreting of the beam box-frame;
— removing the ears of the auxiliary structure.

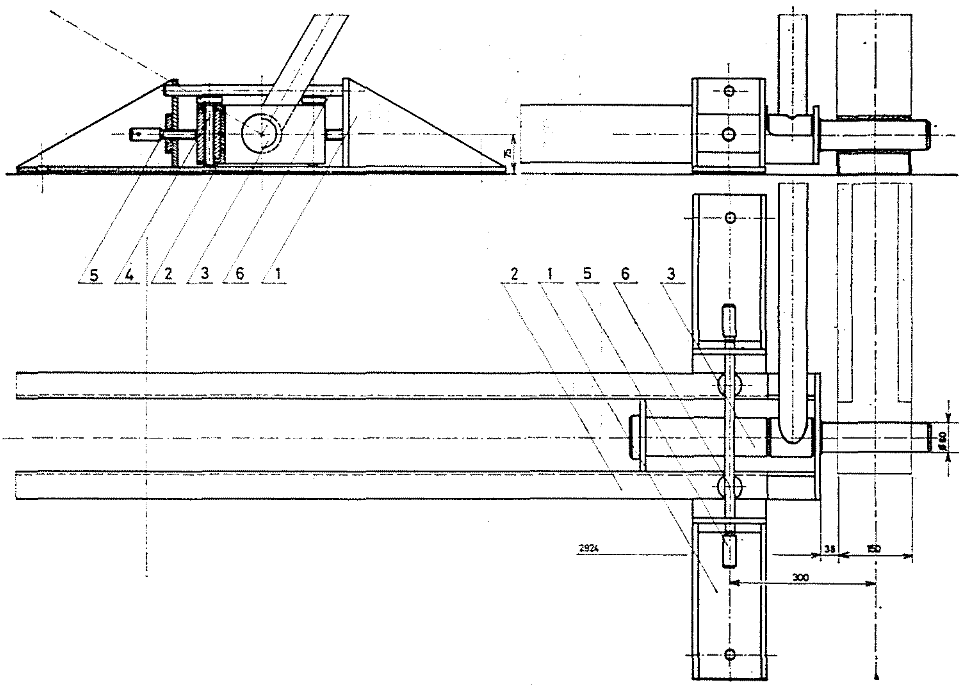


*Fig. 18. Apparatuses and auxiliary tools for tilting pillar box-frames: the tilting bridge. Details: Plans; Vertical section.* 1. The cradle for fixing the tilting bridge jointed to the heterogeneous anchoring points embedded into foundation; 2. The beam element of the tilting bridge; 3. The end-tenon pushed into the auxiliary structure; 4. The vertical adjusting screw built into the beam element of the tilting bridge; 5. The horizontal adjusting screw built into the cradle; 6. Fixing rod threaded through the diaphragms of the cradle

3. *Tilting pillar box-frames into vertical position. (Fig. 17. and Fig. 18.)*

— location and junction of the cradles;
— location of tilting bridge on the cradles; location of tilting frame; pushing the end-tenons through the tilting frame into the calyxes of the auxiliary structure; adjusting the final position of tilting bridge on the cradles first in the vertical direction with setting screws and then, fixing this position between the diaphragms of the cradles by means of horizontal fixing screws built into the cradles;
— adjusting of the twin-crabs mounted on winch vehicle; setting vehicle on its legs;
— fixing of pulling ropes on the winding drum;
— jointing the pulling rod first to the tilting frame and then to the heterogeneous turning point built into the pillar box-frame;
— tilting;
— adjusting vertical position of pillar with setting screws;

