OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

D03387

Distr.
LIMITED

ID/WG.122/21
28 March 1972

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Meeting on Prefabrication in
Africa and the Middle East

17 - 29 April 1972

Budapest, Hungary and Bucharest, Romania

PREFABRICATION WITH CLAY [1]

by

J. Bryrup

Director

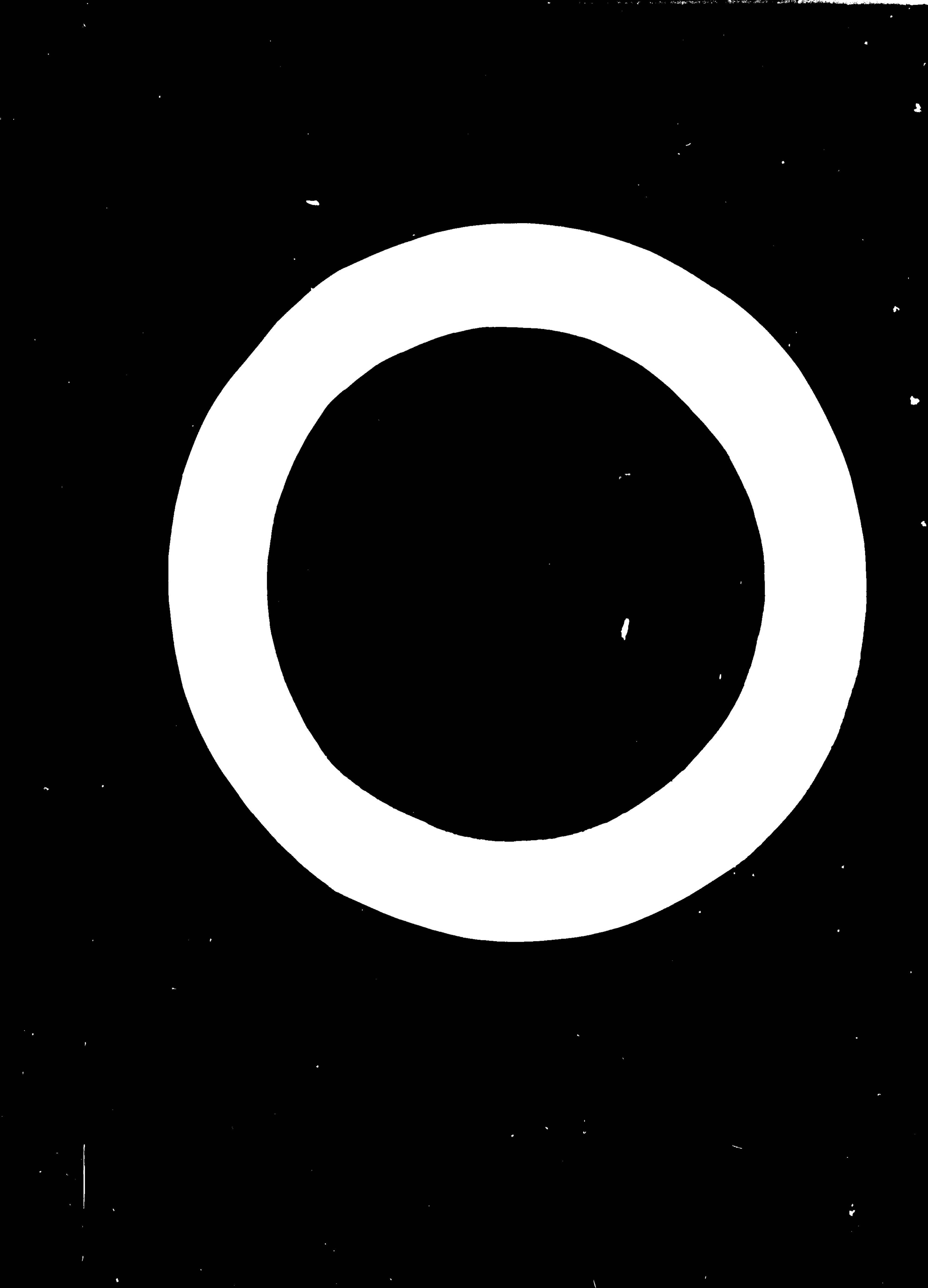
Technical Information Office

Teglindustriens Tekniske Tjeneste

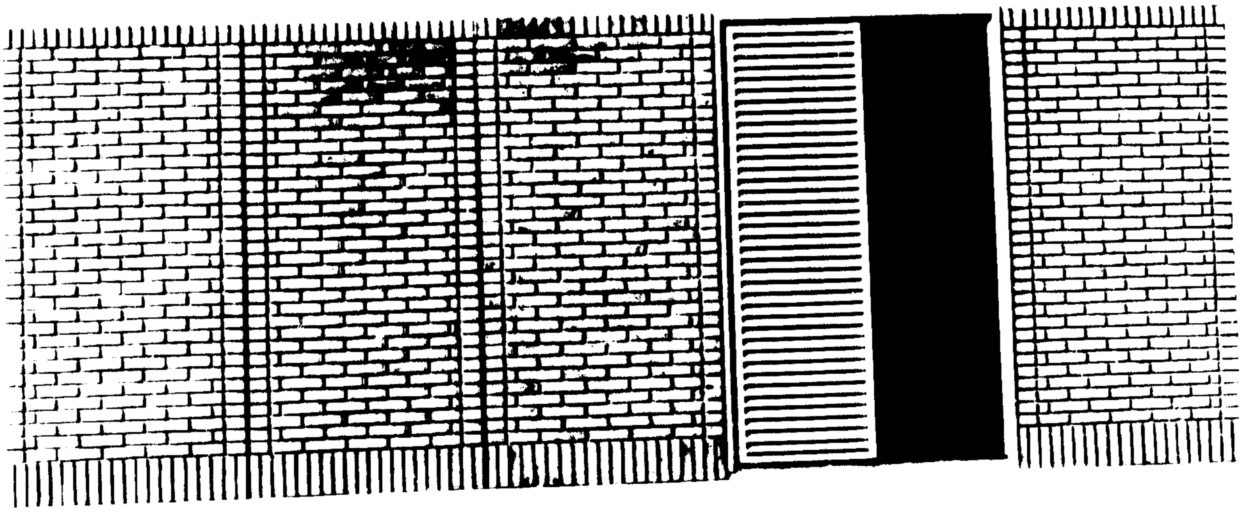
Copenhagen

[1] The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

id.72-1923



Contents



Example of facing wall with brick
panels and a window panel
(The Danish Montage-Tegl system)

Introduction.

Utilization of local raw materials is of importance to the building industry. Clay is a such raw material which is found almost anywhere and which is easy to use, if necessary with additives. Meanwhile, brick production per capita in the developing countries is about half that found in industrialized countries. Further the quality of bricks in the developing countries is often much lower than the quality of bricks in developed countries.

Use of burnt clay bricks is not only a question of tradition. The burnt clay in itself has got properties of aesthetical and technical sort which makes it comparative. Technical properties may be expressed in following values:

Table 1 - Technical Properties.

