NON-TECTONIC SYSTEMS*

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(Received December 30th, 1972)

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Introduction

This report is a short summary of a many years' research work, done by the author and BÉLA SÁMSONDI-KISS, the aim of which was to elaborate a new, coherent, technological and economic approach to solving problems of mass-housing in developing countries.

It is designed to give only an indication of how non-tectonic systems may be conceived. The emphasis will, therefore, be on illustrating the principles.

The report is divided in two parts corresponding to the main — theoretical and practical — aspects of the problem.

Part I — *Theory of non-tectonic structures* —

is devoted to an analysis of non-tectonic systems. This part is predominantly concerned with ideas and their clarification. The meaning of the terms used to express concepts is described, and an illustration of these terms by drawing has also been given.

The headings on each page follow the train of thought.

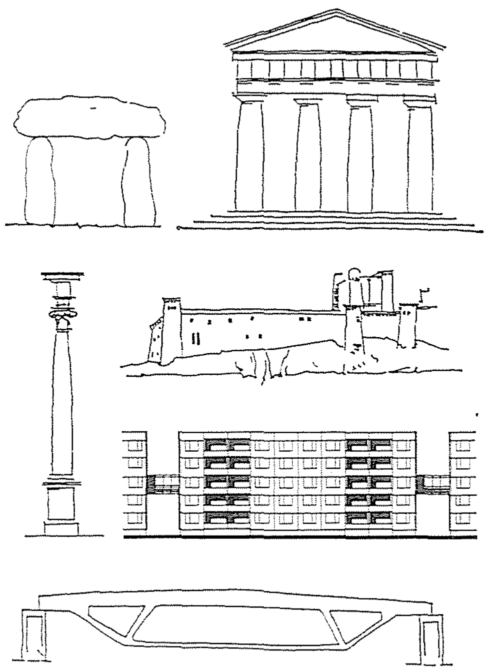
Part II — *The experimental, non-tectonic structural unit* —

deals with the implementation of the theory of non-tectonic systems to the design, manufacture and assembly of non-tectonic building components through giving a report on the laboratory experiments. This part is divided in three sections corresponding to the main — design, manufacture, assembly — aspects of the subject. Verbal description of the sequence of operations is illustrated by drawings and photographs.

* Abridged text of a report prepared for UNIDO in 1971.

Part I
GENERAL PROBLEMS OF THE THEORY OF NON-TECTONIC STRUCTURES

1. The Principle of Tectonics

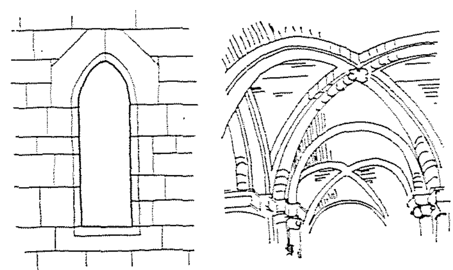


As known to all, traditional building as a process is based on the axiom of *tectonics.* This simply means that

you first put down an element (i.e., a piece of stone, a column, etc.) strong enough to *support*, and then you place on it something to be *supported.*

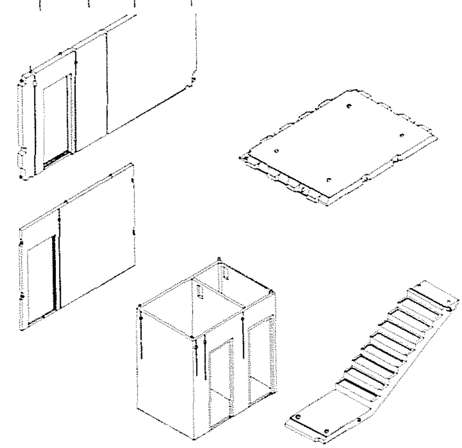
Now, exactly the same principle is applied in the age of industrialized building. This means actually that

you first put down an element (i.e. a column, a block, a large panel etc.) which is *manufactured* (in the factory or on the site), again strong enough to *support*, and then you place on it another, also *manufactured* element (a beam, a floor slab, etc.) to be *supported.* The axiom of tectonics, in other words: the simple principle of putting load-bearing elements on one another (according, of course, to a certain order). This is the essence of every **tectonic** structure, be it traditional or industrialized.



In *traditional tectonic* structures, emphasis is on the load-bearing *elements.* Since these elements are *not finally shaped*, therefore

architectural *variability* is created through *additivity* of individually *workable* tectonic building elements.



Modern *manufactured tectonic* systems put the emphasis on the usual manufacture of the *frame* (i.e. of universally accepted load-bearing elements as beams, blocks, panels, slabs, box units, etc.). Since all these manufactured elements are *finally shaped*, therefore

architectural *variability* is based on the *additivity* of individually *unworkable* manufactured tectonic building components.

2. What is meant by non-tectonic structures?

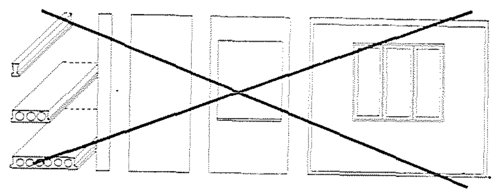
Now, the question raised at the very beginning of our research was the following:

— can we achieve a really fundamental change in the building industry through changing the principle of construction? or in other words

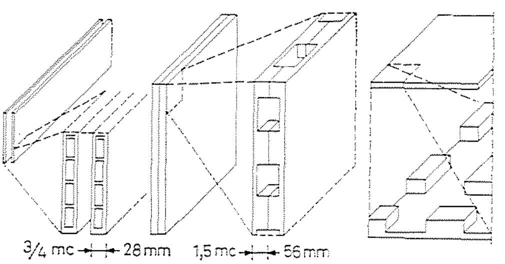
— is the axiom of tectonics in the age of industrialized building the only possible axiom of building or can it be substituted by other principles, and if yes, by what principles and how?

and this is how we finally came first to develop the theory of **non-tectonic structures**, and then, to establish the first non-tectonic, industrialized system, the **tissue-structural, cellular building method.**

First of all, we changed the principle of construction through switching over from the use of manufactured **tectonic** structures to **non-tectonic** systems. This is done as follows:



As opposed to any other manufactured **tectonic** system, in which the emphasis is always put on the usual manufacture of the *frame*, that is, on the manufacture of the components of the *load-bearing structure;*



the **non-tectonic** system puts the emphasis of manufacture of the *surface*, that is, on the manufacture of the *non-load-bearing surface* elements, and

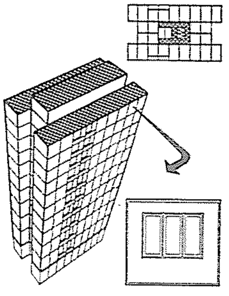
instead of manufacturing heavy, load-bearing **tectonic** beams, wall or floor elements, etc., light, **non-load-bearing, non-tectonic surfaces** of beams, walls, floors, etc. are mass-produced.

3. An architectural problem: aesthetic neutrality; systems of tectonic and non-tectonic bricks

The change-over from the present **tectonic** structures to **non-tectonic** systems means a qualitative change in the industrialization of building, in so far as it creates a real technical basis for raising the level of building industry from the present stage of **mechanization-based, building** represented by the *housing factories* towards that of "Gutenberg-principled" building represented by the "*blind manufacture*" of non-tectonic elements.

Let us first examine the features of these two fundamentally different conceptions.

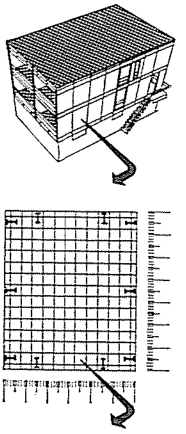
Mechanization-based building breaks up the final product, that is, the building, into large-size tectonic elements, of parameter size in two directions. The elementary part, the large panel is a structural element. This means the smallest unit for manufacture.



The large panel actually is a finally shaped, load-bearing, manufactured **tectonic brick** and as such, it is *semantically meaningful*. This means that aesthetically — from the aspect of architecture — it is *not neutral*, since, as opposed to the traditional brick, it is not only a part but a determinant part of the building, consequently it definitely influences the final shape of the building.
Systems of tectonic bricks inevitably create closed systems.

The **"Gutenberg-principled"** building breaks up the final product, that is, the building, into medium-size, non-tectonic elements of parameter size in one direction.

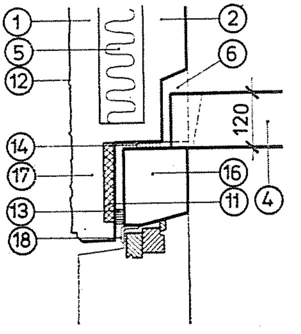
The elementary part is a surface element. This means the smallest unit for manufacture.



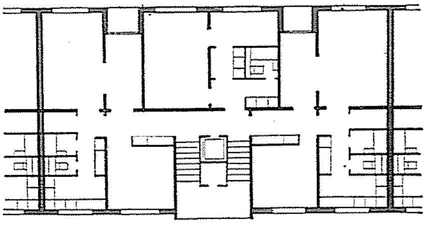
The surface element actually is a finally shaped, non-load-bearing, manufactured *non-tectonic brick*, and as such, it is *semantically meaningless*. Thus, from an architectural point of view it is neutral since — similarly to the traditional brick — it is only a part of the building but not a determinant part; it does not influence the final shape of the building.
The aesthetic neutrality of non-tectonic bricks is based on the *neutrality of the surface*, and this explains why in all these systems it is practically irrelevant whether we produce elements of *wall* or elements of *floor*, the surface being the same in either case. **Systems of non-tectonic bricks** operate with *open systems*.

4. Why we call the manufacture of non-tectonic bricks "blind manufacture"

Mechanization-based building operates with systems of tectonic bricks.

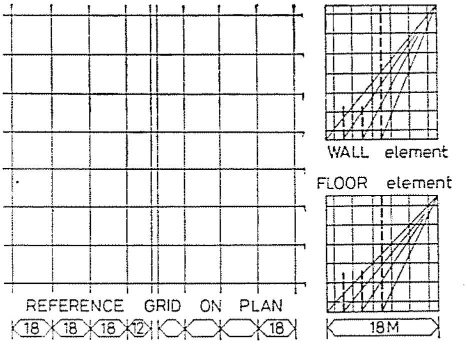


You cannot start, however, the process of *manufacture of tectonic bricks* unless you see the completed whole, that is, the final product: the building. This means that you not only have to know the ground plans, sections, etc., but to see all the details of the manufactured elements as well.
The manufacture of systems of tectonic bricks spells closed-system industrialization. The housing factories see the final product.



The Gutenberg-principled building operates with systems of non-tectonic bricks.

You start out directly from the elements since the manufacture of non-tectonic bricks is not bound to the knowledge of the completed whole, i.e. the final product. All you have to know is the system of grids on plan and in section, because the manufactured non-tectonic surface elements will fit into that grid system anyway.

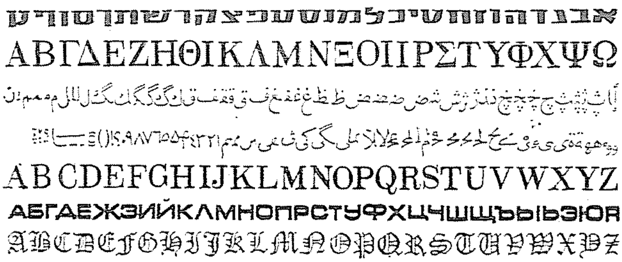


The manufacture of systems of non-tectonic bricks spells open-system industrialization. The factory does not see the final product.

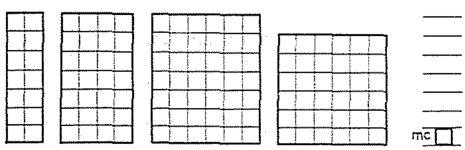
The manufacture of non-tectonic bricks means "blind manufacture".

5. Why we call the process of non-tectonic building "Gutenberg-principled" building? The "Alphabet" and the "Typography" of the structural system

We have already seen that in non-tectonic systems the semantically meaningless surface elements are not bound to a particular building. This, however, means that the building method actually transplants the well-known Gutenberg-principle to the building industry simply by creating a new approach to fragmentation, basis of any kind of mechanization.

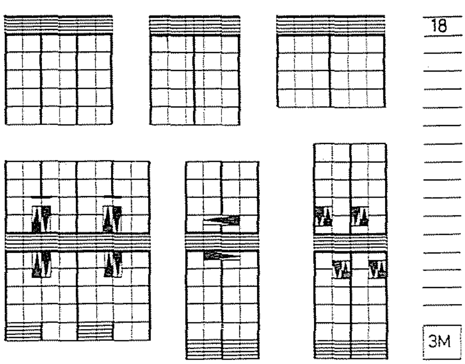


Similarly to the *letters* of the phonetic alphabet — or more accurately — similarly to the types of the printed alphabet — which in themselves have no meaning yet allow any kind of texts to be printed; the elements of the non-tectonic system are no structures themselves, yet they permit to assemble any kind of structure required for housing or communal building.



THE ALPHABET

In the Gutenberg-principled building the *elements* — i.e. the non-tectonic bricks — constitute the *letters* of the structural system.
This means in other words that the role of the non-tectonic bricks in the Gutenberg-principled building corresponds to that of the movable types in the Gutenberg-principled printing, and this explains why by analogy
we call the non-tectonic bricks the letters of the structural system.



THE TYPOGRAPHY

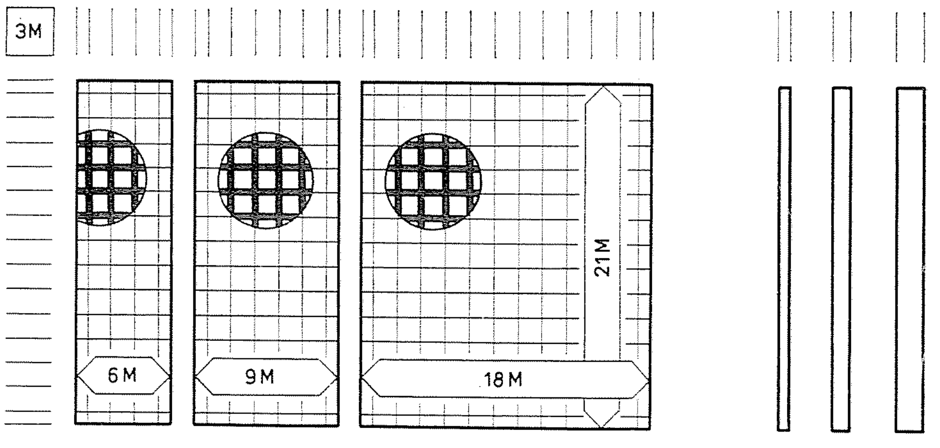
In Gutenberg-principled non-tectonic building the non-tectonic bricks constitute a system, and this explains why, again by analogy

we call the system of non-tectonic bricks the alphabet of the structural system, and we call the final product — i.e. the building composed of the "letters of the alphabet" — **the typography of the structural system.**

6. The constancy of the alphabet and the variability of typography; selection of form for non-tectonic elements and structures

It is important to note here that as long as the structural system does not vary the **alphabet keeps constant** because it contains the *elements* — in other words: the *letters* or the *non-tectonic bricks* — of the structural **system.** This, however, does not apply to the typography.