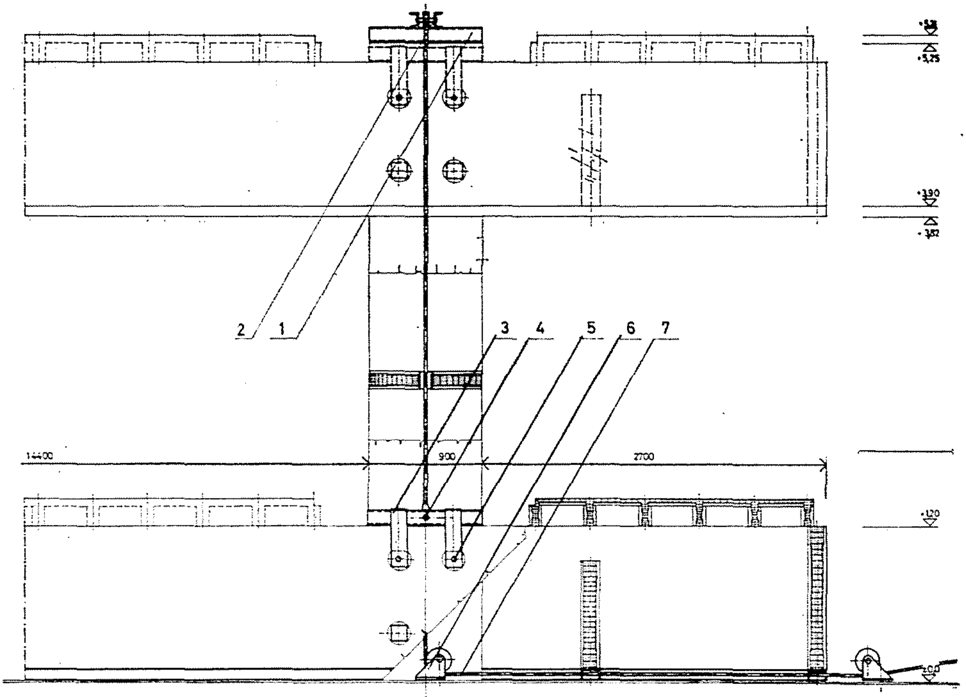


*Fig. 19. Apparatuses and auxiliary tools for lifting beam box-frames: the lifting bridge and the lifting beam. Vertical section in span direction.* 1. Twin-beam supports fixed to the heterogeneous jointing points built into the upper end of pillar walls; 2. Cantilevered upper lifting bridge jointed to the twin-beam supports; 3. Lifting beam fixed to the heterogeneous jointing points built into the beam box-frames; 4. Jointing point for connecting the lifting bridge with the lifting rope; 5. Jointing point for connecting the lifting beam with the beam box-frame; 6. Rope-wheel fixed to the anchoring points embedded into foundation

— creating the homogeneous junction of pillar box-frame through concreting of the calyxes of the foundation;
— unfastening of the apparatuses and auxiliary tools of tilting;
— removing the U-profiles of the auxiliary structures for erecting pillar box-frames;
— pushing in the U-beams into the calyxes of the pillar box-frame for creating heterogeneous junction with the beam box-frame.

## 4. *Assembly of the ribbed r.c. shell floor underneath in-situ position*

— removal of the linear structural elements (beam-elements) manufactured on multi-level stack in groups from the stack plate one by one and by hand; location of beam-element on the beam box-frame underneath in-situ position; jointing the beam element to the periodic heterogeneous jointing points fixed to the upper reinforcement of the beam box-frame;