Airpenetration (dry brick, around 11 cm thickness)	$\frac{1}{500} - \frac{1}{50}$ $m^3/h \times m^2 \times mm\ Hg$
Permeability	$0.007-0.03\ g/h \times m \times mm\ Hg$
Specific weight	$1200-2000\ kg/m^3$
Dimensional stability	
temperature	$0.005\ mm/m$ per ^oC
moisture (wet to dry)	$0.1-0.2\ mm/m$
Chemical resistance	excellent
Fire resistance	excellent
Resistance to weathering (patination)	excellent
Heat insulation	$0.30-0.50\ kcal/h \times m \times {}^oC$
Heat capacity	$0.23\ kcal/kg \times {}^oC$
Compressive strength	$200-600\ kp/cm^2$
Tensile strength	$20-60\ kp/cm^2$
Modulus of elasticity	$100.000-250.000\ kg/cm^2$

Note 1 Above given figures refer to structural clay products of high quality.

Note 2 The figures may be compared with figures concerning other construction materials. A such comparision will show that the structural clay material represents a such combination of excellent properties that the interest in developing its use is justified. Use of structural clay products is not only a question of tradition.

In compared with other structural materials it is evident that these properties place structural clay as a unique material. However, high labour costs represent a strong need for rationalization and mechanization in the use of the products. One of the means to achieve this is prefabrication.

Prefabrication of walls.

This item has been treated in different earlier papers, f.inst. UNIDO INTER-REGIONAL SEMINAR ON THE DEVELOPMENT OF CLAY BUILDING MATERIALS INDUSTRIES, Copenhagen, August 1968, Subject 10: Structural Clay Wall Panels, and the 5th CIB Congress in Versailles, June 1971: An International Survey on Brick Panels (both available in English and French).

The intention of this paper is to give a short survey of the actual situation in brick panel production, and in lining different ways of manufacture, and expressing some views as to which systems might be the easiest to adopt in developing countries. Before giving this survey a principal evaluation should be given as to the idea of expanding the brick industry and so the brick panel industry.

First point of view - which is previously noted - is the availability of raw materials for the brick industry which means that the infra-structure will not be a big problem for a brick industry being well distributed as to consumption in the countries in question.

Another point of view is that investing in the brick industry does not mean that the building industry in itself will stay at a less mechanized level compared with investments in other building material industries, but invite a progress in mechanization at any time depending on economy, technical level in general inside the building industry, infra-structure etc.

As is the case in many developed countries the consumption of structural clay materials will be both in the traditional section and in the industrialized section, and the ratio between the two sections will be based on the circumstances mentioned above.

Brick panel production is common in Europe - West as well as East - in America, even in Cuba and in Southern Africa. Production tecnique represents - roughly spoken - all degrees of machanization, and so it should not be difficult to choose a system which is fit in any country under certain given circumstances.

Design of brick panels.

The design of brick panels depends on climatical conditions, manufacturing process chosen and kind and sizes of the traditional brick- or block production, and last but not least local building tradition generally spoken. In table 2 you will find a survey of the different principal designs, and figures 1 - 5 show the most typical designs. It is worthwhile noting that the tradition in many countries for non-rendered brickwork has influenced the panels produced in said countries, so that also the panels have got non-rendered brick surface. It means to some extend a complication in the manufacturing, but it shall be underlined that the wish to use the non-rendered brick wall is also due to the excellent properties of the bricks in relation to local climate, f.inst. maintenance costs may be considerable with other materials, or - if not maintained - the aesthetic result will not be satisfactory.

TABLE 2 - Principal Designs.

Type	System	Country	Illustrated
Hollow clay blocks	Montagebau	Germany	
	Preton	Switzerland	
	Lamelteql	Denmark	Fig. 1
	Bulgarian	Bulgaria	
	CSSR	Czecho-slovakia	
	Finnish	Finland	
	Fiorio	France	
	Costamagna	France	
Sandwich:			
Brick-mineral wool-brick	Prefanova	Denmark	Fig. 2
	E. Mikkelsen	Denmark	
Brick-urethane foam-brick/block	Prefategl	Denmark	Fig. 3
	M.C.B.	U.K.	
Brick veneer - min.wool - brick	Skarategel (Fecab)	Sweden	
- min.wool-lightweight concrete	Mälardalens Tegelbruk	Sweden	
- lightweight concrete	Teglment	Denmark)	Fig. 4
	SHT-Tegl	Denmark)	
- min. wool-concrete	Montage-Tegl	Denmark	Fig. 5
Brick or brick veneer-insulation-gypsum plaster board	L.E. Shaw	Canada	
Brick-cavity-lightweight concrete	BMB	Netherlands	
Brick or brick veneer with reinforced concrete or reinforced concrete mortar	Medicine Hat	Canada	
	Diamond Clay	Canada	
	Kurtz-Gery	U.S.A.	
	Panelcraft	U.S.A.	
	R.B. Masonry	U.K.	
	R.D.B., Piacenza	Italy	
	Fricker	South Africa	
High strength (Sarabond) mortar	Skurup Tegel Montage	Sweden	
Storey-heigh planks	M.G. Planks	U.K.	

Note: This List may not be complete.

