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BUILDING WITH BLOCKS AND PREFABRICATED ELEMENTS OF AERATED CONCRETE[1]

by

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PREFACE

The housing problem in developing countries has, in recent years, received increased attention by various national and international organisations.
Population growth and an obvious trend towards rapid urbanisation have made apparent that the finding of a solution to this problem is a matter of greatest urgency.
Its solution is perhaps uniquely important since it is, at the same time, a prerequisite for political stability and a basis for continued economic growth.

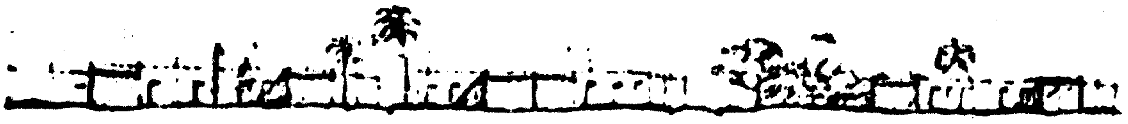
An increasing urbanization is also a characteristic feature of many developed countries In the wake of mass migration from rural to urban life, the housing industry, in these developed countries, has introduced technically and economically sophisticated methods of manufacturing and marketing.
A number of attempts have been made to transfer these relatively advanced methods directly to areas which are now in their initial phase of industrialisation.
Many of those attempts have unfortunately resulted in disappointment and loss of invested capital, the applied schemes being unrealistically costly and out of line with local customs and habits.

It is important that the introduction of new manufacturing and application techniques is carefully planned in cooperation with local participants, in order to ensure that the end product is commensurate with locally prevalent cultural traditions and existing infrastructures.

In most regions, the level of urban and industrial development is reflected in the locally existing infrastructures as well as in the prevailing construction methods.

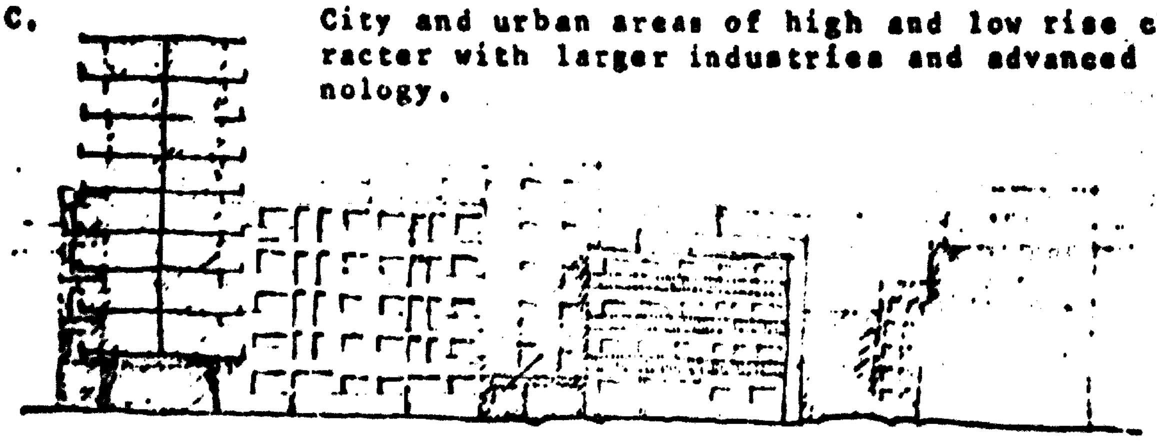
Somewhat simplified, we may thus distinguish between three levels of development:

A. The village structure where traditional technical methods are employed in the field of housing construction.



B. Building areas with low rise urban character where activities in housing construction are dominated by small scale industry using intermediate technology.

C. City and urban areas of high and low rise character with larger industries and advanced technology.



Each particular developing area may demand a different approach, and a thorough investigation of potential market for Aerated Concrete should therefore preceds the selection of manufacturing and application techniques to be introduced in that area.

Our purpose here will be to illustrate why Aerated Concrete is a building material for developing countries and how it meets the needs and requirements of the local construction markets.

As the necessary raw materials are, in fact, readily available in most countries, and since the basic manufacturing process is nearly identical for all Aerated Concrete products, the manufacturing program is uniquely adaptable to various degrees of industrialized application.

