NON-TECTONIC SYSTEMS: COMMUNAL BUILDINGS THE "LIFT-CELL" BUILDING METHOD*

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Abstract

The lift-cell building method examplifies an adaptation of the non-tectonic systems for mass-construction of multi-level communal buildings. This fundamentally new building method of technological relevance for hot arid tropical areas is equally realizable by planted or transplantable factory and has been designed in such a way as to give optimum solution for any requirement prevalent today in these areas. The nontectonic systems are based on the recognition that tectonics is not the only possible axiom of building and the lift-cell 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: Nature and scope of the research

Preliminaries 1971—84

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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[*] This report was compiled by the Institute of Building Constructions Faculty of Architecture, Technical University Budapest prepared on the invitation of the Ad-hoc IYSH** Committee of the Hungarian Academy of Sciences. It was designed to give only an indication of our contribution to the cause of the "Habitat".

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, S. 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.

Scope of the research 1985—87

Having finished elaboration of the seven basic methods of non-tectonic building, 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, climatic 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 *third* in the series of articles to introduce the non-tectonic systems.

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Section 1

Adaptation of non-tectonic systems to communal 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, silicatebased 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.

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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 first of all, because this system of requirements keeps constantly changing in space and in time. *A technology satisfying a system of determined requirements*

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* See: References 13, 14.

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 massproduction 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 primary loadbearing structures in low-cost housing may reach even 80—90% of the total building cost!*

General description of the lift-cell building method

The lift-cell building method spells *adaptation of non-tectonic systems to multi-level communal buildings.*

From the point of view of principle of construction the building method is actually *a special combination of the lifting and box-frame unit building methods,* 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 both in *planted and transplantable factories.* In any case, however, the structures called into being by this building method are composed of three materials; gypsum, reinforced concrete and steel.

In the lift-cell building method we manufacture on a *medium degree of readiness.*

In the factory—more accurately: in the planted or transplantable factory — we produce on the one hand: Gutenberg-principled non-tectonic, periodic *plane gypsum surface elements for beams* and periodic *cellular gypsum surface elements for floors;* on the other hand: mechanization principled tectonic linear *reinforced concrete column elements for pillars.*

At the same time we also start in the factory the preassembly of these basic elements, on the one hand into mechanization-principled tectonic *structural elements*(beam-elements), on the other hand into mechanization-principled tectonic *small box-units* (that is: heterogeneous beam box-frame units and heterogeneous pillar skeleton-frame units). According to this:

The heterogeneous beam box-frame—this small box-unit of parameter size in one direction—is constructed in such a way that first we preassemble the non-tectonic periodic gypsum surface elements into tectonic beam elements —that is frozen r.c. shell plane structural elements—and then, we join them in pairs by means of steel diaphragms, whereby we unite them into empty beam box-frames; whereas

The heterogeneous pillar skeleton-frame—again a small box-unit of parameter size in one direction—arises in such a way that we couple the column elements—that is the manufactured tectonic linear r.c. structural elements— in fours by means of steel cradles and diaphragms, whereby we unite them into empty pillar skeleton-frames.

On the building site the skeleton construction of the multilevel building, that is the pillar skeleton-frames and the beam box-frames are always assembled immediately in their final in-situ position and connected to each other by heterogeneous junction, whereas the horizontal primary floor structures, that is the cellular floor-fields of parameter size in two directions are always assembled underneath in-situ position immediately on top of each other, and then, they are lifted in due order into their respective in-situ position and fixed by heterogeneous junction. The cellular floor-zones above the beam box-frames are assembled in-situ and their concreting includes the final pouring as well.

Variability of the lift-cell building method

Amongst the non-tectonic systems the variability of the lift-cell 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, the relative height-indifference of the pillar skeleton-frames and finally the relative two-way span-indifference of the large-size cellular floor-fields keep the most important parameters of communal building—the spans and the heights—theoretically open.

On the other hand, however, the degree of freedom of planning is decreased, since the two-way ribs of the beam-zones and cellular floor fields unambiguously restrict the divisibility of interior spaces, location of partition walls, etc.

The cell, the box-frame and the skeleton-frame as principles of construction

The cell as principle of construction—in general—has been dealt with in detail in our previous studies, therefore, here it seems sufficient only to remind the Reader that working with the cell as principle of construction for the frozen reinforced concrete primary structures always means the use of many different forms of the folded shells. The cellular systems, as is well known, may operate with beams, beam-grids, or with the room-units (room-cells) themselves. These forms represent the visible forms of non-tectonic structures.

In the lift-cell building method the visible form of the primary structure is characterized by the *beam-grid.*

The lift-cell building method realizes the beam-grid in two steps, through superposition. First, the system of the *primary beam-grid* is assembled through additivity and heterogeneous jointing of beam box-frames and pillar skeleton-frames, then—in the second step—the system of the *secondary beam-grid* is completed through assembling the cellular floor-fields underneath in-situ position on top of each other, lifting them into final position and fixing by heterogeneous junction.

The box-frame as principle of construction—in general—has been analized in detail, with the box-frame unit building methods [14]. It is very important to note here, however, that *in the lift-cell building method* (at least in this particular case) *the construction of the box-frame is modified both from manufacture and from assembly points of view;*

— from *manufacture* point of view, because the box-frame here—in contrast to the box-frame unit building method — is not a homogeneous reinforced concrete folded shell construction composed of two materials (gypsum + reinforced concrete) but a heterogeneous small space element composed of three materials, in which we joint beam elements (that is frozen r.c. shell plane structural elements composed of two materials) by pairs, by means of steel diaphragms into beam box-frame units;

— from *assembly* point of view, because the heterogeneous beam box-frame is not put *on top of* the pillars, but located *next to* it and consequently the method of jointing—in contrast to the box-frame unit building method—will be characteristically non-tectonic *heterogeneous* junction.

The pillar skeleton-frame as principle of construction is characteristically connected with the lift-cell building method. The constructor here works with manufactured linear reinforced concrete structural elements—that is factory made columns—which are tectonic from the outset, and uses these elements for assembling the heterogeneous pillar skeleton-frames—that is small space units of parameter size in one direction—through uniting them in fours by means of steel cradles and diaphragms and accepts that these pillar skeleton-frames can only be connected with the beam box-frames at points, through heterogeneous junction.

The lift-cell building method is founded on the simultaneous application of the cell, the box-frame and the skeleton-frame as principles of construction. In this building method — in contrast to all the other non-tectonic building methods— *manufacture has three immediate objects.*

The first immediate object of manufacture is, of course, the non-tectonic *surface* element, more accurately: the periodic plane gypsum surface element for beams (non-tectonic plane element) and the periodic cellular gypsum surface element for floors (non-tectonic small space element). These elements are used by the architect on the one hand: for the preassembly of beam elements (that is frozen r.c. shell plane structural elements of parameter size in one direction) through a proper additivity of the non-tectonic plane elements in the factory, and on the other hand: for the assembly of the cellular floor-fields (that is frozen r.c. shell plane structural elements of parameter size in two directions, with ribs in two directions rigidified with a membrane) through a proper additivity of the non-tectonic cellular small space elements underneath in-situ position, on the building site;

The second immediate object of manufacture is the *column* (that is a linear reinforced concrete structural element) which is tectonic from the outset since its construction is not based on the additivity of surface elements; and finally

the third immediate object of manufacture is the *cradles and diagphragms*, that is steel frames constructed of U-profiles.

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Section 2

The lift-cell building method

Design

Introduction. A short description of the structural variations on communal buildings. (See: Fig. 1)

Varations on plan and in section, on:

- structural systems of multi-level communal buildings, applying the cell, the box-frame and the skeleton-frame as principles of construction;
- variable systems of disposition;
  variable heights;
  variable spans in two directions;
  variable cellular floor-fields;
- composite primary grid systems with
  variable floor-fields and constant pillar zones;
  monotonous secondary grid systems with
  variable grid dimensions.

Determination of the constant and variable constituents of the structural variations

In the lift-cell building method, as we have seen, the cell, the box-frame and skeleton-frame are simultaneously applied as principles of construction. This combination is characteristically manifested by the grid system, more accurately: by the primary and secondary grids on plan and in section, which unambiguously determine the location of the beam box-frames, pillar skeleton-frames and the two-way ribs of the cellular floor-fields. According to this:

- *length of beam box-frame* is variable but always equals the span which, in turn, is a multiple of the applied secondary grid-unit;
- *o/a dimensions of cellular floor-fields* are again variable in two directions, but the centre-lines of the ribs always fit on the applied monotonous secondary grid;
- *width of pillar-zone* is variable but its dimension advantageously equals two secondary grid-units; whereas
- *width of zone of tolerances* around the pillar skeleton frames and beam box-frames is constant: M = 10cm. From the abovesaid it follows that
- *width of pillar skeleton frame* is variable but always equals two secondary grid units minus two tolerances, and the same applies to the width of beam box-frames, as well, etc.

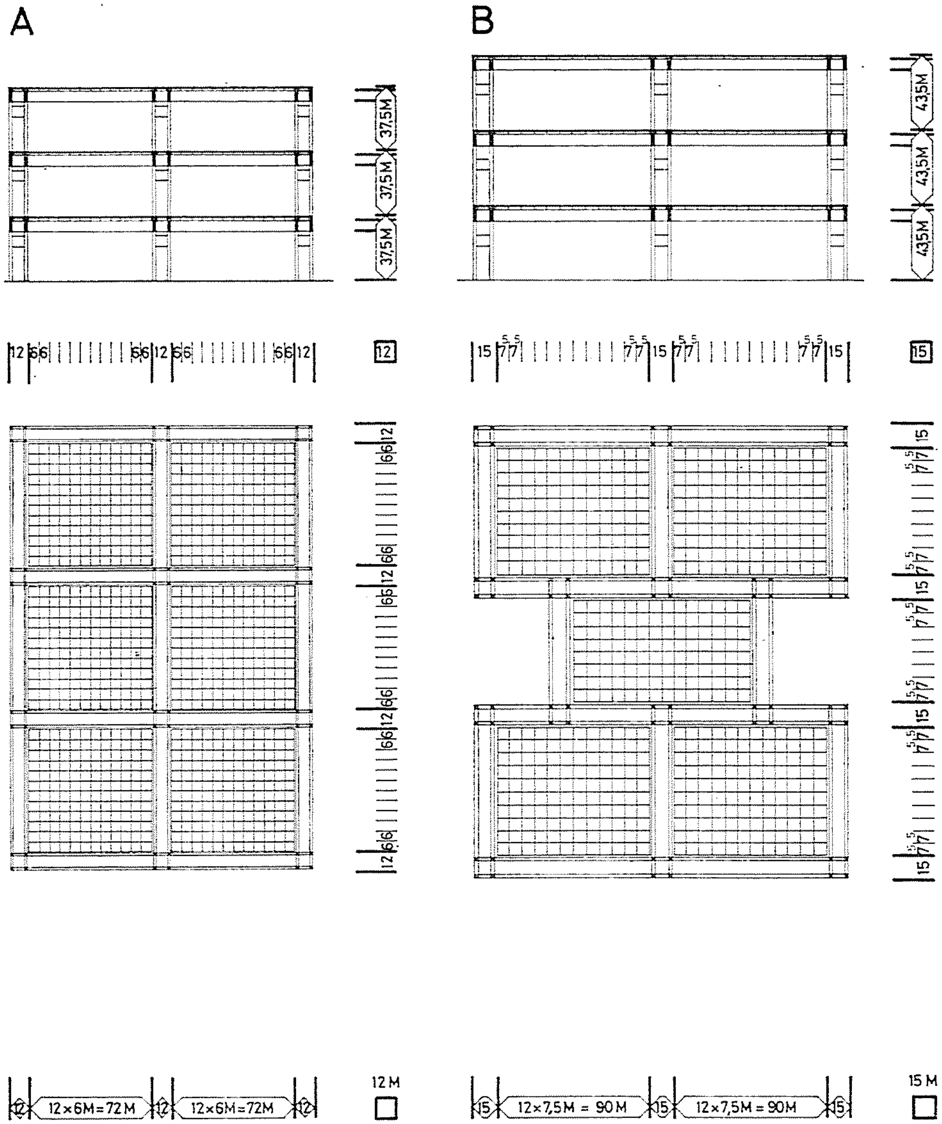

Fig. 1. The lift-cell building method: Structural variations on communal buildings. The system of primary and secondary grids on plan and in section. A series of variations have been elaborated on the 6M; 7,5M; 9M; 10,5M and 12M monotonous secondary grids. Fig. 1 shows only two of them, schematically. From points of view of design and manufacture, selection of Variation "A" seemed most expedient. In the following the *repetitive structural unit* of Variation "A" will be analysed exclusively

Analysis of the repetitive structural unit of Variation "A": 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 skeleton frames* and the *beam box-frames* within the grid system. For this purpose the "pillar-zones", the "beam-zones" and the cellular floor-fields are kept constant in both directions and each constant dimension is derived from the 6M monotonous secondary grid unit, as follows:

- co-ordination dimension of *pillar zone:* (2×6M)×(2×6M) = 12M×12M
- co-ordination dimension of *tolerance zone:* 10 cm = 1M
- exterior dimension of pillar skeleton-frame: (12M-2TOL)×(12M-2M) = 10M×10M
- dimension of columns: 1,5M×1,5M
- interior dimension of pillar skeleton-frame: (10M-3M)×(10M-3M) = 7M×7M
- co-ordination dimension of *beam-zones:* (12×6M)×(2×6M) = 72M×12M
- length of beam box-frame: 12M×6M = 72M
- width of beam box-frame: 10M
- interior dimension of beam box-frame: 7M
- width of beam unit: 4mc = 1,5M
- co-ordination dimensions of cellular *floor-field:* (12M×6M)×(12M×6M) = 72M×72M
- grid unit of the ribs of cellular floor: 6M×6M
- o/a dimension of the lifted floor-fields: (72M + 2mc)×(72M + 2mc) = 73,5M×73,5M

(Let us mention here between brackets that the cellular floor-fields always fit on the 72M×72M grid with the centre-lines of the perimeter ribs and therefore the actual overall dimension arises as follows: mc + 72M + mc = 3,75 cm + 720 cm + 3,75 cm = 735 cm = 73,5M)
From the above said it follows unambiguously that the primary grid is a composite grid, the smaller grid dimension of which (12M) always designates the location of pillar skeleton-frames, the larger dimension (72M) determines the legnth of beam boxframe, whereas the field dimension (72M×72M) determines the location of cellular floor fields through determining the centre lines of the perimeter ribs.

Lines of the primary grid *in section* are used for determining the following planes: the zero level (±0,00); the lower level of beam box-frames (+2,92 m); the upper level of beam box-frames (+3,52 m) which, at the same time, coincides with the lower level of cellular floors; finally, the top of pillar skeleton-frames (+3,75 m) which, at the same time, coincides with the upper level of cellular floors. Thus, the lines of primary grid in section establish a face-line reference, which practically means that all the horizontal border planes of the pillar skeleton-frames, beam box-frames and cellular floors coincide with these lines.

The two-way span dimensions were supposed to be constant throughout the building, increments were not applied. The smallest possible modular increment is 6M, but the expediently choosable minimum increment is given by the width of pillar-zones. In the lift-cell building method application of modular increments is possible in both directions.

The secondary grid

Lines of the secondary grid *on plan* determine on the one hand the centre-lines of the ribs of cellular floors, that is the border lines of the cellular surface-of-floor elements with their monotonous 6M grid-units, on the other hand the edges of the surface-of-beam elements of the beam box-frame with the 12M grid lines.

Lines of the secondary grid *in section* determine in the vertical direction the edges of the cellular surface-of-floor elements and the periodic surface-of-beam elements with a face-line reference, whereas in the horizontal direction they always fit on the upper and lower levels of the steel diaphragms of the pillar skeleton-frames.

Within a determined building the unit dimension of the secondary grid is always constant, modular increments are not applied here.

The tertiary grid

Lines of the tertiary grid both *on plan* and *in section* are determined by the $1{,}5M \times 1{,}5M = 4mc \times 4mc$ grid-unit, this is the basic grid of each surface element. In case of the cellular floors, lines of the tertiary grid determine the centre-lines of the two-way ribs of the r.c. tissue, whereas in case of beams, the centre-lines of the vertical ribs of the r.c. shell. Thus, the tertiary grid has a fundamental relo both in the manufacture of periodic surface elements and in the reinforcement of structural units both in the factory and on the building site.

Basic grids and the submodular increments

The module grid

Basic grid of the international modular co-ordination, where the distance between the lines—$M = 10$ cm—is the *Basic Module* (the parameter grids described above are actually modular grids where the distance between the lines is the multiple of the Basic Module).

The micro-grid

Basic grid of the double co-ordination, where the distance between the lines—$mc = 37{,}5$ mm—is the *microcell.* The microcell is a submodular dimension. Any dimension occurring within the tertiary grid is immediately related to the micro-grid. The thicknesses of the various surface elements, the dimensions of the channels of the periodic surface elements, the structural thicknesses including the dimensions of cross-sections of the various r.c. folded shell and tissue structures, etc. are all derived from the microcell. Each structural detail is elaborated in the $mc = 37{,}5$ mm micro-grid system. These detailed drawings mean the actual starting point for any design and show exact location and junction of the elements in the modular and submodular grids on plan and in section.