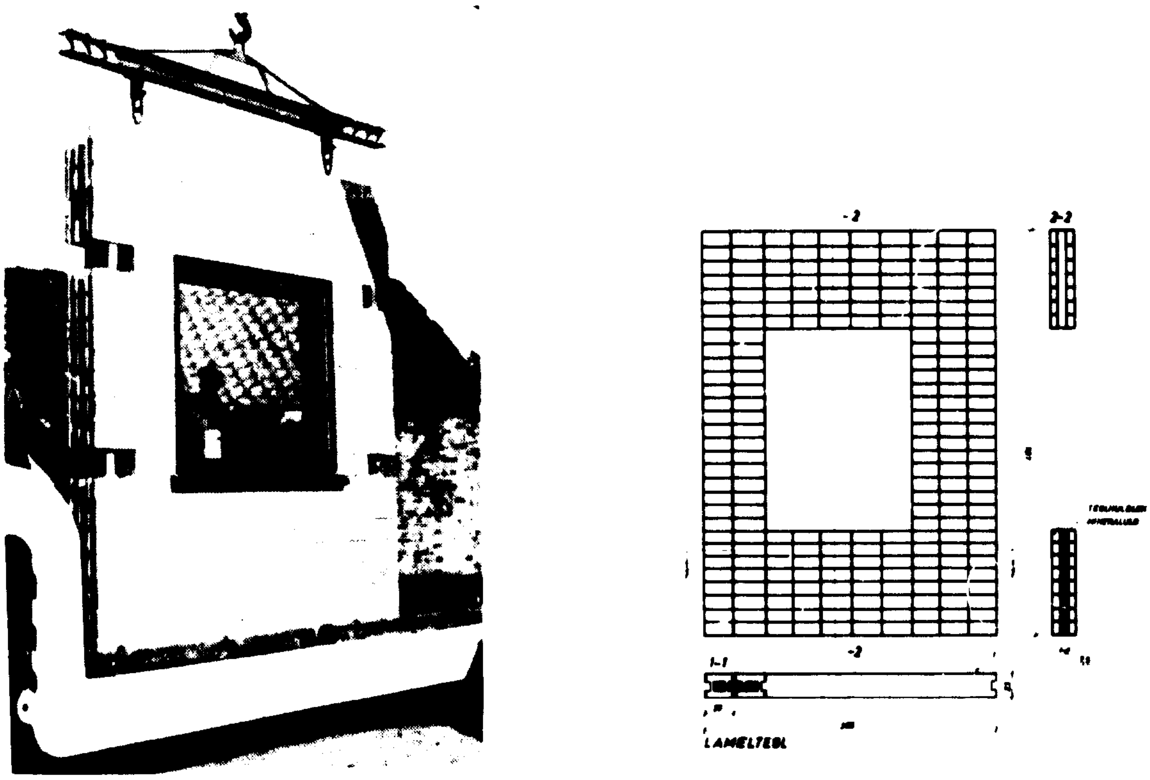


Figure 1 - LAMELTEGL

Development of this panel was started in 1963 using a hollow clay block af size L x H x W = 29 x 9 x 23 cm. This panel is reinforced both horizontal and vertical. A later development consists of panels having bricks of the size L x H x W · 28.5 x 8.5 x 9.5 cm both in the facing part and the interior part of the wall with mineral wool in between and a total thickness of 3o cm. The manufacture is done by non-skilled, but specially trained workers using corner posts and marked line. k-value for the original panel is o.65. Biggest size of panel 2o m^2. Most used type of panel is L x H x W = 3.o x 2.8 x o.23 m. It is easy to understand that this type of panel - like the PRETON-system - is a good first step into industrialization. The initial costs to start a plant are low, and a plant is very flexible as to sizes of panels being produced.

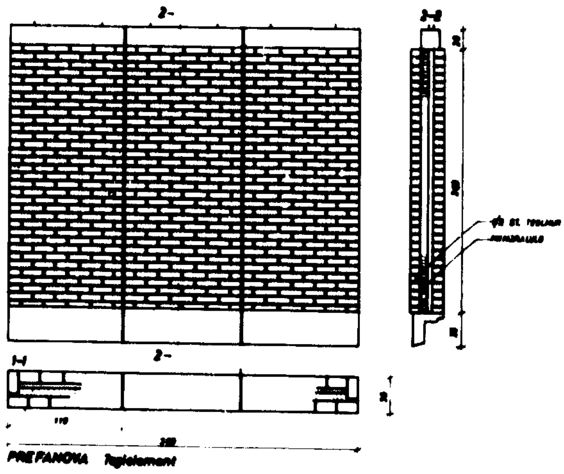


Figure 2 - PREFANOVA

The illustration shows 3 panels of the PREFANOVA-type. The system was developed in 1963. Panels are manufactured traditionally by use of bricklayers, but on a lift which is lowered into the basement thus making it possible for the bricklayer to work under the most comfortable conditions possible. The job is done on a prefabricated beam of concrete or brick. The panels are usually without reinforcement. Biggest size of panel is L x H x W = 3.6 x 3.6 x o.49 m. Heat insulation is normally mineral wool. Installation and components like windows etc. are placed according to the architects drawings. Due to the use of the lift this system demands a higher investment than the LAMELTEGL-system does.

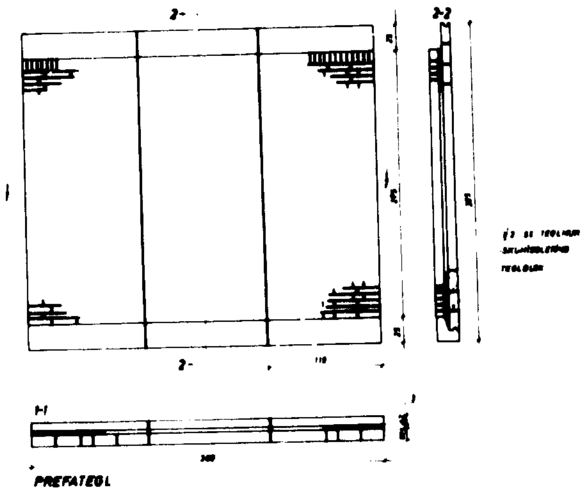


Figure 3 - PREFATEGL

Development started in 1966 and shortly after a plant was erected and production started. In principle a a normal size brick is used, but it has got 3 vertical holes through which the reinforcement can pass. A panel consists of an 11 cm thick exterior wall of bricks and a 9 cm interior wall of structural clay blocks. The interior wall is reinforced in the same way as the interior wall. Between the two walls is an insulation made either of polyurethane foam or of mineral wool. The figure shows the insulation with polyurethane foam. The plant makes not only this type of sandwich walls, but also partition walls and curtain walls based on the same principle. Biggest size of panels is L x H x W = 18o x 28o x 33 cm. Maximum weight of panel is 25oo kg. Heat transmission with 28 mm polyurethane foam k = abt. o.4 and with 5o mm mineral wool k = abt. o.5.