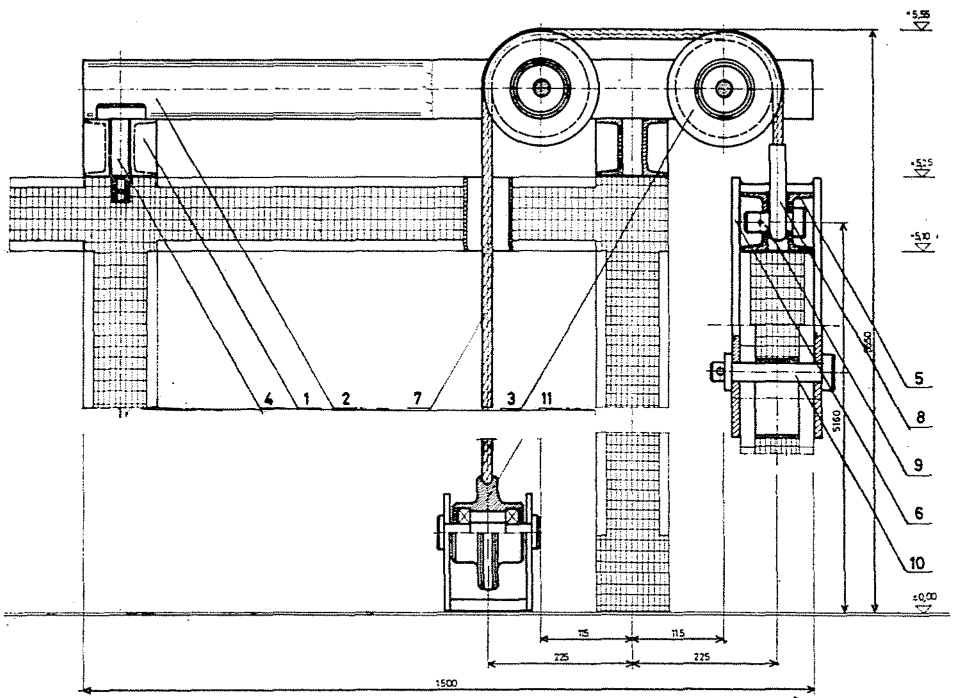


*Fig. 20. Apparatuses and auxiliary tools for lifting beam box-frames: the lifting bridge and the lifting beam. Detail. Vertical section at right angle to span.* 1. Twin-beam supports fixed to the heterogeneous jointing points built into the upper end of pillar walls; 2. Cantilevered upper lifting bridge jointed to the twin-beam supports; 3. Rope-wheel; 4. Fixing screw; 5. Lower twin lifting beam; 6. Saddle welded to twin lifting beam; 7. Lifting rope; 8. Heart of rope; 9. Tenon; 10. Tenon

— location of plane gypsum surface-of-floor elements casing the reinforced concrete shell from below between the beam elements;
— location of mesh wire on top of the uppermost "free" longitudinal reinforcement of beam elements;
— Concreting the shell fields above the beam elements in sections ensuring exact structural thickness with "etalon" rods.

5. *Lifting beam box-frame rigidified with the ribbed r.c. shell floor into in-situ position (Fig. 19. and Fig. 20.)*

— location of twin-beam supports on top of the pillar walls and fixing them to the heterogeneous jointing points built into upper end of pillar walls;
— location of the cantilevered upper lifting bridge on top of the twin-beam supports and jointing them to one another;
— location of the lower twin lifting beam on top of the beam box-frame and fixing it to the heterogeneous jointing points built-into the beam box-frame;

— location of the jointing point connecting the lifting rope with the lifting beam; location of the jointing point connecting the lifting beam with the beam box-frame;
— location of the rope wheel and fixing it to the heterogeneous jointing point embedded into the foundation-block;
— adjusting of the twin-crabs mounted on the winch-vehicle, setting the vehicle on its legs; threading in of rope;
— lifting;
— creating heterogeneous junction between pillar box-frame and beam box-frame;
— unfastening of lifting apparatuses and auxiliary tools;
— concreting of the "tolerance gap" at the places of the heterogeneous junctions;

6. *Assembly of the ribbed r.c. shell floor in in-situ position*

— taking down the linear structural elements (beam elements) from the stack plate one by one and by hand; putting down the beam element on the zero level underneath in-situ position;
— lifting beam elements one by one into in-situ position from above with ropes and by hand; location of beam elements on the beam box-frame in in-situ position;
— location of plane gypsum surface-of-floor elements casing the reinforced concrete shell between the beam elements from below;
— location of mesh-wire on top of the uppermost longitudinal "free" reinforcement of beam elements;
— concreting the shell fields above the beam elements in sections ensuring exact structural thickness with "etalon" rods;
— final concreting of the zones above the longitudinal beams of the beam box-frame; location of profiled surface-of-beam elements; on top of the longitudinal beam of the beam box-frame; location of "extra" reinforcing wires for connecting the longitudinal reinforcement of the beams; concreting, final pouring.

* * *

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