AERATED CONCRETE AND ITS MANUFACTURE

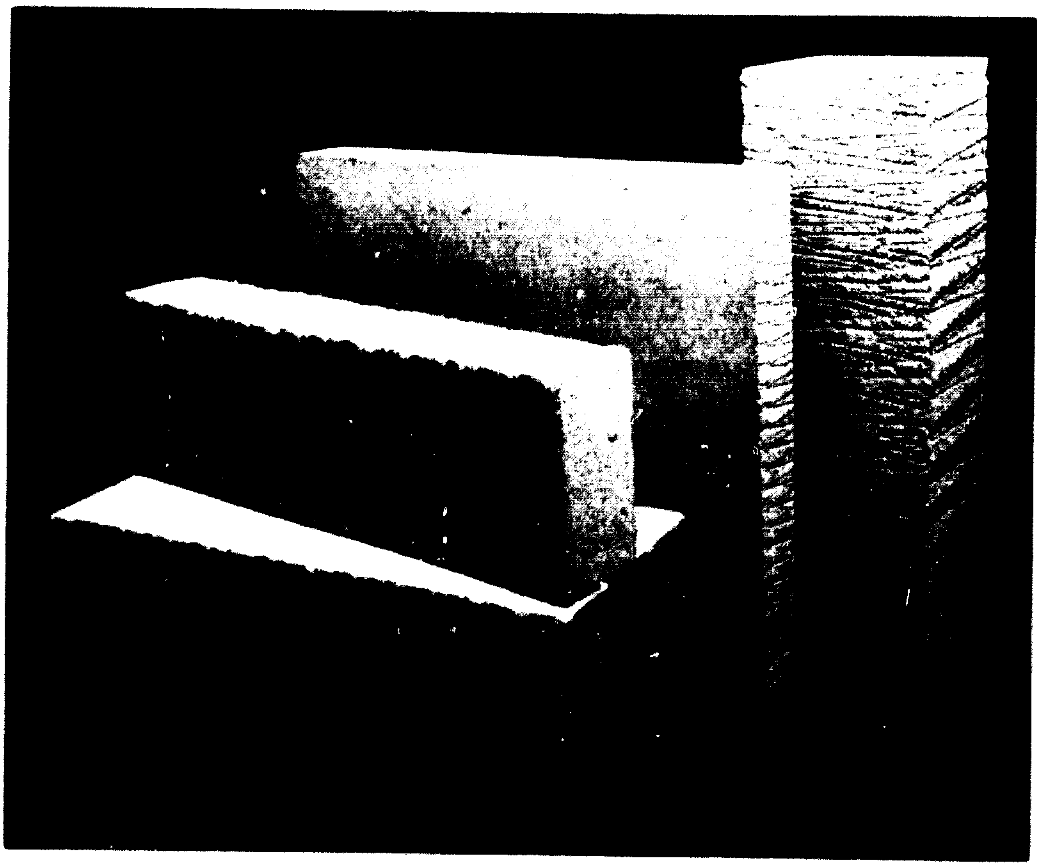


Fig. b1. Zig-zag pattern and smooth surface of various aerated concrete products.

Aerated Concrete is a precast lightweight concrete, steam cured and made from similar materials as regular dense concrete. Its low weight, good workability and high thermal insulating value are due to the small and uniformly distributed air cells it contains.

The steam curing process, which is accomplished in autoclaves, ensures good physical strength of the material and high dimensional stability, in spite of its low weight.

a- Raw Materials

The bulk of the raw materials for Aerated Concrete can vary within wide limits, and, in most cases, it is possible to adjust the manufacturing process to locally available products and minerals.

The production in Denmark is based on quicklime, Portland cement, quartz sand and fly ash. The choice of raw materials has here been dictated by local availability, quality demands of the and product and processing economy.

In England and other coal producing countries it was found feasible to produce Aerated Concrete on the basis of fly ash and Portland cement.

Quartz sand of reasonable purity and free of clay is the most common silica raw material.
Fly ash, a waste product from coal fired power generating stations, or blast furnace slags are other alternatives.
Sand, fly ash or blast furnace slags may be used individually or in combination, depending on the properties of the matarial.