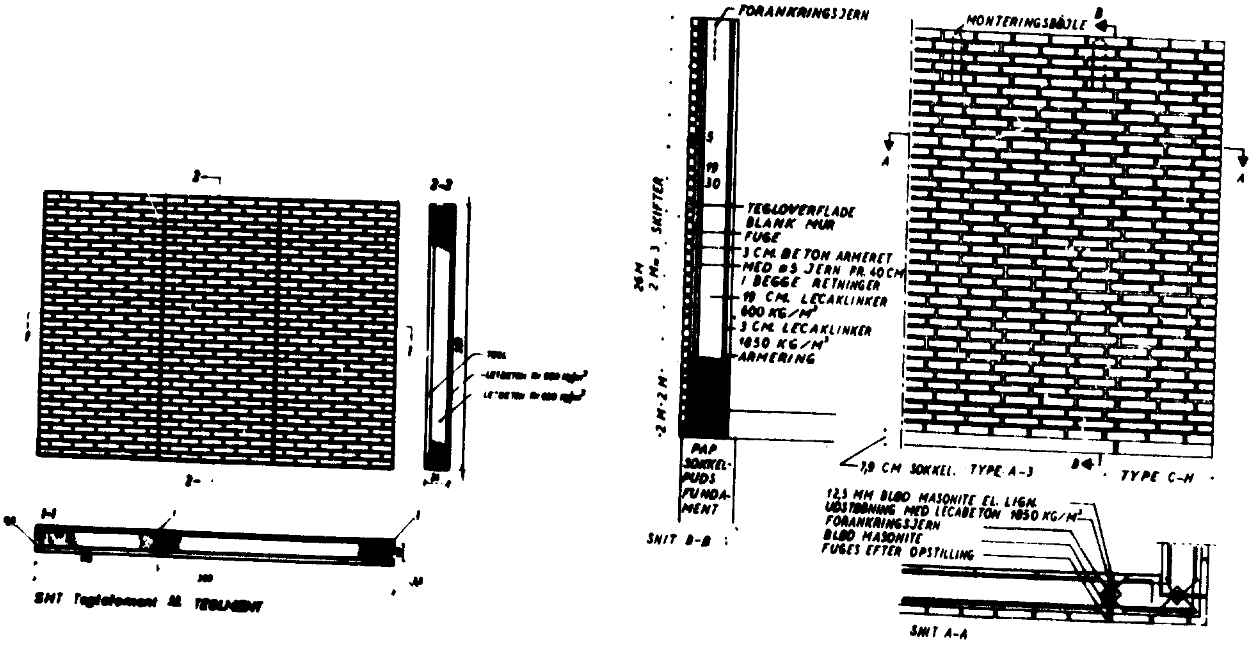


Figure 4 - SHT TEGLELEMENT and TEGLMENT

The design of these two panels is the same. They are described in common. The panels are based on bricks in half width, which is L x H x W = 23 x 5.5 x 5.5 cm. The bricks are laid down in a special form, and mortar and a thin layer of concrete is poured out. After this a layer of lightweight concrete is poured out in the thickness wanted according to the necessary strength and insulation. The layer of lightweight concrete may be reinforced and installations may be laid in the concrete. Production of TEGLMENT started in 196o, and of SHT TEGLELEMENT in 1964. The biggest market for both panels is for single family houses. Sizes are L x H x W = 24o x 26o x 3o cm for SHT TEGLELEMENT and L x H x W = 12o x 26o x 24 cm for TEGLMENT, but TEGLMENT is also manufactured in bigger panels to avoid too many joints, and reduce number of operations.

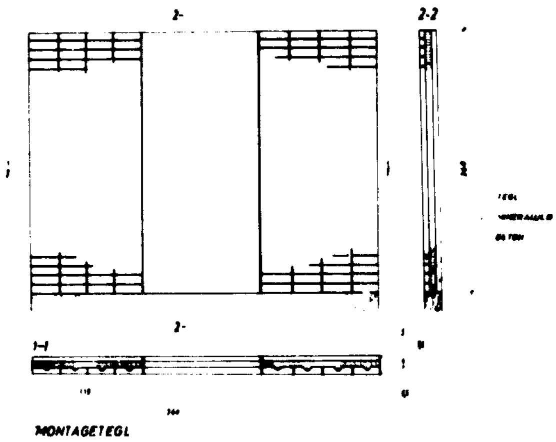


Figure 5 - MONTAGETEGL

The development was initiated 196o by five manufacturers. The size of bricks used is L x H x W = 23 x 5.5 x 11 and 23 x 5.5 x 5.5 cm. Production was started in 1964, and development has been in progress since, so that the plant has been able to solve a lot of production problems, due to architects special wishes as to their panels. At first bricks are put down with their facing side down and then a cement mortar is poured out. Then a sort of ladder reinforcement is installed, mineral wool insulation laid down and a thin layer of concrete is poured out to form the interior side of the panel. Such panels are used for load bearing as well as non load bearing constructions. Biggest size is L x H x W = 9.3 x 1.8 x o.3 m and biggest weight is 45oo kg. Heat insulation corresponds to k = o.4. The process is rather mechanized and demands rather big investments.

Production methods.

As mentioned before brick panel production spans from the most simple sort of manual laying of bricks or blocks in a form and manual spraying of mortar and laying of reinforcement to highly mechanized, sophisticated methods with setting machine etc. It is evident that the simple production methods do not cost very much in initial costs and is rather flexible as to size of panels and size of structural clay material being used, whereas generally spoken the highly mechanized system represents high initial costs, unfortunately, often a rather stiff system, which means that changes in size of panels, patterns of brickwork etc. are very costly. The idea with the following remarks is to give some general information about the different production methods and thus to facilitate a choice between the systems.

System	Position of panel under construction			Specially low investment	Specially simple design & manufacture	Brick- or block laying in mortar
	Horizontal	Vertical	Inclined			
Montagebau	x			(x)	x	x
Preton			x	x	x	x
Lameltegl		x		x	x	x
CSSR	x			(x)	x	
Bulgarian	x			(x)	x	
Finnish			x	x	x	x
Fiorio	x				x	
Costamagna	x				x	
Prefarova		x			x	x
E. Mikkelsen		x		x	x	x
Prefategl	x					
BFC	x					
Skarategel Hälardalens	x					
Tegelbruk	x					
Teglment	x				x	
SHT-Tegl	x				x	
Montage-Tegl	x					
R.E. Shaw	x					
B.B	x					
Medicine Hat	x					
Diamond Clay	x					
Kurtz-Gery	x					
R.B. Masonry	x					
R.D.B. Piacenza	x					
Brickor	x					
Hedland		x				
Skurup Tegel						
Montage	x					x
G.G. Planks		x				

As shown in table 3 there are 3 different ways of manufacturing panels, namely either horizontal or vertical or inclined (slightly inclined from the vertical position). The two first mentioned are represented by several plants, but the third is only represented by one system.

Inside the two first ways there are highly mechanized as well as rather primitive production methods. Meanwhile, the inclined production system represented by the PRETON-system, but used in several other countries is a system based mainly on handwork. (Laying by hand of bricks or blocks in mortar.) It is essential to underline that rationalized handwork may be very difficult to compete with for the more mechanized systems. Mechanization in itself is not a must, a purpose in itself. More important is optimal total economy and even in the most industrialized countries you will find some between the vertical systems which have got a manufactural process best covered by the words "rationalized brickwork".

It should be understood that these systems compete rather well with more mechanized methods and so must be recognized as competitor on the free market in developed countries with high labour costs. This shall indicate that they must be of basic interest in developing countries. The same is the case when you consider horizontal panels. Some production methods are complicated because the design of the panel is complicated, which is specially the case with the sandwich-system of panels. Some are rather simple both in design and in production and this is specially the case with those with some sort of rendered surface and consisting of hollow clay blocks.

It has often been discussed between brick panel manufacturers, architects and others that the use of traditional bricks and blocks in such panels is not adequate; thus it shall be possible to design a new type of block, being specially fit for the panel production. However, on the free market it has been an advantage for the brick industry that traditional bricks or blocks also may be used in the panels, but this point of view is specially correct, when it is in those cases where brick and panel are used non-rendered, as it gives the architect and the consumer the biggest choice as to colour and surface of the brick in the panels.

It may not be right to point out a certain panel or system to be specially worth-while considering; anyhow if one should be chosen representing a certain first stage in industrialization, it should be one of the block systems manufactured horizontal. A such panel may by unskilled labour be manufactured direct on the building site and erected in its form by a tilting process thus giving a vertical panel with smooth and plane surfaces, see figure 14.

To illustrate production technique a few glimpses from different types of plants shall be given (fig. 6 - 11).