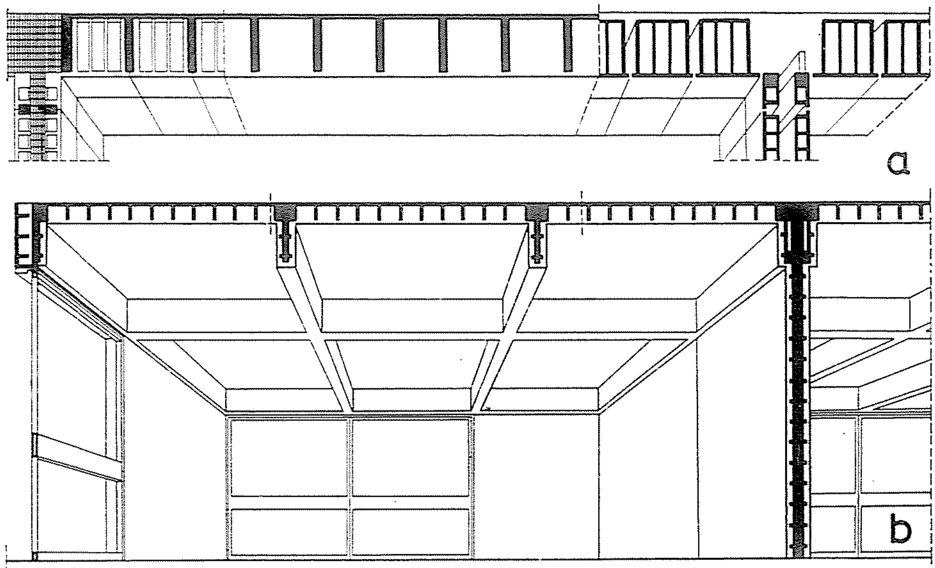
The typography varies because — analogically speaking — it is the *text* written or printed with the *letters* — or types — of the *alphabet.* By "typography" we always mean a particular **building** composed of the **elements** of the structural **system.**



The *elements* of the *Gutenberg-principled* building are **open elements** the *sizes* and *thicknesses* of which may vary according to requirements because the *satisfaction of requirements of variability* of the elements is based on the *convertibility of the manufacturing apparatus.*

In order to achieve *small weight* and proper *structural rigidity:*

The *microcellular* form was chosen for the *microstructure*, that is, the structure arising within the non-tectonic wall or floor *elements* (a), whereas the *cellular* form of *primary structure* proved the most practical form for the design and assembly of the *building* (b).



This means that in the structural system we determined the *tissue* of the structure by the manufactured negative channel system of the gypsum *elements*, and we determined the *form* of the structure by the *cells.*

7. Establishment of a complementary building method; the process of non-tectonic building

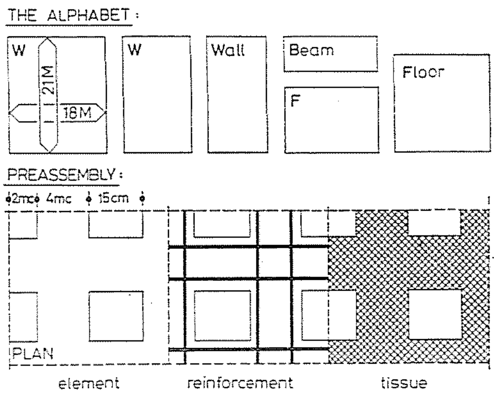
In non-tectonic systems, building is a complementary process, that is, a process combining the **factory** *production of surface elements* with an **in-situ** *technology of pouring.*

Let us follow this complementary process first in the factory, then on the site.

In the factory there are two basic types of operations:

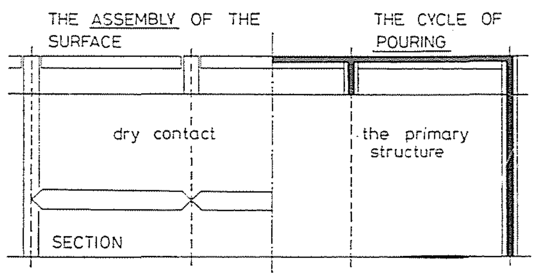
A. *The manufacture of the alphabet.* This includes the manufacture of all the elements (surface of wall, surface of floor elements) equivalent to *creating the system of non-tectonic bricks.*

B. *The preassembly of floor units.* In this operation, the non-tectonic floor elements are placed first in the reinforcing apparatus, constructed so that the reinforcement is located at an absolute accuracy within the channels, and then the channels are poured out to create the *microstructure*, i.e. the structural *tissue* within the floor unit.



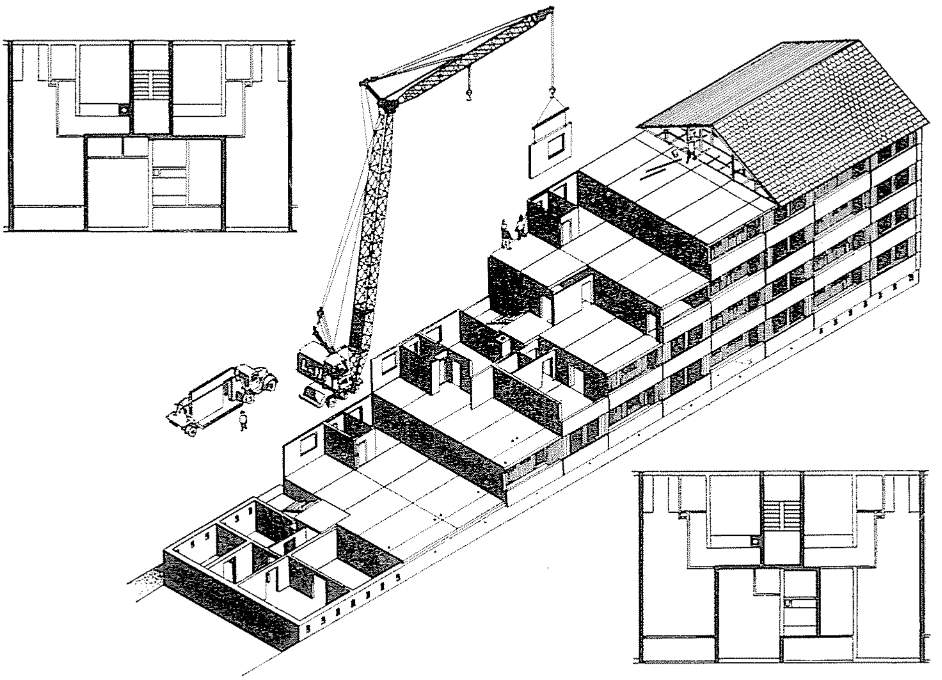
On the site there are again wto basic types of operations corresponding to the complementary character of the building method. It is very important to note here that *the process of non-tectonic building is exactly the opposite of the usual tectonic building*, since the sequence of operations is as follows:

A. *The assembly of the surface.* First of all, the surface of the load-bearing structure is assembled by establishing a *dry contact* between the non-tectonic *surface* elements placed in, actually this means to create the *negative* of the load-bearing primary structure, be it horizontal or vertical, and then in an in-situ operation called
B. *the cycle of pouring*, these surface elements are united by the primary structure, that is, by the r.c. structure poured in between the surface elements.



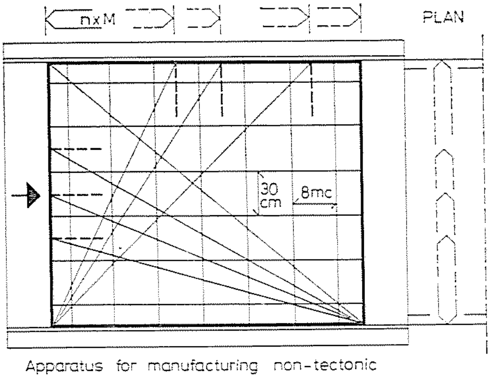
8. Essentials of architectural variability in the non-tectonic systems; workability of structure and convertibility of the manufacturing apparatus

In *mechanization-based building*, the workability of a structural system can only be scaled by the number of architectural variations possible, which in turn is a direct function of the additive (combinatorial) qualities of the elements. Now, as opposed to this:



the Gutenberg-principled building offers practically unrivalled possibilities to increase architectural variability, because by having shifted the emphasis of manufacture from the load-bearing structure to the non-tectonic surface, new, hitherto unrealized features arise in reinforced concrete structures:

blind manufacture combines the workability of the structure with the convertibility of the machine;
whereas in any tectonic system, variability of the final product can only be based on the additivity of finally shaped tectonic elements, as shown by the figure above.



Apparatus for manufacturing non-tectonic bricks

In the non-tectonic systems, the surface elements themselves become variable: in blind manufacture, the variability of the elements will be based on the convertibility of the manufacturing apparatuses and thereby the sizes selectable for the elements may reach a maximum.

Architectural variability in the non-tectonic systems is founded on a simultaneous workability of the structure and convertibility of the machine.

9. The system of double co-ordination: a tool for satisfying the twin requirements of planning for change and producing for change

Now: in order to be able to combine workability of structure (a precondition of *planning for change*) with the convertibility of the manufacturing apparatus (in turn, a precondition of *producing for change*) we elaborated the system of double co-ordination.

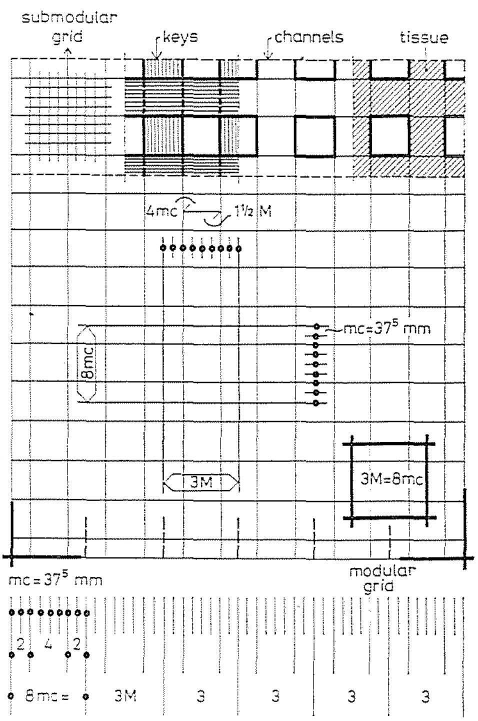
*

In non-tectonic systems, the shaping of the building, that is, the architectural variability, can only be based on the additivity of surface elements. Since, however, the elements, that is, the *non-tectonic bricks* are finally shaped, therefore we cannot dispense with modular co-ordination, that is, a modular reference between the non-tectonic elements and the modular grids on the building site.

As opposed, however, to any other tectonic system, in the non-tectonic systems the elements themselves are variable, because the blind manufacture of the elements is based on the convertibility of the manufacturing apparatus, and this is why we cannot dispense with submodular co-ordination, that is, a sort of submodular reference between the non-tectonic elements and the submodular (micro) grid built into the apparatus. The ratio of modular to submodular (micro) grids can be expressed in a simple mathematical form. This formula of double co-ordination in our case is

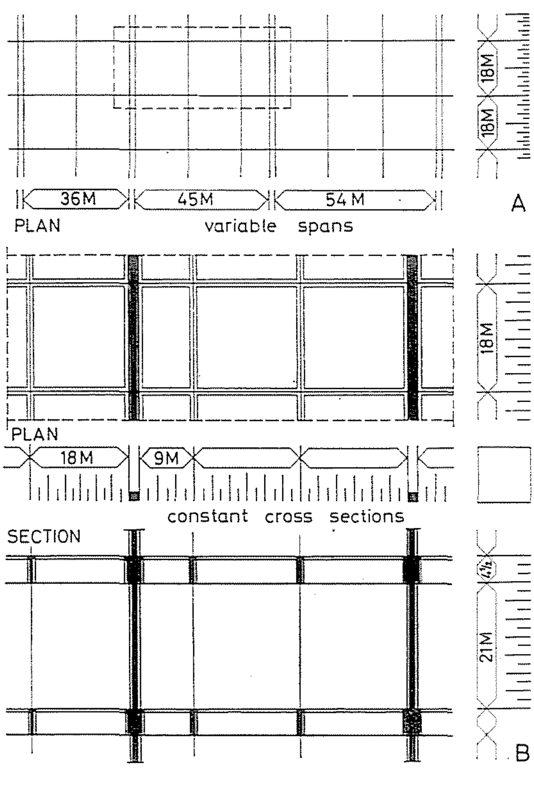
$$3M = 8mc$$

as illustrated by the figure. This formula means that 3 basic module grid units (M = Module = 10 cm) within the structural system correspond to 8 micro grid units (mc = microcell = 37.5 mm) within the manufacturing apparatus.



10. Creating monolithic structure through the additivity of surface elements; the "span-indifference" and "height-indifference" of non-tectonic systems

The fact that the shaping of the building — or, more accurately said: the construction of modular spaces required for housing — is based on the additive quality of surface elements is an extremely important factor from design points of view because it not only allows the cells to have additivity in two directions but it makes something possible that we could never realize in reinforced concrete structures, namely to combine monolithic structure with the additive principle of construction. Through this achievement, the tissue-structural system introduces two basic innovations into building industry from technical point of view: "span-indifference" and "height-indifference".

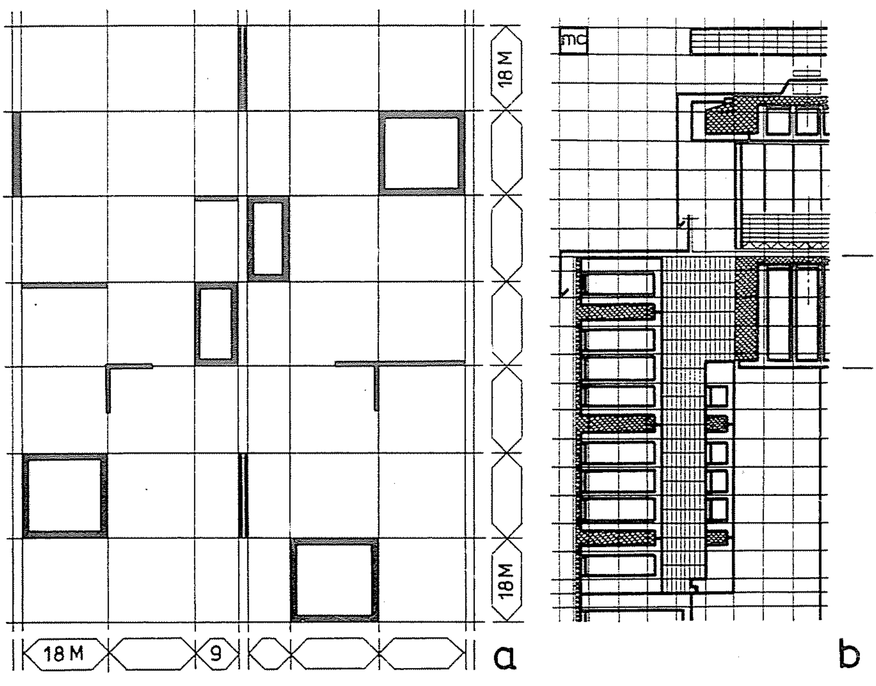


By keeping the cells, the surface elements of the horizontal load-bearing structure, below parameter size, the non-tectonic, tissue-structural systems make the span independent of the structure, the span is not a question of manufacture but of additivity: instead of manufacturing one large floor slab, we achieve the same by additivity of medium size cell units (A).