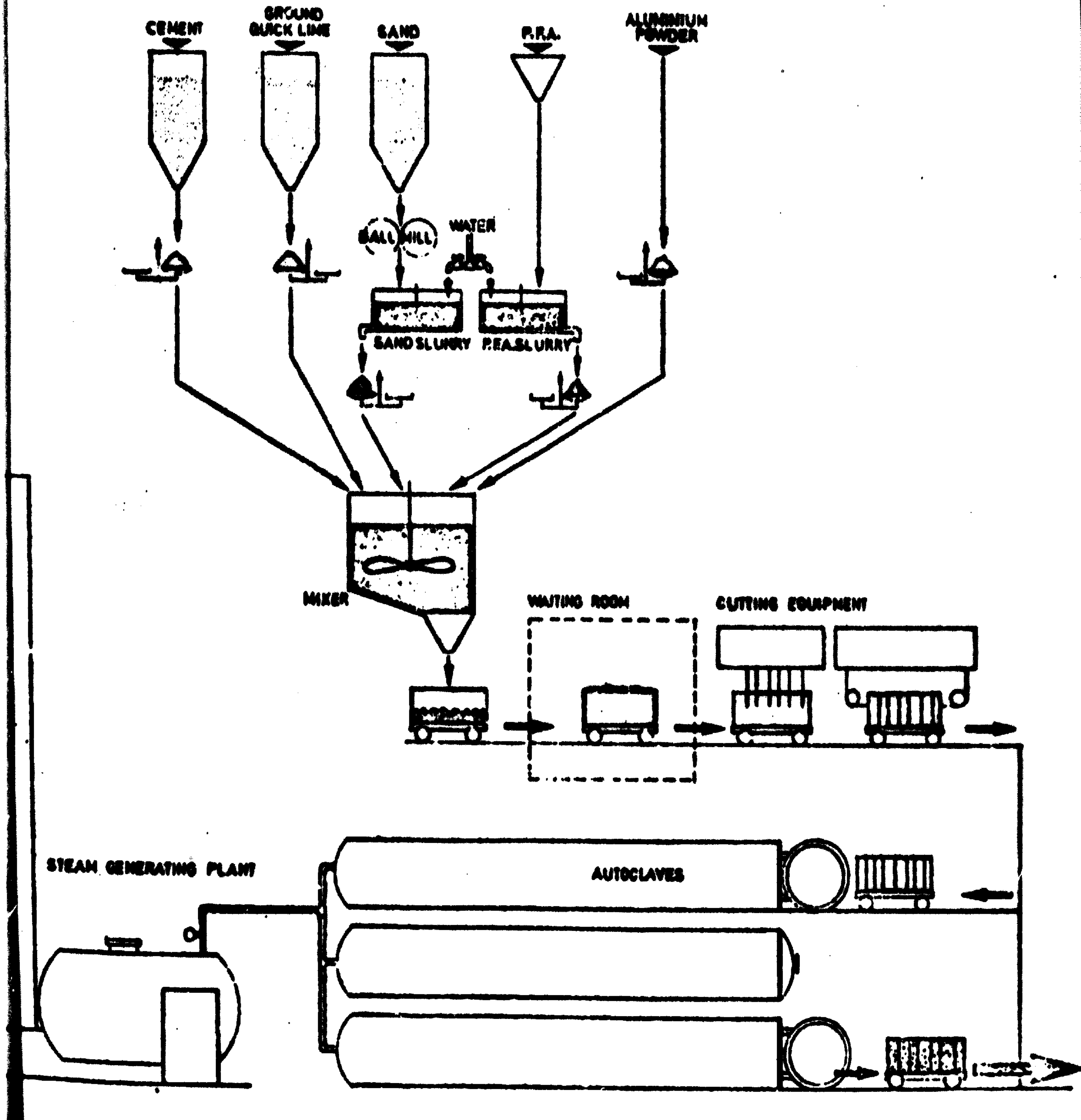
Fly ash can normally be used without further procession whereas quartz sand and blast furnaca slags must be ground to a fineness almost similar to that of Portland cement.

Portland cement and quicklime are suitable binders. In countries where an adequata supply of qualitatively satisfactory lime is available, a combination of those two matarials can be used.
It is possible to produce Aerated Concrete, using Portland cament alone as binder, provided that cement of uniform quality can be produced or delivered.

Aluminum powder, which is used in small quantities, is obtained from suppliers in Europe manufactured according to specifications for Aerated Concrete.

A number of other additives are incorporated in small quantities for the purpose of controlling the process and to ensure a uniform finished product.

AERATED CONCRETE PROCESS



b- The Manufacturing Process

On page b4, we have illustrated the manufacturing process for a plant in Denmark.
The production is here based on sand and fly ash as bulk raw materials, and quicklime and Portland cement as binders.
Ground sand and fly ash arrive as a slurry at the mixing station where the binder components are also added.
Aluminium powder is then accurately proportioned into the mix. It acts as an aerating agent and causes formation of hydrogen, as a result of its reaction with the binder components.