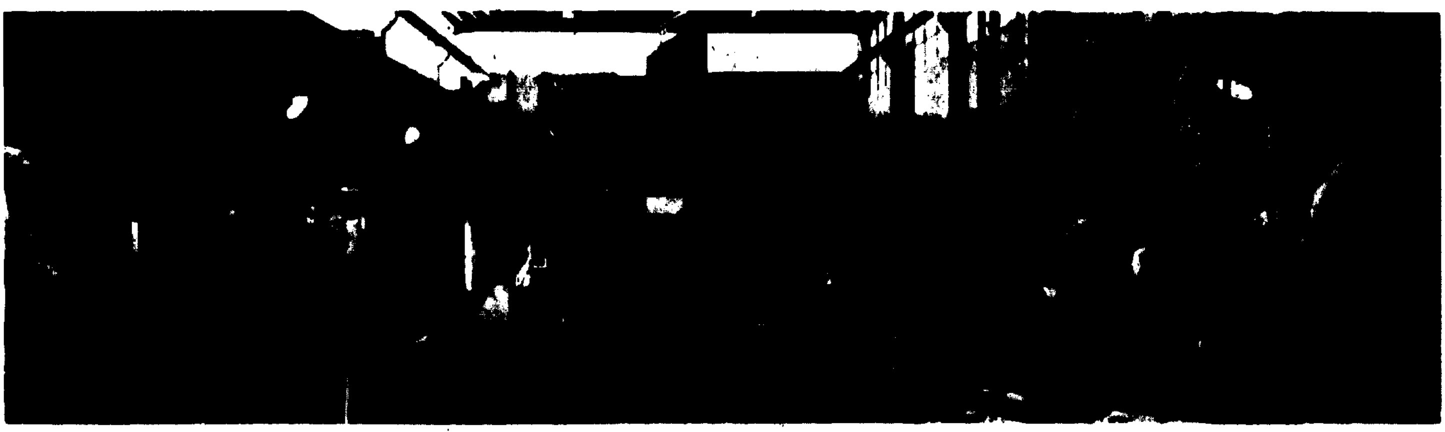


Figure 6 - PREFANOVA

At the PREFANOVA plant rationalized brickwork is used. The panel in construction is lowered into the basement, which means that the bricklayer is always able to work under optimal conditions.

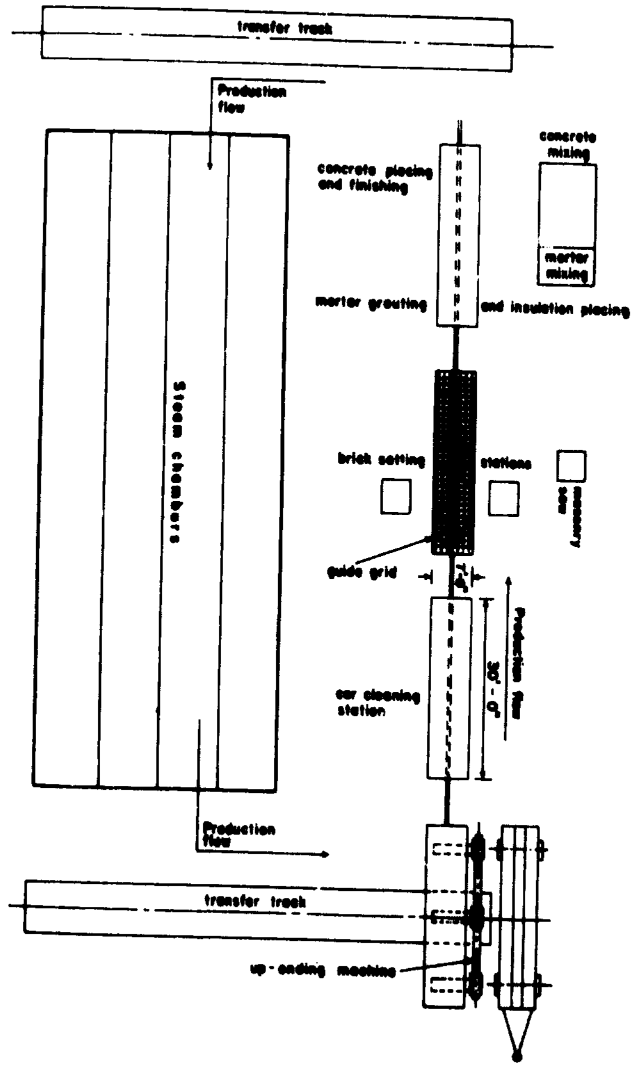


Figure 7

This figure shows a layout of the MONTAGETEGL plant where the circle is the following: the cars running on railes, go from the bottom left to the bottom right at the picture where the panel is erected from a car. At the next place the car is cleaned, then bricks are laid down, later mortar is poured and insulation placed, and then the cars go to the steam chamber and run through these. The total circle is 4 hours.

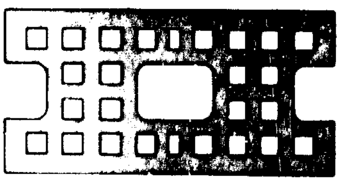
Figure 8 - The BMB-system.

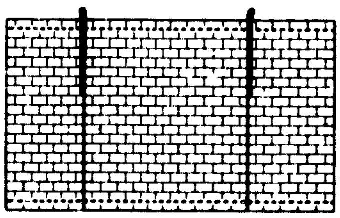
From the BMB - plant the picture above shows laying of bricks in the form, and the picture to the right shows the circle at the plant with the cars designed as forms for the panels.

Figure 9 - PRETON-system.

From the PRETON plant a glimpse given of how the brickwork is organized with inclined forms and movable scaffoldings.

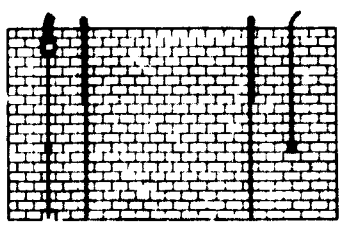
Site plant. In this special case the total construction is movable, so that construction of panels takes place as close to the final position of the plant as possible. High flexibility and easy installation on the site is an advantage of the PRETON-system. Further - illustrated below a through section of the block being used, the normal reinforcement installed in the panel and an example of electric installations in a panel.





