# NON-TECTONIC SYSTEMS: BASIC BUILDING METHODS AND PRINCIPLES OF CONSTRUCTION*

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## Abstract

The non-tectonic building methods exemplify the possible adaptations of the non-tectonic systems for mass construction of dwellings, communal and industrial buildings. These fundamentally new, open, light-weight silicate-based building methods of particular technological relevance for hot arid tropical areas are equally realizable by planted or transplantable factories and have been designed in such a way as to give optimum solutions for social-sociological, technical-economic, climatic-geographic, architectural-constructional requirements which ever keep changing in space and in time. The scientific results of the research work — carried out in the Institute of Building Constructions, Technical University Budapest since the early seventies — have been summarized in twelve theses in our previous article entitled "Characteristic features of the non-tectonic systems" and this article is its immediate continuation.

In this study — exclusively devoted to the detailed analysis of the non-tectonic building methods and their principles of construction — we put a special emphasis on the expounding and illustration of these principles. The non-tectonic systems are based on the recognition that tectonics is not the only possible axiom of building and the basic building methods — the in-situ, the lifting, the box-unit, the box-frame unit, the closed-cellular, the lift-cell and the tilt-lift building methods — give a definite 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. The basic building methods in themselves and even in their complements can expediently be combined with each other as well, and thereby the non-tectonic systems really establish almost boundless possibilities for the architect and the constructor for solving problems of the various tasks.

## Introduction

This study is an immediate continuation of our previous article entitled "*Characteristic features of the non-tectonic systems*" in which we dealt with the mass adaptation of the non-tectonic systems, or rather some fundamental theoretical and practical problems of the adaptation.

This study is exclusively devoted to the detailed *analysis of the non-tectonic building methods and their principles of construction*. Let us remark here by way of introduction, that the basic building methods — the in-situ, the lifting, the box-unit, the box-frame unit, the closed cellular, the lift-cell, and the tilt-lift building methods — can expediently be combined with each other as well.

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## 1. The in-situ building method

The in-situ building methods is characteristically connected with the low and medium degree of complementarity, as follows:

*Short description: 1. A In-situ building method*

| | |
|---|---|
| | — *on low degree of complementarity (on low degree of readiness in the factory);* |
| | — *on applying the surface as principle of construction;* |
| in design: | — housing and communal buildings (variations on plan and in section); |
| in the factory: | — on one-fold disintegration (on *Gutenberg*-principled decomposition); |
| on the site: | — on the in-situ additivity of surface elements (on calling into being the loadbearing structure exclusively on the building site). |

**Characteristic features of the in-situ building method in case of low degree of complementarity (1. A)**

*In the workshop* non-tectonic surface elements are produced exclusively, so disintegration is one-fold and *Gutenberg*-principled; additivity in the factory is zero since the elements are not rendered tectonic either individually or in jointed form.

*On the site* all the surface elements of the vertical and horizontal load-bearing structures are assembled immediately in their final position, so the additivity on the building site is in-situ and final, which means that the load-bearing structure is called into being exclusively on the building site through pouring in of concrete.

*Short description: 1. B In-situ building method*

| | |
|---|---|
| | — *on medium degree of complementarity (on medium degree of readiness in the factory);* |
| | — *on applying the surface as principle of construction;* |
| in design: | — housing and communal buildings (variations on plan and in section); |
| in the factory: | — on two-fold disintegration (on *Gutenberg*-principled and mechanization-principled decomposition), |
| | — on preassembly of plane structural elements; |

on the site: — on the in-situ additivity of surface elements and plane structural elements
(on calling into being the loadbearing structure determined by the surface elements through in-situ pouring in of concrete, on location of tectonic plane structural elements in in-situ position, and final pouring).

## Characteristic features of the in-situ building method in case of medium degree of complementarity (1.B)

The method of disintegration changes. The decomposition here is two-fold (*Gutenberg*-principled and mechanization-principled); the degree of readiness in the factory increases to "medium" level.

*In the workshop* not only non-tectonic surface elements are produced any more but we already start rendering them tectonic either individually or in jointed form, that is to say we already start the production of tectonic, plane structural elements.

*On the site* we call into being the load-bearing structure on the one hand through in-situ alignment of non-tectonic surface elements and pouring in of concrete, on the other hand through location of tectonic plane structural elements in-situ position and final pouring.

## Variability of the in situ building method

Amongst the non-tectonic system the variability of the in-situ building method is of the highest degree, since in this case the surface as principle of construction can be enforced the most clearly both in the factory and on the building site; since the sizes and increments of the elements and components — including their thicknesses as well — can be the most freely chosen; since the degree of complementarity of the building method can be the lowest, since there is no inevitable need of additivity in the factory, consequently the degree of freedom of planning is relatively the least restricted.

## The surface as principle of construction

*The in-situ building method* — the first possibility of the non-tectonic systems — *is founded on surface as principle of construction.* (Fig. 1)

The non-tectonic systems break with the axiom of tectonics and substitute it for the principle of surface. This — as we have seen — simply means that in these systems the immediate object of manufacture is not the loadbearing structure but its surface.

## The surface as principle of construction, in general

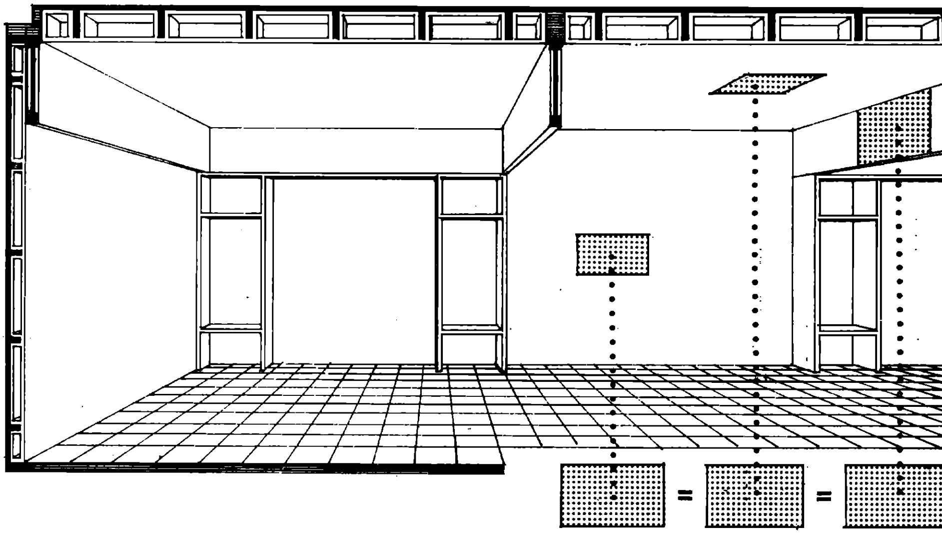


*Fig. 1. The surface as principle of construction, in general.* The non-tectonic systems break with the axiom of tectonics and substitute it for the principle of surface. This simply means that in these systems the immediate object of manufacture is not the loadbearing structure but its surface. The surface elements of the loadbearing structure are of low specific gravity (they are mostly made of gypsum), consequently they have no carrying capacity; they are very thin, after all they are a skin construction and thus they have no immediate stability either. In brief: they are non-loadbearing, non-tectonic elements.

The non-tectonic elements with their glass-smooth surface on their final visible side never "betray" what they are the surface of, they are aesthetically neutral and semantically meaningless, in brief: they are Gutenberg-principled

The surface elements of the loadbearing structure are of low specific gravity (they are mostly made of gypsum), consequently they have no carrying capacity; they are very thin, after all they are a skin construction and thus they have no immediate stability either. In brief: they are non-loadbearing, non-tectonic elements to be kept in position by simple regainable auxiliary structures during concreting.

As a consequence of the moisture absorbing capacity of gypsum, the concrete — poured into the very thin cavities and channels arising between the surface elements — become stabilized almost immediately: it freezes on the gypsum.

The new — non-tectonic — construction arising as a result of this process is a light-weight, silicate-based, rigid, monolithic r.c. structure and as such it is really unique in the industrialized building.