By keeping constant cross-sections for the vertical load-bearing structure the non-tectonic systems make the height of the building independent of the elements. The height of the building is not a question of manufacture but that of keeping constant cross-sections. In the non-tectonic systems the horizontal and vertical additivity of the surface elements results in the continuity of the primary structure (B).

11. Flexibility through blind manufacture: degree of flexibility in design, detail design and town planning

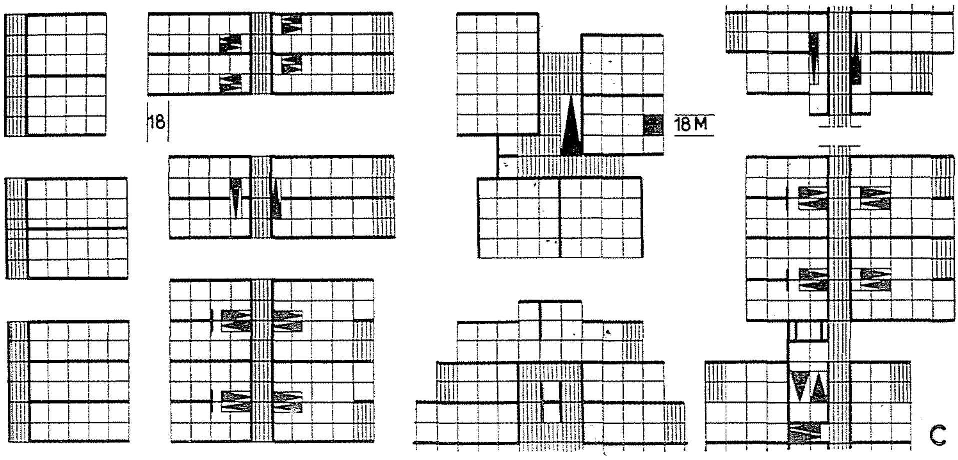
Having cleared the essential questions of variability and co-ordination, we can now determine the degree of flexibility both in design and detail design through selection of proper modular dimensions for the elements, and submodular dimensions for the thicknesses of elements. In the non-tectonic systems, the satisfaction of requirements of flexibility is closely connected to blind manufacture, because any dimension — be it modular or submodular — is directly derived from the manufacturing apparatus.



a shows an example of how to establish a 9M modular (cellular) flexibility in design by selecting 9M and 18M as two basic horizontal dimensions for wall and cell (floor) elements.

Bearing in mind that the architectural variability in the non-tectonic systems is founded on the twin basis of workability of structure and convertibility of machine, it goes without proving that a degree of 3M, 1.5M or even 1M cellular flexibility in design can easily be achieved — if required.

b shows an example of how to establish a 1 mc = 37.5 mm submodular flexibility in detail design, simply by relating all the thicknesses of the elements to the submodular micro-grid.



c finally indicates how to provide a technical possibility for the architect to create various compositions in town planning whilst using the same technology and the same grid system, and shows examples of how to establish a 9M modular (cellular) flexibility in town planning as well.

Through blind manufacture of surface elements, non-tectonic systems do away with type planning in urbanism (since — instead of working with the building — they work with the dwelling as the largest unit of repetition) and thus, they significantly increase the number of possible variations on layout and thereby they may eliminate the threatening monotony of industrialized building in town planning.

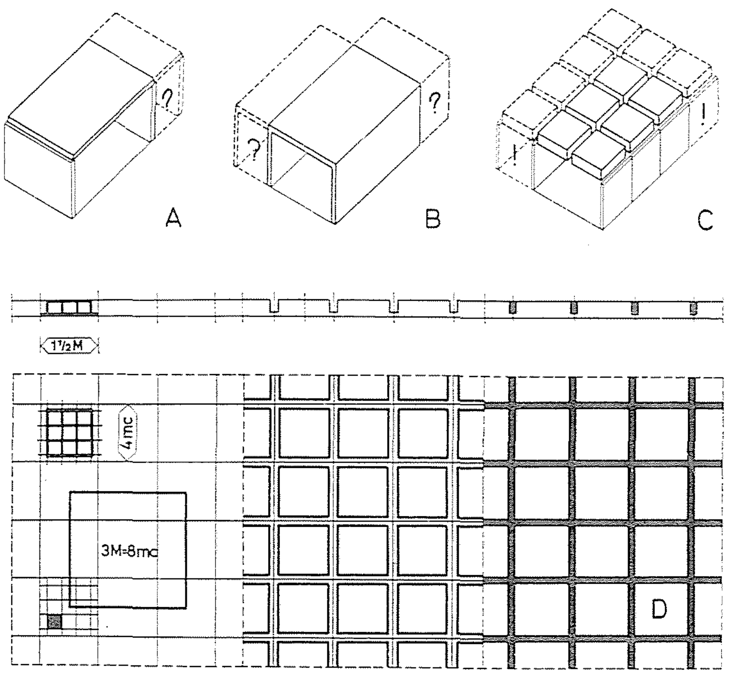
* * *

12. Lessons and implications of non-tectonic systems: the tissue-structural, cellular building method

The tissue-structural, cellular building method is an open system of non-tectonic construction, maintaining the Gutenberg principle of fragmentation in production and combining the additivity of surface elements with monolithic structure. Tissue-structural systems lead to complementary building methods in which the blind manufacture of non-tectonic bricks is coupled with an in-situ technology of pouring.

13. Changing the principle of construction in reinforced concrete structures: the cell and the microcell

The aim was to establish a fundamentally new, industrialized building method based on a new approach to reinforced concrete through changing the existing principles of construction and technology. According to this the first consideration was that of changing the principle of construction We knew from the very beginning that we could not create new systems based on reinforced concrete unless we succeeded in enormously increasing the number of variations possible.



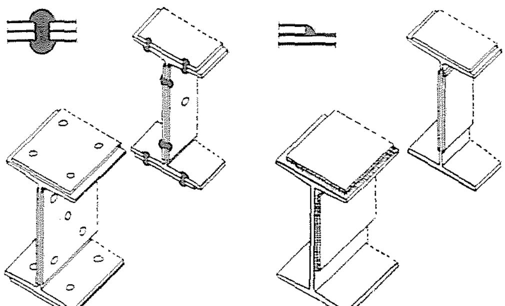
The thorough analysis of contemporary closed systems clearly shows that the tendency towards increasing the spans or the sizes of the elements runs counter the open-system industrialization anyway. Therefore we came to the conclusion that we had to give up the idea of working either with the slab (A) or with the box (B) as principle of construction, and this is how we decided to elaborate working with the cell as principle of construction (C) for the primary reinforced concrete structure and the microcell as principle of manufacture for the non-tectonic bricks and for the reinforced concrete microstructure (i.e. the tissue) arising within the elements (D).

14. Changing the principle of technology in reinforced concrete structures: the tissue and the frozen shell

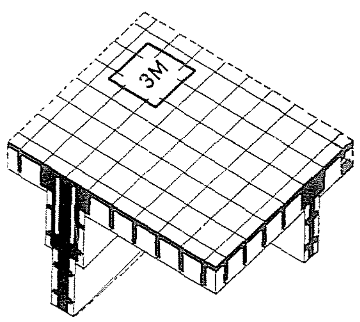
The second consideration was that of changing the principle of technology. The theory of Gutenberg-principled building conceives each (building) technology as a particular *language* which can be translated to the language of other (building) technologies. The tissue-structural cellular building method was conceived as a translation of the language of steel structures to the language of reinforced concrete structures.

Starting out from this consideration we now carefully examined if we could derive solutions of jointing for reinforced concrete technology, similar to those of steel constructions — in principle.

We came to the conclusion that reinforced concrete technology has to be transformed:

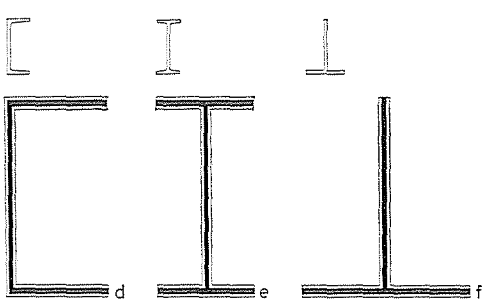


a b



c

— first, by translating the well-known methods of *jointing*, so well proved in steel structures (*a* riveting, *b* welding, etc.) into the language of the reinforced concrete tissue *(c)*;



d e f

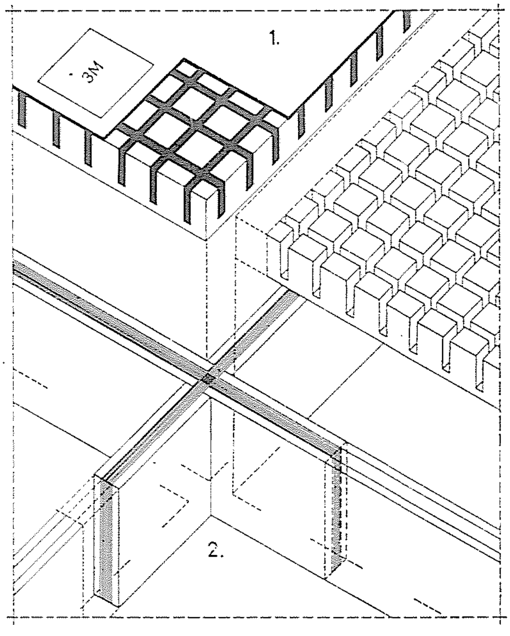
— then, by translating the well-known *forms* (profiles, sections etc.) so well proved in steel structures, into the language of reinforced concrete structures, switching over from the traditional r.c. structures to the inhomogeneous, anisotropic r.c. frozen shell constructions *(d, e, f)*.

This translation actually is the technological essence of the tissue-structures.

15. Some remarks on isotropic and anisotropic reinforced concrete structures: the two basic types of anisotropic r.c. structures: the tissue and the frozen shell

A body is said to be *isotropic* if its physical properties are not dependent upon the direction in the body along which they are measured. According to this definition, a body is said to be *anisotropic* if its physical properties vary with the *direction* in the body along which they are measured.

As opposed to traditional r.c. structures representing the homogeneous, isotropic, monolithic structures, *non-tectonic systems* create inhomogeneous, anisotropic, monolithic r.c. constructions. They are:

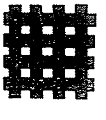


inhomogeneous, insofar as the final structure is composed of two materials (reinforced concrete stabilized between surface elements of low density);

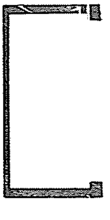
anisotropic, since the physical property of the final r.c. structure varies with the direction in the body;

monolithic, because the additivity of surface elements actually leads to creating *continuous* structures.

Two basic types of anisotropic reinforced concrete structures are:



1. The *tissue:* the r.c. microstructure stabilized within the channel-system of surface elements, always appearing in the form of a r.c. grid reminding of the form of tissue of woven cloth.



2. The *frozen shell:* the r.c. primary structure stabilized between the surface elements. Its form is that of a *steel section* or rather of a cardboard carton with reinforcement led around the corners. The frozen shell is namely a thin folded r.c. *membrane.*

16. The importance of selecting traditional materials; reduction of weight through reduction of material

In the non-tectonic systems the building material is *traditional:* it is reinforced concrete and gypsum. The selection of traditional hydraulic materials (materials stabilized with water) is extremely important in *developing countries* from three points of view:

1. because these traditional (stabilized or reinforced, natural or artificial) silicate materials can be found anywhere;
2. because they eliminate the use of synthetics, which at present have no real material or technological basis in developing countries;
3. because with this technology the weight of the structure can be reduced significantly. Results of laboratory research show that this reduction may be one-third to one-fifteenth, as compared to traditional structures. This result is important because it scientifically proves that the anisotropic tissue and shell structures represent the lightest weight constructions manufacturable on silicate basis.

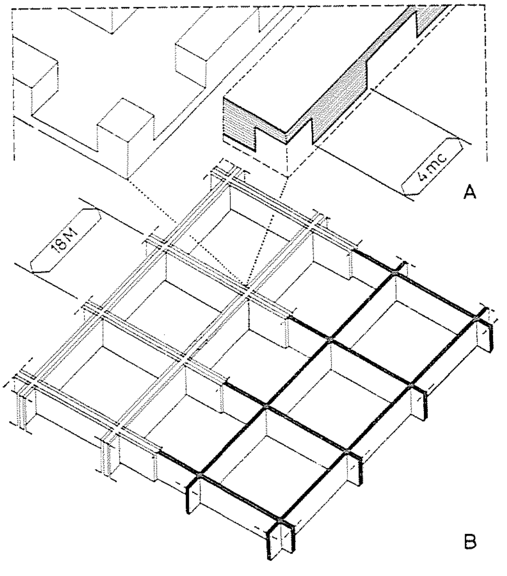
The significant reduction of weight of building through reduction of material — particularly in developing countries — is an extremely important demand both from industrial and technological points of view:

1. because it radically changes equipment of transportation and hoisting, absolutely eliminates the use of heavy trucks, trailers, cranes etc., thus — as opposed to mechanization-based industrialized systems — it is not bound to a built-out *infrastructure;*
2. because the non-tectonic systems totally eliminate the long-distance transportation of heavy elements with a high degree of readiness, only raw materials are hauled over a long distance, while the lightweight surface elements are transported over short distances, and then quickly and easily moved, lifted and placed by two or four men;
3. in the Gutenberg-principled building, the factory itself is transplantable since the simple, lightweight manufacturing apparatuses are constructed only of linear elements to be packed favourably, thus when dismounted and when transported they cannot get distorted.

17. The surface as principle of manufacture: why surface elements are called "negatives" of the structural system

When constructing the system, the final *surface* is manufactured first — this is the process called "blind manufacture of non-tectonic bricks" — and then, this casing is filled with thin concrete. Now, irrespective whether this process takes place in the factory (as e.g. in the case of floors) or on the site (as in case of walls) the form of the structure will be determined by the surface, since the surface is nothing else but the negative of the structure. This factor is very important because it means that the design of non-tectonic elements is equivalent to designing the negative of the structural system.

For the manufacture of the surface, a material of low specific gravity was chosen of course. *Gypsum* showed the most suitable. If the concrete meeting the gypsum surface requires *ribs* then the negative of the rib has to be manufactured.

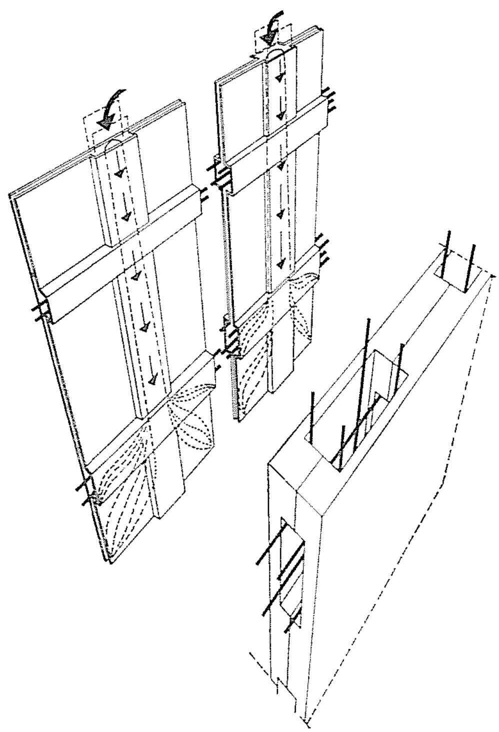


In case of a *tissue* — i.e. the *r.c. microstructure* — the rib is formed within the elements, therefore the negative of the microstructure is cast in the surface element in form of a two-way channel system. The tissue is always constructed on a submodular (micro) grid (A) (Remember: 3M = 8mc).