Normal reinforcement

Through section of block



Electric installations

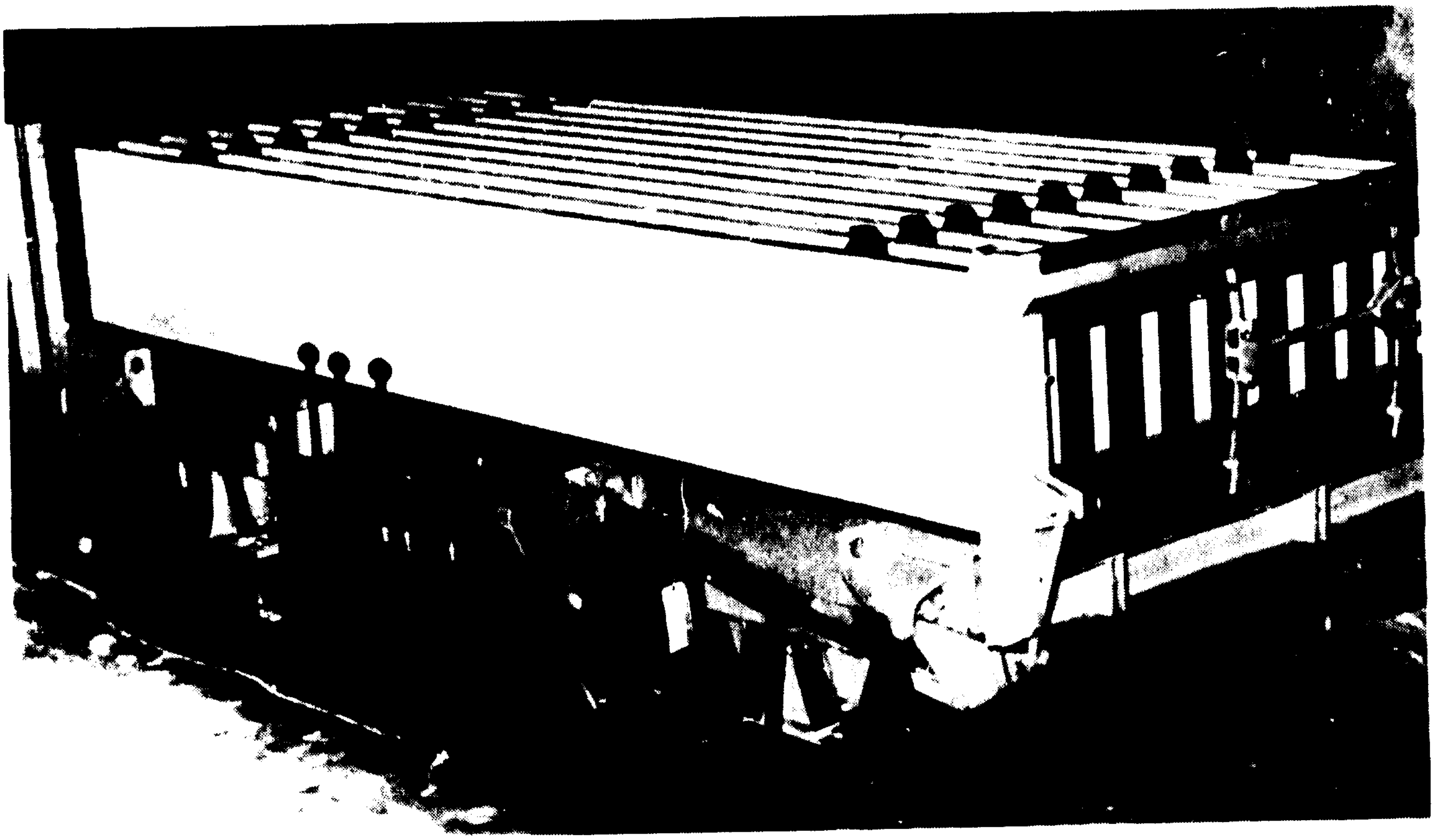


Figure lo - COSTAMAGNA

Where both gypsom and clay are available, panels after the COSTAMAGNA partition wall system might be of interest. They consist of hollow clay blocks cast together with reinforced gypsom. The reinforcement most often used is glass wool. Due to the very fast setting of the gypsom mortar the total cycle in the process is only lo minutes which means a high production compared with number and size of forms.

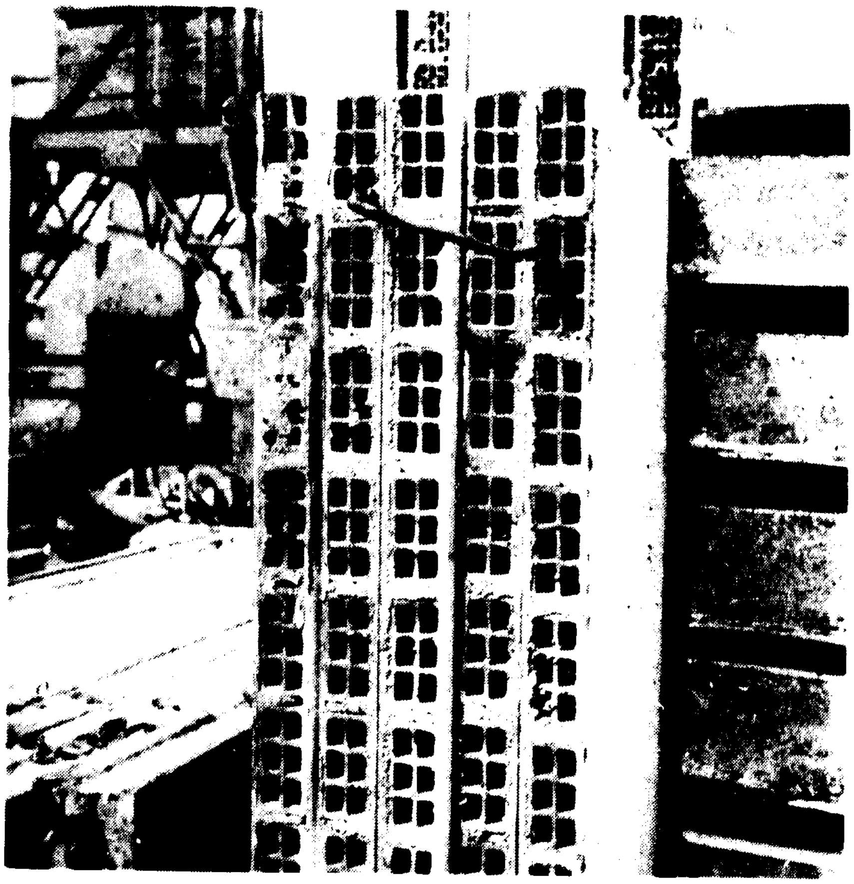


Figure 11 - Brick panels made of hollow clay blocks.

The development of such types of panels is done specially by the French firms COSTAMAGNA and FIORIO, but this type of panel is also seen in Eastern Europe. They might be called semi lightweight panels, and it must be emphasized that the light weight is a considerable advantage when handling, transporting and erecting the panels. The production is rather simple as there are no wishes to show the bricks or blocks in the facing side. A thin layer of gypsom mortar or cementlime mortar is poured into the form. Thereafter the blocks are placed into the mortar and reinforcement laid down. Then cement mortar is poured into the joints and on top of the blocks, and an even surface is obtained. The gypsom side is used as the interior side, and the facing side may be painted or treated with some sort of coulered mortar. The production is characterized of low investments and easy adoption of any size of panels desired by the market.

Transport and use of panels.

Most often special vehicles are used for panel transport which means empty return drive and considerable investments. It might be thought that a panel plant would not be competitive except in a rather close area to the plant. Meanwhile, there are many examples of transport of panels for more than 200 km. It shall also be noted that there are no principal differences in the use of brick panels compared with concrete panels. Exceptions are the following:

1. brick panels are normally lighter than concrete panels (which means reduced transportation and erection costs),
2. brick panels are dimentionally stable.

   Generally spoken dimensional changes due to moisture and temperature are rather small in brick panels, which means that joints between panels may be designed less complicated and so less expensive.

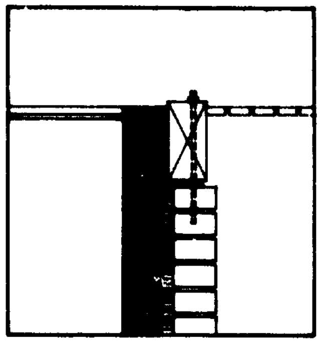
Information about transportation and erection of brick panels is estimated to be unnecessary, according to above given remarks. As to design of houses with brick panels it shall also be stated that there is no principal difference between designing with concrete panels and with brick panels. If compared to traditional brickwork, care of course shall be taken to secure necessary stability of construction.

Illustrations 12 and 13 give glimpses of brick panel erection.

Figure 12.