## The surface as a universal principle of construction

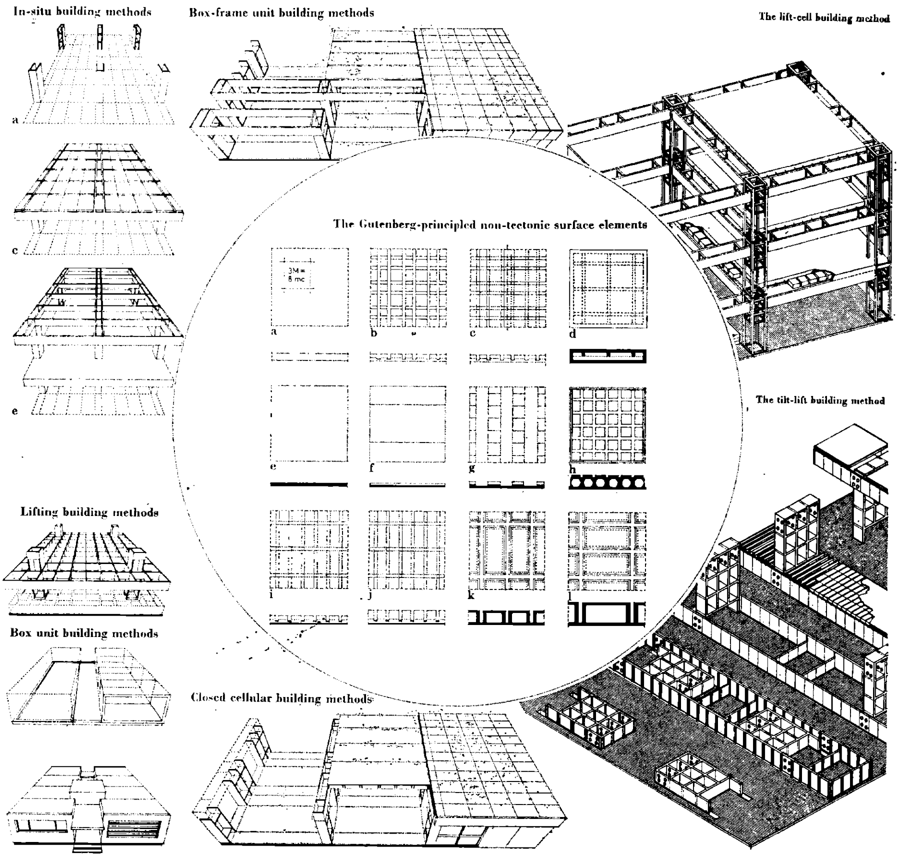



*Fig. 2. The surface as a universal principle of construction.* In the non-tectonic building the surface as principle of construction is universal, since in each building method the immediate object of manufacture is the surface of the loadbearing structure, consequently there is no such non-tectonic building method which could eliminate the application of the surface as principle of construction, as also illustrated by the figure, symbolically

## The universality of the surface as principle of construction in the non-tectonic building

*In the non-tectonic building the surface as principle of construction is universal,* since in each building method the immediate object of manufacture is the *surface* of the load-bearing structure, consequently there is no such non-tectonic building method which could eliminate the application of the surface as principle of construction (Fig. 2).

In the building methods of low degree of complementarity the surface as principle of construction is always enforced explicitly, whereas in those of medium and high degree of complementarity (working with the grid, cell, box etc. as principles of construction) it is carried into effect implicitly.

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. nontectonic — 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 a 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.

## 2. The lifting building method

The lifting building method can equally be realized on low and on medium degree of complementarity, as follows:

| | |
|---|---|
| *Short description:* | *2.A Lifting building method* |
| | — *on low degree of complementarity (on low degree of readiness in the factory);* |
| | — *on applying the grid as principle of construction;* |
| in design: | — communal and industrial buildings (variations on plan and in section); |
| in the factory: | — on one-fold disintegration (on *Gutenberg*-principled decomposition); |
| on the site: | — on the additivity of surface elements in in-situ or underneath in-situ position (on calling into being the load-bearing structure partly through in-situ assembly partly through a preassembly operation underneath in-situ position). |

### Characteristic features of the lifting building method in case of low degree of complementarity (2.A.)

*In the workshop* exclusively surface elements are produced, so disintegration is one-fold and *Gutenberg*-principled; additivity in the factory is zero since the elements are not rendered tectonic either individually or in aligned form.

*On the site* all the vertical structures are assembled immediately in their final position, whereas the horizontal primary structures are first preassembled underneath the final in-situ position, then lifted into in-situ position and fixed by heterogeneous or homogeneous junction. The additivity of surface elements on the building site underneath the final in-situ position is a characteristic feature of the building method.

*Short description: 2.B Lifting building method*

| | |
|---|---|
| | — *on medium degree of complementarity (on medium degree of readiness in the factory);* |
| | — *on applying the grid as principle of construction:* |
| in design: | — communal and industrial buildings (variations on plan and in section); |
| in the factory: | — on two-fold disintegration (on *Gutenberg*-principled and mechanization principled decomposition), |
| | — on preassembly of plane structural elements; |
| on the site: | — on the additivity of surface elements in in-situ or underneath in-situ position (on calling into being the load-bearing structure partly through in-situ assembly partly through preassembly operation underneath in-situ position), |
| | — on location of plane structural elements in in-situ position and final pouring. |

**Characteristic features of the lifting building method in case of medium degree of complementarity (2.B)**

*In the workshop* the method of disintegration changes, the decomposition here is two-fold (*Gutenberg*-principled and mechanization-principled); the degree of readiness in the factory is increasing to "medium" level. In the workshop, namely, we start the preassembly of the surface elements (manufactured on the basis of the *Gutenberg*-principled decomposition) into plane structural elements (manufactured on the basis of the mechanization principled decomposition) of parameter-size at least in one direction.

*On the site* the vertical structures are assembled in final in-situ position whereas the horizontal structures are first preassembled underneath in-situ position, then lifted into in-situ position and fixed by heterogeneous or homogeneous junction. After location in in-situ position the plane structural elements and fixed by final pouring.

The in-situ additivity characterizing the building method again spell preassembly underneath in-situ position.

## The grid as principle of construction

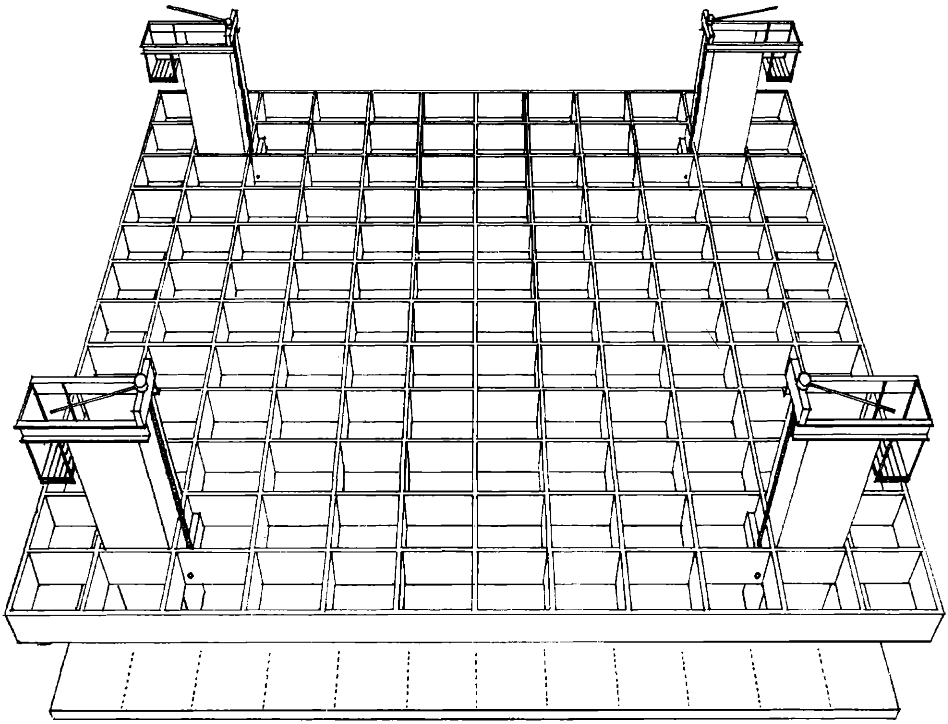
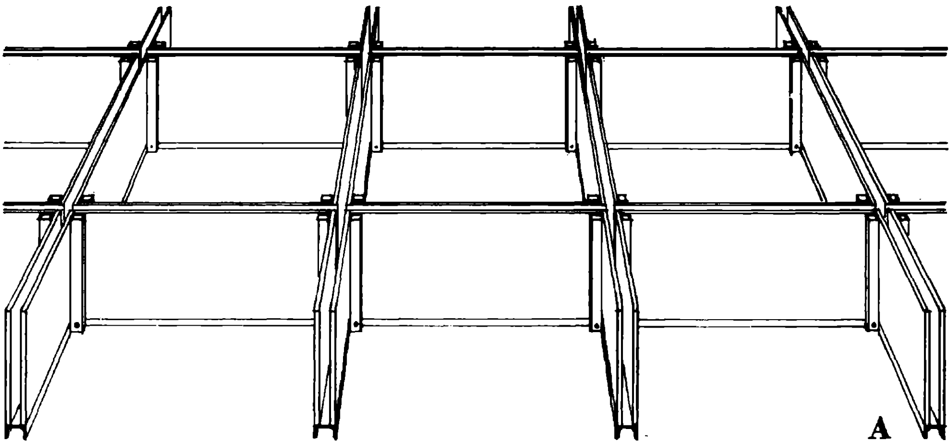


*Fig. 3. The grid as principle of construction.* The lifting building methods are founded on the grid as principle of construction. The architect here works with grids visibly appearing as a primary — cellular — structure (see also: Fig. 4) determined by the form of the gypsum surface elements and rigdified by the two-way reinforced concrete membrane poured in-between the gypsum elements, and accepts that the horizontal grid and the folded shell pillers can only be jointed (by homogeneous, or heterogeneous junctions) at jointing point designated by the perforation of the gypsum elements. It is very important to note here that in the lifting building methods *the grid as principle of construction* is inseparably connected with the principle of the technology of lifting, more accurately: with the *principle of lifting through integration of the lifting equipments with the vertical loadbearing structure itself*, and therefore we tried to illustrate these two principles simultaneously: the figure shows the empty beam-grid (field-unit) built underneath the in-situ position lifted continuously with spindle driven by hand through mechanical transmission; the lifting equipments are fixed on top of the in-situ pillars

## Variability of the lifting building method

Amongst the non-tectonic systems the variability of the lifting building method is of medium degree, since in the systems applying the grid as visible structural form the selection of the sizes and increments of the elements and components is relatively more restricted than in the in-situ building method. The degree of freedom of planning is further decreased since the position of walls is restricted by the grids.