The finished mix is poured into suitable forms and moved to the waiting room where the gas-forming reaction causes the mass to raise to a predetermined height. The gas is entrapped as small spheres in the mass and is thus responsible for the porous character and low weight of Aerated Concrete. The density of the end product is predeterminable and depends upon the mixing formulae. It follows that it can be adjusted to suit the application for which the mix is designed.

When the mass, in the waiting room, has hardened to a semi-plastic consistence, it is divided into units of suitable size by cutting machines of various designs.

The surface of blocks shows usually a characteristic zig-zag pattern.
Slabs and panels show a smooth surface, requiring a minimum additional surface treatment.
The figure b1 illustrates the various surface patterns, and the pore structure of Aerated Concrete.

After the cutting process, the moulds are transferred on tracks into one of the large autoclaves. Steam pressure is then, by a predetermined schedule, raised to 10 ato. with a corresponding temperature of 180 degrees Centigrade.

A number of complex hydrothermal reactions take place in the autoclave and convert the amorphous mass into a microcrystalline structure. Under this process, quicklime combines with silica from sand or ash and forms a binder phase consisting of hydrated calcium silicates.

The curing time, in the autoclave, varies between 7 and 20 hours, depending on the density, shape and size of the product.

After relieving the steam pressure, the moulds are removed from the autoclave and further curing is not required.

Although the product, at this time, contains some moisture, no drying time is required, and it may thus be shipped directly from autoclave to building site and used after cooling down to normal temperature.

c- Physical Properties of Aerated Concrete

The great succes of Aerated Concrete as a building material is attributable to the fact that it may be easily cut, sawn and worked with carpenter's ordinary tools.

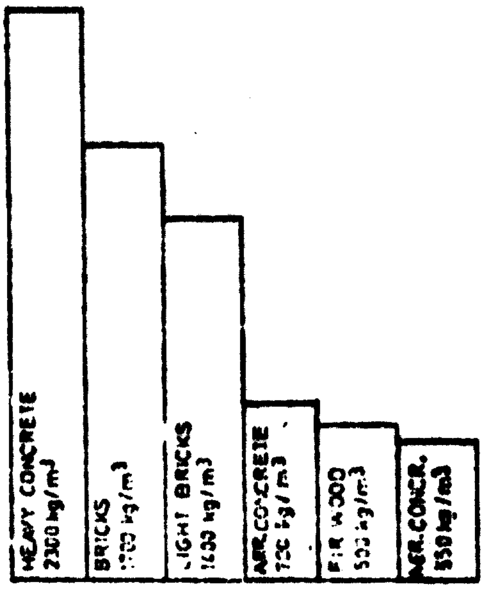
Like most of its other properties, the workability of Aerated Concrete is closely related to its pore structure and low density. The material can be produced with densities ranging from 400 to 900 kilograms per cubic meter.

The low density of Aerated Concrete reduces the cost of transportation and gives a plant an increased marketing range in comparison with heavier materials as clay bricks, sand-lime bricks and prefabricated ordinary concrete.
The low density makes it possible to use simple and light equipment for erection of prefabricated panels and slabs at the building site.

Lightweight concrete panels and slabs reduce the dead load and gives considerable savings in the loadbearing structure and foundations of high-rise buildings. This fact is of special importance, where foundation-conditions are unfavourable.

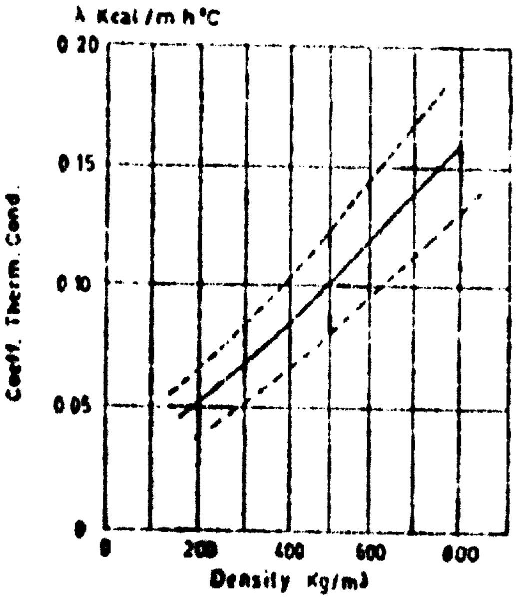
Aerated Concrete with low unit weight is suitable for applications where high insulating value combined with moderate mechanical strength are desired, and a greater unit weight is chosen where mechanical strength is of major importance.