An important part of construction with panels is a study of all details concerning connections between panels and floor slabs and other parts of the construction, and also the connection between panels themselves. As an example you will see details in scale 1:2o concerning PREFATEGL panels.

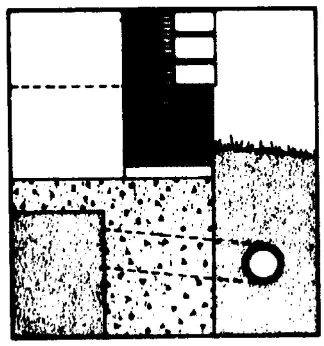
Load bearing facing wall in one-storeyed building.



Vertical through section through top of panel with beam for roof construction.

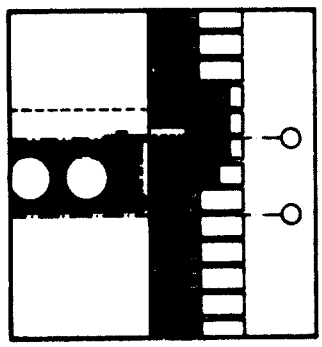
Vertical through section in .

foundation without basement.

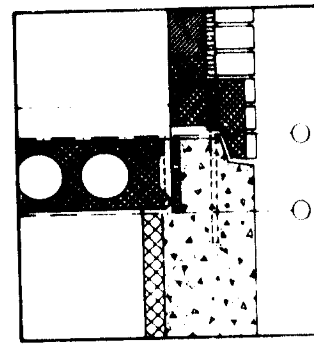


Non load bearing facing walls in multi-storeyed houses.

Vertical through section showing connection between panels and floor slab.

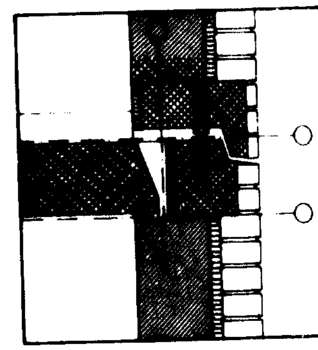


Vertical through section showing basement wall, floor slab and brick panel.



Load bearing facing wall in multi-storeyed houses.

Vertical through section showing brick panels and floor slabs.



Vertical section showing basement wall, floor slab and brick panel.

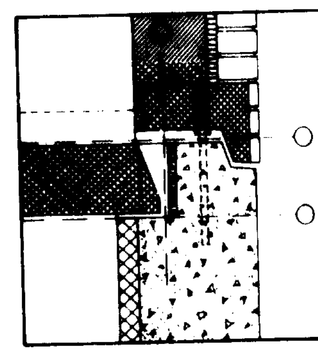


Figure 13.

An example of installation of a facing panel of the COSTAMAGNA-system manufactured by the German licence plant (system DIN). The picture illustrates fairly well that use of this kind brick panels is similar to that of concrete panels.

A low investment panel system.

As previously stated prefabrication may be achieved at many levels. It is advisable to start with a system which does not demand high initial costs in the plant and for transporting and handling the panels at the building site. Therefore if a system should be prefered it should be a such which is adoptable without much investment.

To illustrate a such idea a Swedish system is shown. The panels are not bigger and heavier than any truck can transport them, and they are erected by 2 or 3 people using a special tilting device, which is manually operated. It may be argumented that compared with the actual state in the industrialized countries this system does not represent a building technique being specially industrialized. However, a close calculation and comparasion may show that it - even in industrialized countries - is able to compete.

Figure 14.

An example of a simple system of brick panels is developed in Skåne, Sweden. The panels are L x H x W = 49 x 24o x 12 cm, and the bricks have got vertical holes for the reinforcement. Panels are manufactured horizontal like the PREFATEGL process. Advantages are high flexibility, easy handling, transportation and erection, so that the system is adoptable where no heavy equipment exists.

Floor construction.

Hollow clay blocks are easy to produce and when used in connection with concrete and reinforcement give a rather cheap and light floor construction which can be made without a normal concrete form. Any degree of prefabrication may be adopted to this sort of construction:

1. the blocks may be put on a sort of scattered formwork, then reinforcement laid down and concrete poured out,
2. blocks may be prefabricated with reinforcement and cement mortar to beams which are laid down without any sort of form work,
3. prefabricated floor slabs may be laid down.

It should be stated that the possibility of the choise of degree of prefabrication is an advantage for the brick plant, the builder, and the architect in that sence that any of the procedures described may be chosen according to which one is most advantageous in the actual case. More sophisticated uses of the hollow clay blocks are for different sorts of shell construction. This principle has been specially developed in Italy. I admit that it has only been possible to give some few examples of the use of hollow clay blocks for slabs, floors, and shell constructions. However, I find it evident that the high flexibility of the design and use of such blocks make them very adoptable in any developing country and under any degree of prefabrication wanted.

Figure 15.

Production of hollow clay block beams at the building site. By means of a thin layer of paper or sand the beams will not stick together although one is manufactured on top of another.

Figure 16.

Laying out of the beams on the building site may be done by hand and by means of a special tool.

Figure 17.

Use of structural clay beams for a roof construction.