**The grid and the cell as principles of construction**

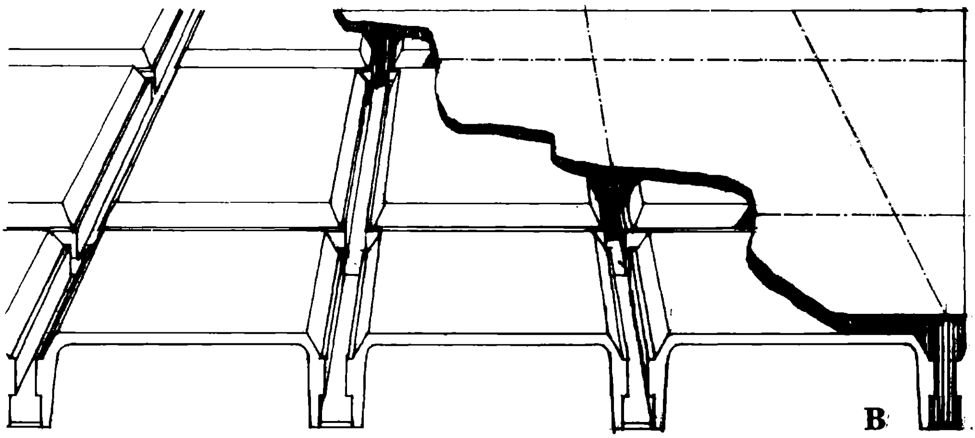



*Fig. 4. The grid and the cell as principles of construction.* In the non-tectonic systems the cellular structures — more accurately: the visible cellular forms of the primary loadbearing structures — can be realized in two ways: through applying the grid or the cell as principles of construction.

If *grid* is applied as principle of construction — and this is the case of the *lifting building methods* — then we work with plane gypsum surface elements. These two-dimensional non-tectonic wall-of-cell elements are semantically meaningless, they have no carrying capacity and no immediate stability;

If *cell* is applied as principle of construction — and this is the case of the *lift-cell building methods* — then the work with cellular gypsum surface elements. These three-dimensional surface-of-cell elements (gypsum small space elements) are already semantically meaningful (in so far as they determine a visible form) they have no carrying capacity after all they are non-tectonic) but, as a result of their cellular form, they do have an immediate stability

## The grid as principle of construction

*The lifting building method* — the second possibility of the non-tectonic systems — *is founded on the grid as principle of construction* (Fig. 3). The architect here works with grids visibly appearing as a primary structure — cellular — (see also: Fig. 4) determined by the form of the gypsum surface elements (or by that of the auxiliary structures) and rigidified by the two-way reinforced concrete membrane poured in between the gypsum elements (or, in case of freezing from inside, around the gypsum elements), and regards this as the leading idea. Thereby, however, the architect has to adapt himself to the restrictions of the grid. He accepts that the horizontal grid and folded shell pillars can only be jointed (by homogeneous or heterogeneous junction) at jointing points designated by the perforation system of the gypsum elements, and designs the building according to this.

Since, however, the buildings, in their solutions on plan and in section can be reduced — in the last analysis — to the additivity of the semantically meaningless *Gutenberg*-principled surface elements, therefore there opens a relatively broad possibly for the selection of sizes of spans, interior heights, grid-heights etc. without having this tendency run counter the grid as principle of construction.

### 3. The box-unit building method

The box-unit building method can only be realized on high degree of complementarity since its characterizing structural unit — the box-unit — is a large space element and as such it is unavoidably connected with the high degree of readiness in the factory. The building method expediently calls into being its structures with a combination of three materials (polystyrene + gypsum + reinforced concrete).

*Short description:* *3. Box-unit building method*

— *on high degree of complementarity (on high degree of readiness in the factory);*
— *on the simultaneous application of the slab and the box as principle of construction;*

in design:
— housing (variations on plan and in section on one or two level arrangements);

in the factory:
— on two-fold disintegration (on *Gutenberg*-principled and mechanization principled decomposition);
— on preassembly of plane structural elements and large space units;

on the site:
— on the in-situ additivity of large space units and plane structural elements (on location of box-units and plane structural elements in in-situ position and final pouring).

### Characteristic features of the box unit building method

*In the workshop*, or more accurately: *in the planted factory* we not only produce *Gutenberg* principled non-tectonic (gypsum + polystyrene) surface elements but at the same time we also begin to preassemble these surface elements first into mechanization principled tectonic plane structural elements (that is wall, or floor elements), and then into large space elements (that is box-units); the additivity in the factory, thus, is already an additivity "in-space".

*On the site* the tectonic large-space elements (the box-units) and the plane structural elements (the wall and floor units) are assembled immediately in final (in-situ) position.

### Variability of the box-unit building method

Amongst the non-tectonic systems the variability of the box-unit building method is *of the lowest degree* since the system — simultaneously founded on the slab and the box as principles of construction — allows only a very restricted selection of sizes and increments for the elements and components as compared to any other non-tectonic building method. At the same time the degree of complementarity of the elements is the highest since additivity in the factory may reach a maximum, consequently the freedom of planning is relatively the most restricted.

### The slab as principle of construction, in general

*The slab as principle of construction* — as it is known — is closely connected with the housing factories, more accurately: with the panel building method, that is one of the most widely spread practice of the industrialized housing of our age. Its basic units, namely, the large panels are slabs of parameter size in two directions, constructed with different methods, of ceramic or of hydraulic materials, with reinforcement. This is regarded as the leading idea for manufactured houses. Thereby, however, the architect has to adapt himself to the severe restrictions of the structural system. He has to accept that these plane-units can only be jointed along the edges, can only have openings on the surface, etc. The architect uses these slabs to produce cells, more accurately said: boxes. Seeing that his units, the wall and floor panels are of parameter size in both directions, the boxes constructable will automatically be of parameter size in three directions. The number of variations designable on the basis of the structural system will depend on the sizes of the spans and widths of the floor panels. The claims for creating varied plans for dwellings will inevitably strengthen the tendencies towards increasing the spans, and it is exactly this tendency towards increasing the span — whilst maintaining the slab as principle of construction — which leads to the characteristic inner contradiction of the panel building method and this at the same time designates the reasonable limits of the application as well.

## The box as principle of construction, in general

*The box as principle of construction* is characteristically connected with the practice of the space-unit building methods. The architect here uses factory made stiffened space-units: boxes. He regards this as the starting thought for industrialized housing. He accepts that these space units can only be jointed at points and along lines, and uses these boxes for assembling the building. Since, however, these elements, the space-units, are automatically three dimensional, and what is more, are of parameter size in three directions, hence it follows:

first, that the variability of the box-unit building methods is an immediate function of the additivity of the manufactured large space units, which means a very limited variability, since these units are not only unworkable any more, but at the same time — as a consequence of the severe technological restrictions resulting from their parameter sizes in three directions — they almost have to give up the use of increments as well, from the very beginning;

second, that the demands of variability in the box-unit building methods again strengthen the tendency towards increasing the sizes of the horizontal parameters and it is exactly this tendency towards increasing the sizes — whilst maintaining the box as principle of construction — which again leads to almost insoluble inner contradictions in the space-unit building methods as well.

## The slab and the box as principles of construction in general, and in the non-tectonic systems

As opposed to the two above-mentioned fundamental mechanization-principled manufactured tectonic systems of the industrialized building which separate the slab and the box as principles of construction and apply them one by one within the systems,

*the box-unit building method* — realizable with the *Gutenberg*-principled manufactured non-tectonic systems which combine the blind manufacture of surface elements with the double complementarity of the building methods — *applies the slab and the box as principles of construction simultaneously and side by side within the system* (Fig. 5).