The superposition of grids

Creating reference between modular structural parameters and structural thicknesses

Now, in order to be able to combine the workability of the structure (a precondition of planning for change) with the convertibility of the machine (in turn, a precondition of producing for change) the non-tectonic systems relate the variable *modular parameters* (spans, heights etc.) to the variable *submodular thicknesses* (structural thicknesses, thicknesses of elements, etc.) and thereby the non-tectonic systems establish a double-reference: on the one hand a *modular* reference between the *elements* and the *modular (parameter) grids* on the building site, on the other hand a *submodular* reference between the *thicknesses* and the *submodular (micro) grid* built into the manufacturing apparatus.

The formula of double co-erdination

The ratio of modular to submodular grids can be expressed in a simple mathematical form. This *formula of double coordination* in our case is

$$3\text{M} = 8\text{mc}.$$

This formula means, that 3 basic module grid units (M = module = 10cm) within the structural system correspond to 8 micro grid units (mc = micro-cell = 37,5mm) within the manufacturing apparatus.

Basic structural thicknesses

in case of beam box-frames:

- width of beam element: 4mc = 150mm
- thickness of r.c. shell within beam: 1mc = 37,5mm
- thickness of gypsum surface element: 5mc = 56mm
- thickness of rib in the shell: 1mc = 37,5mm
- thickness of shell at perimeters: 2mc = 75mm
- steel diaphragm, width of profile: 4mc = 150mm
- steel diaphragm, flanges: 2mc = 75mm

in case of pillar skeleton-frames:

- r.c. column: 4mc × 150mm
- steel cradle, width: 4mc = 150mm
- steel cradle, flanges: 2mc = 75mm
- steel diagphragm, width: 4mc = 150mm
- steel diaphragm, flanges: 2mc = 75mm

in case of cellar floor-fields:

- thickness of floor-field: 6mc = 225mm
- height of cellular surface of floor element: 197mm
- thickness of top of cellular element: 5mc = 56mm
- thickness of r.c. rib within channels: 1mc = 37,5mm
- thickness of r.c. shell in the floor: 0,75mc = 28,0mm

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

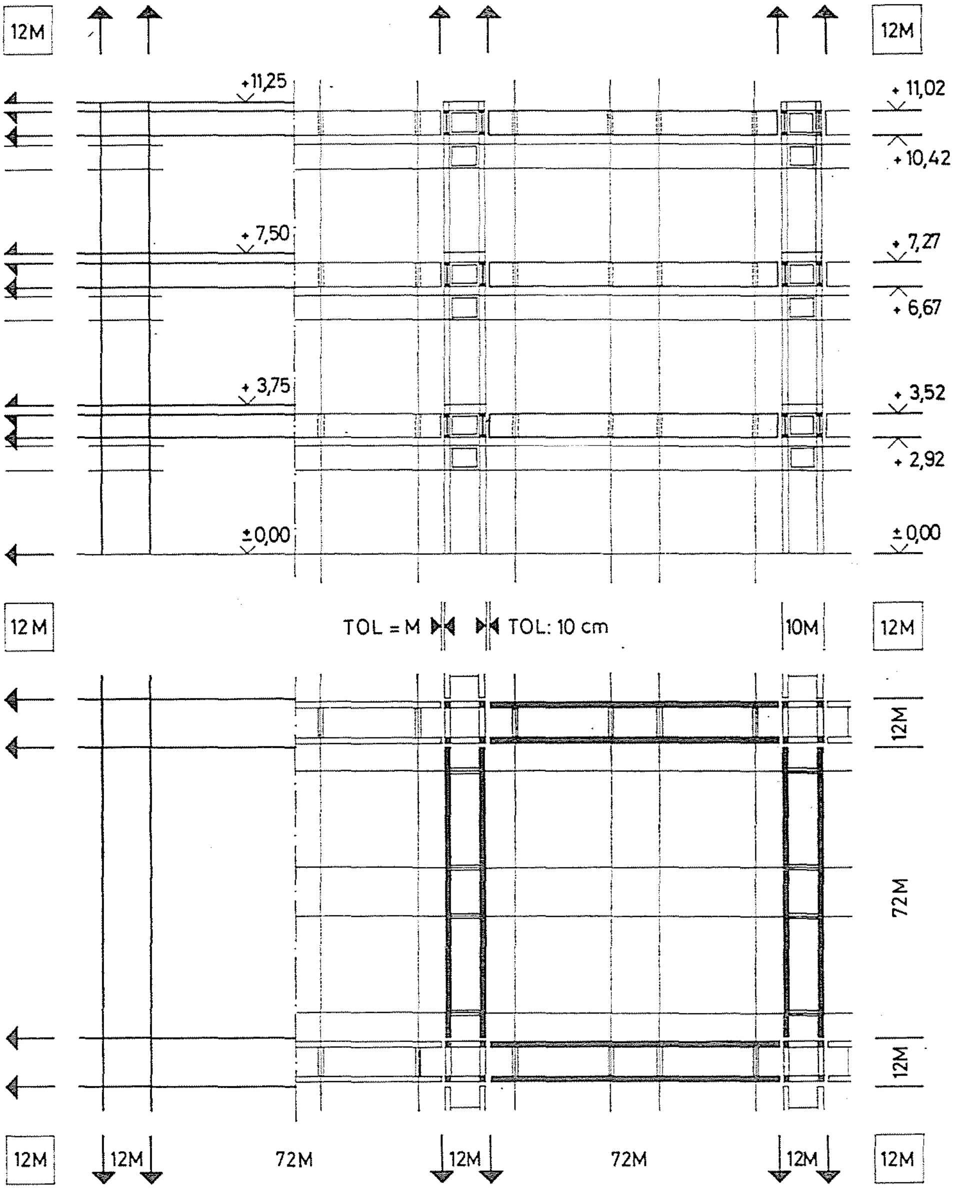


Fig. 2. The lift-cell building method. The repetitive structural unit of variation "A": The system of primary and secondary grids on plan and in section. The decomposition of the structure: the location of the pillar skeleton-frames and the beam box-frames in the system of grids on plan and in section. The primary grid: basic grid of the skeleton of the multi-level buildings. The secondary grid: basic grid of the steel diaphragms of the skeleton structure

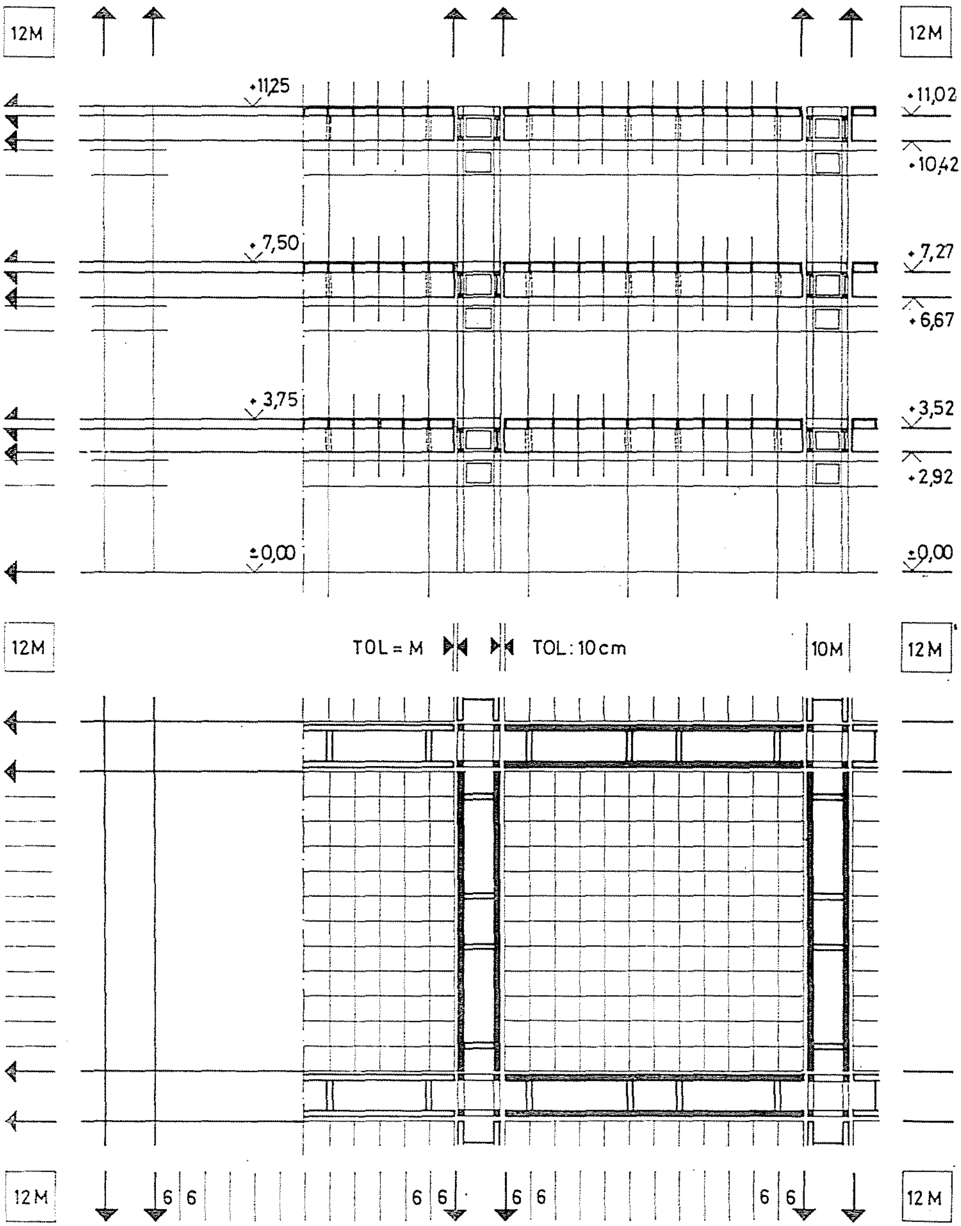


Fig. 3. The lift-cell building method. The repetitive structural unit of variation "A": The system of primary and secondary grids on plan and in section. The decomposition of the structure: the location of the pillar skeleton-frames, the beam box-frames and the cellular floor-fields in the system of grids on plan and in section. The primary grid: basic grid of the skeleton of the multi-level buildings. The secondary grid: basic grid of the cellular surface elements of the floor-fields

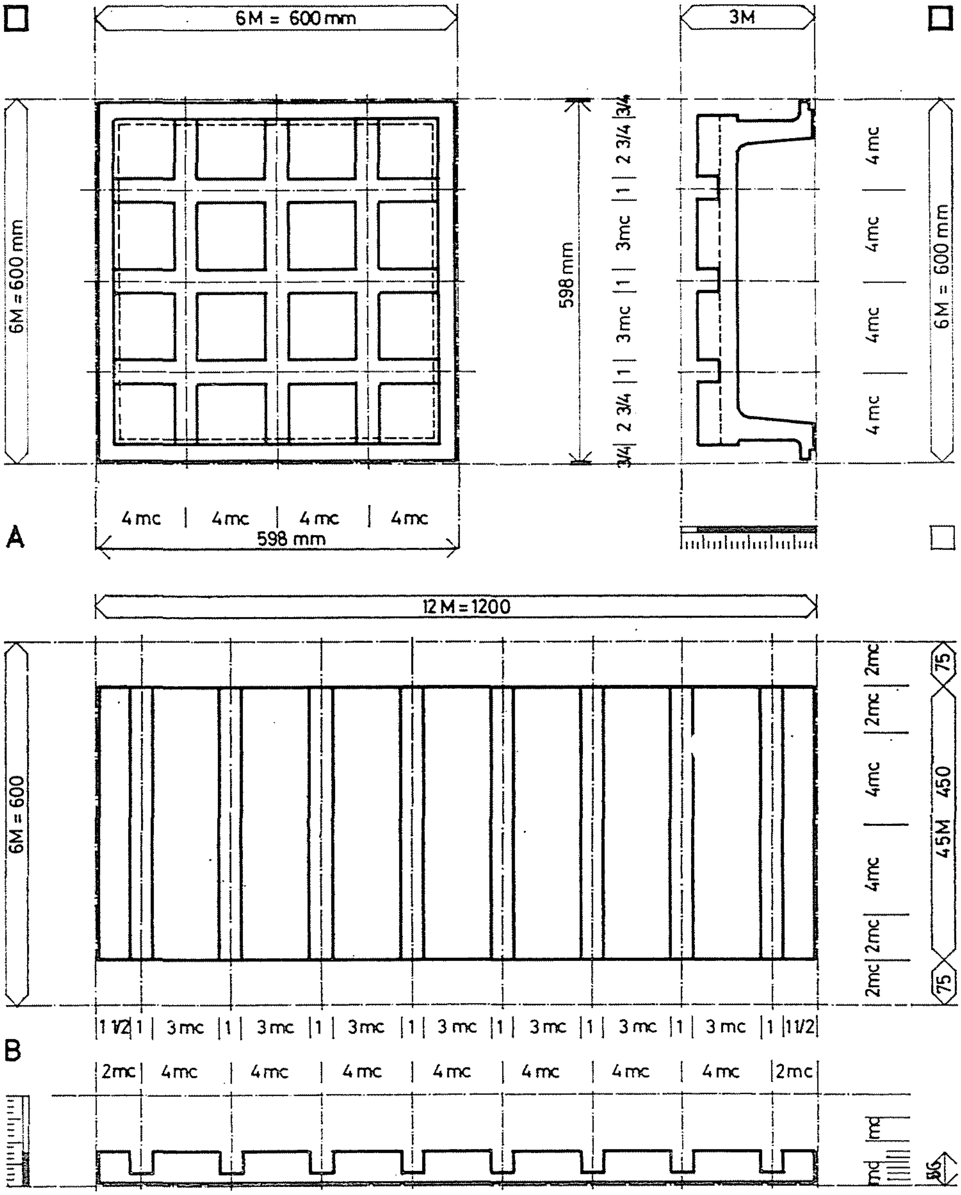


Fig. 4. The lift-cell building method. Basic non-tectonic elements: Periodic surface elements for floors and beams. The system of the 1,5M = 4mc tertiary grid. The decomposition of the structure: A. periodic cellular gypsum surface element (non-tectonic small space element) for floors; B. periodic plane gypsum surface element (non-tectonic plane element) for beams. The tertiary grid: basic grid of the surface elements

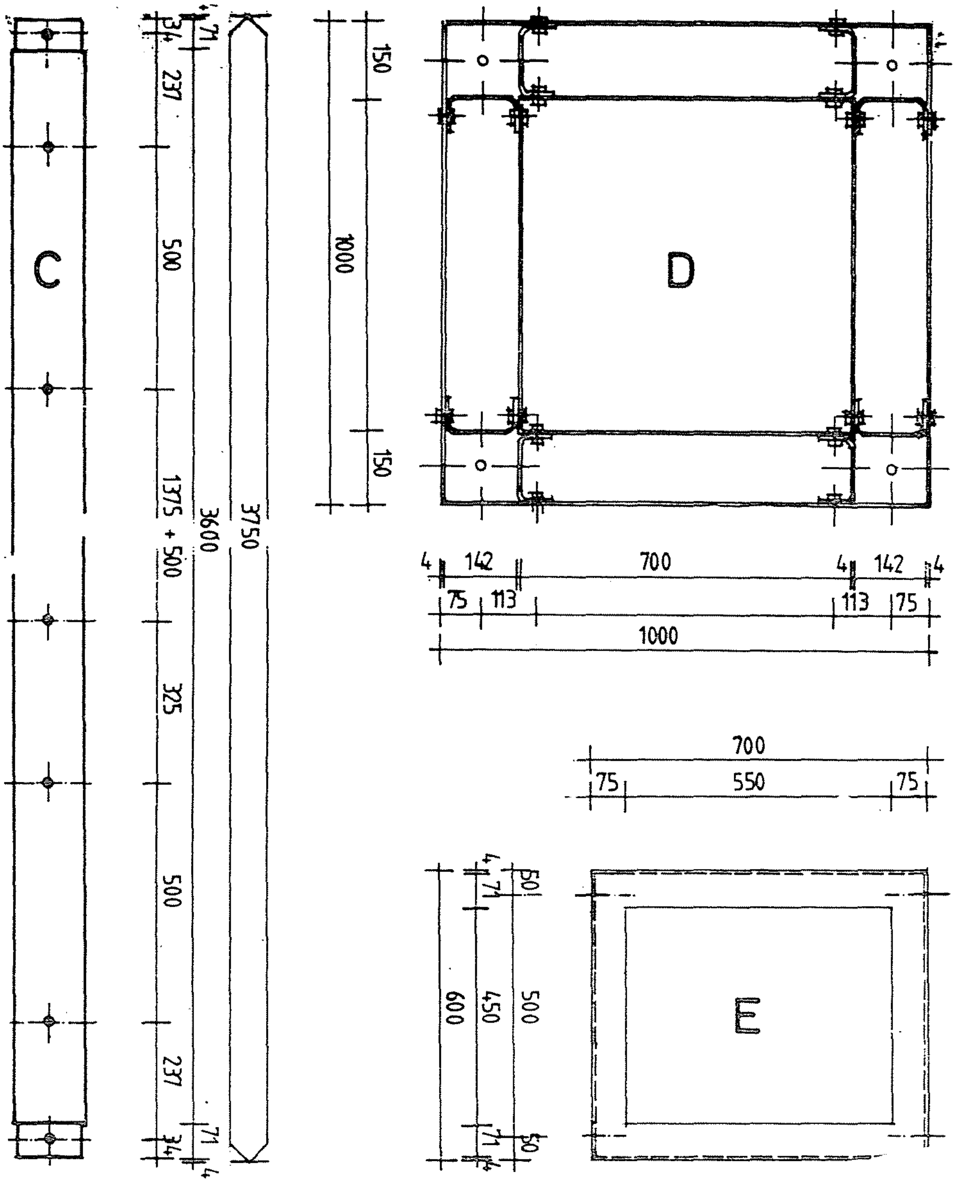


Fig. 5. The lift-cell building method. Basic tectonic elements: r.c. column elements, steel cradles and diaphragms. The decomposition of the structure: C. Reinforced concrete columns (tectonic linear elements with built-in periodic heterogeneous jointing points); D. Cradles (tectonic steel frames with periodic holes for pillar skeleton frames); E. Diaphragms (tectonic steel frames with periodic holes for pillar skeleton-frames and beam box-frames). The tertiary grid and the micro grid: The superposition of modular and submodular grids in this case is used for designating the heterogeneous jointing points and periodic holes required for structural connections