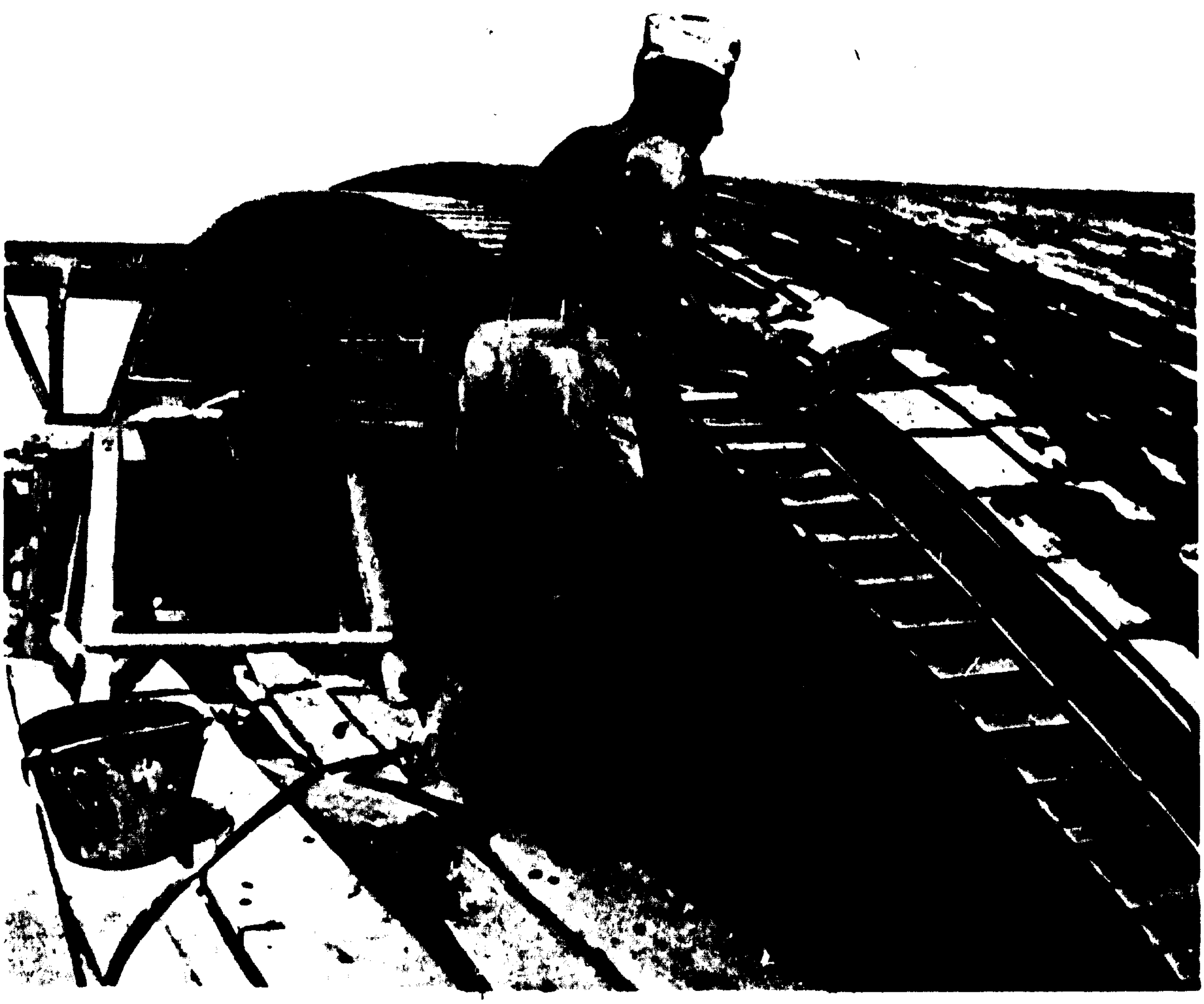


Figure 18. Many special types of blocks for roof construction are developed. The idea of lightweight and semi prefabrication is clearly illustrated.

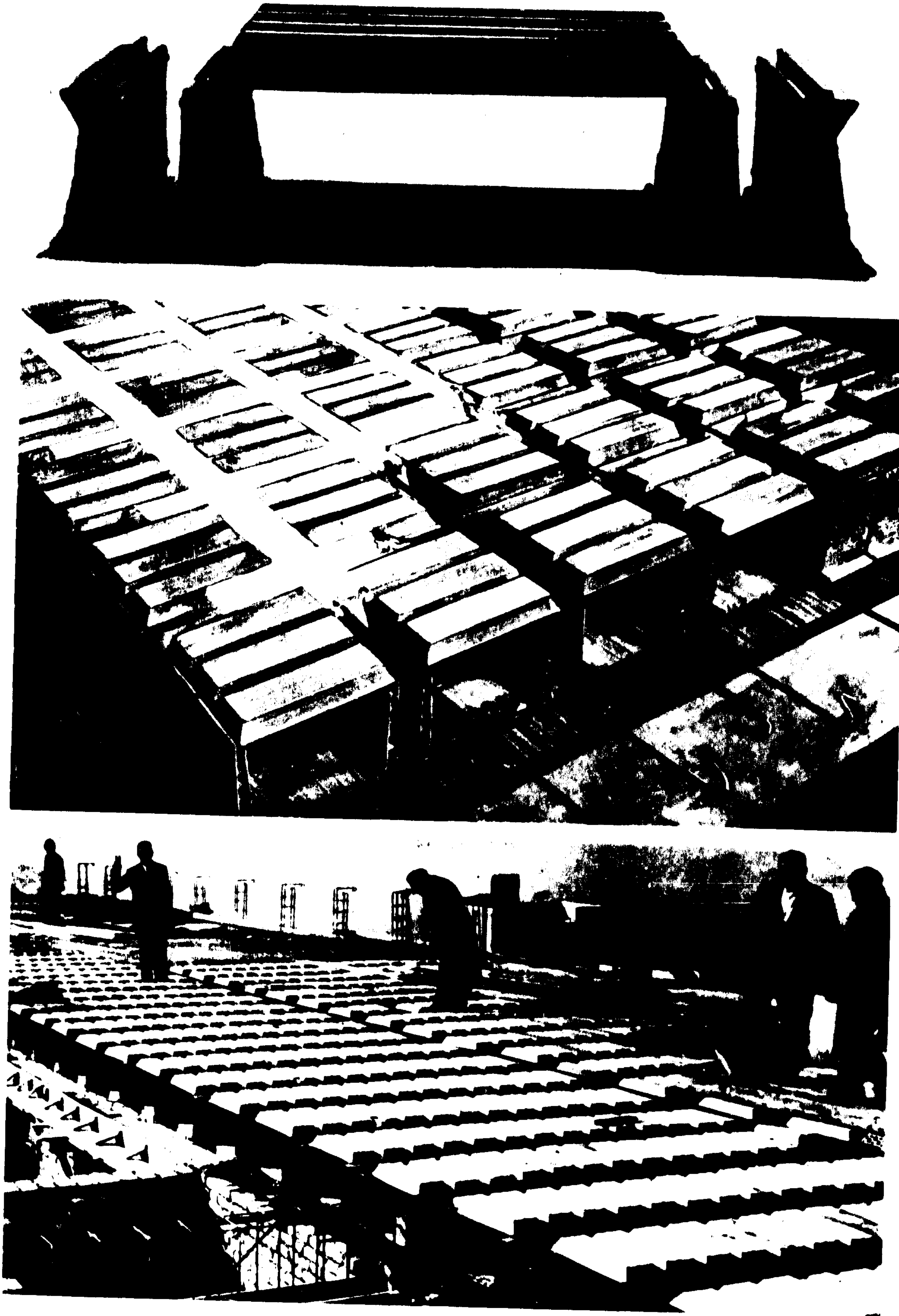


Figure 19.

A special use of structural clay block is for shell constructions. These may be constructed either by hand or in form of prefabricated elements.

List of literature.

The International Conference on Masonry Structural Systems, Austin Texas 1967:

Development of structural clay facing wall panels in Denmark - Jørgen Bryrup, Denmark.

Some investigations concerning design, technology, and test of cored brick panels - Ilia Mitev and Rocen Malchev, Bulgaria.

14-story buildings in Switzerland with brick wall elements prefabricated by Preton process - G.V. Zenobi and D. Szerdahelyi, Switzerland.

Prefabricated brick panels in Colerado - Donald A. Wakefield, Denver, Colerado.

UNIDO INTER-REGIONAL SEMINAR ON THE DEVELOPMENT OF CLAY BUILDING MATERIALS INDUSTRIES, Denmark 1968:

Structural Clay Wall Panels - Jørgen Bryrup, Denmark.

SECOND INTERNATIONAL BRICK MASONRY CONFERENCE, England 1970:

Brick Facing Wall Panels - an International Survey - Jørgen Bryrup, Denmark.

CIB, 5th Congress, France 1971:

Panneaux a parement en briques-un tour d'horizon international - Jørgen Bryrup, Denmark.

Reponses de: J. Charriere, France,
D.G. Grenley et de J.G. Terzes, Etats-Unis,
R.F. Wyss et de B. Kindberg, Suisse et Suede.

19.12.73