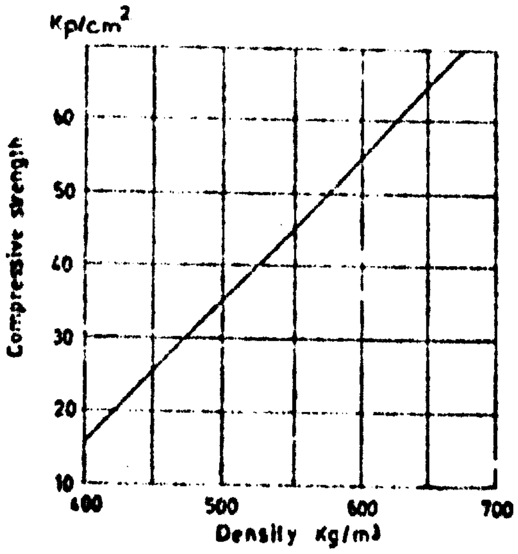
A considerable variation of physical characteristics is thus possible for Aerated Concrete, and this makes it a very attractive multi-purpose construction material.



AERATED CONCRETE DENSITY COMPARED WITH TRADITIONAL MATERIALS' ONE

The diagrams illustrate some of the physical properties of Aerated Concrete in relation to its density





The low thermal conductivity is of great value in areas with extreme climatic conditions. In cold areas, it reduces the cost of heating and, in hot climates, it improves living comfort by delaying heat transfer from the outside.

In this and many other aspects, Aerated Concrete is superior to many traditional wall constructions, such as adobe bricks, hollow concrete or clay bricks and similar materials.

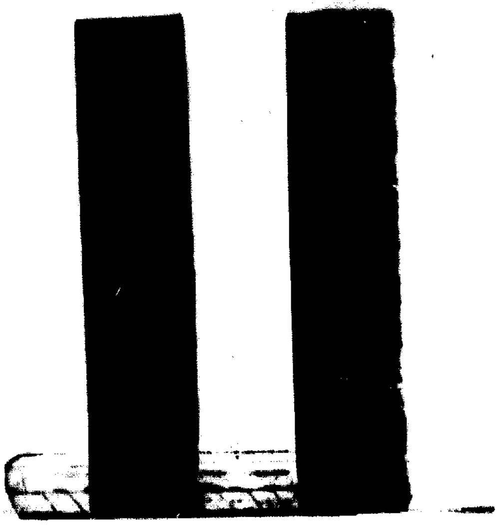
When air-conditioning is used, the low heat-transfer value (K-value) of Aerated Concrete results directly in substantial savings, owing both to reduction in power consumption and difference in installation costs of smaller air-conditioning units versus larger ones.
The actual savings should be calculated on the basis of local price patterns.

The K-value in kcal/m^2 • h •^{o}C of some external wall constructions may illustrate this point:

thickn	wall construction type	k value
30 cm	aer. concrete plastered on both sides	0,66
23 cm	" " " " " "	0,81
19 cm	" " " " " "	0,94
30 cm	cavity wall with back wall of insulating bricks, plastered internally	1,06
30 cm	cavity wall with flamed brick back wall, plastered internally	1,35

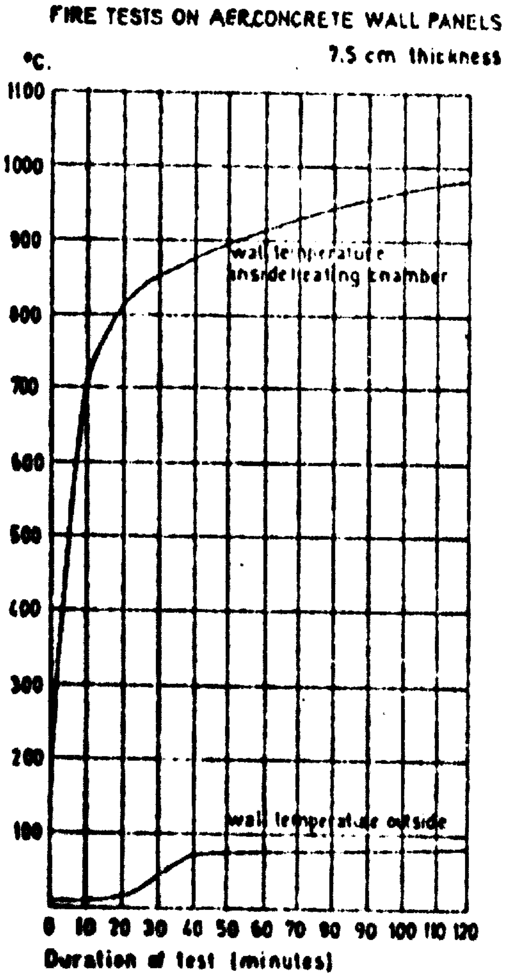
The steam-curing process is responsible for the exeptional volumetric stability of Aerated Concrete.
The linear shrinkage, on drying from water saturated to completely dry, amounts to 0,2-0,4mm/m. In practice is the variation in moisture content smaller and the effective shrinkage is 0,1 - 0,2 mm/m.