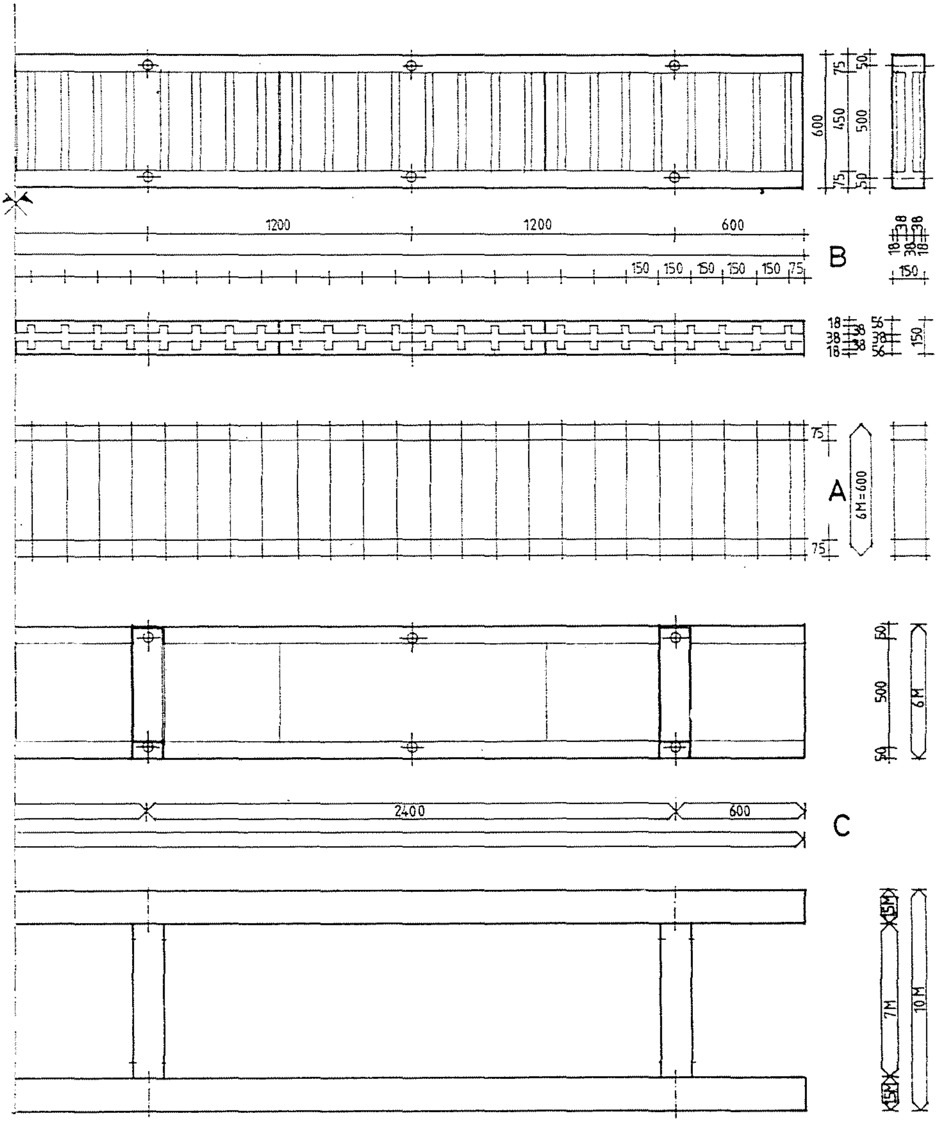


Fig. 6. The lift-cell building method: the heterogeneous beam box-frame. A. The system of the tertiary grid; B. The mechanization principled tectonic beam-element; C. The mechanization principled beam box-frame. The heterogeneous beam box-frame—a small box-unit of parameter size in one direction—is constructed in such a way that first we preassemble the non-tectonic periodic (Gutenberg-principled) beam elements—that is frozen r.c. shell plane structural elements—and then, we joint them in pairs by means of steel diaphragms, whereby we unite them into empty beam box-frames

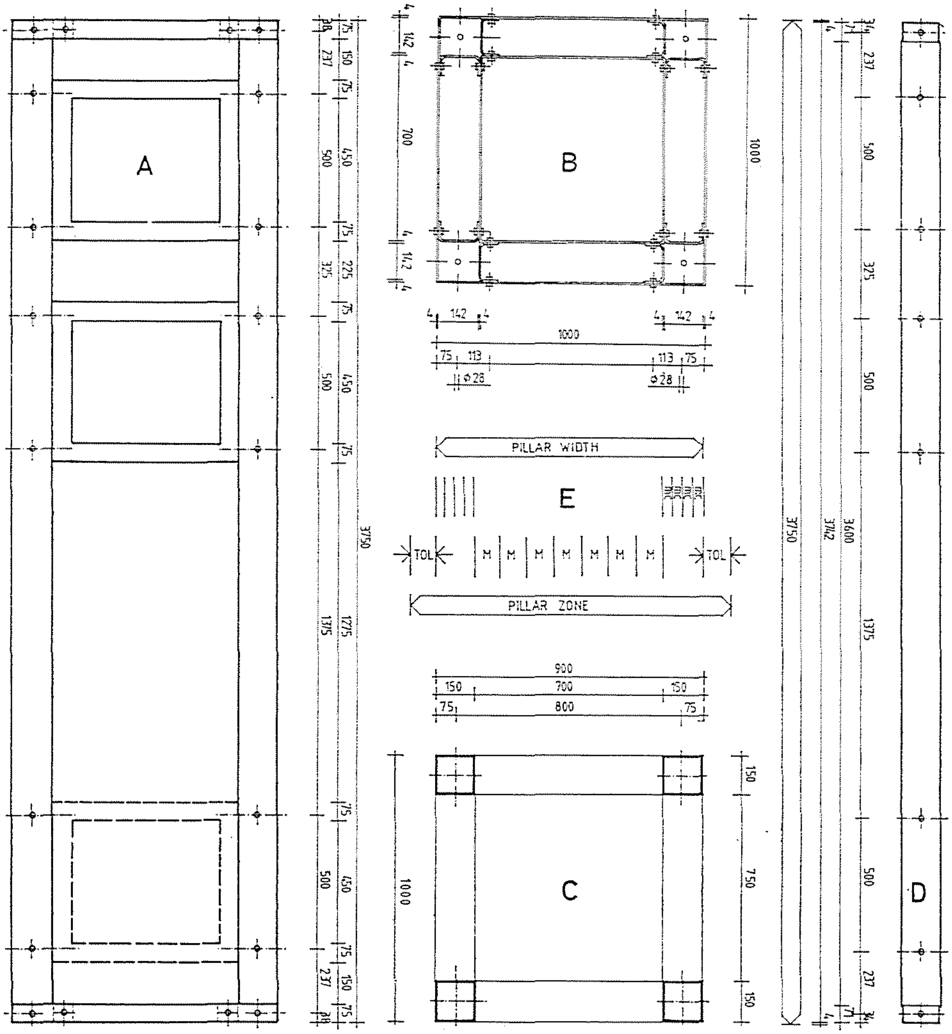


Fig. 7. The lift-cell building method: the heterogeneous pillar skeleton frame. A. Elevation; B. Horizontal section through cradle; C. Horizontal section through jointing points embedded into r.c. column; D. Vertical section through diaphragms; E. The zone of tolerance around pillars: the module grid and the micro grid on plan. The heterogeneous pillar skeleton-frame—again a small box-unit of parameter size in one direction—arises in sucha a way that we couple the column elements—that is the manufactured tectonic linear r.c. structural elements—in fours by means of steel cradles and diaphragms, whereby we unite them into empty pillar skeleton-frames

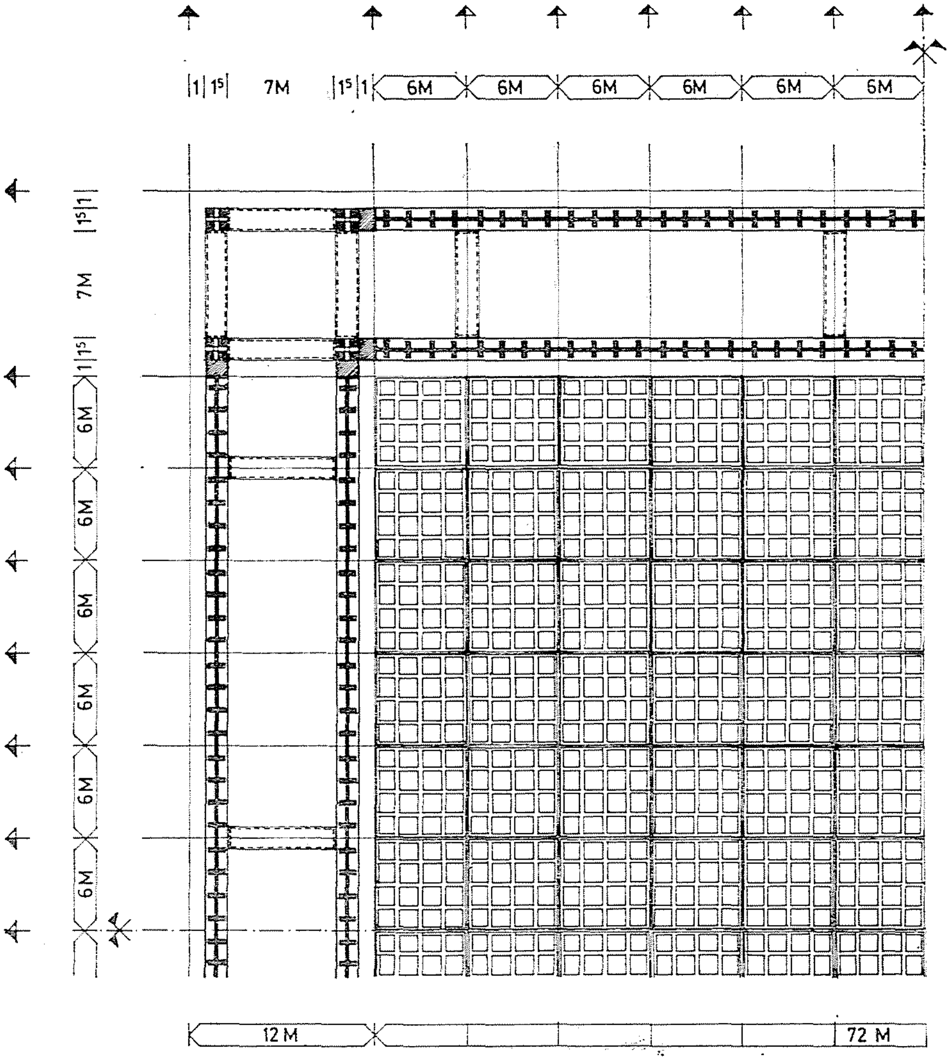


Fig. 8. The lift-cell building method: The repetitive structural unit. The location of the pillar skeleton-frames, the beam box-frames and the periodic cellular gypsum surface-of-floor elements in the system of primary, secondary and tertiary grids on plan. Note the principle of construction: the heterogeneous beam box-frames always fit on the 72M × 72M primary grid; the pillar skeleton-frames with their 1M tolerance zones on each side on the 12M × 12M grid; the perimeters of the cellular surface-of-floor elements on the 6M × 6M secondary grid, whereas the vertical ribs of the beam elements and the two-way channels of the cellular floor elements on the 1,5M × 1,5M = 4mc × 4mc tertiary grid. The formula of double co-ordination: 3M = 8mc

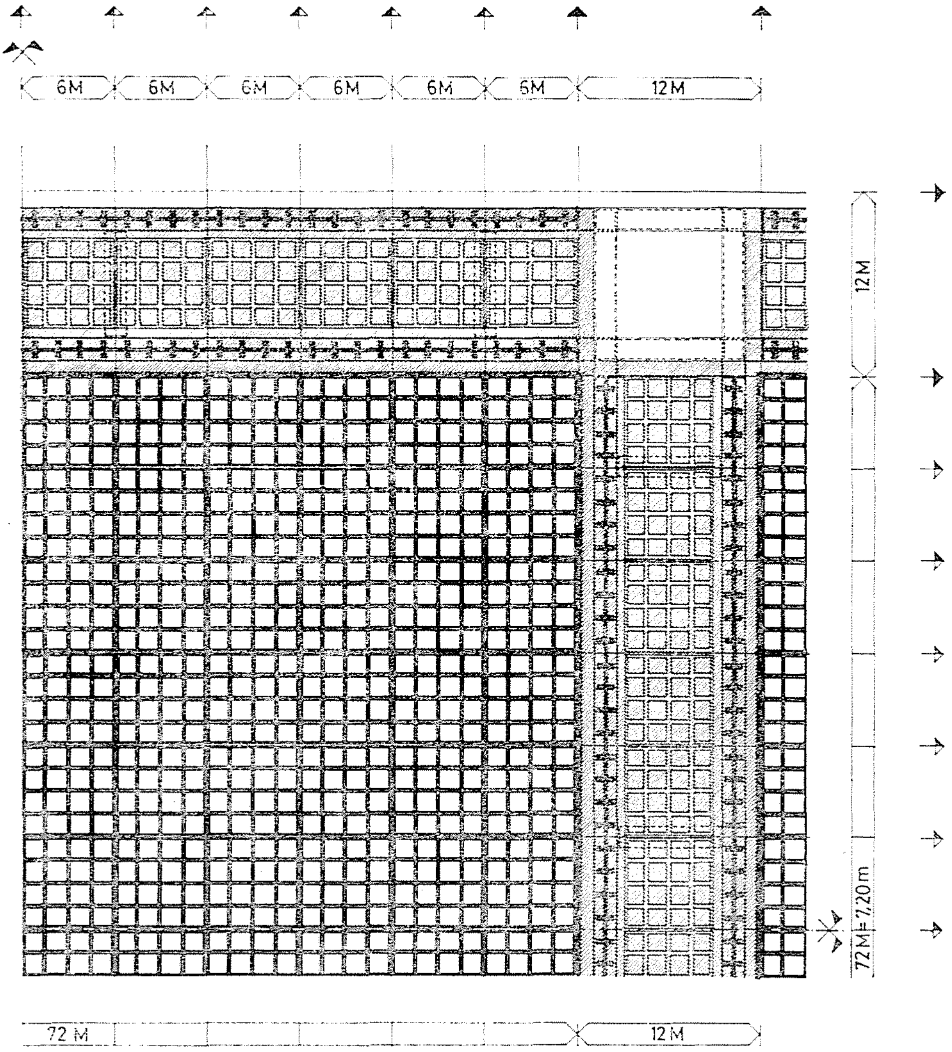


Fig. 9. The lift-cell building method: The repetitive structural unit. The location of the pillar skeleton-frames, the beam box-frames, the cellular floor-fields and the floors above the beam-zones in the system of primary, secondary and tertiary grids on plan. The two-way ribs of the cellular floor-field (that is a frozen r.c. shell plane structural element of parameter size in two directions) always fit on the 6M × 6M secondary grid. The cellular floor-field is rigidified with a membrane which, in turn, is fortified by the two-way ribs of the structural tissue. The r.c. ribs of the structural tissue always fit on the 1,5M × 1,5M = 4mc × 4mc tertiary grid. The same applies for the floors above the beam-zones. The formula of double co-ordination: 3M = 8mc