This is a fundamental difference because it means no less that the variability of the non-tectonic box-unit building method is never an immediate function of the manufactured plane- or space-elements but first of all that of the additivity of the semantically meaningless surface elements, and so the

**The slab and the box as principles of construction in general and in the non tectonic systems**

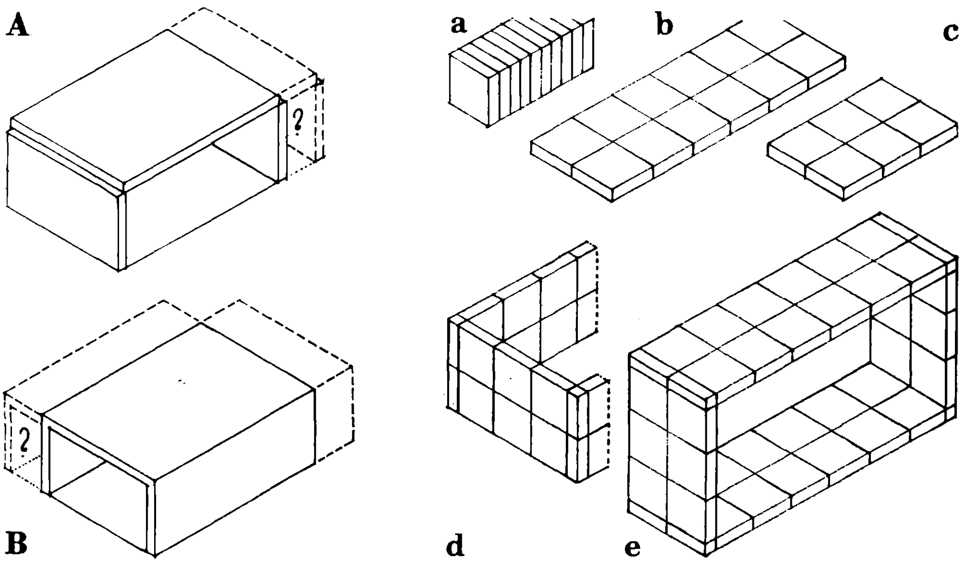



*Fig. 5. The slab and the box as principles of construction in general and in the non-tectonic systems.* The slab as principle of construction — as it is known — is generally connected with the panel building method, that is one of the most widely spread practice of the industrialized housing of our age, whereas the box as principle of construction is characteristically connected with the practice of the space unit building methods. The architect here uses factory made stiffened space-units: boxes. Since the inevitable tendency towards increasing the span (in the panel building methods) or the sizes of the parameters (in the space-unit building methods) runs counter the slab (A) or the box (B) as principles of construction therefore — in order to eliminate these disadvantages — the non-tectonic systems apply the slab and the box as principles of construction simultaneously and side by side within the system. In case of the *box-unit building method* the box units constituting the building are produced in a factory in such a way that first we manufacture the non-loadbearing surface elements (a) then the load-bearing plane (wall- and floor) structural elements (b, c) and finally we assemble them into rigid loadbearing box-units (d, e). On the site the building process is confined to the assembly of box-units

"closedness" of these systems resulting from their space-unit construction is rather relative as compared to the tectonic systems.

**The simultaneous application of the slab and the box as principles of construction**

*The box-unit building method* — the third possibility of the non-tectonic systems — *is founded on the simultaneous application of the slab and the box as principles of construction.* The architect in this case works on the one hand: with anisotropic tissue-structural slabs determined by the form of the gypsum (or gypsum + polystyrene) surface elements and rigidified by the ribbed reinforced concrete membrane poured in between and on top of the two-way chan-

## The simultaneous application of the slab and the box as principle of construction

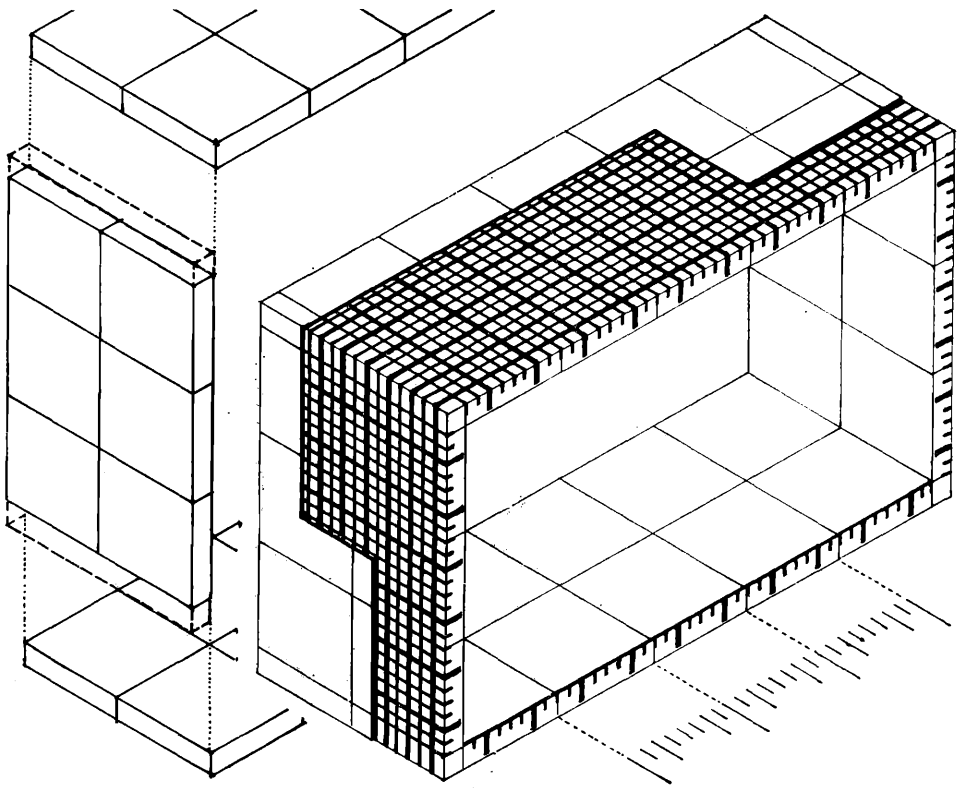


*Fig. 6. The simultaneous application of the slab and the box as principle of construction.* As opposed to the already mentioned panel building method and space unit building method (Fig. 5) which separate the slab and the box as principles of construction and apply them one by one within the system, the box-unit building method is founded on the simultaneous application of the slab and the box as principle of construction. The architect in this case works on the one hand: with anisotropic tissue structural slabs determined by the form of the gypsum (or gypsum + polystyrene) surface elements and rigidified by the ribbed reinforce concrete membrane poured in-between and on top of the two-way channel system of the surface element, on the other hand: with inhomogeneous anisotropic monolithic boxes preassembled from these slabs in the factory

nel system of the surface elements, on the other hand: with inhomogeneous anisotropic monolitic boxes preassembled from these slabs in the factory (Fig. 6), and regards this as the leading idea for manufactured building. He has to accept that these slabs (that is the wall and floor elements of parameter size in two directions and constructed with the two-way alignment of surface elements) can only have openings on the surface, jointing edges and point for heterogeneous or homogeneous junctions only on the perimeters, and constructs from these slabs first (in the factory) the cellular large space-units, and then (on the site) the buildings, through the proper alignment of these boxes.

Since, however, the building in their solutions on plan and in section can again be reduced — in the last analysis — to the additivity of the semantically meaningless *Gutenberg*-principled surface elements, therefore — as compared to the wellknown tectonic slab- or box-principled systems — there opens an essentially roader possibility for the selection of parameter-sizes in three directions, that is for the flexible alteration of the dimensions of the space-units without having this tendency run counter the slab and the box as simultaneously applied principles of construction.

## 4. The box-frame unit building method

The box-frame unit building method — the fourth possibility of the non-tectonic systems — can only be realized on high degree of complementarity since its characterizing manufactured structural unit — the folded r.c. shell box frame — is exclusively connected with this degree. The building method calls into being its structures with a combination of two materials (gypsum + reinforced concrete), as follows:

*Short description:* *4. Box-frame unit building method*

— *on high degree of complementarity (on high degree of readiness in the factory);*
— *on the simultaneous application of the slab and the box-frame as principle of construction;*

in design:
— housing and communal buildings (variations on plan and in section on one or two-level arrangements);

in the factory:
— on two-fold disintegration (on *Gutenberg*-principled and mechanization principled decomposition);
— on preassembly of plane structural elements and small space units;

on the site:
— on the in-situ additivity of small space units and plane structural elements (on location of small space units — pillar- and beam box-frames — in in-situ position and heterogeneous junction; on location of plane structural elements in in-situ position and final pouring).

## Characteristic features of the box frame unit building method

From the point of view of principle of construction, the box-frame unit building method is actually a special case of the so called small-box-unit building method (Fig. 7).

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 can be most expediently realized in transplantable factories.

*In the workshop*, more accurately: *in the transplantable factory*, we not only produce *Gutenberg*-principled non-tectonic *surface elements* for wall and floors, pillars and beams but at the same time we also begin to preassemble these surface elements into *mechanization*-principled tectonic structural elements into *mechanization*-principled tectonic structural elements, that is to say, we start the manufacture of tectonic wall-elements, floor-elements, pillar box-frame units, beam box-frame units etc. as well.

*On the building site* the additivity is always in-situ and final, which means that these tectonic structural elements are always located immediately to their final in-situ position, in due order of course.