In case of a *frozen shell* — i.e. *the r.c. primary structure* — the rib is formed between the surface elements, therefore the negative of the primary structure is assembled through the additivity of surface elements in form of a two-way channel system — the cellular grid system of the primary structure. The frozen shell is constructed on the modular (secondary) grid of the cells (**B**).

18. The cycle of pouring: elimination of hydrostatic pressure; the use of gypsum for freezing the concrete

The concrete itself meets the gypsum in the phase of pouring when, as a consequence of the moisture-absorbing capacity of the gypsum, the concrete poured in gets immediately stabilized. It *freezes* on the gypsum.



This phenomenon led to interesting results in the use of gypsum materials for structural purposes. After many years of laboratory research we came to the conclusion that in the technological cycle of pouring (bringing about the inhomogeneous, anisotropic, monolithic structure) the hydrostatic pressure of the concrete could be eliminated if a properly chosen concrete was poured in between properly formed gypsum layers.

The recognition of this phenomenon made us aware of the inherent technological and economic possibilities of gypsum materials for mass housing in developing countries. Gypsum, by its *pourability*, *porosity*, *low specific gravity*, *cheapness* and *availability*, is a building material for mass housing likely to open new vistas for the building industry of developing countries.

19. Conclusion: the inherent possibilities of complementary building methods in developing countries

The Gutenberg-principled non-tectonic systems are products of a *complementary* building method insofar as they combine the factory production of surface elements with an in-situ technology of pouring.

The selection of a complementary building method is very important, particularly in developing countries,

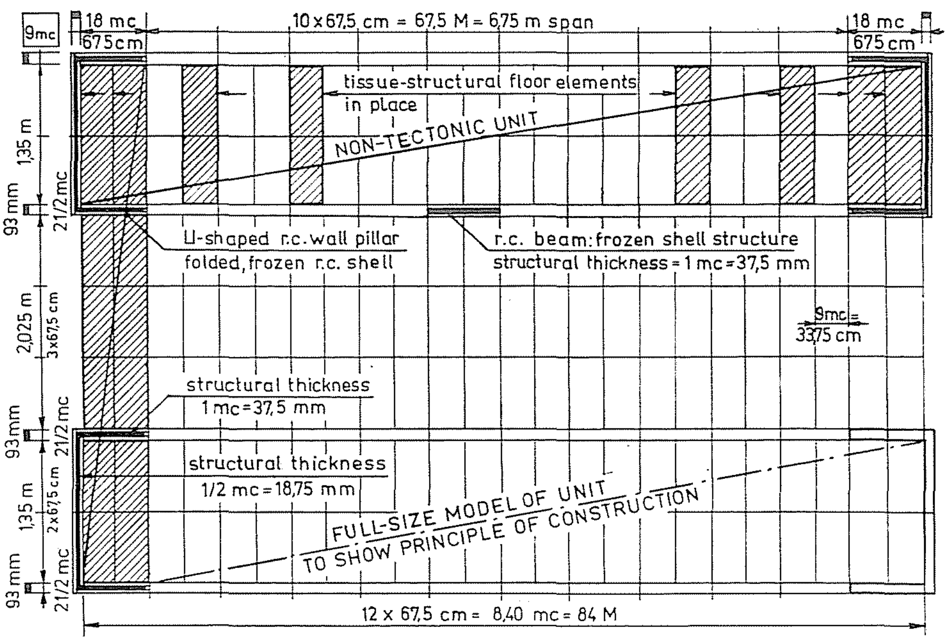
a) because by basing the technology on pouring, an unusually high degree of mass production of surface elements on an unusually high degree of precision can be achieved with handicraft forms of production, whilst using only traditional materials;

b) because thereby the technical advantages of capital-intensive technologies combine with the inherent social-economic possibilities of labour-intensive technologies, thus offering a possible solution for eliminating the well-known inner contradiction of building in developing countries;

c) because the complementary building method combines the additive principle of construction with monolithic structure and thereby — beyond satisfying twin requirements of planning and producing for change — it produces buildings that are structurally rigid and earthquake resistant;

d) because factory-production — i.e. blind-manufacture — can be realized through elementary manufacturing apparatuses requiring very low investment costs; and

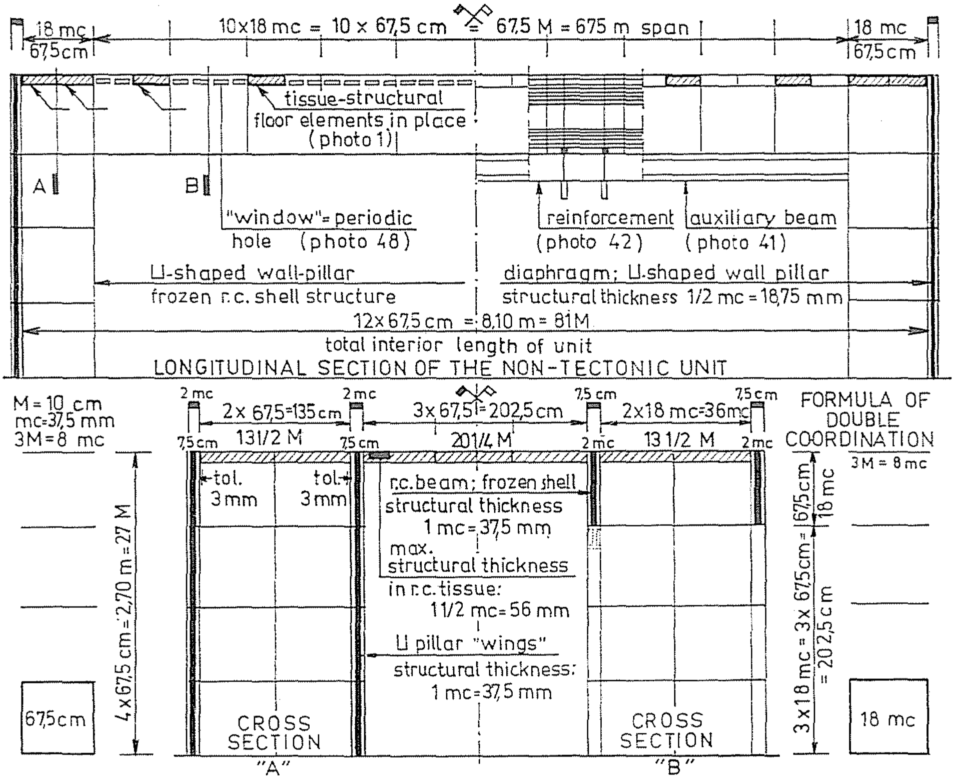
e) last but not least, the resulting open-system *industrialization* basically changes the whole structure of the building industry — both from social-economic and from technological aspects. Instead of requiring huge planted factories established at enormous investment costs, the structure of the industry consists of a system of elementary factories (micro-building-industrial units) which can be scattered throughout the country, and which mass-produce non-tectonic bricks by means of cheap, easily mass-producible, convertible, transportable and transplantable elementary manufacturing apparatuses.



Ground plan of the unit. Location of wall and floor elements in the grid system. See also photo 1. Each dimension can be expressed in a decimal (modular) and a geometrical, micro-cellular (submodular) value according to the formula of double co-ordination: 3M = 8mc (M = 10 cm; mc = 37.5 mm).

Basic floor element (surface element; non-tectonic brick: floor negative: letter of the structural system). The gypsum element is constructed on the micro-grid (mc = 37.5 mm). The tissue of the reinforced concrete is determined by the channel system manufactured into the gypsum element. Floor units are composed of two or three basic gypsum elements.

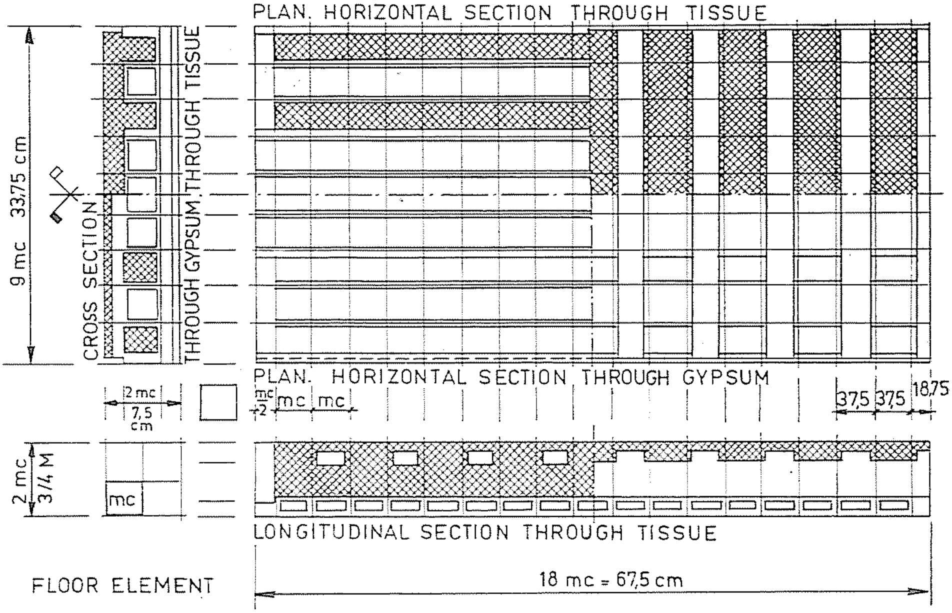
*

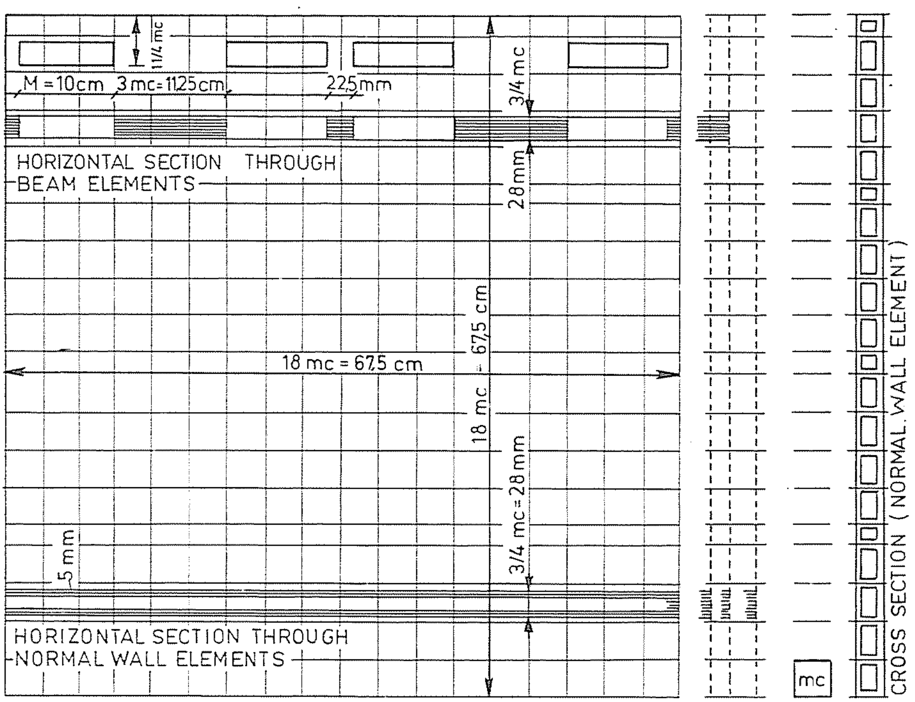


Longitudinal and cross-sections of the structural unit. Location of wall and floor elements in the grid system.

*

Basic wall element (surface element: non-tectonic brick: wall negative: letter of the structural system). The gypsum element is again constructed on the microgrid (mc = 37.5 mm). In wall elements, the channels are closed channels. The frozen shell always develops between two surface elements. In walls and beams of the experimental unit, six different elements were used.


PLAN. HORIZONTAL SECTION THROUGH TISSUE
THROUGH GYPSUM. THROUGH TISSUE
CROSS SECTION
9 mc 33,75 cm
2 mc
7,5 cm
mc
PLAN. HORIZONTAL SECTION THROUGH GYPSUM
mc/2 mc mc
37,5 37,5 18,75
2 mc 3/4 M
LONGITUDINAL SECTION THROUGH TISSUE
FLOOR ELEMENT
18 mc = 67,5 cm


1 1/4 mc
M = 10cm 3 mc = 11,25cm 22,5mm
3/4 mc
HORIZONTAL SECTION THROUGH BEAM ELEMENTS
28mm
18 mc = 67,5 cm
18 mc 67,5 cm
3/4 mc = 28 mm
5 mm
HORIZONTAL SECTION THROUGH NORMAL WALL ELEMENTS
mc
CROSS SECTION (NORMAL WALL ELEMENT)

Part II

THE EXPERIMENTAL NON-TECTONIC STRUCTURAL UNIT

1. Design

The experimental non-tectonic unit is first of all destined to give a clear indication of how non-tectonic systems can be conceived. The emphasis of the experiments therefore was laid on showing the principles of design, manufacture, and the process of construction.

In order to show both the structural system and the process of construction, the experimental unit is divided in two parts: the one is the very system, the second part is built in a full-size model directly exhibiting the interior structure.

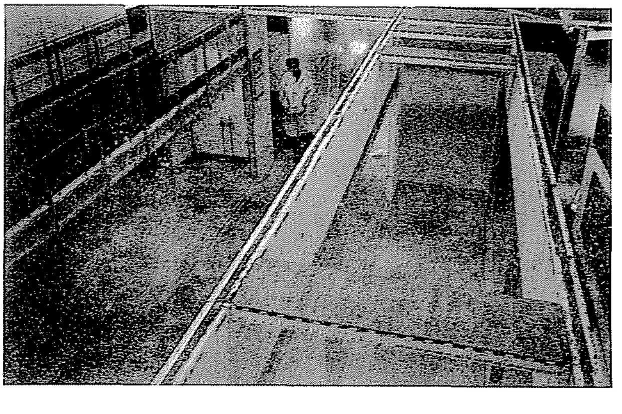


Photo 1. Overall view of the experimental structural unit. The part on the left-hand side is a full-size model of the structure. The principle of the very system is shown on the right side. Span of the beam: 10 by 18 mc = 10 × 67.5 cm = = 6.75 m.

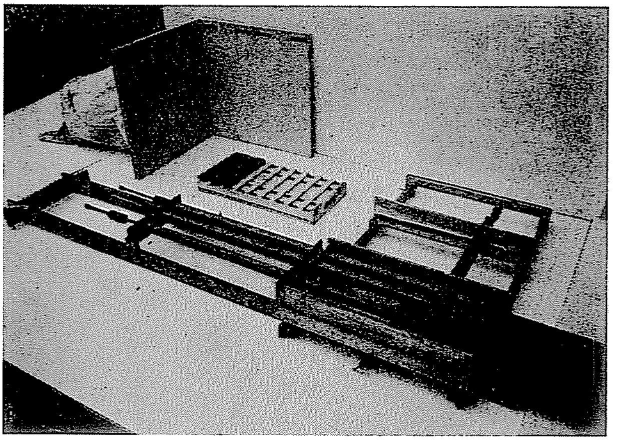


Photo 2. *Full-size wooden model of the manufacturing apparatus.* To explain the manufacturer the kind and composition of the machine for making non-tectonic bricks, each apparatus and element was modelled in full size. The actual design of the apparatus was thus preceded by modelling. *Full-size models of the elements* show the channel systems in the surface (wall, beam, floor) elements. Each channel within an element corresponds to a key (a simple linear forming bar within the manufacturing apparatus, as shown by photos in section 2).