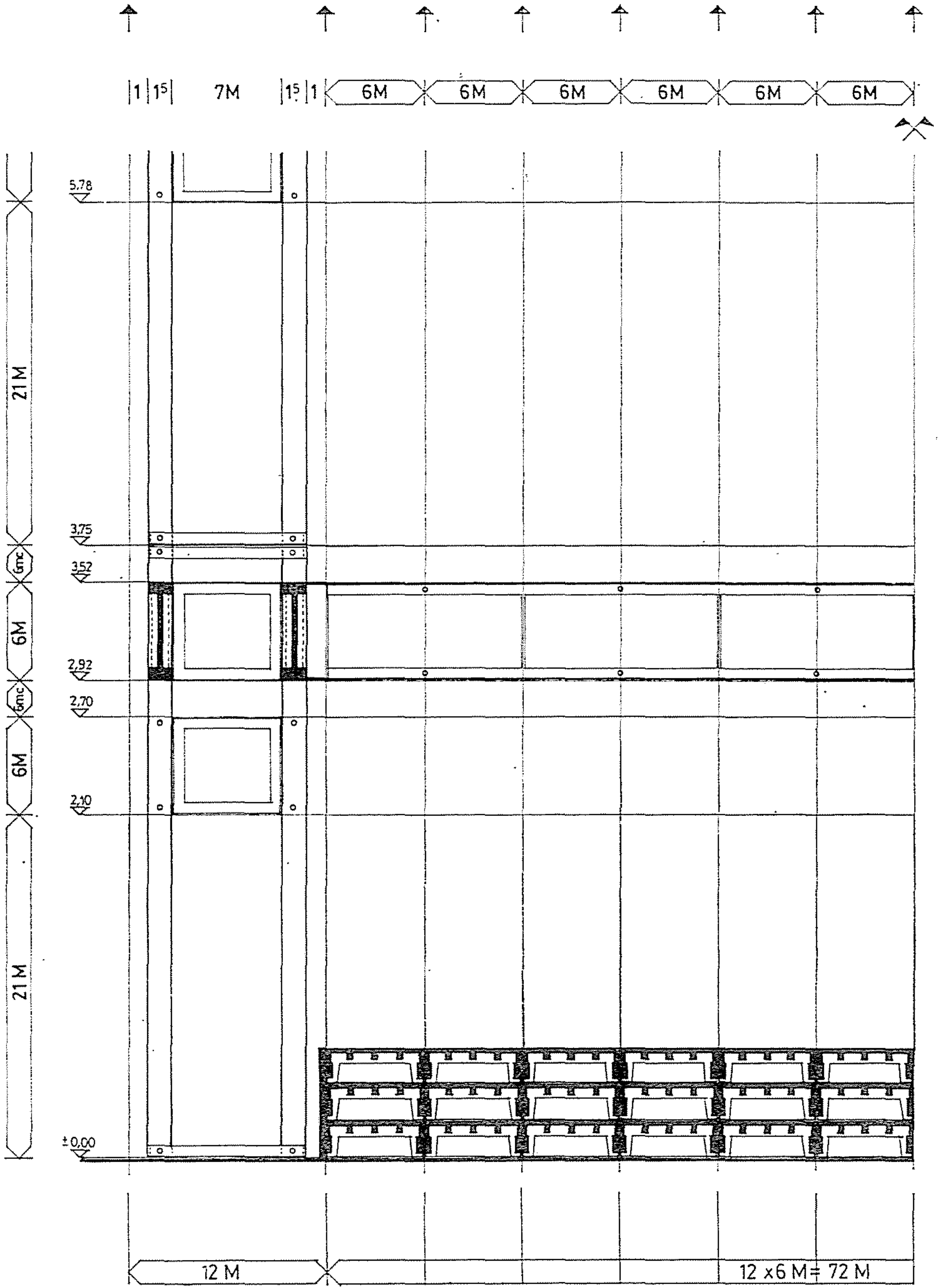


Fig. 10. The lift-cell building method: The repetitive structural unit. The location of the pillar skeleton-frames, the beam box-frames and the cellular floor-fields underneath in-situ position in the system of primary and secondary grids, in section. The skeleton construction of the multi-level buildings, that is the pillar skeleton-frames and the beam box-frames are assembled immediately in their final in-situ position and connected to each other by heterogeneous junction, whereas the cellular floor-fields of parameter size in two directions are always assembled underneath in-situ position immediately on top of each other and fit on the 72M × 72M primary grid with the centre lines of the perimeter ribs as shown by figure

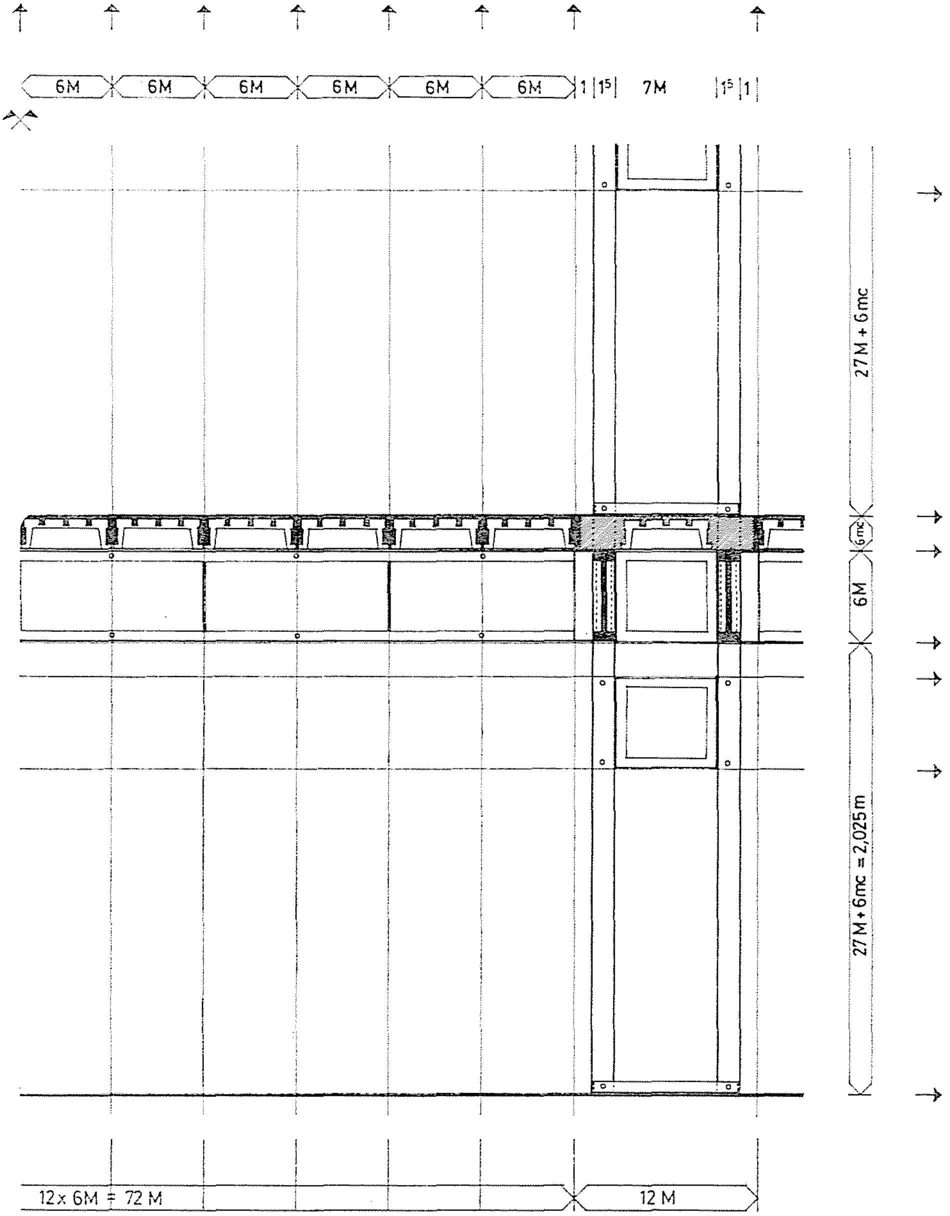


Fig. 11. The lift-cell building method: repetitive structural unit. The location of the pillar skeleton-frames, the beam box-frames and the cellular floor-field in final in-situ position in the system of primary and secondary grid, in section. The r.c. ribs fitting on the 6M × 6M secondary grid appear on each side of the completed floor-field. When lifted into in-situ position steel supports —"doglegs"—are inserted into the steel □ tubes embedded into the butt-ends of the ribs, whereby the total width of the cellular floor-field becomes bigger than the span and the heterogeneous junction can be called into being. It is now the steel supports which fix the field unit in dry, temporary in-situ position until final structural homogeneous connection is established. This is realized in the next step when the cellular floor-zones above the beam box-frames are assembled and concreted. (See also: Fig. 13.)

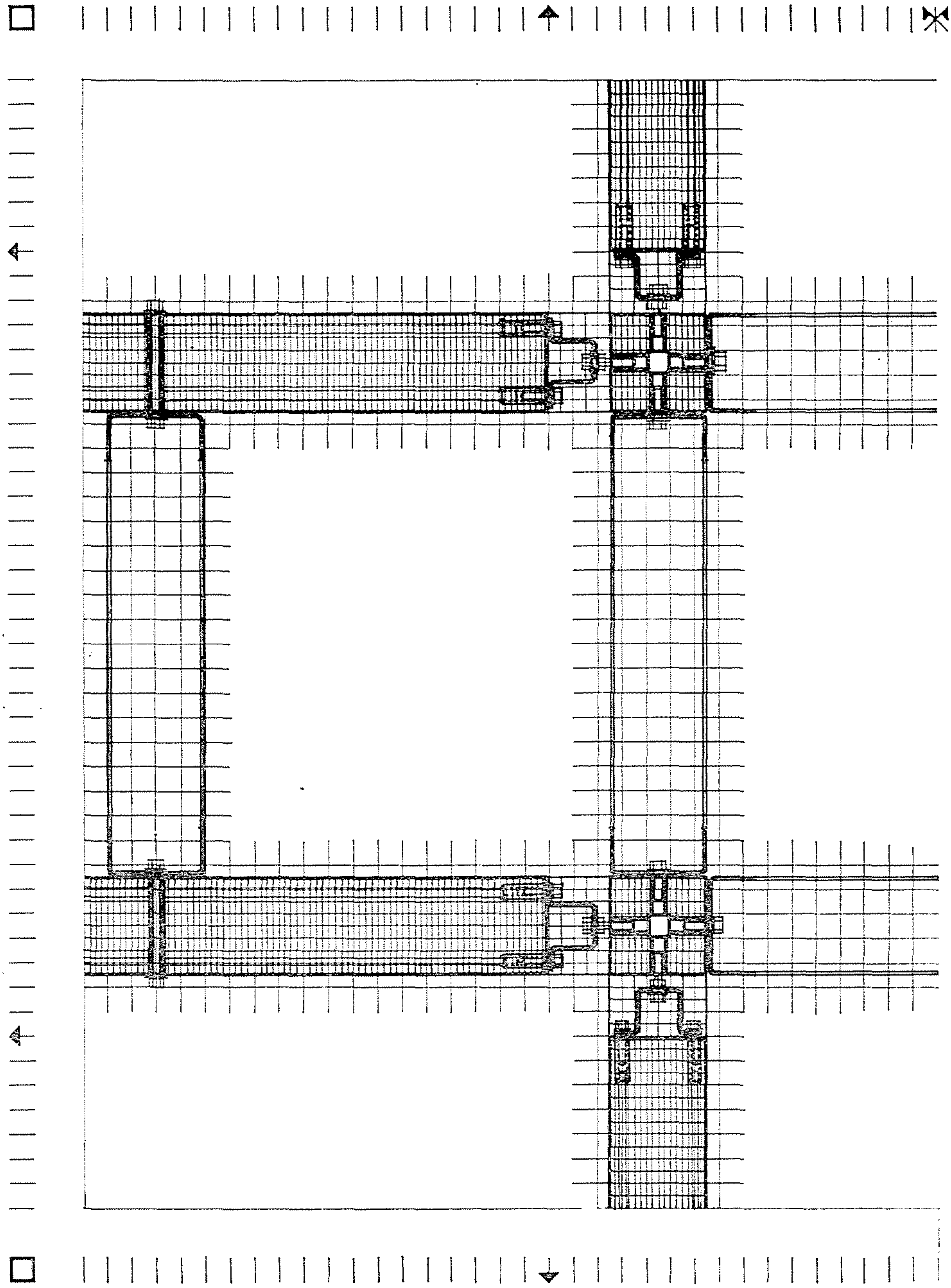


Fig. 12. The lift-cell building method: The repetitive structural unit; micro-grid details. Horizontal section through beam box-frames and pillar skeleton frames; location of the heterogeneous junctions in the system of the micro-grid, on plan. The heterogeneous junction between steel diaphragm and beam elements is shown on the left hand side in the micro grid system. The heterogeneous jointing point in this case is a simple steel tube with internal thread, fixed periodically to the reinforcement of the r.c. frozen shell beam element; the heterogeneous junction between steel diaphragms and r.c. column-element is shown on the right hand side. The jointing point in this case is called "tetradent", ie. a jointing point accessible from all four sides, fixed periodically to the reinforcement of the r.c. column; finally: the heterogeneous junction between beam box-frames and pillar skeleton-frame is represented in the micro grid on plan

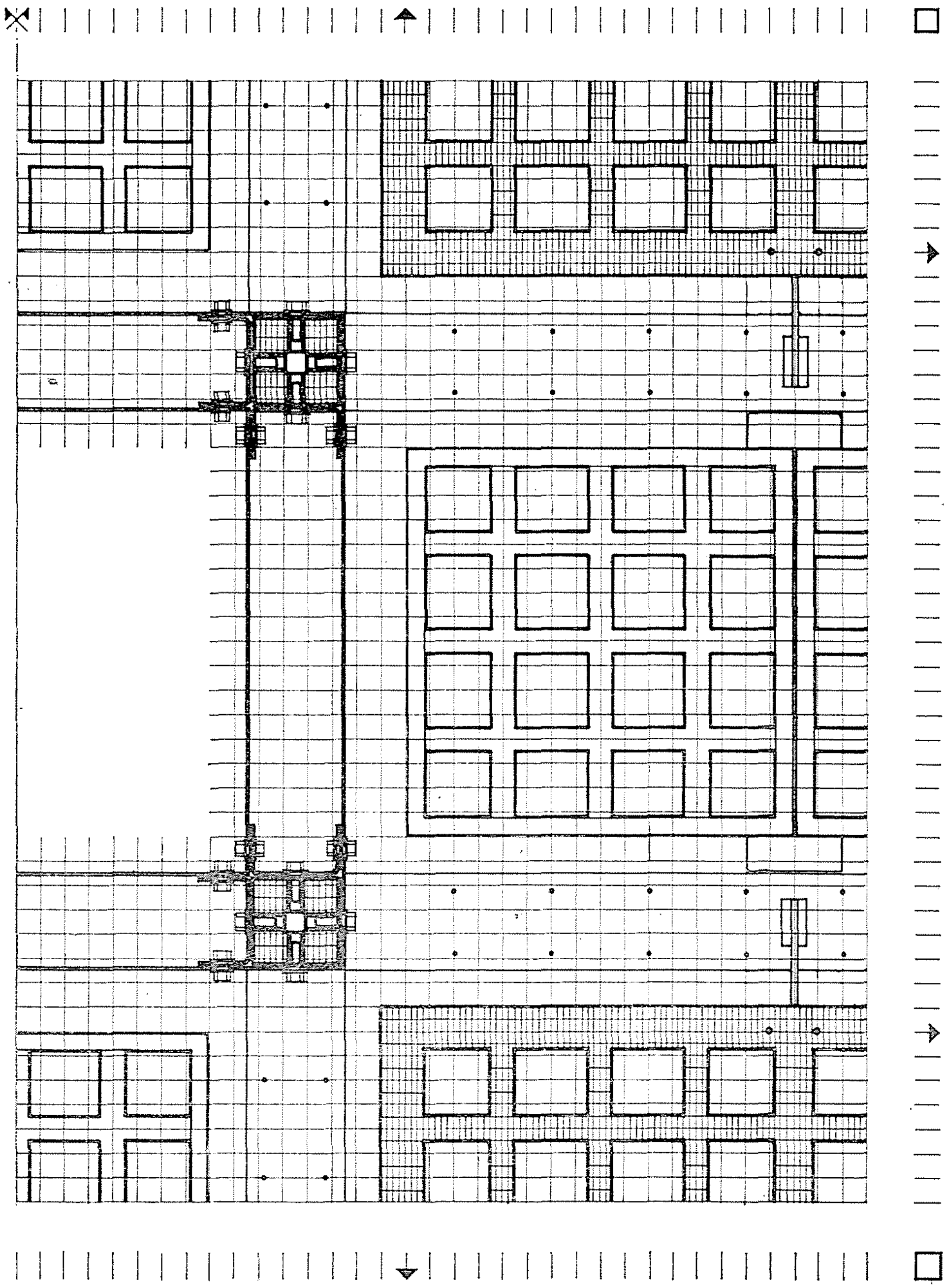


Fig. 13. The lift-cell building method: The repetitive structural unit; microgrid details. Horizontal section through pillar skeleton-frame above beam box-frame level. The location of the cellular floor-field and the floors above the beam-zones in the system of the micro grid, on plan. The heterogeneous junctions between the upper steel cradle and r.c. column elements is shown on the left hand side; the position of the cellular floor-fields in the system of the parameter and micro grids is shown on the right hand side. The perimeter ribs of the cellular floor field fit on the 72M×72M primary grid, the normal ribs on the 6M×6M secondary grid whereas the ribs of the r.c. tissue on the 1,5M×1,5M = 4mc×4mc grid. The floor-field already lifted into in-situ position is temporarily fixed by the "legs"; finally: the position of the cellular, periodic surface-of-floor elements above the zone of beam-frames is shown in the micro-grid on plan, in the situation preceding the pouring in of concrete