The pors structure of Aerated Concrete deviates radically from that of ceramic materials. This is due to the presence of large cells which reduce capillary action considerably in comparison to most other construction materials.



WATER ABSORPTION AFTER THREE HOURS EXPOSURE

Ceramic Block   Aerated Concrete



Its inorganic structure and low heat transmission value due to the high porosity gives the Aerated Concrete material excellent fire resisting qualities.

APPLICATION AND APPLICATION TECHNIQUES

a- Application and Manufacturing Programme

A large variety of Aerated Concrete products has been developed over the years, and this variety now covers all stages of traditional and industrialized applications. This is the main reason for believing that it can readily and successfully be introduced, also in areas where traditional or intermediate technology now dominates the construction industry. A block factory will therefore, in such areas, normally be recommended initially. The production of Aerated Concrete blocks is technically comparatively simple and they can be readily introduced in competition with traditional building materials.

The introduction of Aerated Concrete blocks does not require major training programs for local labour in the proper application techniques. A production of blocks, being limited to few sizes and types of products, makes the maintenance of stock manageable.

Aerated Concrete has also, in addition to its use for the manufacture of building blocks, been successfully adapted to the more advanced construction methods. The use of larger prefabricated units and load bearing structural elements, has become increasingly emphasised.
The development of reinforced Aerated Concrete has made it possible to produce a large number of products which combine good structural properties and high thermal insulation with low unit weight.

The building and construction industry has taken advantage of these developments, with the result that Aerated Concrete is now used extensively.

Aerated Concrete products have also been sussessfully adopted in areas where earth-quakes are frequent by placing 10 mm steel-reinforcements in joints between vertical slabs. The steel is anchored in dense concrete beams.

The manufacturing program includes a large selection of reinforced beams, floor, roof and ceiling slabs as well as partition and exterior wall panels with various designs and degrees of finish. A density of between 500 - 800 kg per cubic meter is normally preferred for use in reinforced Aerated Concrete products.

When considering an extension of an Aerated Concrete manufacturing program to include reinforced products, a thorough knowledge of the potential market is an important prerequisite to the selection of a feasible production and to ensure optimal return on investments. The importance of this cannot be overemphasised since considerable capital outlay is required, not only for manufacturing equipment, but also for the maintenance of a reasonable stock of a large variety of finished items.

The local modular system, building customs and preferences should guide the choice of standard items to be carried in stock. Obviously, the combinations of various sizes, shapes and finishes leads to a nearly infinite number of different products.

It may be of interest here, to point out that reinforced beams and lintels for doors and windows are easily made in standard block equipment. Such products supplement the sales program for blocks and are readily introduced on existing markets. These relatively simple reinforced products thus provide a natural first step towards the inclusion of larger and more complicated reinforced elements in the manufacturing program.

Despite the higher cost of reinforced products, substantial savings can be obtained in form of shorter erection time and reduced expenditure of manual labour. But here again, it is important to select types of products and application technology which are commensurate with the capacity of the local construction industry.

A production of slabs and wall panels of various designs may be seriously considered where short erection time and economy with labour expenditure are important factors. This often coincides with a rising demand for building materials with a higher degree of finish. The steel reinforcement used in slabs and panels is comparatively inexpensive, and the magnitude of such manufacturing program is still at a manageable level. Moderate investment in cranes and other handling equipment is now required at the building site in order to ensure speedy erection and to prevent damage to the slabs and wall elements. Structural slabs and panels of Aerated Concrete have big marketing possibilities in areas with unfavourable foundation conditions.

Existing block facilities can, at moderate cost, be expanded for this production and certain specialty items may be made, using the standard manufacturing process with simple modifications.
Examples of the use of these products, in various building systems, are presented in the following sections.

The latest developments in Aerated Concrete production include factory assembly of full scale wall units for prefabricated buildings and the manufacture of wall elements with various types of surface treatments. These, and other Aerated Concrete products, are supplied to the more sophisticated building materials markets.