## Variability of the box frame unit building method

Amongst the non-tectonic systems the variability of the box-frame unit building method is of medium degree since the system — simultaneously founded on the slab and the box-frame as principles of construction — allows a relatively more restricted selection of sizes and increments for the elements and components as compared to the in-situ building method. At the same time the degree of complementarity (that is, the expediently choosable ratio of operations in the factory and on the building site) is the highest, since the degree of readiness achievable in the manufacture of elements and components — similarly to the box-unit building methods — may reach a reasonable maximum, consequently, the freedom of design is relatively more restricted.

## The slab as principle of construction in the box frame unit building method

*The slab as principle of construction* — in general — has become rather well-known through practice of the housing factories. This is why it is extremely important to note here that *in the box-frame unit building method — specifically — the slab as principle of construction completely changes both from design and from manufacture points of view:*

— from *design* point of view, because in the box-frame unit building method the tendencies towards increasing the span can not run counter the

## The box frame as principle of construction

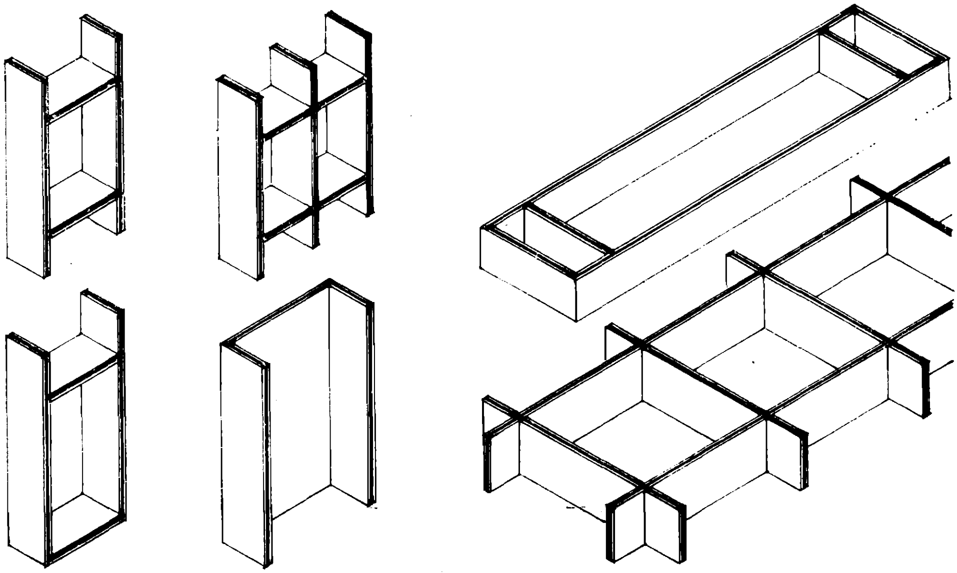


*Fig. 7. The box-frame as principle of construction.* The box-frame as principle of construction — in general — typically belongs to the small box-unit building methods. The architect here uses factory made stiffened small-box units: box-frames.

In the non-tectonic systems these small-box-units (the pillar box-frames and beam box-frames) are actually empty monolithic boxes, more accurately: frozen reinforced concrete folded shells arising through pouring concrete in between plane or profiled gypsum surface elements aligned properly in two directions. These pillar- and beam box-frames can only be of parameter-size in one direction but the demands of structural variability are relatively easily met since, in the last analysis, variability in the box-frame unit building method can immediately be reduced to the additivity of the Gutenberg-principled surface elements

slab as principle of construction since *in this case the load of the slab is taken up by the beam-frame.* Thus, the *span-dimension* of the slab gets free, or even, it *becomes theoretically unrestricted* since the load of the tissue-structural slab is carried by the short threads at right angle to the span and transferred immediately onto the beam-frame;

— from *manufacture* point of view, because *in the box-frame unit building method — the technological relevance of which can be most expediently enforced in hot arid tropical or subtropical areas — the manufacture of the slab can be organized on a completely new basis.* Under these climatic conditions, namely, it becomes possible to apply such a method for mass-production of slabs *in a factory transplantable next to the building site,* which simply cannot be realized in an identical form under different geographic circumstances:

the manufacture of the tissue structural (gypsum + reinforced concrete) floor elements, namely, is realized in this case in a determined technological order in horizontal position on a stack, above one another and in such a way, that first we manufacture the non-tectonic periodic gypsum surface element of parameter size in one direction by one single casting, then, almost immediately after setting of gypsum, we call into being the tectonic structural floor element by pouring concrete into the channel and on top the gypsum surface element which, thus, does not require either storing, moving or any further manipulation.

## The box frame as principle of construction in general and in the non-tectonic systems

*The box-frame as principle of construction* typically belongs to the small-box-unit building methods. The architect here uses factory-made stiffened spaceunits: box-frames. He regards this as the starting idea for mass-construction of homes, schools etc. He accepts these small-box-units — these "empty" pillar box-frames or beam box-frames — for assembling the building (Fig. 7).

Since, however, these elements — the pillar box-frames or beam box-frames — can only be of parameter size in one direction, consequently first of all, the variability in the box-frame unit building method will — intermediately — become a function of the additivity of manufactured tectonic small-box-units, which is very advantageous,

first, because these box-frame units — although they cannot be shaped any more in themselves — need not dispense with increments in any direction;

second, because the requirements of variability — which in the last analysis inevitably strengthen the tendencies towards increasing the sizes of the parameters — in the box-frame unit building method cannot lead to inherent contradictions so well known from the box-unit building methods. In this specific case, namely, where the slab and the box-frame as principles of construction are simultaneously applied within the system and side by side, the slab and the box-frame do not stay in the way of increments, thus, variability can be enforced within rather broad limits.

*The box-frame unit building method — based on the use of non-tectonic systems — applies the slab and the box-frame as principles of construction simultaneously and side by side.* This is very important because it means that the variability of the box-frame unit building method is not a direct function of the manufactured tectonic plane elements or box-frame units, but first of all, it is the direct function of the semantically meaningless, Gutenberg-principled non-tectonic surface elements, consequently demands of variability are relatively easily met. All in all:

## The simultaneous application of the slab and the box frame as principle of construction

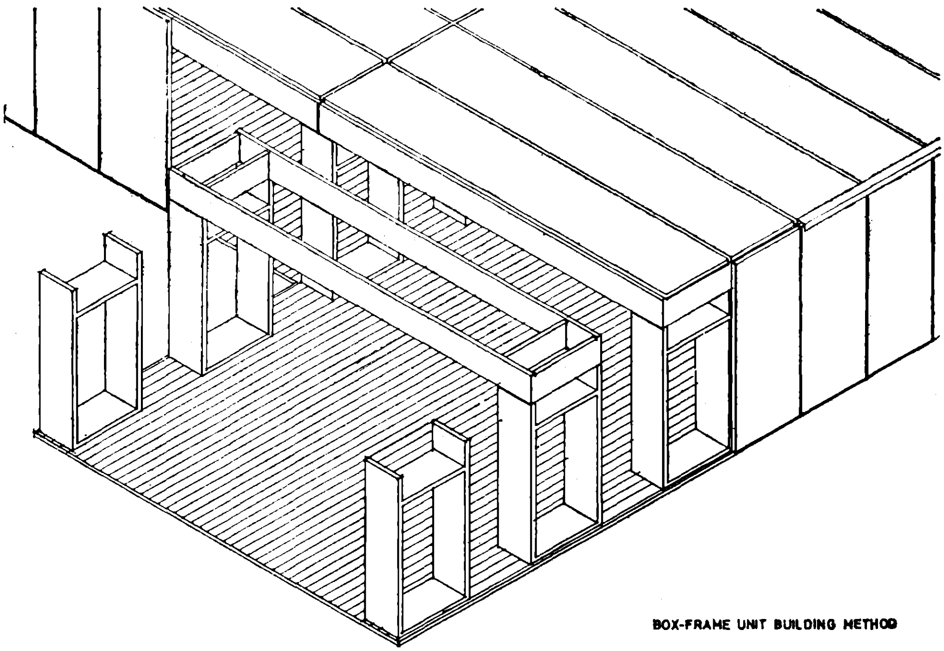



*Fig. 8. The simultaneous application of the slab and the box-frame as principle of construction.* The box-frame unit building method is founded on the simultaneous application of the slab and the box-frame as principle of construction. The architect here uses slab elements and box-frame units of parameter size always only in one direction. The shape of these units (the pillar box-frames and the beam box-frames) is always determined by the gypsum surface elements. The plane elements (the wall- and floor elements) are actually anisotropic tissue-structural reinforced concrete slabs stiffened by ribs and a membrane arising through pouring concrete into and on top of the two-way channel system of the surface elements, but in this case the load of the slab is taken up by the beam frame. Thus, the span dimension of the slab gets free or even, it becomes theoretically unrestricted since the load of the tissue structural slab is carried by the short threads at right angle to the span and transferred immediately into the beam-frame, whereas the small box units (the pillar box-frames and the beam box-frames) are actually empty monolithic boxes: frozen r. c. shells as we have already seen (Fig. 7) and as, schematically also shown by figure above

## The simultaneous application of the slab and the box-frame as principles of construction

*The box-frame unit building method is founded on the simultaneous application if the slab and the box-frame as principles of construction* (Fig. 8). The architect here uses slab-elements and box-frame units of parametersize always only in one direction. The shape of these units is always determined by the gypsum surface elements. He regards this as the starting idea for manufactured buildings. The plane elements (the wall- and floor-elements) are actually anisotropic, tissue-structural reinforced concrete slabs stiffened by ribs and a membrane arising through pouring concrete into and on top of the two-way channel system of the gypsum surface elements, whereas the small-box units (the pillar box-frames and beam box-frames) are actually empty monolitic boxes, more accurately: frozen reinforced concrete folded shells arising through pouring concrete in between the plane or profiled gypsum surface elements aligned properly in two directions. He accepts that these small-box units that is the box-frames can only be jointed — heterogeneously or homogeneousy — along lines and assembles his buildings — through a proper additivity of these box-frames and slabs — on the building site.