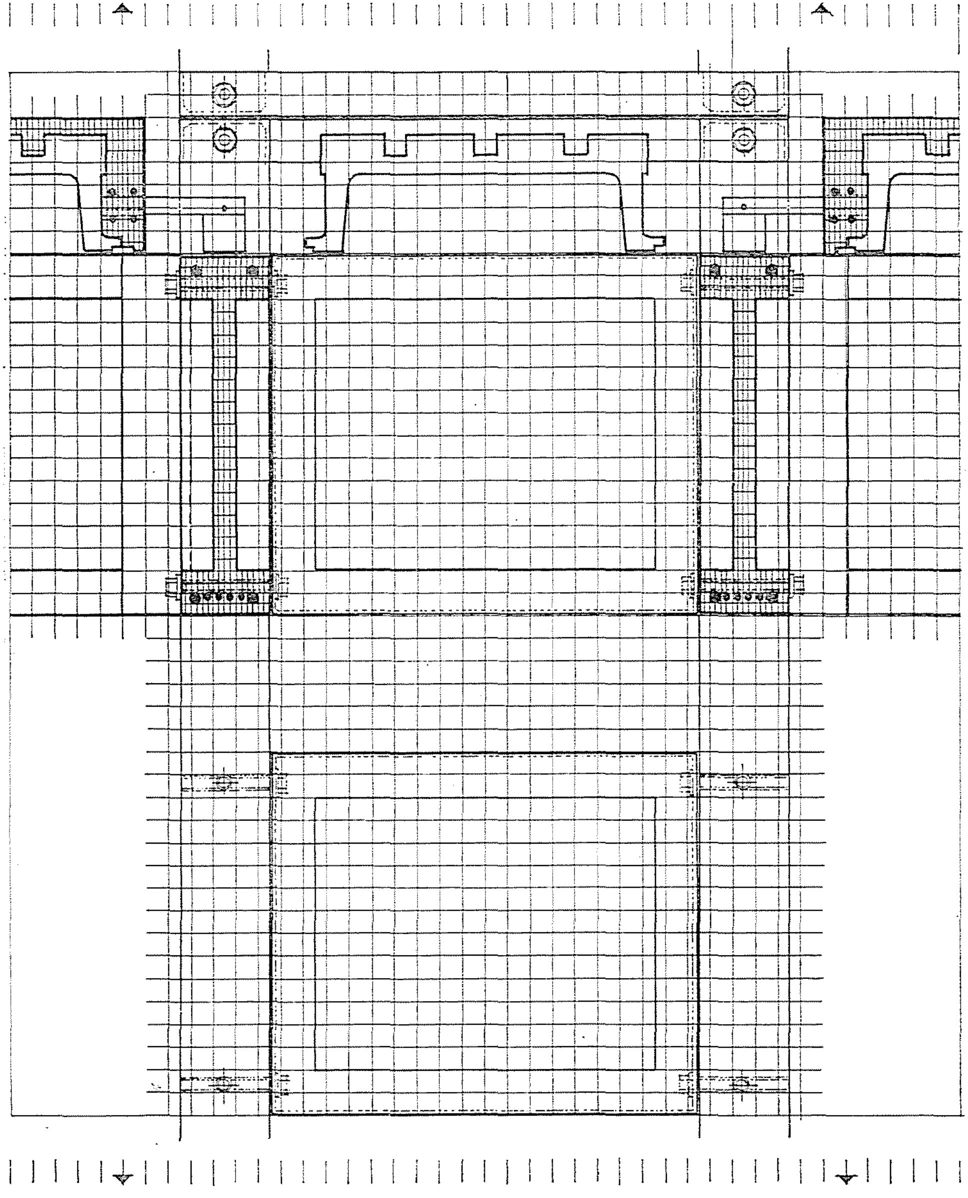


Fig. 14. The lift-cell building method: The repetitive structural unit; micro-grid details. Vertical section through beam box-frame and cellular floor-field. Position of the heterogeneous junctions in the system of the micro grid in section. The situation preceding the concreting of floors above the beam-zones. The heterogeneous junctions between steel diaphragms and beam elements and between steel diaphragms and r.c. column element are shown here in the system of grids in section together with the temporary heterogeneous junction between the floor-field and the beam box-frame. The cellular floor-field completed underneath in-situ position is first lifted slightly above its final position, then, the steel supports (the "doglegs") are inserted into the steel → tubes embedded into the butt-end of the ribs and the floor field is lowered into final position, whereby the temporary heterogeneous junction is called into being

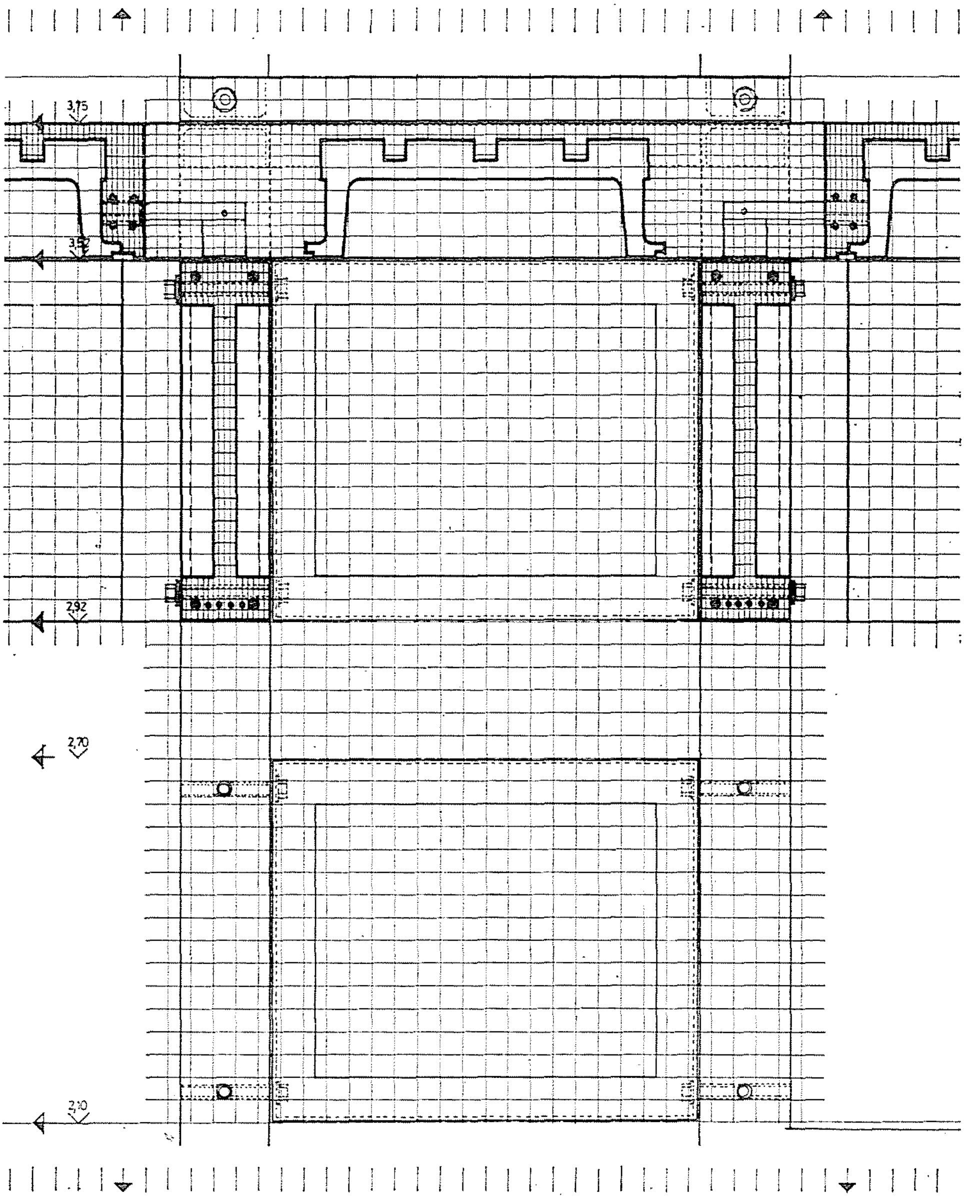


Fig. 15. The lift-cell building method: The repetitive structural unit; micro-grid details. Vertical section through beam box-frame and cellular floor-fields. Position of the heterogeneous and homogeneous junctions in the system of grids in section. The situation following the concreting of floors above the beam-zones. The heterogeneous junctions between steel diaphragms and beam elements and between steel diaphragms and r.c. column elements are shown here in the system of grids in section, together with the final homogeneous structural junction between the floor-fields and the beam box-frames. Having created a temporary heterogeneous junction between the floor-field and the beam box-frame we start the assembly of the floor-zones above beam box-frames: the non-tectonic cellular gypsum surface-of-floor elements are located first in in-situ position, then, reinforcement is placed into the two-way ribs and channels and finally concrete is poured in, whereby the final homogeneous structural junction is called into being

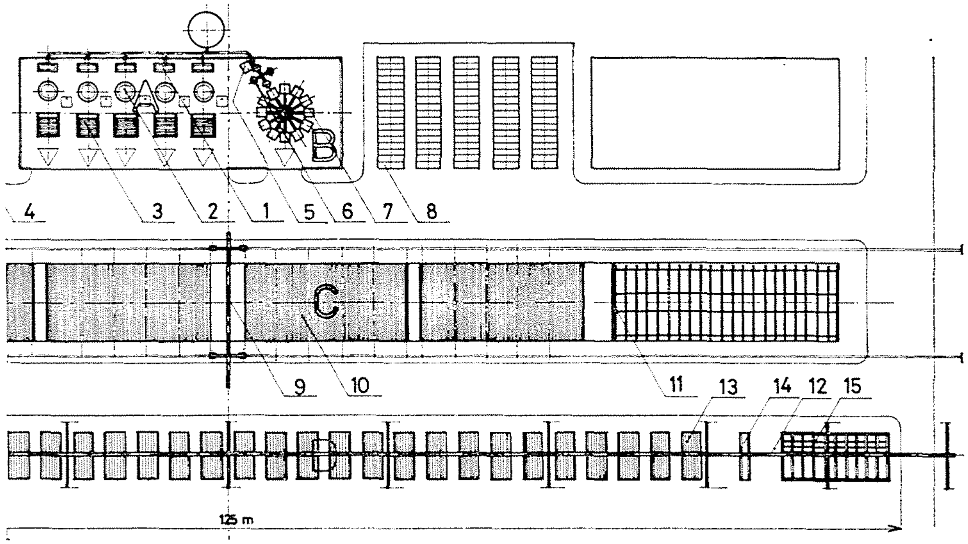


Fig. 16a

Manufacture

Layout plan of the planted factory for producing 100,000 m² multi-level communal buildings per annum

The layout plan of the planted factory is shown by Fig. 16a and 16b. The technology elaborated is only concerned with the production of the primary structures necessary for erecting 100.000 m² multi-level communal buildings per annum. The factory itself is composed of the following workshop-units:

A. Covered shed for manufacturing periodic plane gypsum surface elements (non-tectonic plane elements) for beams;
B. Covered shed for manufacturing periodic cellular gypsum surface elements (non-tectonic small space elements) for floors;
C. Area for open-air manufacture of heterogeneous beam box-frames (tectonic structural elements, small box-units);
D. Area for open-air manufacture of heterogeneous pillar skeleton-frames (tectonic structural elements, small box-units);

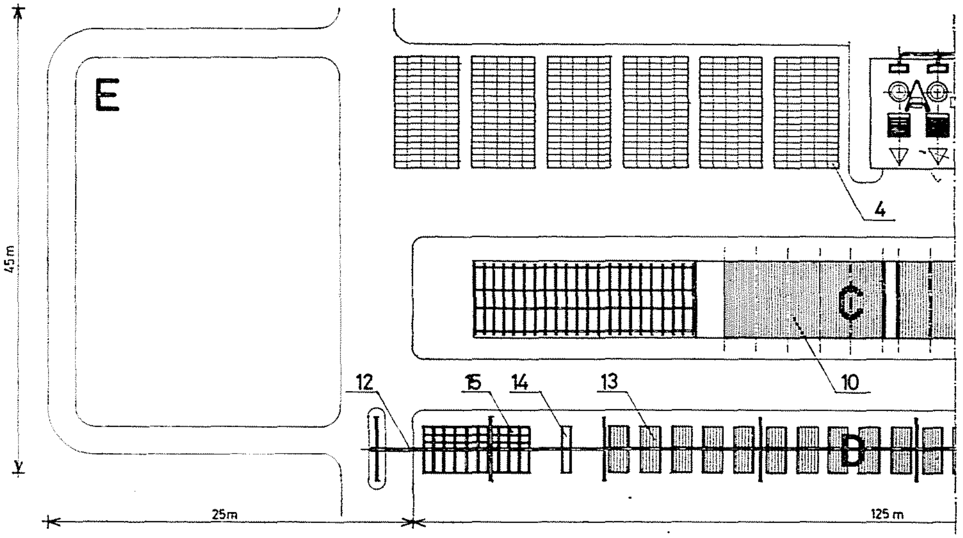


Fig. 16b

E. Concrete factory (storage for aggregates, storage for cement, concrete mixer etc.)

F. Area for open-air manufacture of reinforcement, locksmith's workshop, etc.

Index: 1. place for storing gypsum and gypsum feeder; 2. gypsum mixer; 3. casting battery, apparatus for manufacturing twenty periodic plane gypsum surface-of-beam elements simultaneously in vertical position; 4. dense storage of plane gypsum surface elements in vertical position on storing boards; 5. gypsum and water feeder; 6. gypsum mixer for the carrousel; 7. twelve unit carrousel for manufacturing periodic cellular gypsum surface-of-floor elements; 8. storage of cellular gypsum surface elements in horizontal position on storing boards; 9. gantry crane; 10. battery principled open-air manufacture of plane tectonic structural elements (beam-elements); 11. preassembly and storage of heterogeneous beam box-frames (tectonic structural small box-units); 12. overhead trolley, track; 13. stack plates for open-air manufacture of r.c. columns (linear, tectonic structural elements); 14 bench for preassembly of heterogeneous pillar skeleton frames. 15. storage of heterogeneous pillar skeleton-frames.

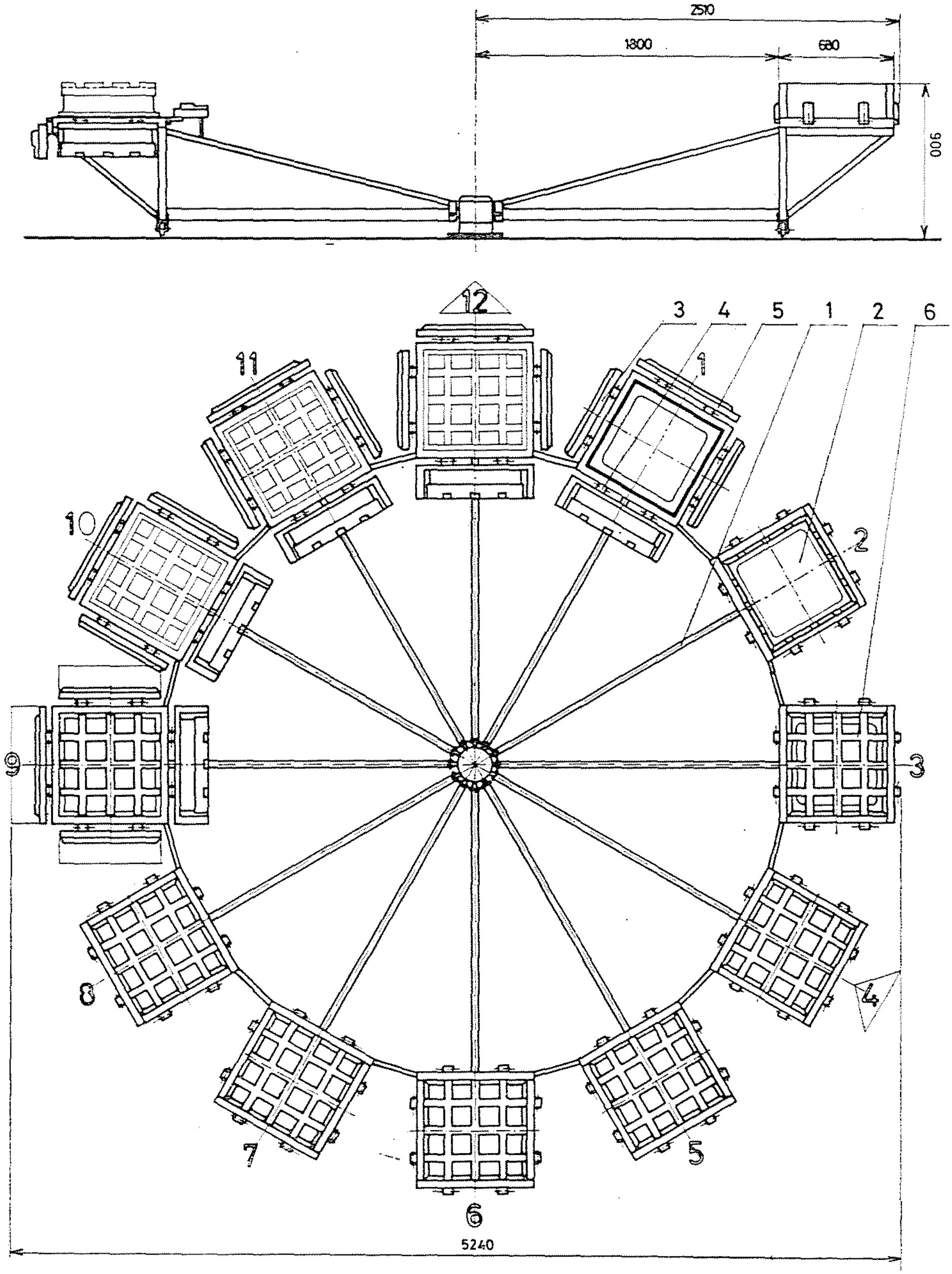


Fig. 17. Twelve-unit carrousel for manufacturing non-tectonic periodic cellular gypsum surface elements for floors