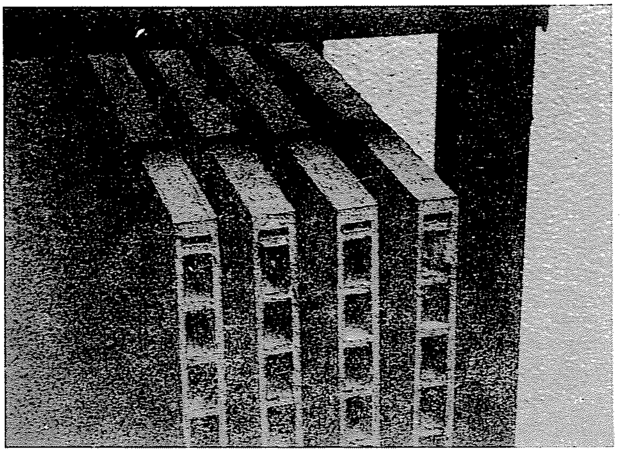


Photo 3. *The first four experimentally manufactured wall elements* of 3/4 mc = 28 mm thickness. Rib inside the gypsum element is 5 mm wide. The photo also shows the way of storage. Only the first element is fixed in position, all the others are clipped on to the preceding one with simple clips (15 mm × 0.75 mm steel bands).

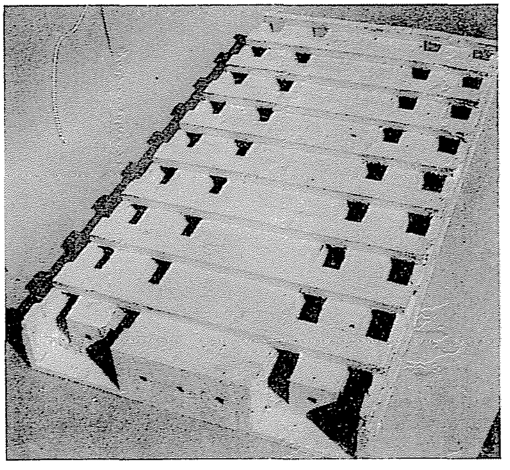


Photo 4. *The first experimentally manufactured floor element.* The two-way channel system within the element determines the form of the r.c. tissue. The floor unit is composed of two or more elements by proper addition. The additivity of non-tectonic bricks results in continuous structures. The *tissue* within the floor unit always goes through: the channels namely become *continuous* by addition.

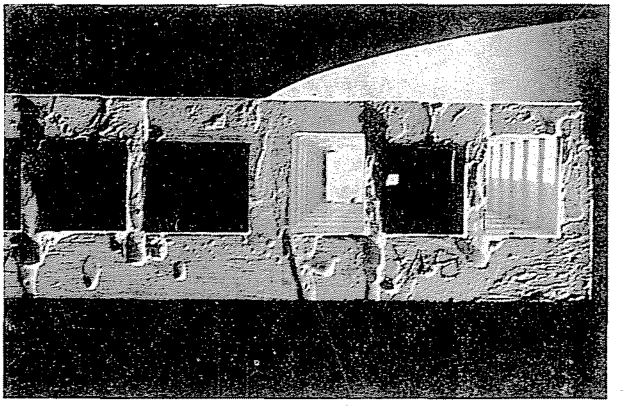


Photo 5. *The internal channel system of the floor element.* A close view of the butt end shows the system of closed and communicating channels. Grid dimension of a closed channel: mc × mc = 37.5 × 37.5 mm.

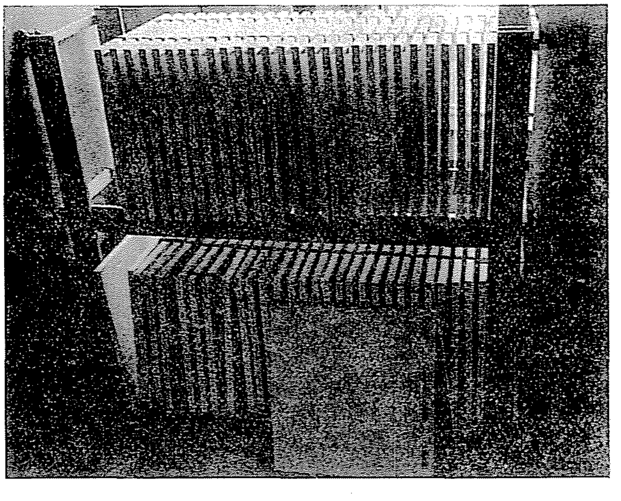


Photo 6. *Storage of wall elements.* Very simple steel clips, cheap to mass-produce, easily store whole sets of elements, avoiding costly means of storage.

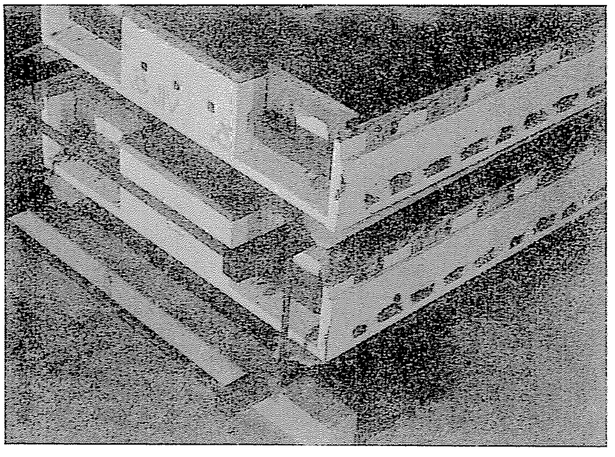


Photo 7. *Storage of floor units.* Another simple storage system. The concrete structural tissue poured into the channels stiffens in less than a minute. This advantage is made use of by taking the unit from the apparatus almost immediately. Now, the frame under the unit is also a part of the apparatus. When the concrete stiffened the unit is taken with the same frame that is applied for storing. In the four periodic holes at the end of the 16×16 mm bars of the frame, simple 100 mm× 0.5 mm "posts" are placed, easily storing eight units above each other. When the unit is built in, the frame is returned to the apparatus.

2. Manufacture

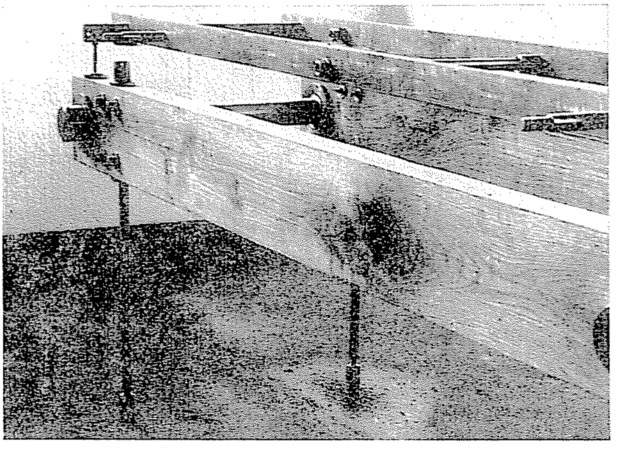


Photo 8. *Manufacturing apparatus for floor elements: the frame.* The process of assembly starts by the timber frame, followed by the steel frame. The photo shows the *fundamental principle of manufacture:* In the apparatus only elementary, *linear components* are applied and the apparatus is assembled by "*stacking*" (principle of "pile of logs"). The quite simple elementary components — that are therefore easy and cheap to mass-produce — finally add up to a *determined system.* The "legs" of both frames are adjustable, to help horizontal adjustment of the steel frame.

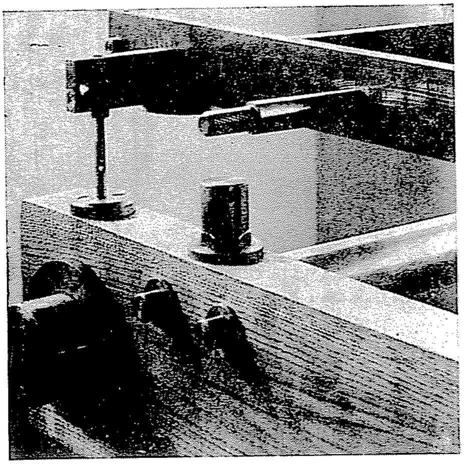


Photo 9. *The end of the frame, detail.* The close view of the end of the frame shows how simply the principle of "stacking" works. The linear timber beams are precisely spaced and stiffened by thin-wall tubes, exactly locating the 8 mm adjusting screws of the superposed steel frame, composed in turn of four linear "beams": a disk with rectangular grooves stiffens corners in position. The legs of the timber frame are simple 14 mm steel bars fixed to the beam through pressure. Further four counter screws eliminate timber warping.

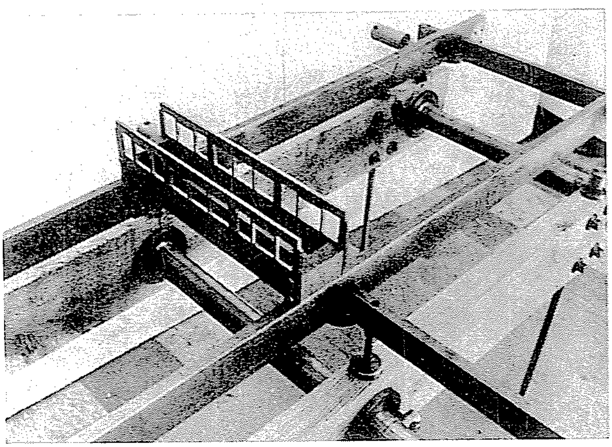


Photo 10. *The cross-comb* (double comb). The combs — again linear elements — are important and relatively "complicated" components of the apparatus. They precisely position and guide the keys. The "windows", i.e., openings in the comb, precisely determine the size and direction of keys, which in turn, create the channel system in the floor elements (to house the r.c. tissue). In conformity with the design of the basic floor elements the comb is constructed on the "micro-grid" (grid dimension: mc × mc = 37.5 mm × 37.5 mm)

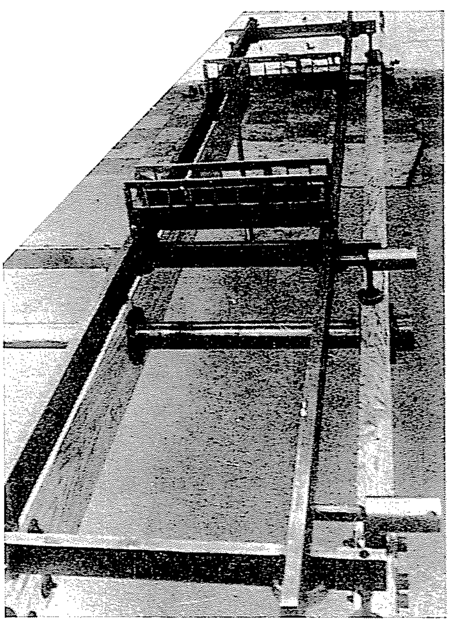


Photo 11. *Manufacturing apparatus for floor elements: longitudinal frame and cross-combs*

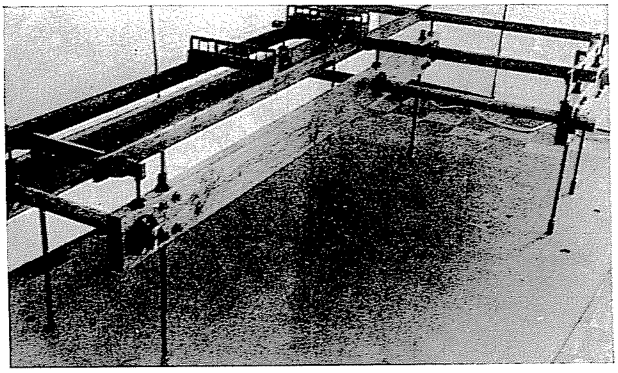


Photo 12. *Cross-combs* in place. The frames are assembled, the plate required is already set in and adjusted by the screws. Now, cross-combs (a double comb and a simple comb) are positioned in a simple operation by means of holes in the steel frame, and fixed by screws. In the case shown, the cross-combs are all fixed.

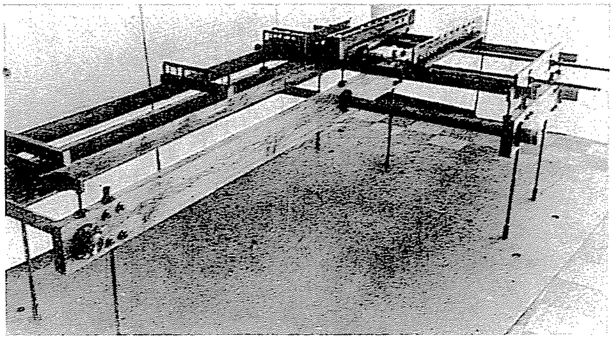
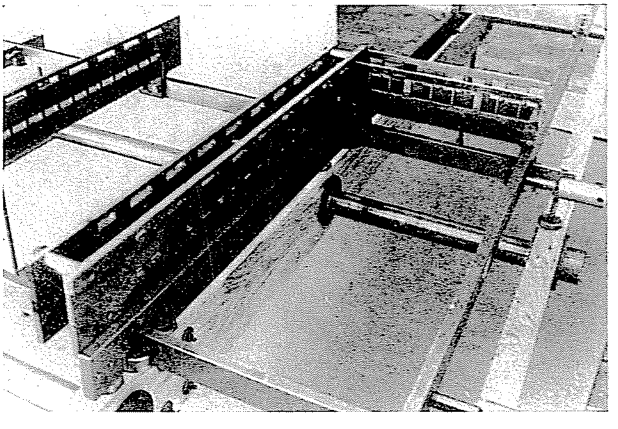


Photo 13. *Longitudinal combs* in place. Longitudinal combs guide the cross-keys forming the cross-wise channels in the floor element. There is again a double comb and a simple comb, the double comb being movable. Before the element is taken from the apparatus, the double comb is slightly moved away from the frame in parallel position, by rotating the two bars.

Photo 14. *Manufacturing apparatus for floor elements: the combs and the system of double co-ordination.* The principle of double co-ordination is seen by the combs which actually determine a two-way channel system in the floor elements. The manufactured *elements* fit into *modular* grids on the site. Any dimension that occurs on the site can be composed of surface elements. In manufacture, however, the *modular* dimensions of elements are produced through additivity of *submodular* keys fitting into the combs. In non-tectonic systems any dimension that occurs *on the site* is directly derived from the manufacturing *apparatus*. That is why the system of co-ordination is a double one.



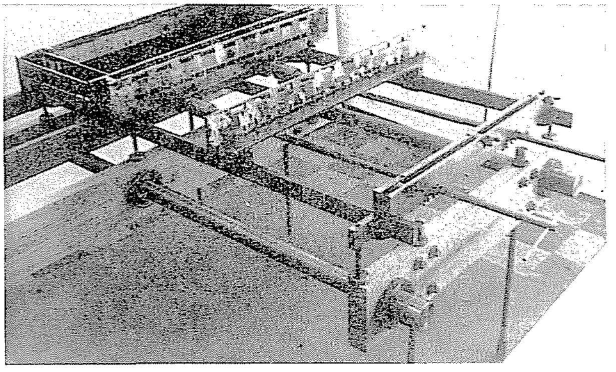


Photo 15. *The "mould"*. The mould of the basic elements is surrounded by four plates: 1. fixed cross-comb; 2. mobile longitudinal combs (both are double, in order to help drawing the keys out of the mould without deviation); 3. a removable longitudinal plate, and 4. a removable butt end. The bottom of the mould is a removable, smooth hard vinyl plate.