Since the architectural solutions of the buildings — ground plans, sections, details etc. — can immediately be reduced to the additivity of semantically meaningless Gutenberg-principled surface elements, therefore in the box-frame unit building method wide possibilities arise for flexibly changing the parameters of the buildings in the redirections without having this tendency run counter the slab and the box-frame as simultaneously applied principles of construction.

## 5. The closed-cellular building method

The closed-cellular building method — the fifth possibility of the non-tectonic systems — is characterized by a special structural form, more accurately: by the *anisotropic slab* containing internal cells.

The building method can both be realized on a low and on a high degree of complementarity. In any come, however, the structures called into being by this building method are composed of two materials; gypsum and reinforced concrete.

If the *degree of complementarity* (that is, the ratio of operations in the factory to those on the building site) is *low*, then we can only work with the *surface as principle of construction* since in the factory we only manufacture *Gutenberg*-principled non-tectonic surface elements for walls and floors;

If, however, the *degree of complementarity is high* then there are even two different possibilities for the building method, namely:

— either the *anisotropic slab as principle of construction, a special case of the in-situ building method where the building is realized through the additivity* of manufactured tectonic anisotropic slabs;

— or, *combination of the anisotropic slab and the box-frame as principles of construction*, a special case of the box-frame unit building method where the building is realized through the additivity of manufactured box-frames and anisotropic slabs.

The closed cellular building method — if applied on a high degree of complementarity — is at the same time also characterized by the *high degree of technological relevance with geographic-zonal validity* and as such it is again most advantageously applicable to conditions in developing countries, particularly in hot arid tropical or subtropical areas and can both be realized through using transplantable factories or elementary transplantable factory units.

The characteristic features of the individual cases of the closed-cellular building method are as follows:

| | |
|---|---|
| *Short description:* | *5.A Closed-cellular building method* |
| | — *on low degree of complementarity (on low degree of readiness in the factory);* |
| | — *on applying the surface as principle of construction;* |
| in design: | — housing and communal buildings (variations on plan and in section); |
| in the factory: | — on one-fold disintegration (on *Gutenberg*-principled decomposition); |
| on the site: | — on the in-situ additivity of surface elements (on calling into being the loadbearing structure exclusively on the building site). |

**Characteristic features of the closed-cellular building method in case of low degree of complementarity (5.A)**

The closed-cellular building method on a low degree of complementarity is founded on the consistent application of the *surface as principle of construction*, consequently it can be perceived as a special case of the in-situ building method (as it turns out from the above features), and as such a case which calls into being the anisotropic slab through the in-situ additivity of surface elements containing closed internal cells. The surface elements containing closed internal cells are not manufactured by forming "keys" lifted out, but produced by unregainable, lost forming pieces. These forming pieces can be empty or sealed registers containing a phase change material (Fig. 9) in this latter case we call into being the already mentioned heat-storing systems.(See: Ref. 12 pp. 124, 129.)

As an immediate concomitant of the low degree of complementarity the variability of the building method significantly increases, as a matter of course. And if we add to this, that surface elements containing closed internal cells can also be called into being by the in-situ additivity of surface elements in such a way that we use surface elements formed from outside and locate them by pairs as opposed to each other (thus forming the closed internal cells from two "half-open cells") then it is easy to see that this building method may offer

## The anisotropic slab as principle of construction

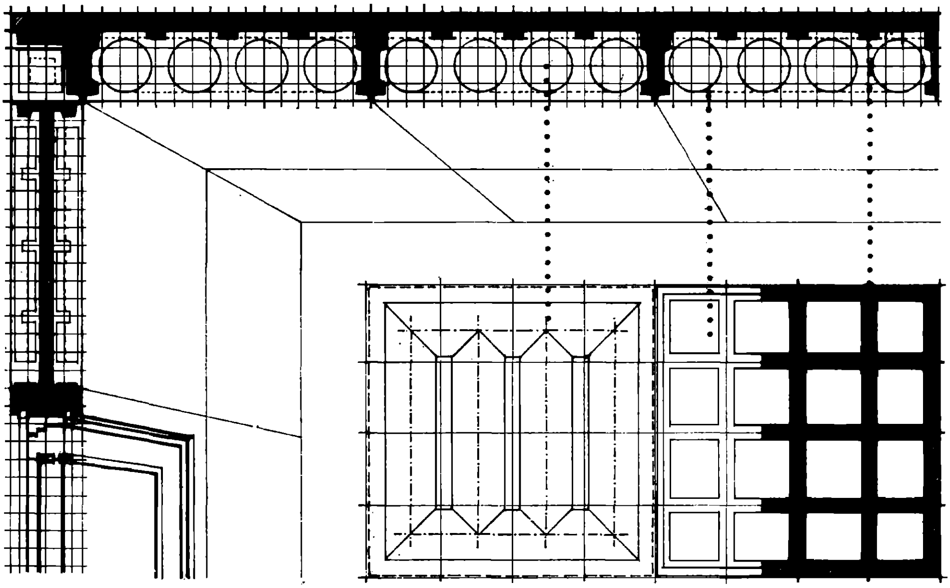


*Fig. 9. The anisotropic slab as principle of construction.* The anisotropic slab — the characteristic structural from of the closed-cellular building methods — can both be realized on low and on high degree of complementarity, but in any case the architect works with inhomogeneous anisotropic monolithic slabs composed of two materials: gypsum and reinforced concrete, supplied by a two-way r.c. rib system stiffened by a r.c. membrane and reduced in weight by a periodic system of closed internal cells. These "slabs" can be of parameter size in two directions. In case of low degree of complementarity — and this is the case of the figure above — we call into being the anisotropic slab through in-situ additivity of surface elements where the closed internal cells are actually sealed registered containing a phase change material for heat-storing

quite a series of new possibilities both from building- and from technological point of view.

*Short description:* *5.B Closed-cellular building method*

- *on high degree of complementarity (on high degree of readiness in the factory);*
- *on applying the anisotropic slab as principle of construction;*

in design:
- housing, communal and industrial buildings (variations on plan and in section);

in the factory:
- on two-fold disintegration (on *Gutenberg*-principled and mechanization principled decomposition);
- on preassembly of plane structural elements;

on the site: — on the in-situ additivity of plane structural elements (on location of anisotropic slabs in final in-situ position and homogeneous junction).

**Characteristic features of the closed-cellular building method in case of high degree of complementarity (5.B)**

This building method as a consequence of its principle of construction can be matched with any non-tectonic building method, its geographic relevance is related to hot arid tropical areas, that it can be most expediently realized through using transplantable factories.

*Short description: 5.C Closed-cellular building method*

— *on high degree of complementarity (on high degree of readiness in the factory);*
— *on the simultaneous application of the anisotropic slab and the box-frame as principles of construction;*

in design: — housing, communal and industrial buildings (variations on plan and in section);

in the factory: — on two-fold disintegration (on *Gutenberg*-principled and mechanization-principled decomposition);
— on preassembly of plane structural elements and small space units;

on the site: — on the in-situ additivity of small space units and plane structural elements (on location of small space units — pillar- and beam-box frames — in-situ position and heterogeneous junction; on location of plane structural elements — anistropic slabs — in in-situ position and final pouring).

**Characteristic features of the closed-cellular building method in case of high degree of complementarity (5.C)**

This building method as a consequence of the combination, that is the simultaneous application of the anisotropic slab and the box-frame as principles of construction can be perceived as a special case of the box-frame unit building method (as it is also shown by the above features) and as such a case which combines the in-situ additivity of anisotropic slabs with the in-situ additivity of small space units. The geographic relevance of the building method is again related to hot arid tropical or subtropical areas thus, it can be realized even by elementary transplantable factory units located immediately on the very zero level. In the building methods of high degree of complementarity (5.B and 5.C) the method of disintegration and the additivity in the factory either leads to plane structural elements or plane structural elements and small space units. On the building site the tectonic elements — the small space units (that is the pillar- and the beam box-frames) and the anisotropic slabs) that is the closed cellular wall- and floor-elements) — are always located in their final position, so the additivity on the building site is always in-situ and final.