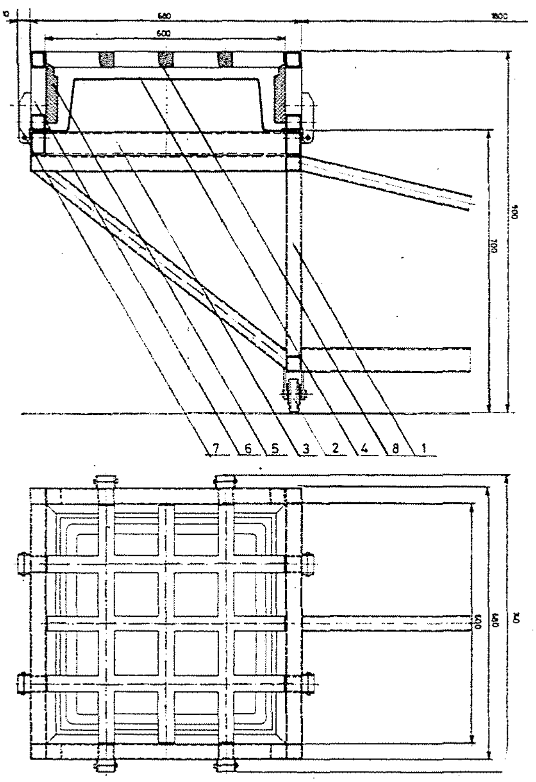


Fig. 18. Twelve-unit carrousel. Detail. Plan and vertical section through pouring board. 1 Bottom frame: cantilevered radial frame and vertical wing-frames; 2 wheel; 3 pouring board: basic frame; 4 pouring board: fibreglass poliester forming element fixed to the basic frame for forming the concave surface of the cell; 5 inlay element fixed to the tilting door for forming the perimeter surfaces of the cell; 6 tilting side-door; 7 hinge; 8 forming grid for producing the two-way channels on top of the cell element

Manufacturing apparatuses and processes of manufacture

1. Apparatuses for manufacturing gypsum surface elements

1a. *Twelve-unit carrousel: apparatus for manufacturing non-tectonic periodic cellular gypsum surface elements for floors.* The elements are produced one by one, in horizontal position The carrousel itself is composed of twelve mould-units mounted on twelve cantilevered radial frame-units with spacing rods and driven mechanically around a central hub. (Fig. 17.) The main components parts are the following: The *bottom frame*—that is a cantilevered radial frame jointed to the hub, with two vertical wing-frames fixed to it at right angle—for supporting and moving the moulds, and the *mould* for producing the elements. (Fig. 18.)

The process of manufacture involves the following cycles: 1. Cleaning; 2. Assembly; tilting and fixing the side-doors; 3. Assembly: location and fixing of the forming grid; 4. Pouring in of gypsum; 5. Smoothing off the upper surface; 6, 7, 8. Hardening; 9. Tilting down the side-doors; 10. Lifting-out the forming grid; 11. Demounting the cellular gypsum surface element through blowing in of air pneumatically; 12. Removing the gypsum surface elements and putting it on the storing plate; moving the elements to the storing place.

1b. *Casting battery: apparatus for manufacturing periodic plane gypsum surface elements for heterogeneous beam box-frames.* This apparatus producing twenty elements simultaneously has been introduced in our previous study (See: references 14.), therefore it is only mentioned here for sake of completeness.

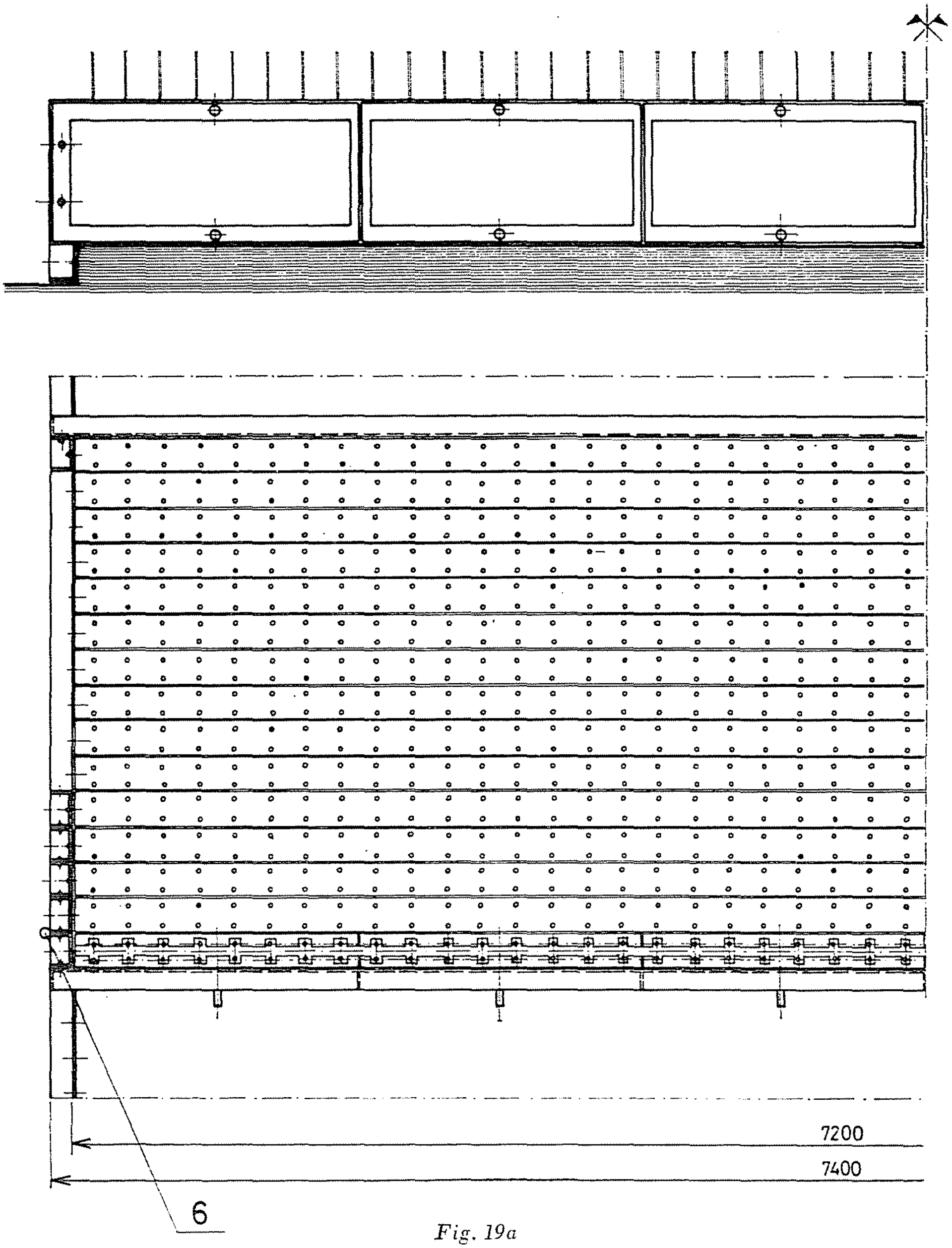


Fig. 19a

2. *Apparatuses for producing heterogeneous beam box-frames*

2a. *Open-air manufacturing plane for the battery-principled preassembly of tectonic beam elements (that is: frozen r.c. shell plane structural elements.) See: Fig. 19a and Fig. 19b.* Index: A. gypsum surface element; B. reinforcement; C. ribbed r.c. shell; 1. the concreted manu-

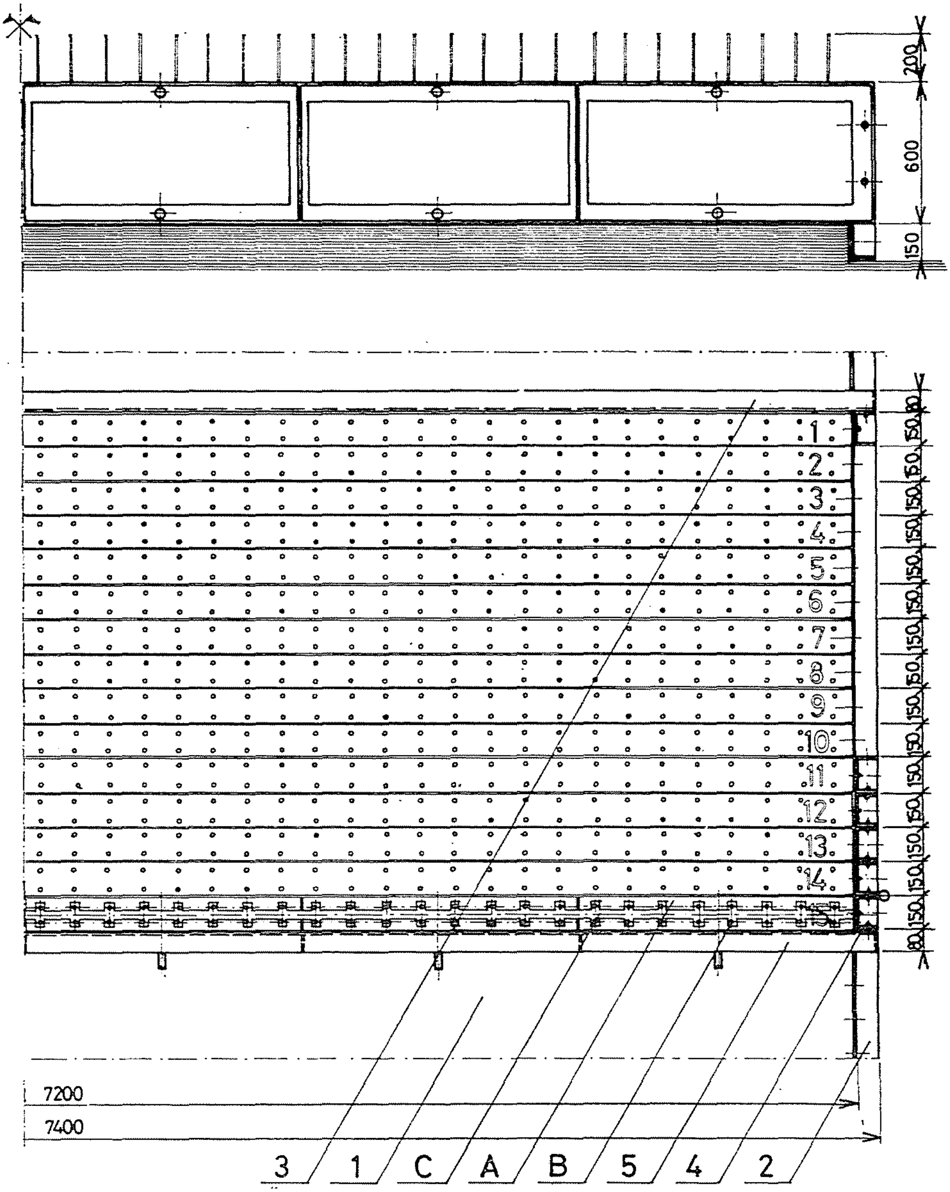


Fig. 19b

facturing plane; 2. L-profile edging the manufacturing plane; 3. starting frame; 4. "ear", U-profile; 5. transplantable closing frame.

The manufacturing plane (See also Fig. 16a and Fig. 16b) is a concreted surface (1) edged with L-profiles provided with periodic threaded hoees (2). The 7,2 m × 125 m plane is used for determining the lower plane and the butt-ends of beam elements.

Tools required for the preassembly of beam elements are the following:

- *starting frame* (3) jointed to the ears determining the butt-ends of the first beam element, an empty plane frame constructed of L-profiles to keep the "inner" surface elements of the first beam in exact position;
- *ears* (4) folded steel U-profiles jointed to the L-profiles (2) for casing the butt-ends of the beam and for fixing reinforcement in exact position;
- *closing frame* (5) an empty plane frame constructed of L-profiles jointed to the ears casing the butt-ends of the element to be manufactured for keeping the "outer" surface elements of the beam in exact position (See also: Fig. 20.)
- *stretchers* (6), tools applied by pairs jointed immediately to the ears casing the butt-ends of the elements for stretching the graboplast stripes separating the upper and lower r.c. flanges of the beam elements manufactured after one another.

The process of manufacture of beam elements (plane structural elements) involves the following *technological cycles:*

- jointing the ears casing the butt-ends of the first beam element to the L-profiles designating the brim of the manufacturing plane with bolts driven into the threaded periodic bores of the L-profiles;
- location of starting frame and bolting it to the ears mentioned above;
- location of inner clips—plastic spacers—periodically to determine the lower plane of the surface elements;
- location of the inner surface elements on the clips and fixing them temporarily to the starting frame, with clips;
- location of the prepared welded reinforcement and fixing it to the ears with bolts, using the inner threads of the jointing points at the end of the reinforcement;
- location of outer clips—plastic spacers periodically to determine the lower plane of the outer surface elements to be kept in position later on by the closing frame;
- location of outer surface elements on the outer clips and fixing them temporarily to the clips already fixing the inner surface elements;
- location of the closing frame and fixing it to the ears;
- concreting, smoothing the upper surface;
- unfastening of the closing frame laying it down on the manufacturing plane;
- the first technological cycle of the manufacture of the second element; jointing the ears casing the butt-ends of the second beam element to the L-profiles, as already mentioned;
- the second technological cycle: jointing the stretchers to the ears of the first and second elements, threading in, stretching and fixing the separating graboplast stripes.

In the following the technological cycles are periodically repetitive according to the above said.

Two brigades—8 workers each—work simultaneously on two batteries and finish every operation. In each battery 100 beam-elements are produced. Producing one beam-element takes 45 minutes. In each battery 10—10 elements are produced daily. Hardening takes 14 days and then, the assembly of beam-elements into heterogeneous beam box-frames can be started. The sequence of the dismounting of the batteries corresponds to the order of manufacture. The hardened elements are transported by a gantry crane to the place of assembly.

Let us mention finally the gantry crane—the tool for lifting and manipulation of beams and beam box-frames—has a 5 ton lifting capacity, 10 m span and length of track 140 m.