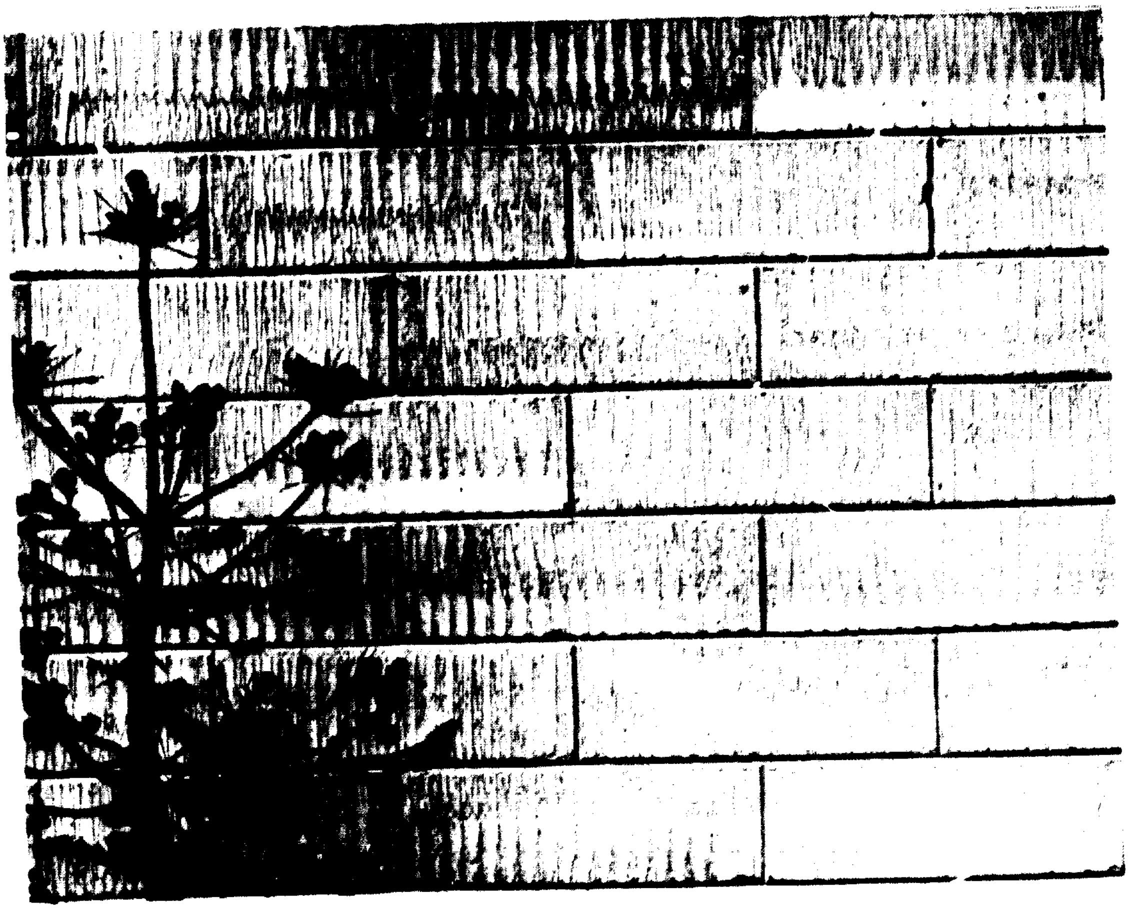
We shall now, in the following sections, demonstrate the various applications of Aerated Concrete, from a strictly technical point of view.