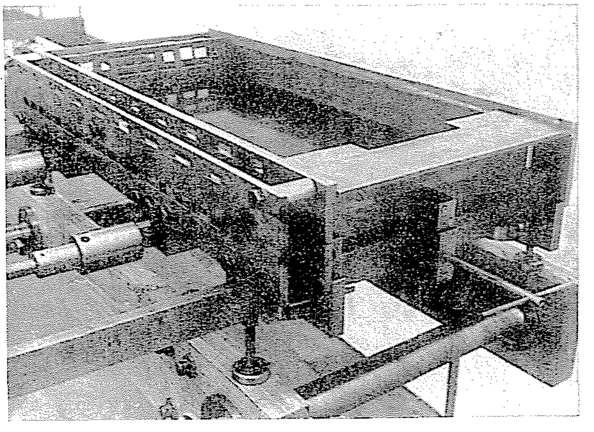


Photo 16. The empty mould is seen here from the butt end toward the cross-combs.

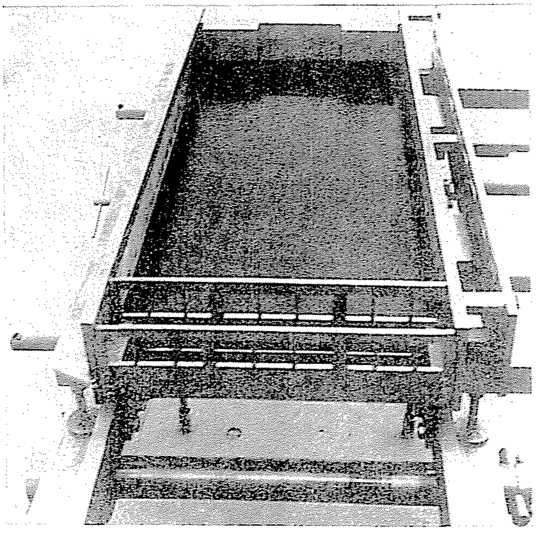


Photo 17. *The "empty" mould*

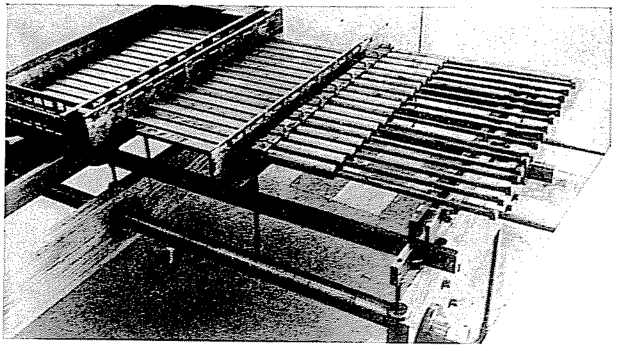


Photo 18. The process of assembly ends by inserting the keys into windows of the combs. The end "hammers" help in removing the keys from the gypsum; they only transmit "axial" strokes.

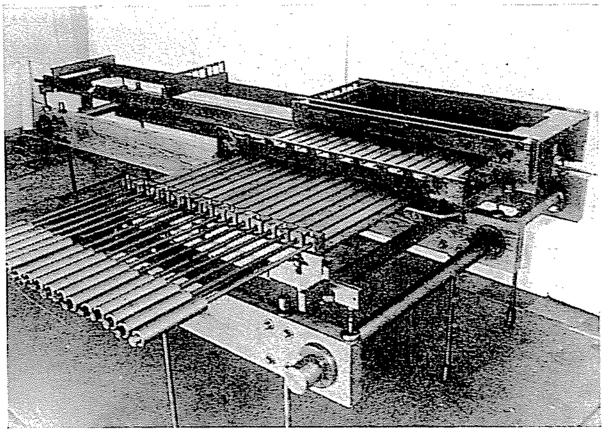


Photo 19. *The row of lower cross-keys.* The keys are simple rectangular steel sections, elementary linear component parts, cheap and easy for mass production. There are seventeen 30 mm × 11.2 mm keys in the lower row. All but the one at the butt-end are of the same size.

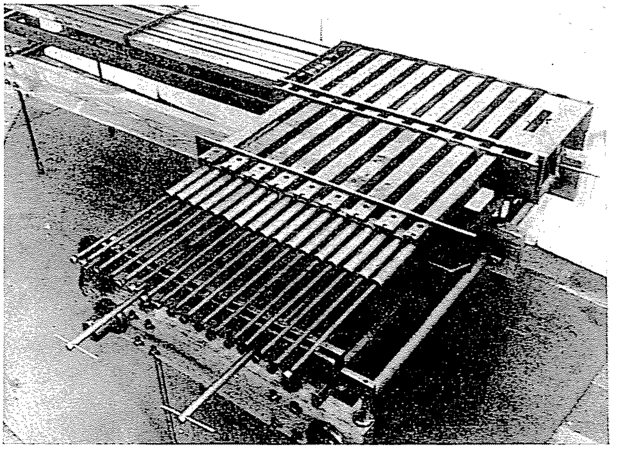


Photo 20. *The row of upper cross-keys* in closed position and *the row of longitudinal keys* in open position. The element is poured when all the keys are "closed", i.e. inside the mould. When the keys are pulled out ("open") the key ends are inside the double comb as shown here.

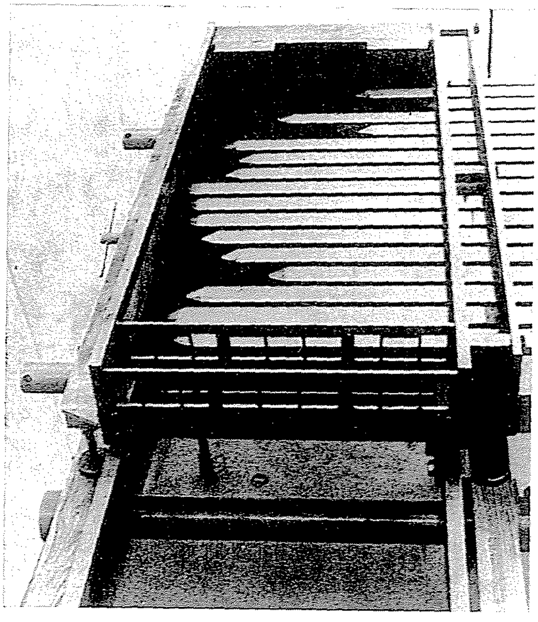
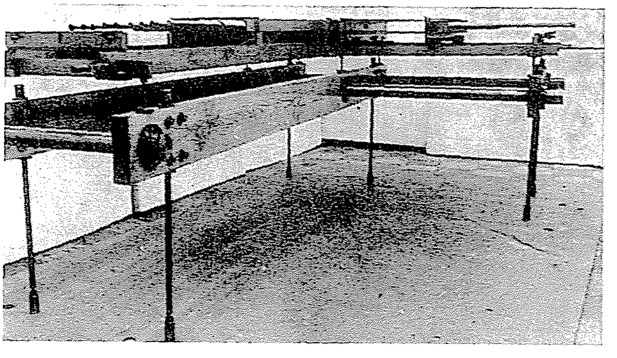


Photo 21. *The row of lower cross-keys*

Photo 22. The *elementary manufacturing apparatus* completed. The apparatus, exclusively composed of linear elements, now appears as a system of frames, combs and keys.



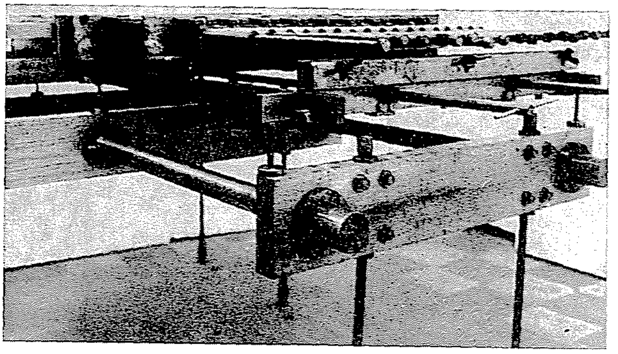


Photo 23. The apparatus ready for gypsum pouring.

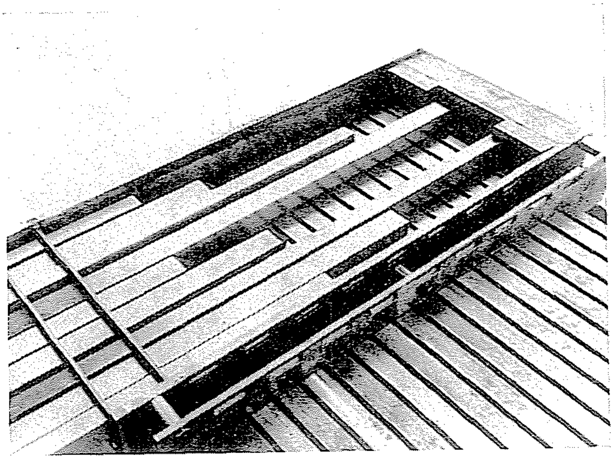


Photo 24. The row of lower cross-keys in "closed" position, the row of longitudinal keys is being fitted in, the "windows" for the row of upper keys are still open.

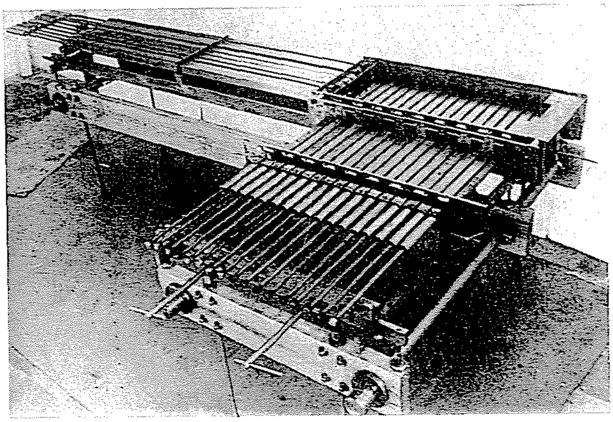


Photo 25. *The system of keys.*

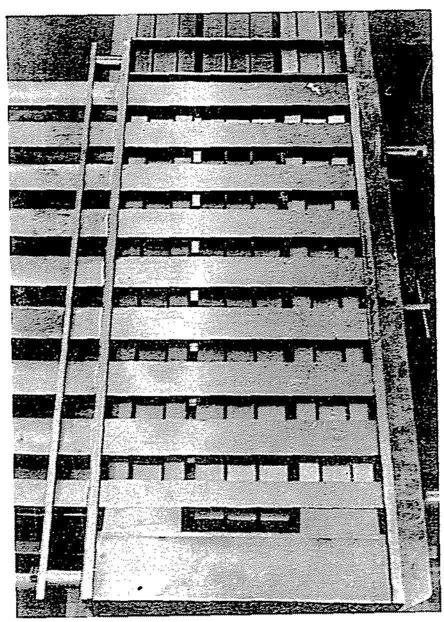


Photo 26. Manufacturing apparatus for floor elements. *The system of keys.*

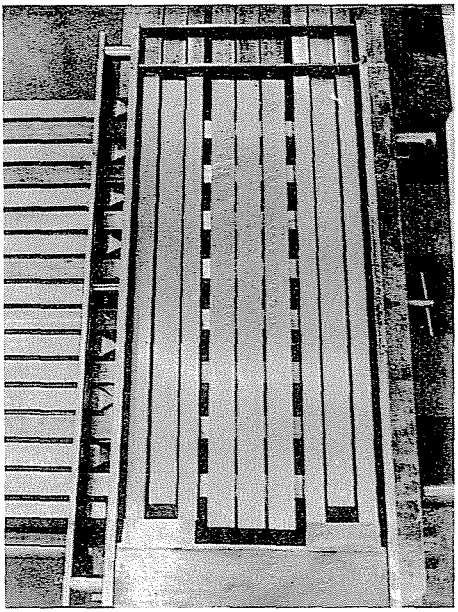


Photo 27. *The system of keys.*

Photo 28. Manufacturing apparatus for *wall* elements. The timber frame is mounted first, followed by the steel frame, then the combs and the keys will be placed. Again, only linear components are used, according to the principle of "stacking". The cross keys in this case come from below and pierce the hard PVC plate.

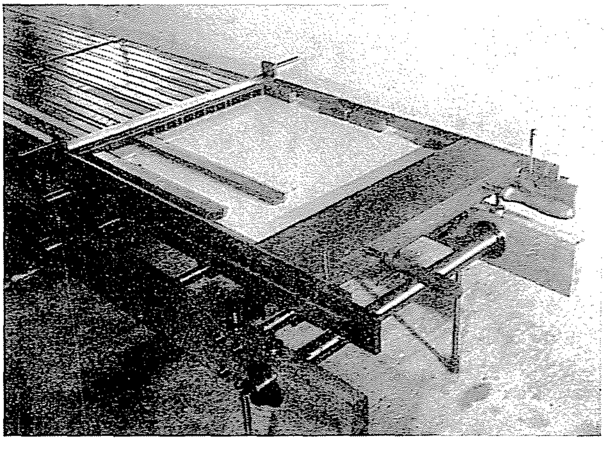
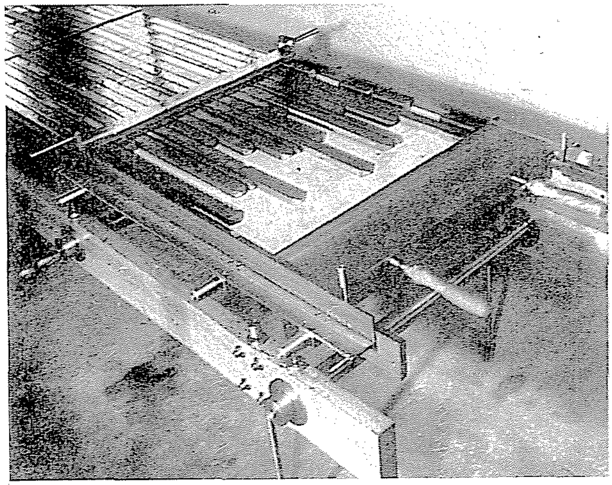


Photo 29. The wall apparatus is composed exactly as the floor apparatus. Wall elements contain, however, a closed channel system. The frozen shell is formed between two elements. In case of wall elements only the longitudinal keys are used, in case of beam elements — as shown by photo — the cross-keys are used, too. This apparatus is *convertible*. The six different sizes and forms required have simply been realized through a combination of keys and proper adjusting of the butt end.



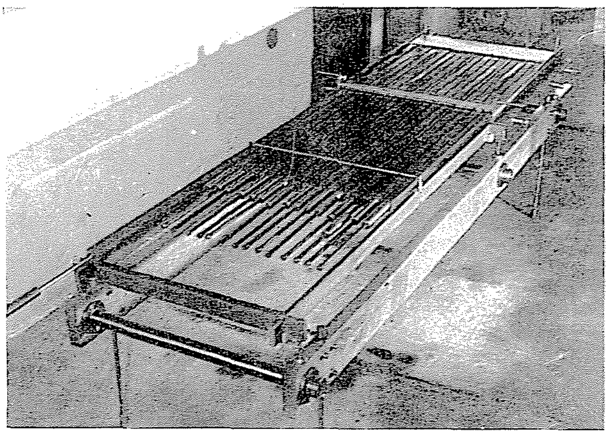


Photo 30. The elementary manufacturing apparatus is completed by inserting the keys, to become a convertible system of frames, combs and keys.