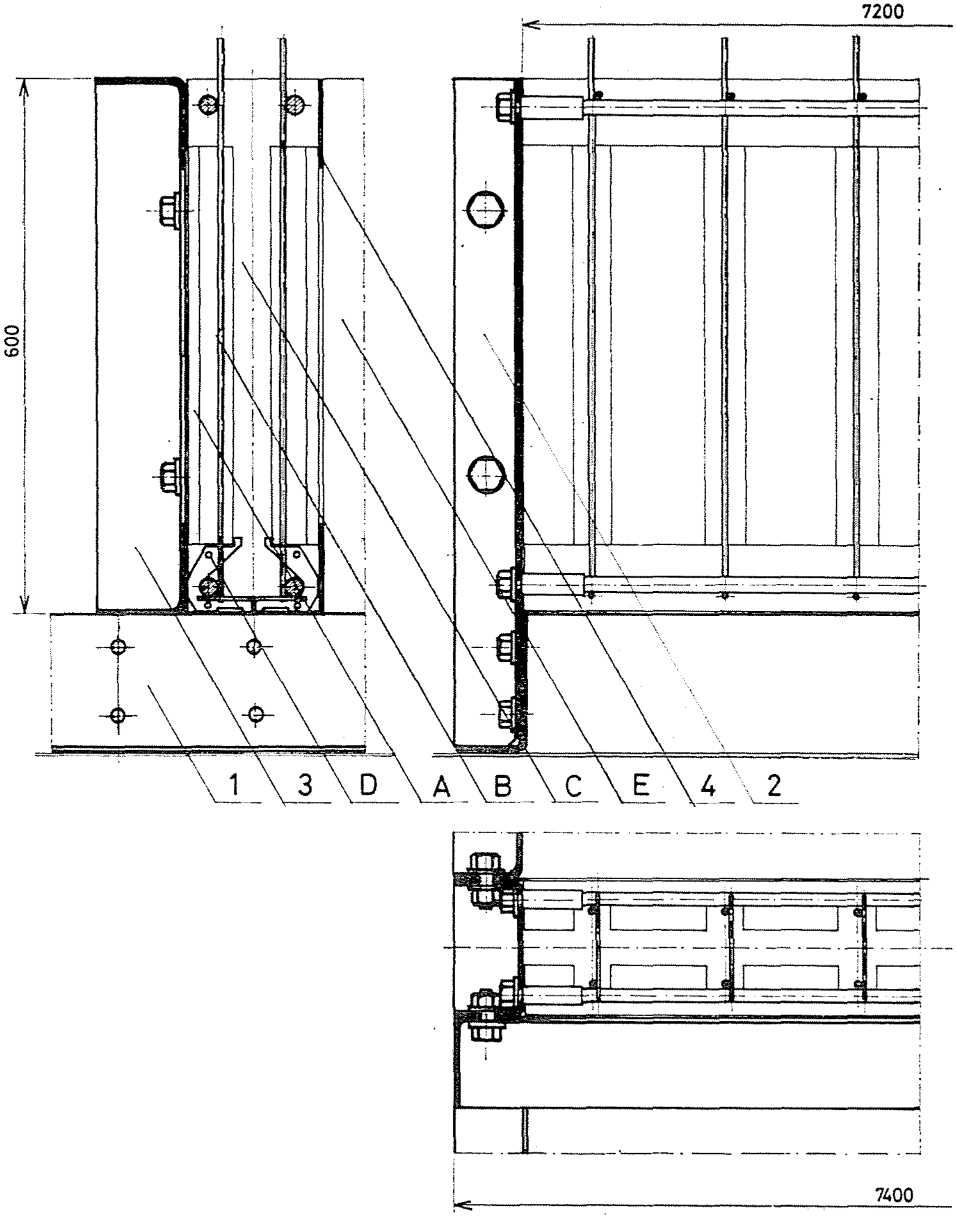
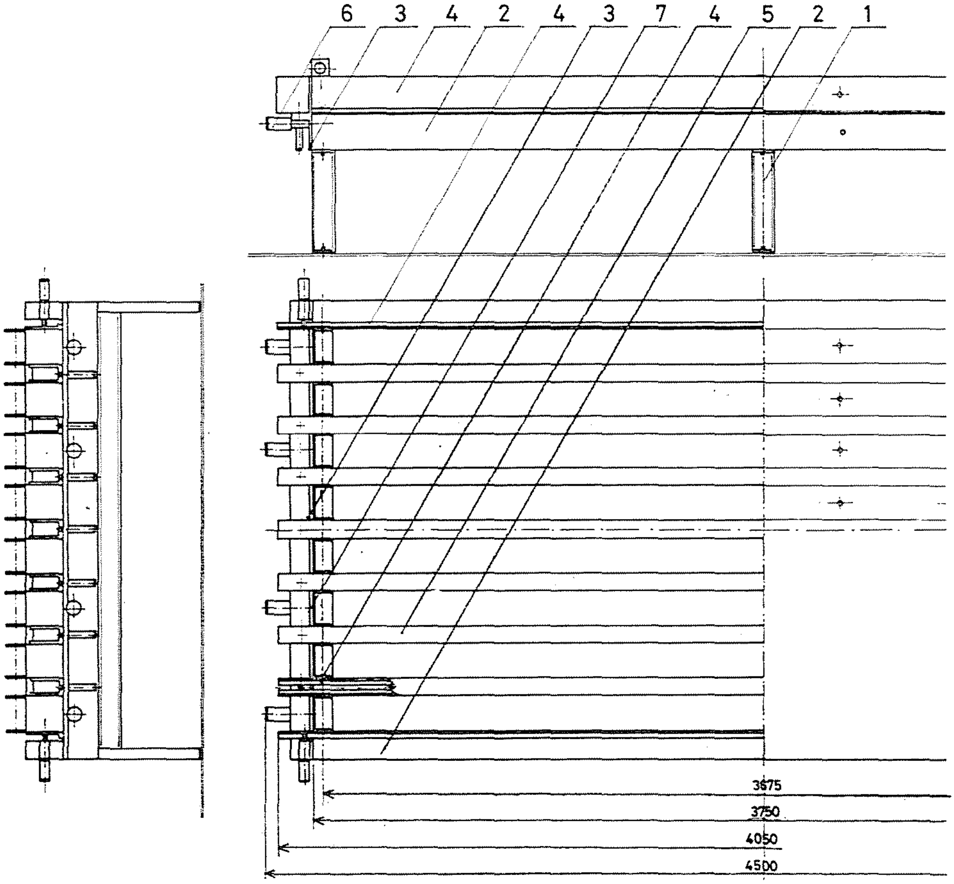


Fig. 20. Battery principled manufacture of tectonic beam elements (plane structural elements). Detail. Horizontal and vertical section through the transplantable closing frame. Index: A. periodic gypsum surface element; B. reinforcement; C. ribbed reinforced concrete shell; D. clips, plastic spacers; E. the finished preceding beam element. 1. L-profile edging the manufacturing plane; 2. ear, folded steel U-profile; 3. the transplantable closing frame; 4. graboplast stripes separating the upper and lower flanges of the beam elements

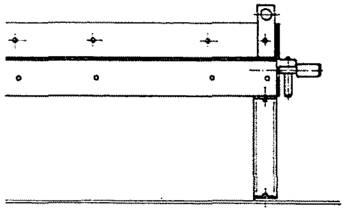


2b. *Open-air manufacturing plane for preassembly of heterogeneous beam box-frames (tectonic structural elements, small box-units).*

The heterogeneous beam box-frames are assembled on the same manufacturing plane on which the beam elements were produced (See also Fig. 16a and Fig. 16b). The *tools* required for the preassembly of heterogeneous beam box-frame are almost the same, the only difference is that the starting frame in this case is provided with periodic perforations corresponding to the heterogeneous jointing points embedded into the beam element.

The process of preassembly of heterogeneous beam box-frames (tectonic structural small box-units) involves the following *technological cycles:*

- location and fixing of the starting ears, then, location of starting frame and bolting it to the ears;
- putting down the beam element next to starting frame and fixing it temporarily with clips;
- jointing the steel diaphragms to the beam element;
- putting down the next beam element next to the steel diaphragms and jointing the beams to diaphragms with bolts;
- location of spacers at the end of the box-frame unit;
- putting down the first beam element of the second box-frame unit next to the spacers and fixing it temporarily.



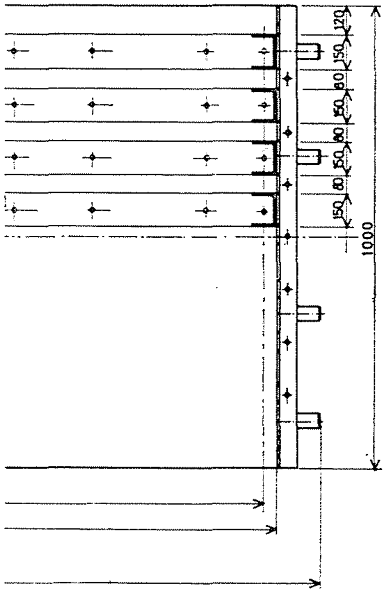


Fig. 21a; Fig. 21b. Stack plate for open-air manufacture of tectonic r.c. column elements (linear structural elements) in groups. Index: 1. foot; 2. pouring plate; 3. cross comb; 4. L-shaped longitudinal forming element; 5. spacer, closing rod; 6. fixing screw; 7. inlay element

In the following the technological cycles are periodically repetitive according to the above-said.

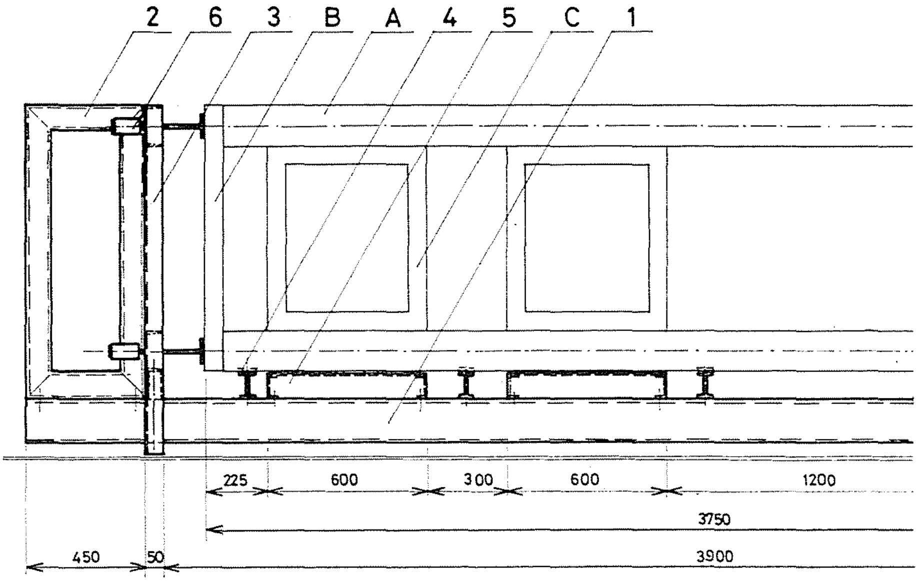
Preassembly of heterogeneous beam box-frame units is done by a four man brigade. Producing one beam box-frame takes 20 minutes, 20 beam box-frame units are produced daily. The brigade works alternately now at the end of this battery, now at the end of the other.

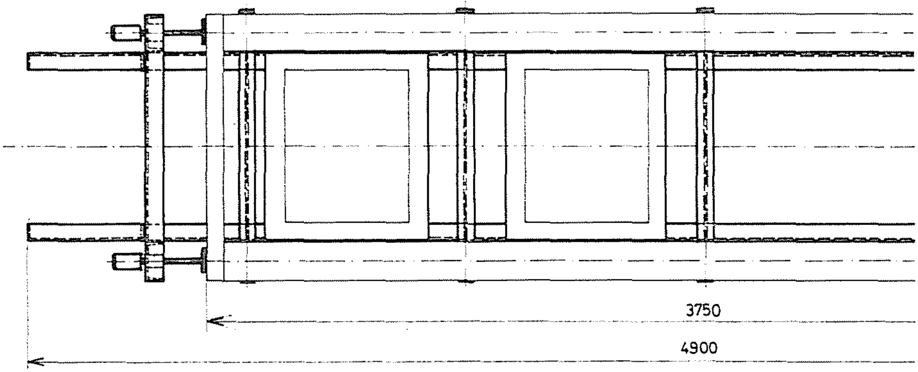
3. *Apparatuses for producing heterogeneous pillar skeletonframes*

3a. *Stack plate for open-air manufacture of tectonic reinforced concrete column elements (linear structural elements) in groups*

The stack plate — in this case a two-functional apparatus serving both for manufacture and storing — is composed of the following parts: (See: Fig. 21a.)

1. feet, constructed of U-profiles; 2. pouring plate: steel frame constructed of U-profiles covered with a steel plate, with 4—4 threaded periodic holes at butt ends; 3. cross combs with clampers — pressure bolts — at the ends with threaded spacing nipples driven out from below; 4. L-shaped longitudinal forming element; 5. longitudinal rods, upwards removable elements for spacing the longitudinal forming elements and for closing down the space between; 6. supporting and claming elements screwed to the threaded periodic holes of the pouring plate; 7. inlay elements forming the ends of the columns, also used for lifting out the column elements from the apparatus.





On the stack plate eight r.c. column elements can be manufactured in one row. The process of manufacture of tectonic r.c. column elements (linear structural elements) involves the following *technological cycles:*

Location and fixing of cross-combs,—driving out the spacing nipples from below — location of longitudinal forming elements in the intermediate positions — location and fixing of the longitudinal forming elements on the brinks—location of inlay elements at the end of the columns—location of the prepared welded reinforcement of the columns—concreting, smoothing the upper surface.

Manufacture is done by a four man brigade on a manufacturing line determined by the track of the overhead trolley (See also Fig. 16a and Fig. 16b). Producing 8 elements (one row) takes 1,5 hour; forms can be stripped the next day; hardening takes one week; the elements are lifted out one by one by the overhead trolley with a balance frame jointed to the inlay elements at the ends and transported to the assembly bench. Five stack-plates are completed daily. The number of stack-plates: 30 pcs.

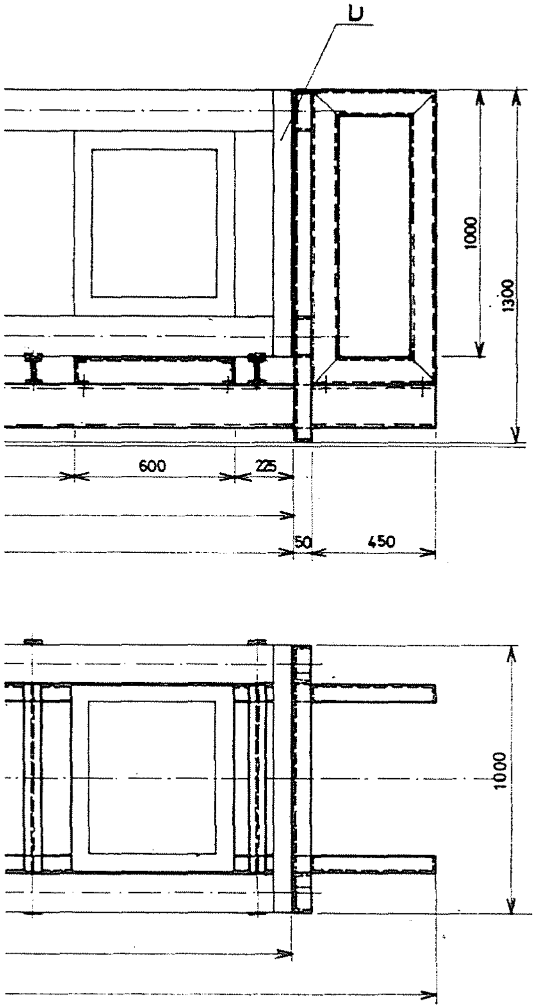


Fig. 22a and Fig. 22b Bench for preassembly of heterogeneous pillar skeleton frames (tectonic structural small box-units). Index: A. R.c. column element; B. Upper cradle; C. Diaphragm; D. Lower cradle; 1. longitudinal beam; 2. longitudinal stiffening frame; 3. Cross stiffening frame; 4. Cross-beam; 5. Box element; 6. Pressing spindle

3b. *Bench for preassembly of heterogeneous pillar skeleton frames (tectonic structural small box-units)*

The apparatus—shown by Fig. 22a and Fig. 22b—is composed of the following parts: 1. U-profiled longitudinal beams; 2. Longitudinal stiffening frame constructed of U-profiles screwed to longitudinal beams; 3. Cross stiffening frames also used for legs, screwed to longitudinal beams and stiffening frames; 4. I-profiled cross-beams supplied on the one end with a bumping plate, welded to longitudinal beams, serving for supporting the "lower" r.c. column elements (A) layed immediately on the bench; 5. Box-elements constructed of U-profiles covered on the top with a steel plate, screwed to the longitudinal beams, serving for supporting the steel diaphragms (C) layed immediately on the bench; 6. Pressing spindles driven through the threaded bores of the cross-frames, serving for pressing the cradles (B and D) to the butt-ends of the r.c. column elements and for adjusting the exact geometric shape of the pillar skeleton-frame.

The technological cycles are as follows:

- location of the "lower" cradle (D) of pillar skeleton-frame and fixing it to the cross stiffening frame;
- location of the first r.c. column element removed from stack-plate by overhead trolley on the I-profiled cross-beams, banging it against the bumping plates, slipping the element axiswise into the cradle by means of the pressing spindle and pressing it to the cross stiffening frame;
- location of the two "upper" (final) diaphragms and one "lower" (temporary) diaphragm on the box elements, screwing them "loosely" to the already located column element;
- location of the second r.c. column element removed from stack-plate by overhead trolley on the I-cross-beams banging it sideways against the diaphragms, slipping it axiswise into the cradle by means of the pressing spindle and pressing it to the cross stiffening frame;
- screwing the diaphragms at right angle to the bench to the reinforced concrete elements from inside;
- location of the third and fourth column elements on the vertical diaphragms slipping them axiswise into the cradle, pressing them to the cross stiffening frame and screwing to the vertical diaphragms;
- screwing the last "horizontal" diaphragms to the r.c. column elements;
- unfastening of the pressing spindles, location of the "upper" cradle (B), pressing it with the spindles and screwing it from inside to the column elements;
- location of the fixing profiles into the cradles and fixing them from inside to the columns and to the cradles;
- unfastening of the pressing spindles, removing the ready unit with the overhead trolley.

Preassembly of one unit takes 45 minutes with a four-man brigade, 10 pillars skeleton-frame units are assembled daily. The number of benches: 2 pcs.

Assembly

The sequence of operations on the building site

The process of assembly in the lift-cell building method is shown in Fig. 21a. and Fig. 21b. The axonometric drawings always represent the operations completed. In the text to follow all the 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 exactly the zero level of co-ordination proceeding from the unprecise towards the precise through assembly of the auxiliary structures of the zero level of co-ordination and on the other hand to assure precise structural junction for pillar skeleton-frames. The cycle is composed of three subsequent operations:

- first: soil preparation and making of unprecise foundations for pillars; location of levellable auxiliary structures for exact positioning of the anchoring rods to be embedded into the calyxes of foundation and the load-distributing steel-frames for exact determining of the zero level under the pillars and the position of the cradles;

- second: concreting the zones between the exact pillar foundations calling into being thereby the exact 0,00 level underneath the beam zones; and
- finally: concreting the exact 0,00 level underneath the cellular floor-fields using the already finished parts as "leading stripes".