## Variability of the closed-cellular building method

Amongst the non-tectonic system the variability of the closed-cellular building method is of high degree since the anisotropic slab as principle of construction stands closest to the surface as principle of construction; since the sizes and increments of the elements and components — including their thicknesses as well — can be selected within very broad limits; finally because in the closed-cellular systems the degree of complementarity can reach a reasonably high level without seriously restricting the freedom of planning.

## The anisotropic slab as principle of construction

The slab as principle of construction has already been dealt with previously. Now, it is important to note here as an addition that the *anisotropic slab* — the characteristic structural form of the closed-cellular buildung method 5.A; 5.B; 5.C — again *endows the technology with completely new features both from design and from manufacture points of view;*

— From *design* point of view, because in the closed-cellular building method the architect works with inhomogeneous, anisotropic, monolithic slabs composed of two materials: gypsum and reinforced concrete, supplied by a two-way r.c. rib system stiffened by a reinforced concrete membrane and reduced in weight by a periodic system of closed internal cellse. These "slabs" can be of parameter size in two directions, consequently the tendency towards increasing the span does not run counter serious obstacles (as would be the case with the traditional — i.e.: homogeneous, isotropic, monolithic — reinforced concrete slabs);

From *manufacture* point of view, because in the closed-cellular building method — the technological relevance of which can again be most expediently enforced in hot arid tropical or subtropical areas — the manufacture of these large-size anisotropic slabs can also be organized on a completely new basis. Under these climatic conditions, namely, the production of anisotropic slabs in horizontal position and above one another not only can be realized in a factory transplantatable next to the building site but also in elementary factory units located immediately on the zero level of co-ordination of the individual buildings.

The non-tectonic closed-cellular building method *(5.B)* completely extends the anisotropic slab as principle of construction to the primary walls and loadbearing floors. This is of crucial importance from the point of view of variability of the building method. In case of working on a high degree of complementarity, namely, the large-size two-way periodic surface elements do not arise any more as a result of the additivity of surface elements but are produced by one single casting which in turn means that variability here becomes an immediate function of the convertibility of the manufacturing apparatus, thus, variability can be enforced within rather wide limits. Finally:

### The simultaneous application of the anisotropic slab and the box-frame as principle of construction

*The closed-cellular building method (5.C) is founded on the simultaneous application of the closed-cellular anisotropic slab and the box-frame as principles of construction.* The architect here uses tectonic box-frame units of parameter-size always only in one direction and anisotropic slabs of parameter size in one to two directions containing closed internal cells, composed of gypsum and reinforced concrete, supplied with a two-way r.c. rib system stiffened by a r.c. membrane (Fig. 10). He regards this as the starting idea units (pillar box-frames and beam box-frames) can only be jointed heterogeneously along lines and accepts at the same time that the anisotropic slabs (the wall and floor elements) can only be jointed homogeneously and along lines; he finally accepts that the large-size anisotropic slabs — when placed on the vertical loadbearing structures — first always rest on their reinforcement protruding from the ribs until the homogeneous junction is created by the concrete poured in.

Since in the closed-cellular building method — if realized on a high degree of complementarity — the large-size gypsum surface elements are produced through continuous casting and not through additive alignment of manufactured surface elements, therefore the architectural solutions of the buildings (i.e.: ground plans, section, details etc.) can be immediately derived from the convertibility of the manufacturing apparatuses, consequently quite a number of possibilities may again arise for flexibly changing the parameters of the buildings in three directions without having this tendency run counter the anisotropic slab and the box-frame as simultaneously applied principles of construction.

The closed-cellular building method as we have seen is characterized by a high degree of technological relevance and is realized in elementary transplantable factory units located immediately on the completed zero level of the individual buildings.

**The simultaneous application of the anisotropic slab and the box frame as principle of construction**

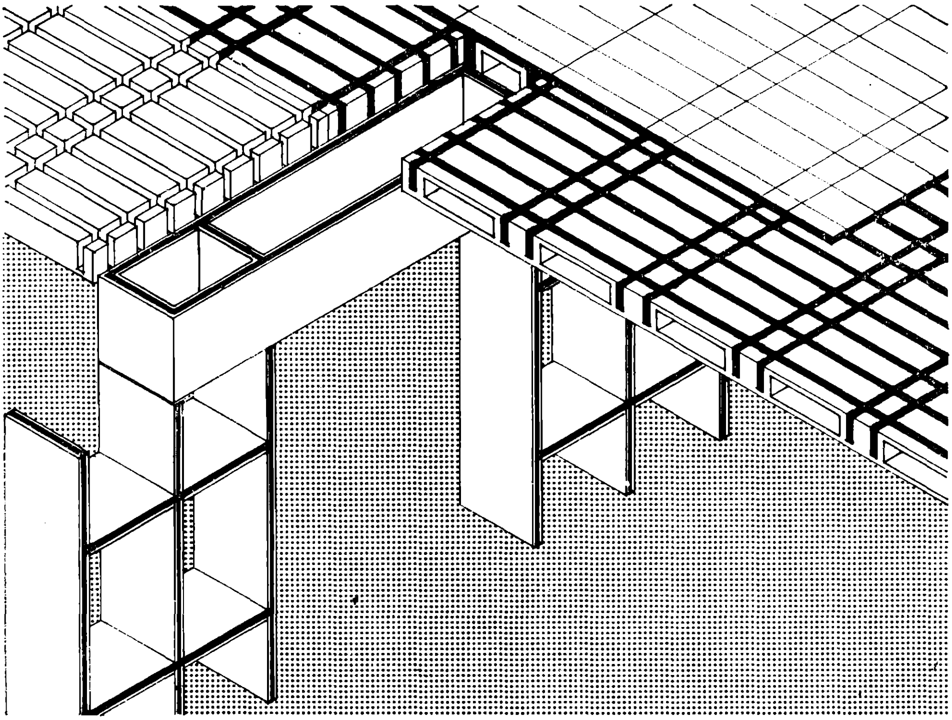


*Fig. 10. The simultaneous application of the anisotropic slab and the box-frame as principle of construction.* The closed-cellular building method — in case of high degree of complementarity — is founded on the simultaneous application of the closed-cellular anisotropic slab and the box-frame as principle of construction. The architect here uses tectonic box-frame units of parameter size always only in one direction, and anisotropic slabs of parameter size in one or two directions containing closed "empty" internal cells, composed of gypsum and reinforced concrete, supplied with, composed of gypsum and reinforced concrete, supplied with a two-way r.c. rib system stiffened by a r.c. membrane

## 6. The lift-cell building method

The lift-cell building method — the sixth possibility of the non-tectonic systems — can only be realized on medium degree of complementarity since its characterizing structural unit — the cellular floor-field — is exclusively connected with this degree. The building method calls into being its structures with a combination of three materials (gypsum + reinforced concrete + steel), as follows:

*Short description:* *6. Lift-cell building method*

— *on medium degree of complementarity*
*(on medium degree of readiness in the factory)*;
— *on the simultaneous application of the cell, the box-frame and the skeleton-frame as principle of construction*

in design:
— communal buildings
(variations on plan and in section on multi-level arrangements);

in the factory:
— on two-fold disintegration
(on *Gutenberg*-principled and mechanization principled decomposition);
— on preassembly of plane structural elements and small space units;

on the site:
— on the in-situ additivity of small space units
(on location of small space units — pillar skeleton-frames and beam box-frames — in in-situ position and heterogeneous junction);
— on the assembly of cellular floor-fields underneath in-situ position on top of each other, lifting them into final position and fixing by heterogeneous junction.

## Characteristic features 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 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 or 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 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 multi-level 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 direction 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 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 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, (see also: Fig. 4), 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 that 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 the 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-