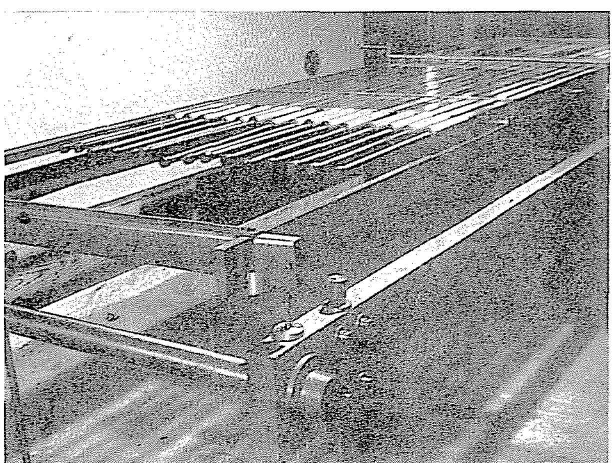


Photo 31. Manufacturing apparatus for *wall* elements, ready for gypsum pouring.

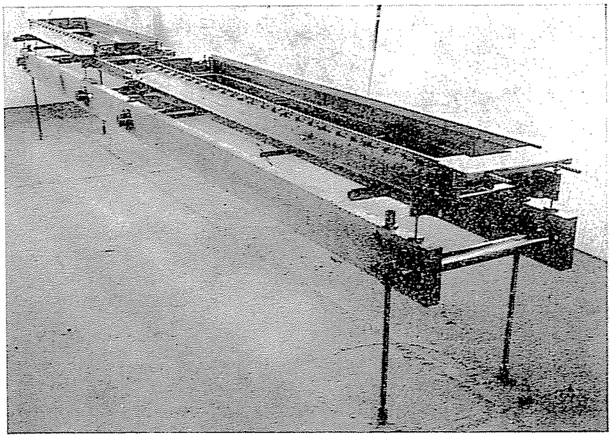


Photo 32. *The completed reinforcing apparatus.* The timber frame is now topped by a steel frame (of linear elements) to keep the combs in place. These combs serve for the *precise location of the reinforcement within the channels*, by means of a *periodic punch system*. Thus, the highest degree of precision can be achieved by *unskilled labour.*

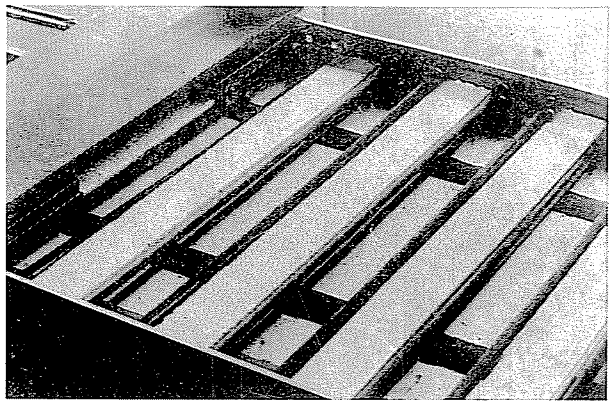


Photo 33. Possibility of any mistake is eliminated: no 4 mm steel can be left out or displaced since reinforcement can only be "threaded in" through proper holes, and any empty hole would show the mistake. Since the form of tissue is determined by the gypsum element and the system of reinforcement by the apparatus, the products — the preassembled floor units — are reliably repetitive.

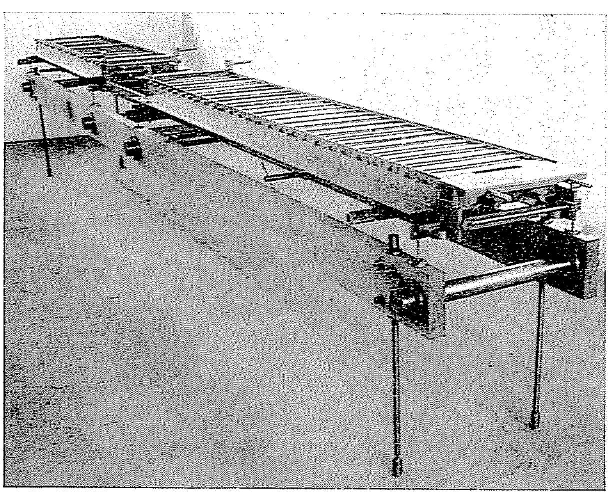


Photo 34. *The process of reinforcement.* First, the auxiliary steel frame (photo 7) is fitted in the apparatus. Then, the required number — two or three — of elements are placed into the apparatus side by side and reinforced as follows: first the longitudinal reinforcing bands are threaded through the respective channels, and fixed at the butt ends. Then the 4 mm wires are threaded through the punch system. The channels of the gypsum elements add up to a periodic channel system locating the reinforcement within the cross-channels. The punch system exactly corresponds to the periodic channel system in the elements, as shown here.

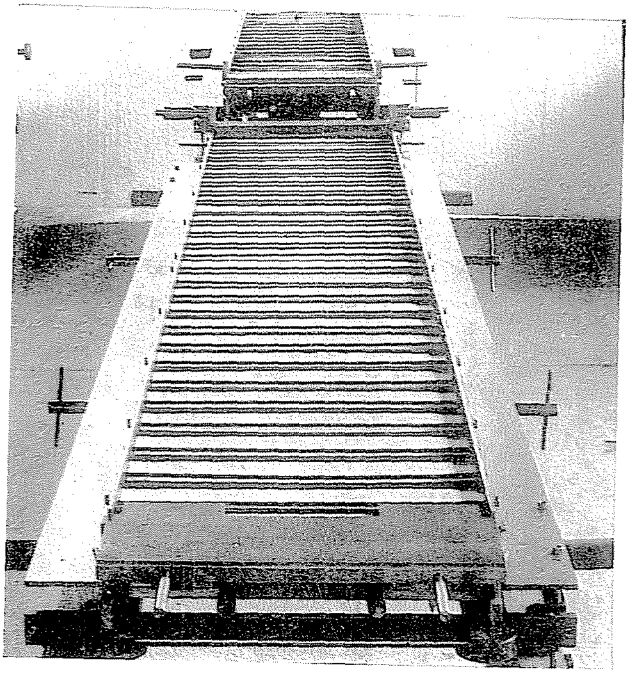


Photo 35. The complete reinforcement seen from the butt end, before the concrete is poured in. The concrete poured into the narrow communicating channel system stiffens in less than a minute. Further 5 to 8 minutes are needed for a quick surface finishing. Ten minutes after the concrete is poured, the completed unit may be taken out for storage.

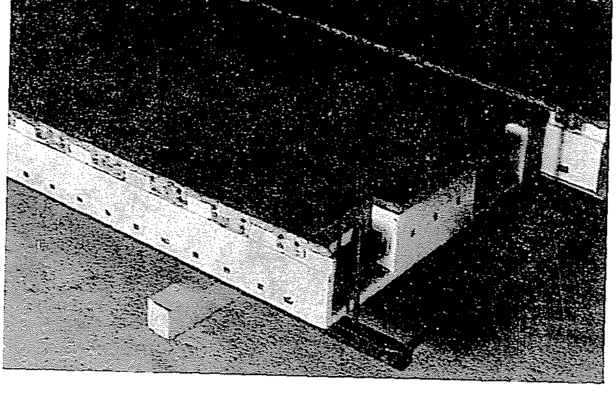


Photo 36. *The complete floor unit.* The structural tissue, cast in the cross-channels, appears on the side, the tissue cast in the longitudinal channels ends in the "nose". The longitudinal reinforcing strip protrudes from the concrete and is folded back to keep within the confines of the element. This is how the elements can be lifted between the beams. After placing, the nose will exactly face a "window" (cavity) of the beam into which the steel strips will be folded out to hold the units until final structural connection is established.
The auxiliary frame beneath the element is seen to help storage. The little ⌀ 5 mm × 100 mm steel "columns" both support and space the units above each other during storage.

3. Building

As stated in item 8, in Gutenberg-principled non-tectonic building there are two basic types of in-situ operations corresponding to the complementary character of the building method. The one is the *assembly of surface*, the other the *cycle of pouring*. It is important to note again that the *process of non-tectonic building is the opposite of the usual, tectonic building.*

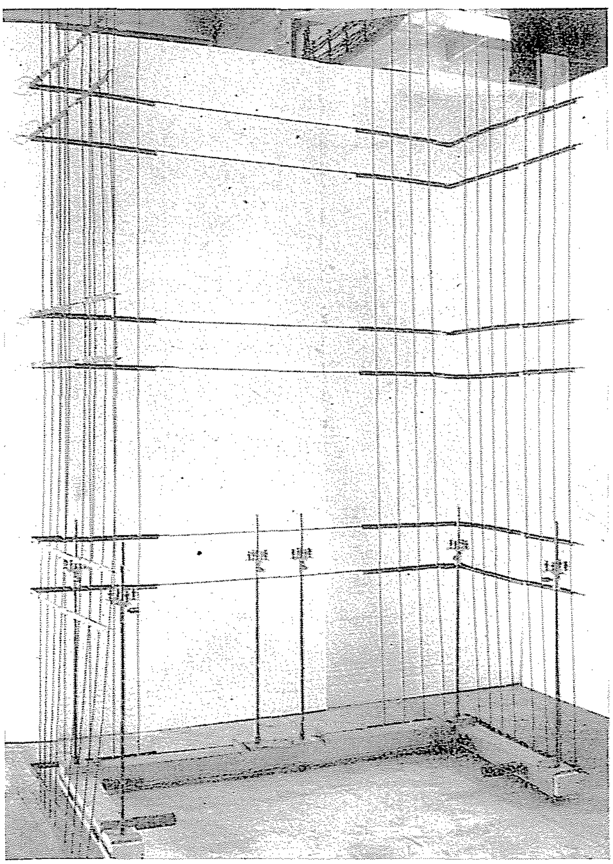
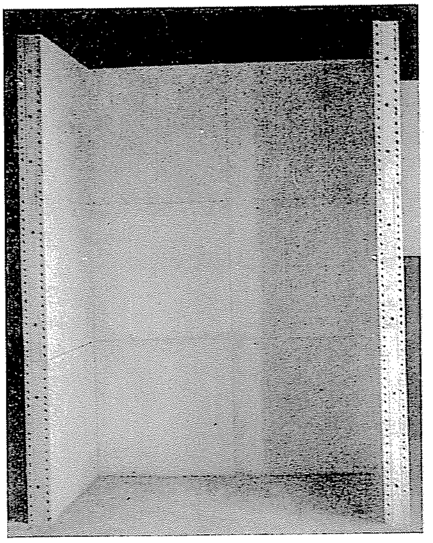


Photo 37. The process of Gutenberg-principled building: *reinforcing the U-shaped wall pillars.* The sequence of operations starts with the assembly of reinforcement for the U-shaped walls.
In non-tectonic building, the smallest unit of vertical additivity of reinforcement is one "row". According to the principle of additivity of elementary linear components, the reinforcement is assembled of ∅ 3 mm wires — without welding, binding, or riveting, — simply by *threading*, keeping the storey-high reinforcement in position without supports. The reinforcing strips led round the corners unite the independent wires into a system, and in final account, lend seismic safety to the whole of the building, since now the corners will be the strong points of the structure. The little U-shaped auxiliary tool seen in the foreground keeps the surface elements in exactly vertical position until concreting is finished.

Photo 38. U-*shaped wall-pillar completed to beam level.* The U-shaped wall-pillar is composed of three "rows" of non-tectonic wall elements. The assembly of reinforcement is followed by that of the surface "row by row". One row of the U-shaped wall is composed of eight surface elements (4 inside, 4 outside), the open butt ends are closed by "specials". The surface elements temporarily fixed by the U-shaped auxiliary tool get concreted, then the auxiliary tool is raised by one row and placed on top of the former one. Note the different jointing points in the butt end "specials". They will serve for supporting the auxiliary beam (see photo 1), and for the connection of window and door frames.



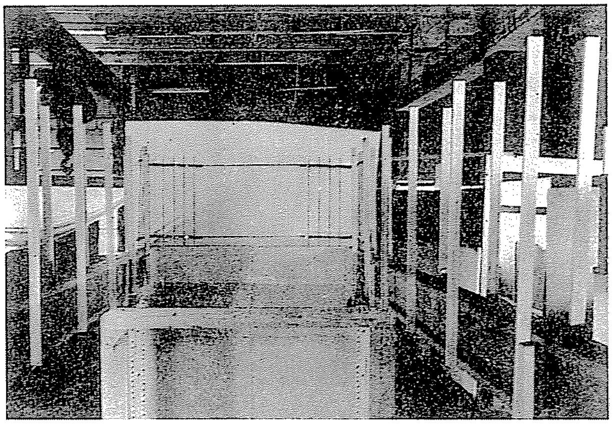
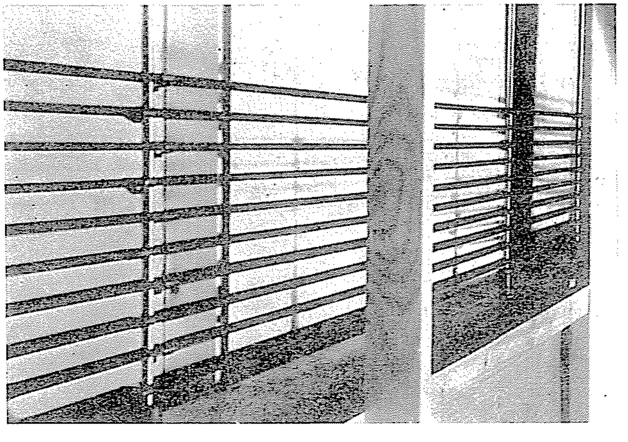


Photo 39. *The assembly of beams, mounting the auxiliary beam.* When two opposite U wall-pillars are ready up to beam level, then the auxiliary beams — light timber I-beams — with a system of holes and "posts" are mounted. The holes will serve for precisely locating the beam reinforcement, the posts support the beam surface elements until concrete is poured in. Reinforcements of beam and wall will be in interaction.

Photo 40. *Beam reinforcement.* A "needle" (a bar with threaded end) is fitted in each hole from underneath — see photos 48, 49 — and screwed into a cylinder with internal thread. From above another, so-called "leading needle" is screwed into the same cylinder. The ∅ 6 mm leading needle is provided with regular indentations to locate a specified number of ∅ 4 mm longitudinal reinforcing wires. Each indentation holds twinned reinforcing wires by means of very simple clips.