2. *Location and junction of heterogeneous pillar skeleton-frames and beam box-frames*

a. *Location of pillar skeleton-frames:* the elementary technological cycle is composed of the following two operations:

- lifting the pillar skeleton-frame unit into in-situ position by means of a mobile crane, precise adjusting by means of auxiliary "etalon" frames and levellers;
- fixing the pillar: creating heterogeneous junction on zero level between pillar and foundation through bolting the cradle to the threaded anchoring rods embedded into foundation; on other levels between pillar and pillar through bolting the cradle to the upper cradle of the pillar below.

b. *Location of beam box-frames:* the elementary cycle in this case is composed of five operations. These are as follows:

- bolting the elements of the steel auxiliary structure used for temporary supporting of the beam box-frames and ensuring at the same time the final concreting of the "tolerance-gap" arising between columns and butt-ends of beams to the heterogeneous jointing points embedded into the columns of the pillar skeleton-frames;
- location of beam box-frame unit on the auxiliary structural elements mentioned above;
- creating heterogeneous junction between columns and beam;
- pouring in of concrete into the tolerance gaps between columns and butt-ends of beams;
- removing the auxiliary steel structures the day after concreting

3. *Calling into being the complete skeleton structure of the multi-level communal building:* with the in-situ assembly of the mechanization-principled, tectonic structural small box-units — that is the pillar skeleton-frames and beam box-frames — the first characteristic period of the building process is concluded. The skeleton structure arises level by level. (In the second period of the building process the complete-floor-structure is called into being, as we shall see.)

4. *Assembly of the cellular floor-fields underneath in-situ position, field by field, immediately on top of each other.* The elementary technological cycle is composed of the following four operations:

- *assembly of auxiliary structures for floors:* Location of the corner-coordinator for determining the corner of all three floor-fields on top of each other,

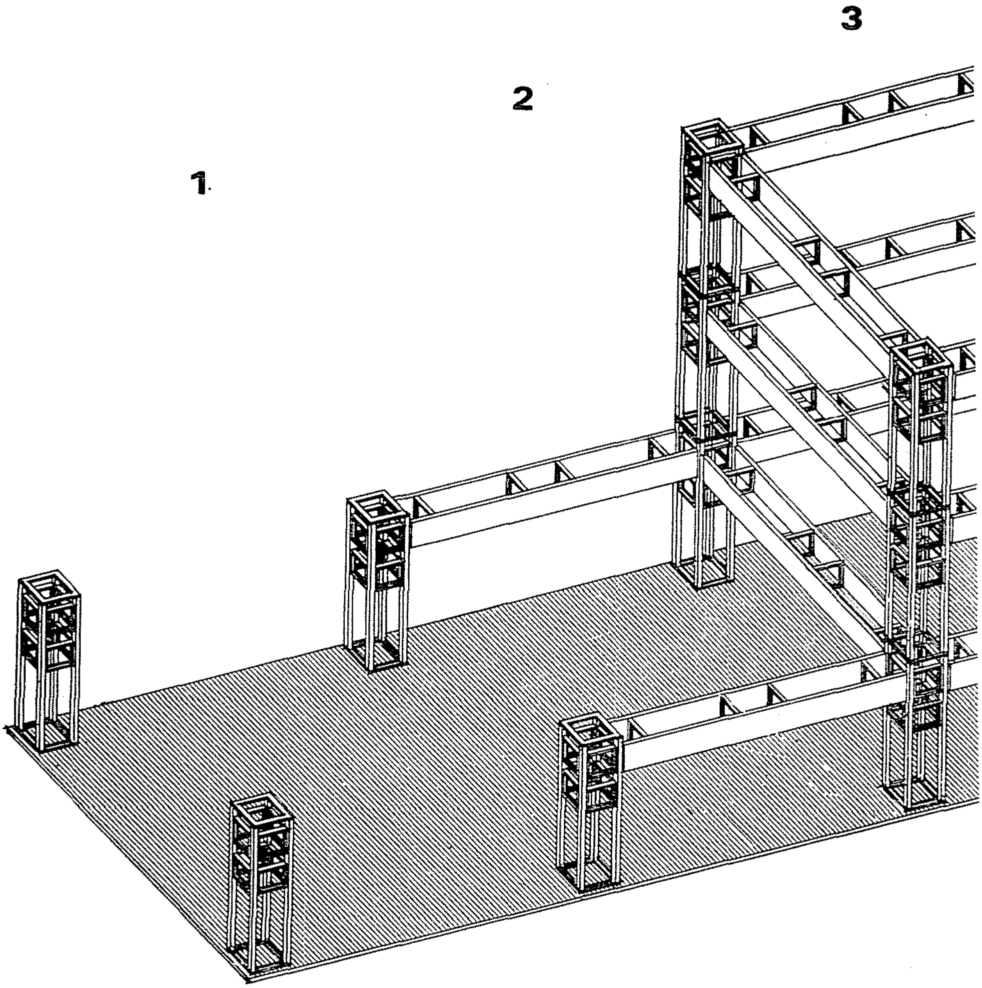


Fig. 23a. The lift-cell building method. Assembly: Basic technological cycles. 1. creating the zero level of co-ordination; 2. location and junction of heterogeneous pillar skeleton-frames; 2. location and junction of heterogeneous beam box-frames; 3. calling into being the complete skeleton structure of the multi-level building

adjusting the tolerances and fixing the co-ordinator to the heterogeneous jointing points embedded into column; location of the steel auxiliary frames used for casing the perimeters of the first floor-field, determining exact position of reinforcement of the ribs and keeping the heterogeneous lifting points in exact position; jointing the auxiliary frames to the corner — co-ordinators and to each other;

— *assembly of cellular gypsum surface-of-floor elements:* manual location of cellular surface elements ranging in two directions; laying plywood spacing strips next to the casing frames to ensure dimension of the perimeter ribs

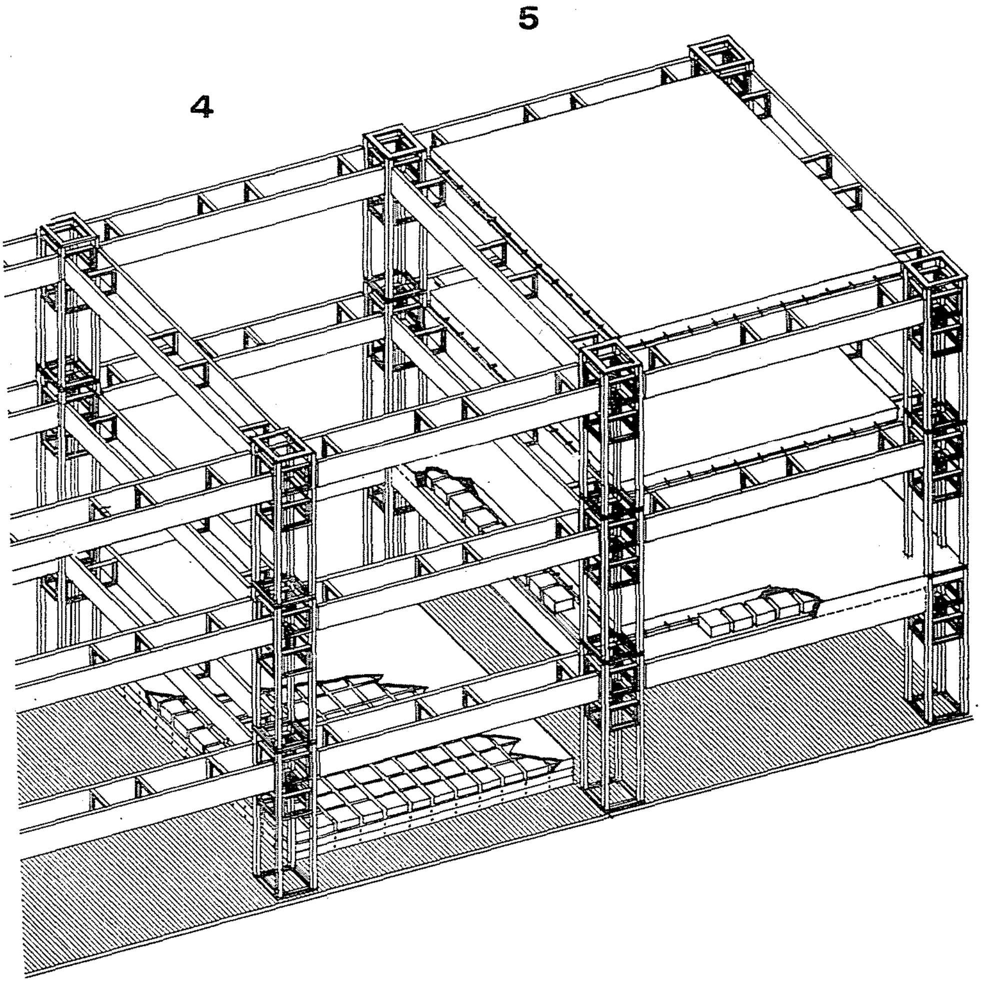


Fig. 23b. The lift-cell building method. Assembly: Basic technological cycles. 4. assembly of the cellular floor-fields underneath in-situ position, immediately on top of each other; lifting the cellular floor-fields one by one into in-situ position; assembly of cellular floor-zones above the beam box-frames; final concreting

and location of timber battens for fixing later on the timber stripes used for casing the final pouring from below;

— *assembly of reinforcement of floor-fields:* location of the "stack" — reinforcement of the two-way ribs on the levelling points fixed to the casing auxiliary frames, ensuring proper intermediate position with spacing rings, fixing the heterogeneous lifting points to the reinforcement and adjusting vertical position by jointing them to the casing auxiliary frames; location of mesh wires in stripes for tissue structural floor;

— *concreting* in stripes using pumps for pouring of concrete, manual smoothing

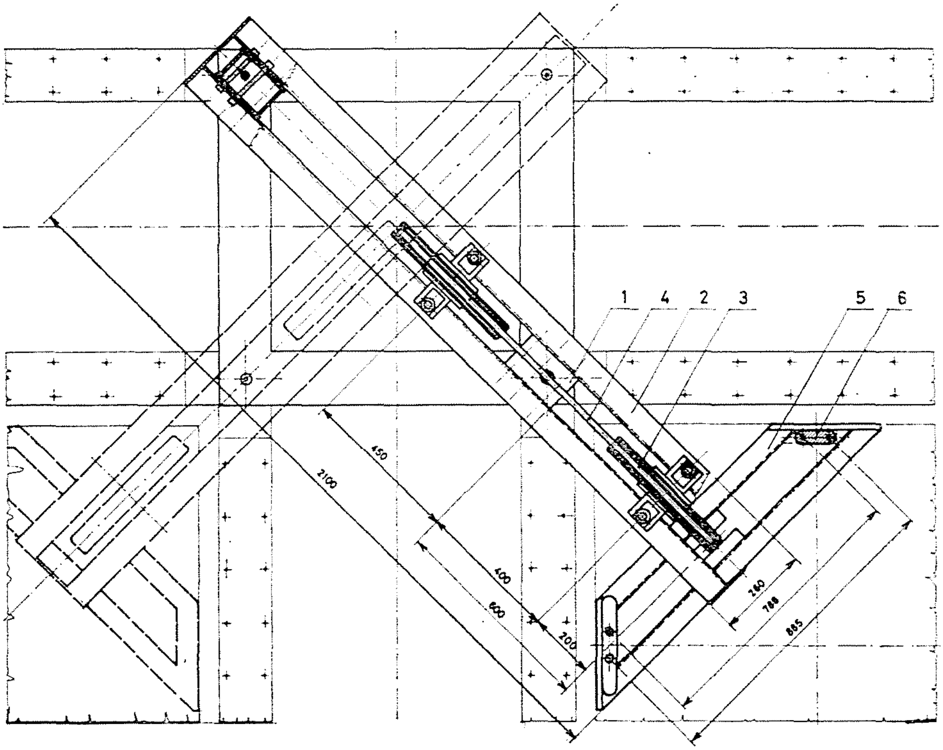


Fig. 24. Lifting equipment integrated with the structure: lifting cantilever jointable in four positions to columns of the uppermost pillar skeleton-frame and lifting bridge fixed to the lifting points of cellular floor-fields. Plan. 1. leg; 2. lifting cantilever; 3. rope-wheel; 4. lifting rope; 5. lifting bridge; 6. pressing bolts

of upper surface using "etalon" rods for ensuring the thickness of the r.c. shell;

The operations mentioned above are repeated three times, field by field, above one another.

5. *Lifting the cellular floor-fields into in-situ position; assembly of cellular floor-zones above the beam box-frames.*

The elementary technological cycle is composed of three operations, as follows:

- *assembly of auxiliary structures for floor-zones above beam box-frames* on all three levels above each other and by fields; location of ladders in the pillar skeleton frames; location of gangways on the lower flanges of steel diaphragms of beam box-frame; assembly of auxiliary structures for floor-zones jointing them to the upper flanges of the beam elements;
- *lifting the cellular floor fields:* fixing the upper lifting bridge, i.e. the lifting cantilever to the top of pillars on the uppermost level (Fig. 24.); location

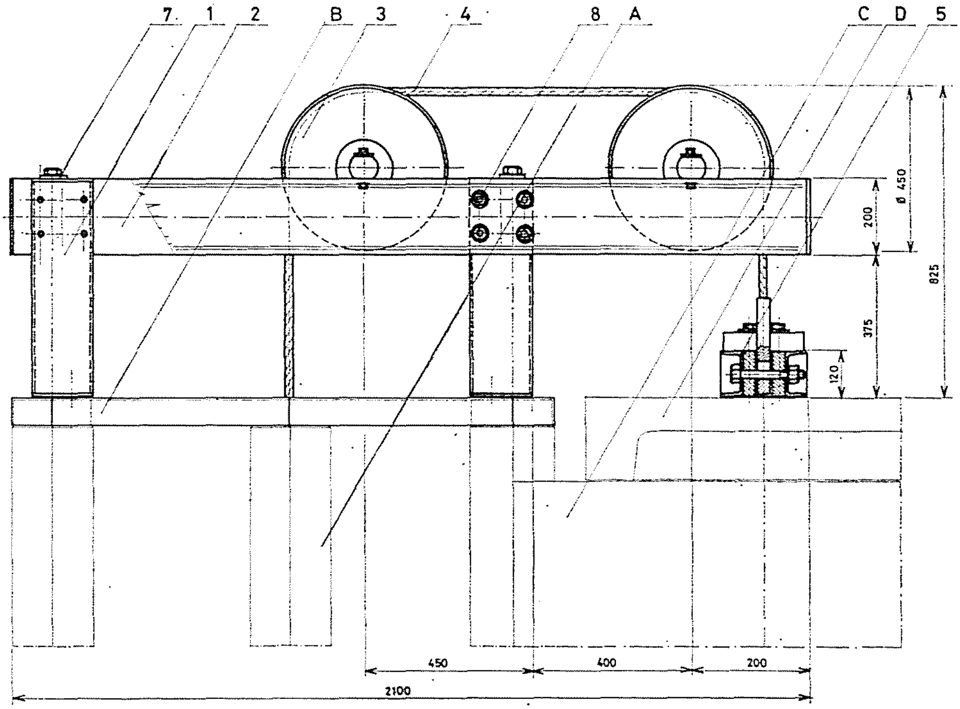


Fig. 25. Lifting equipment integrated with the structure: lifting cantilever jointable in four positions to columns of the uppermost pillar skeleton-frame and lifting bridge fixed to the lifting points of cellular floor-fields. Section. A. column element of pillar skeleton-frame; B. upper cradle of pillar skeleton-frame; C. beam element of beam box-frame; D. the uppermost cellular floor-field lifted; 1. leg; 2. lifting cantilever; 3. ropewheel; 4. lifting rope; 5. lifting bridge

of the lower lifting bridge at the corners of the uppermost cellular floor and fixing them to the lifting points (Fig. 25.); location of crabs within the pillar skeleton-frames and fixing them to the anchoring bolts embedded into foundation; threading in the ropes; fixing rope-ends to the lifting bridges; putting out the cellular surface elements necessary for assembly of floor-zones on top of the floor-field to be lifted; lifting; inserting the steel supports — "doglegs" — into the steel tubes embedded into butt-ends of ribs; lowering floor-field back on the supports; lifting the next floor-field in the same way; threading out the ropes; turning off or transplanting the upper lifting bridge; transplanting the crab; removing the lower lifting bridge.

— *assembly of floor-zones above beam box-frames, completing the homogeneous junction of floor structures:* assembly of the cellular surface-of-floor elements in in-situ position above the beam box-frames on the auxiliary structures; closing the tolerance-zones from below; location of reinforcement of the two-way ribs and the structural tissue; simultaneous concreting of floor-zones above beam box-frames and tolerance-zones around the lifted floor-field; removing auxiliary structures and gangways after hardening of concrete.

The operations mentioned above are repeated three times, downwards.

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