## The simultaneous application of the cell, the box frame and the skeleton frame as principle of construction

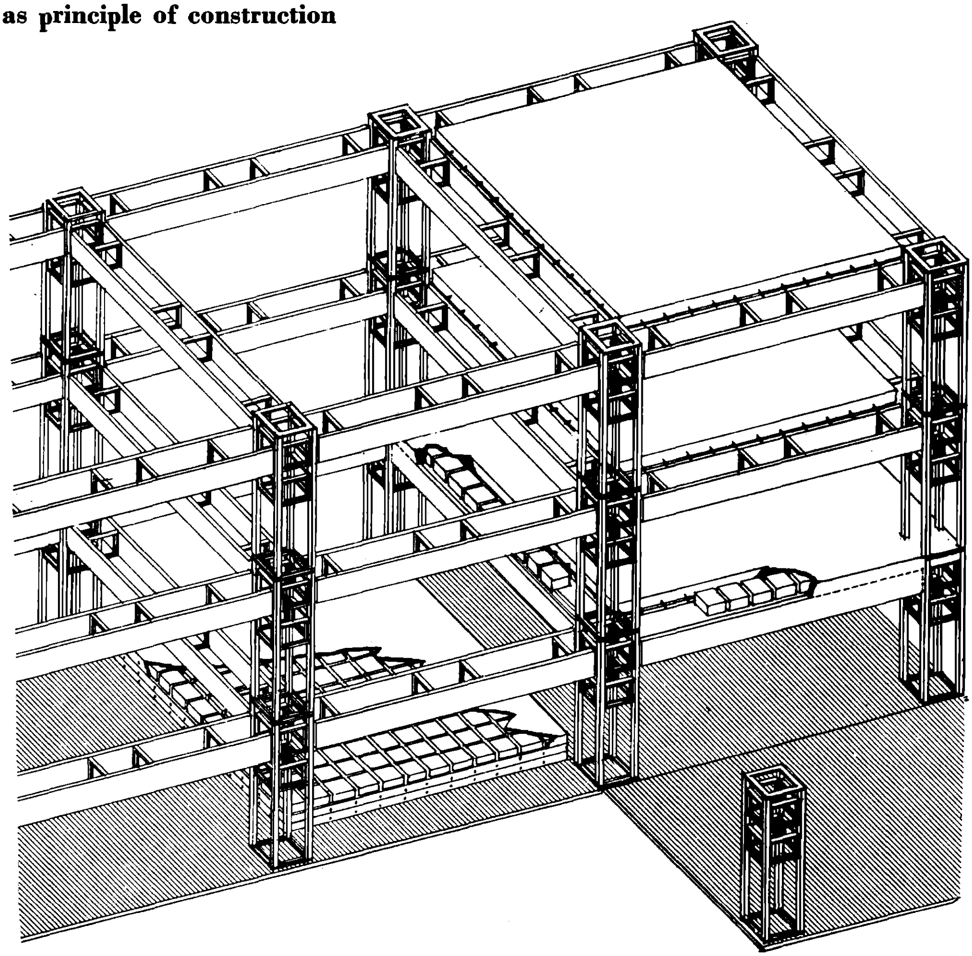


*Fig. 11. The simultaneous application of the cell, the box-frame and the skeleton-frame as principle of construction.* The application of the *cell* as principle of construction has already been introduced and illustrated by Fig. 4. In the lift-cell building method the visible form of the primary structure is characterized by the beam-grid realized in two steps: the primary beam-grid is assembled through additivity and heterogeneous jointing of beam box-frames and pillar skeleton-frames, whereas 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 as again been deal with an illustrated by Figs 7, 8. and 10. It is important to note here, however, that in the lift-cell building method the box-frame is a heterogeneous beam box-frame composed of three materials (gypsum + reinforced concrete + steel) in which we joint beam elements (that is frozen r.c. shell plane structural elements composed of gypsum + reinforced concrete) by pairs, by means of steel diaphragms; the pillar *skeleton-frame* as principle of construction is characteristically connected with the lift-cell building method. The constructor here works with linear reinforced concrete structural elements — that is factory made columns — which are tectonic from the outset and uses the 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

frames can only be connected with the beam box-frames at points, through heterogeneous junction (Fig. 11).

### The three immediate objects of manufacture in the lift-cell building method

*In the lift-cell building method — founded on the simultaneous application of the cell, the box-frame and the skeleton-frame as principles of construction — in constrast 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-wo directions rigidified with a membrane) through a proper additivity of the non-tectonic cellular small space elements unterneath 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 diaphragms*, that is steel frames constructed of U-profiles.

## 7. The tilt-lift building method

The tilt-lift building method — the seventh possibility of the non-tectonic systems, finally — is characteristically connected with the the low degree of complementarity since the load-bearing structure can only be realized on the building site and with the combination of two materials (gypsum + reinforced concrete), as follows:

*Short description:* *7. Tilt-lift building method*

- *on low degree of complementarity (on low degree of readiness in the factory);*
- *on the simultaneous application of the surface and the box-frame as principle of construction*

in design: — industrial workshops
(variation on plan and in section on one-level arrangements);

in the factory: — on one-fold disintegration
(on *Gutenberg*-principled decomposition);

on the site: — on the in-situ additivity of surface elements underneath the in-situ position prior to lifting, in case of beam box-frames,
— on the additivity of surface elements in horizontal position, prior to tilting, in case of pillar box-frames,
— on the in-situ preassembly of linear structural elements, in case of secondary beams and on the in-situ or undernearth in-situ additivity of these structural elements, (on calling into being the load-bearing structure exclusively on the building site).

## Characteristic features 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: (Fig. 12)

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-frame 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 load-bearing 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 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 profield 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 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 simultaneous application of the surface and the box frame as principle of construction

*The surface as principle of construction — in general* — has been dealt with in detail previously (see Figs 1, 2) and the same applies to the *box-frame as principle of construction, in general,* (see Figs 7, 8), so here there is no need for any repetition.

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 contrast to 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* wihout 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 simultancous application of the surface and the box frame as principle of construction**

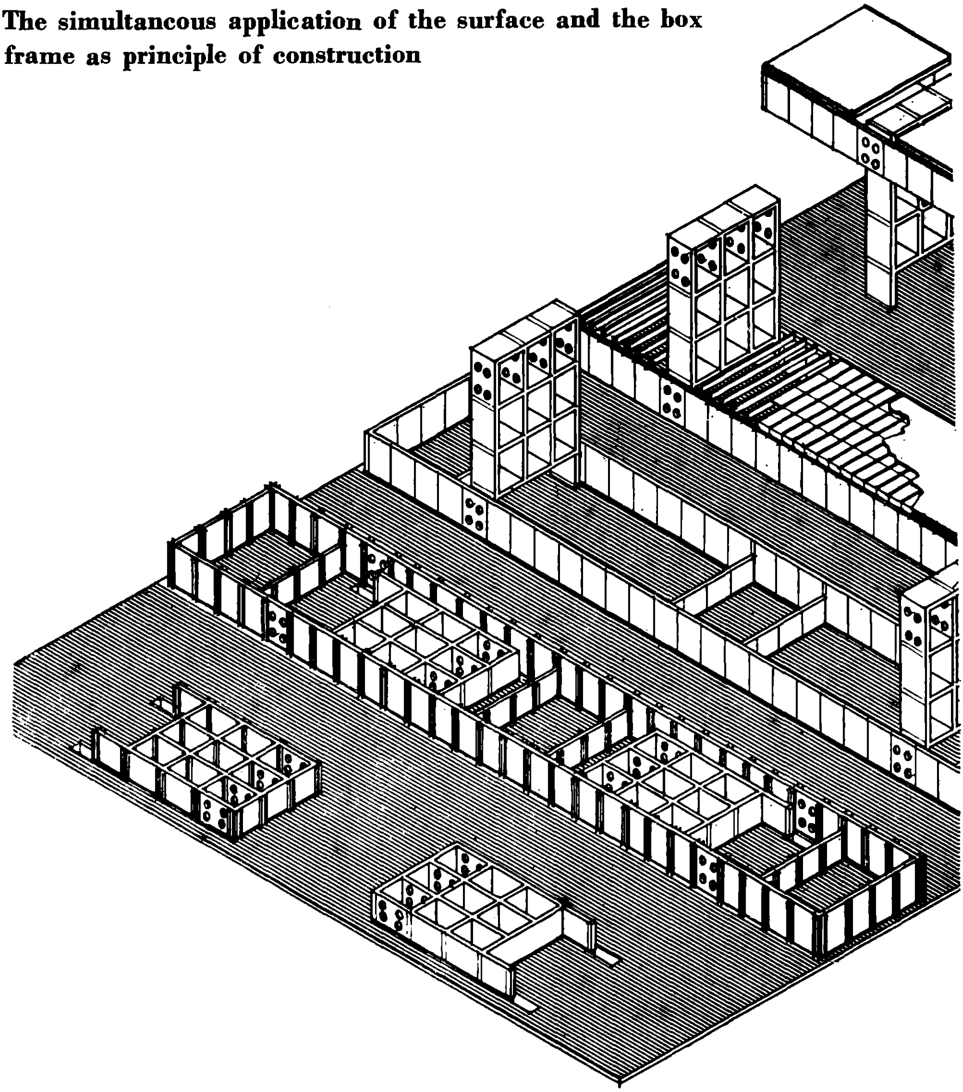


*Fig. 12. The simultaneous application of the surface and the box-frame as principle of construction.* The tilt-lift building method — that is the special combination of the in-situ, the lifting and the box-frame unit building methods complemented with a tilting operation — is founded on the simultaneous application of the surface and the box-frame as principle of construction. In this building methods manufacture has only one immediate object, which simply means that in the transplantable factory we only produce Gutenberg-principle small-size non-tectonic surface elements, consequently on the building site each building operation is based on the additivity of surface elements. The *surface* as principle of construction in general has already been introduced and illustrated by Fig. 1 and Fig. 2 and the same applies to the *box-frame* as principle of construction as shown by Fig. 2 and Fig. 8. It is important to note here, however, that in the tilt-lift building method the pillar box-frame and the beam box-frame is not an 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 position* that is in a situation preceding the operation of *lifting*. Since these 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 course of the operation of tilting and lifting, therefore the structural connection to be created between them — in contrast to the box-frame unit building method (Fig. 8) — can only be a heterogeneous junction

*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 principle 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.

* * *

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