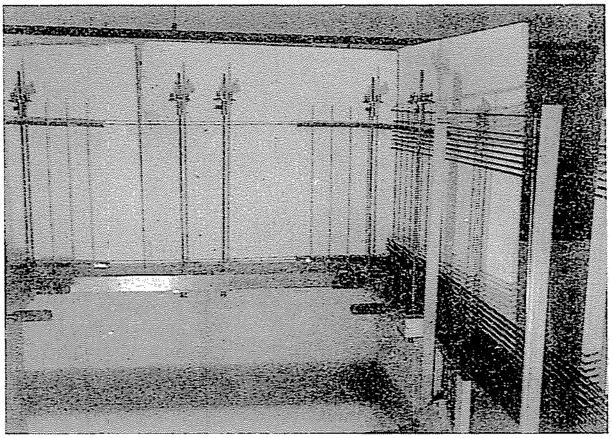


Photo 41. *Beam and wall reinforcement.* The reinforcement of the beam protrudes into the "wings" of the U-shaped wall-pillar to constitute a continuous reinforcement — a "ring" — led round the corner by the reinforcing strips of the wall. The auxiliary positioning tool gets now into top position. It rests on four "tongues" which can be driven out and withdrawn by turning around the handles. After assembly of surface elements, the two beams and the two U-walls finally create a ring to be concreted as a single unit.

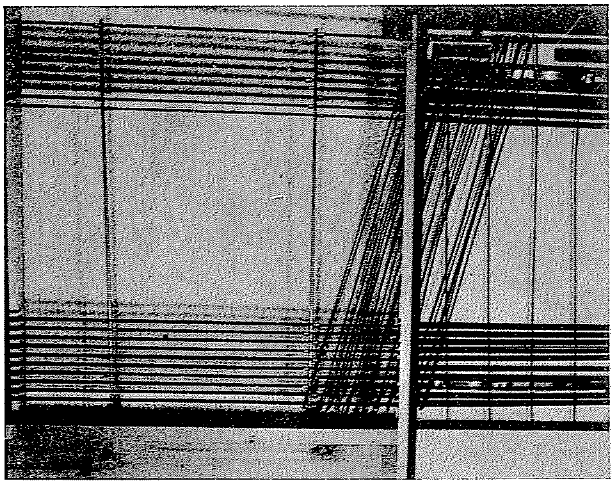


Photo 42. *Beam and wall reinforcement above support.* Twinned wires are used for taking up shear stresses above support at the beam end. Photo clearly shows the interlocking system of different kinds of reinforcement.

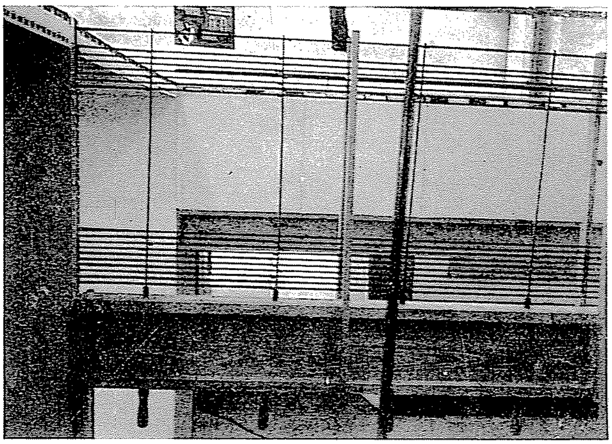


Photo 43. *The system of beam reinforcement.* Now, all horizontal twinned reinforcing wires are clipped to the leading needles. The exactly parallel wires give the impression of prestressed reinforcement. The last two parallel wires at the top of the beam outline the zone where the "windows" of beam elements will appear. The completed beam in the background shows the system of "windows" in the beam.

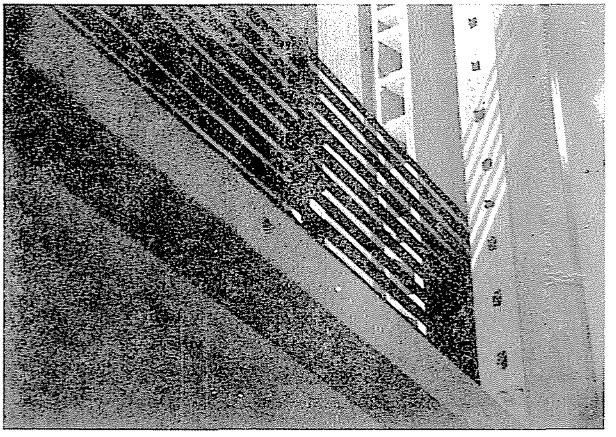


Photo 44. *Connection between beam and wall.* The lower row of the ∅ 3 mm twinned reinforcing wires, clipped to the leading needles, disappears between the surface elements in the top row of the U-shaped wall-pillar. Below, the auxiliary beam is seen on top of which now the beam surface elements will be assembled.

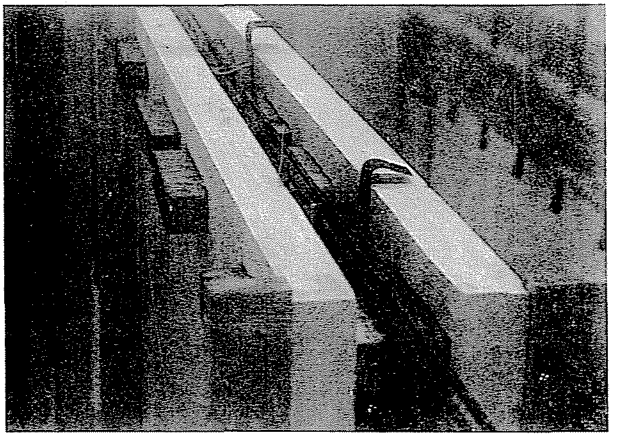


Photo 45. *Assembly of beam, stage before pouring.* When the beam reinforcement is ready, the surface gets assembled. Posts of auxiliary beam exactly locate the beam surface elements. Before concreting the beam the windows are carefully "plugged" to provide for the future connection between beam and opposite floor units. Then little punched clips are fitted on top of the needles, to thrust the opposite gypsum elements against the posts and to maintain exact verticality of the needles. The beam is ready for concreting.

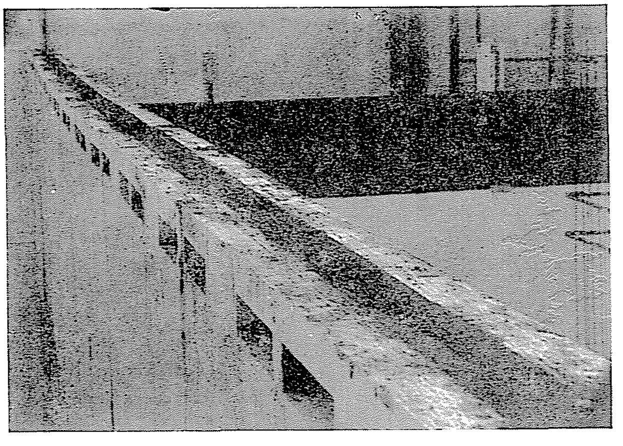


Photo 46. *The beam completed.* Situation immediately after concreting. The auxiliary timber beam is removed and so are the plugs; the windows within the surface elements of the beam now appear as a periodic system of open channels to take the longitudinal reinforcing strips of the floor units. The beam — produced by complementary building method — is seen to be the combined result from factory production of surface (gypsum) elements and an in-situ technology of pouring (frozen r.c. shell "blade").

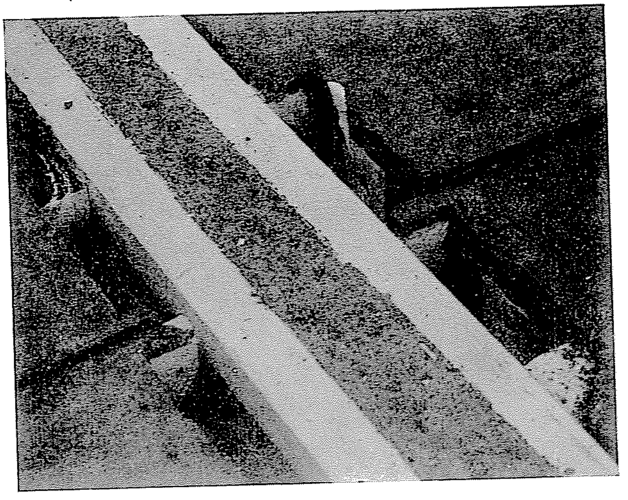


Photo 47. *Junction between floor units and beam.* When the floor unit is lifted in position, its "noses" exactly face windows in the beam. Now, the reinforcing strips fold out from the butt end, as a temporary support for the floor. The opposite steel strips meet within the window. The windows and the noses are seen to form a U-shaped open channel. By pouring in this channel, a homogeneous joint comes about, the structure becomes monolithic. This joint actually is a technological *translation* of riveting of steel structures into the language of r.c. tissue structures.

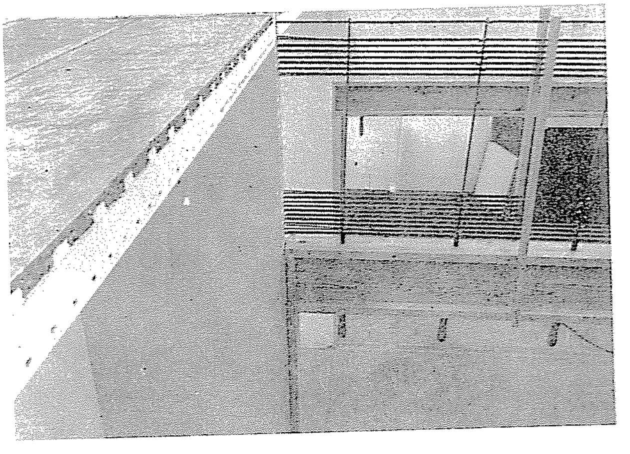


Photo 48. *The "completed" experimental unit.* The longitudinal edge of the floor unit is seen here exposed, showing the tissue-structure. In midfield, floor units are composed of three, and within the U-wall-pillar, of two units. The U-shaped frozen-shell wall-pillar is coherent with a model beam (in the foreground) and a r.c. "blade" (in the background).

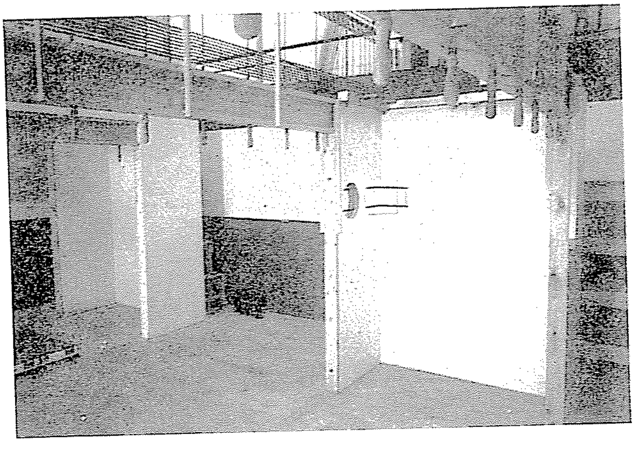


Photo 49. To demonstrate at the same time structural system and process of construction, the experimental unit is presented here in two parts: the actual non-tectonic unit (in the background) and the model unit — showing interior structure (in the foreground). The openings in the model U-shaped wall-pillar expose the system of reinforcement inside the folded r.c. shell structure.

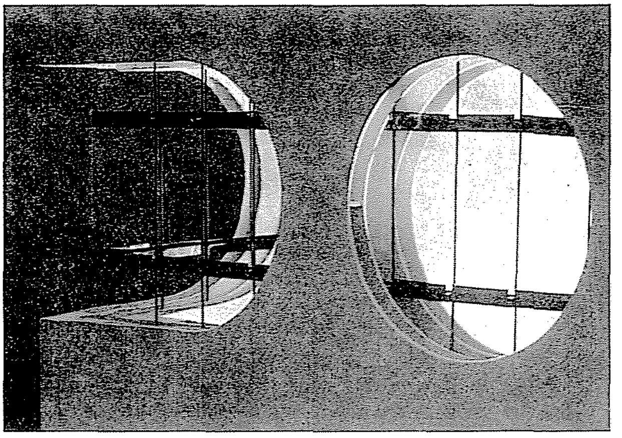


Photo 50. *The experimental unit.* Reinforcement of the folded r.c. membrane is led round the corner by steel strips, making the corner the strong point of non-tectonic structures and providing earthquake safety.

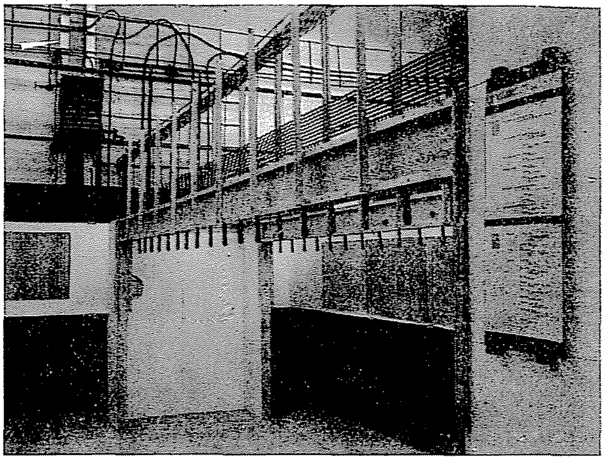


Photo 51. *The full-size model unit seen from the "entrance"*

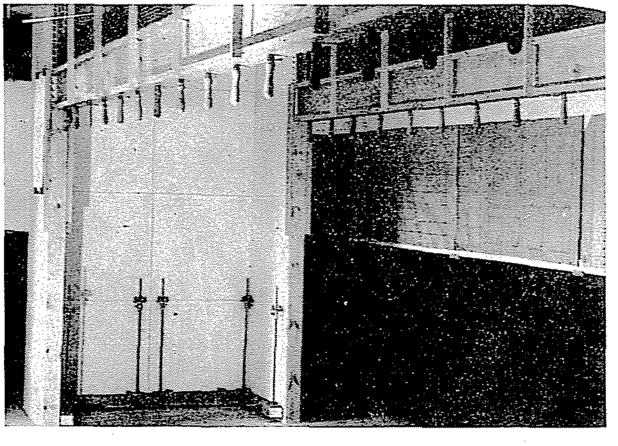


Photo 52. The auxiliary positioning tool is seen within the U-shaped wall-pillar in "zero" position. The auxiliary beam rests on the "door frame", a linear 94 mm timber lath screwed to the r.c. membrane. The last pair of posts at the end of the beam is turned down, creating a safe connection between auxiliary beam, door frame and wall.

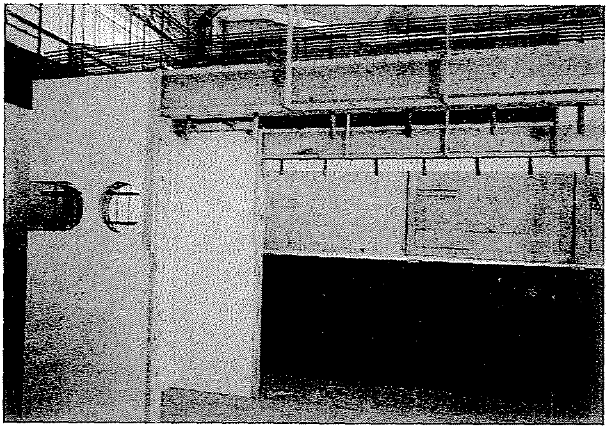


Photo 53. Full-size model unit: stage preceding the assembly of the beam surface elements.

Summary

A fundamentally new building method for solving problems of mass housing particularly in developing countries is expanded. It is founded on the elimination of the principle of tectonics from building. This new system — not relying on skilled labour — works with non-load-bearing gypsum surface elements, assembled on the site and stiffened by pouring in concrete.

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