b- Aerated Concrete Building Blocks

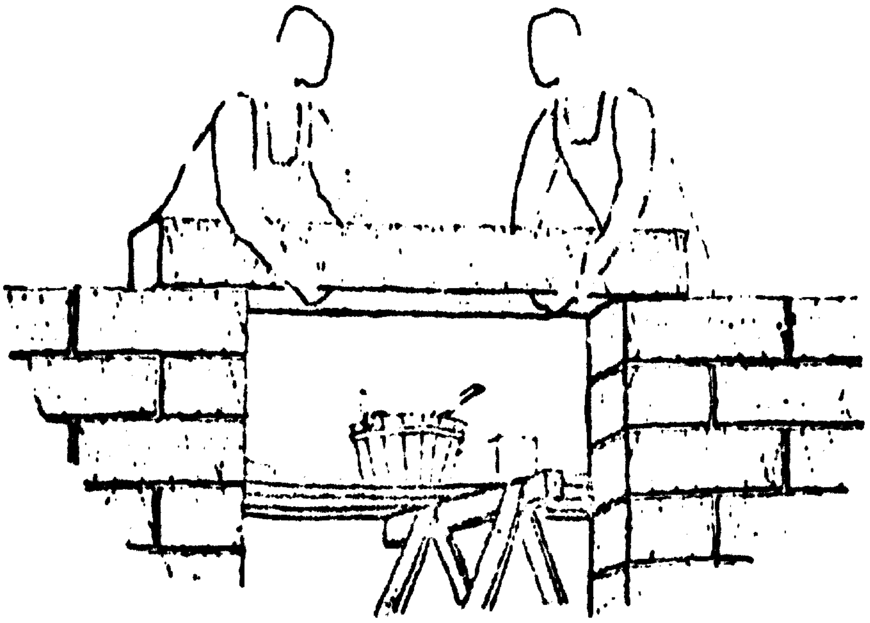
As mentioned earlier, the introduction of Aerated Concrete building blocks is normally accomplished without difficulty in traditional markets. The low unit weight, ease of handling and the outstanding dimensional stability are appreciated by masonry workers, and these qualities also promote speedy construction as well as improve quality and finish of the completed job.

The characteristic zig-zag surface pattern, originally developed to promote the adhesion of plaster, has been utilized to give new effects in the architectural design of houses and factories.

The illustrations show examples of these effects.

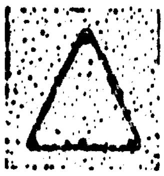


Load bearing lintels are a supplement to the manufacturing program for blocks, and are used for the spanning of door and window openings in Aerated Concrete masonry walls. Lintels are produced in dimensions corresponding to the various types of blocks.



The "G" lintels manufactured in Denmark span up to 2 meters and have a load bearing capacity of 1500 kg (uniformly distributed) per running meter.

For larger openings, "J" lintels are provided. They consist of a reinforced core of dense concrete, faced with 5 cm of Aerated Concrete blocks. These beams are manufactured in lengths up to 3,5 meters and gives a pattern similar to the rest of the aerated facade.



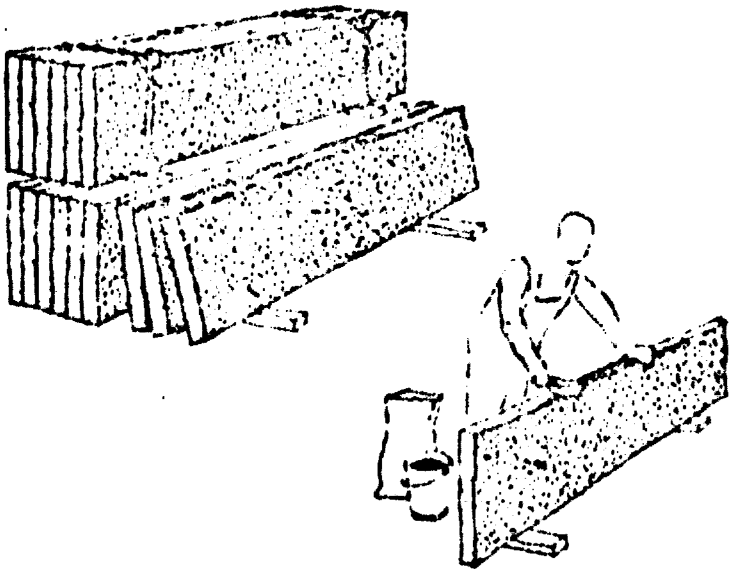
"G" lintels

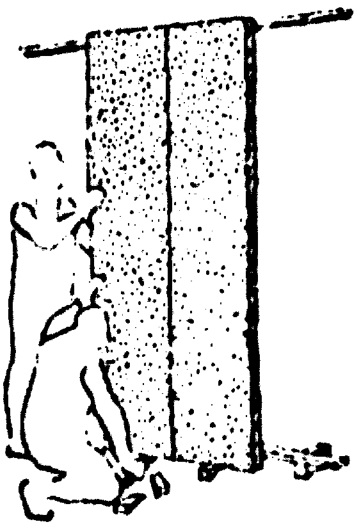
"J" lintels

c- Aerated Concrete Panels and Elements

In the development of Aerated Concrete great empahsis has been placed on high degree of finish, short erection time and the use of unskilled labour. This is why room-hight Aerated Concrete panels have become increasingly popular in many countries. They are widely used for partition walls in commercial and apartment buildings or in single family dwellings, and also as inner leaf in composite wall constructions.

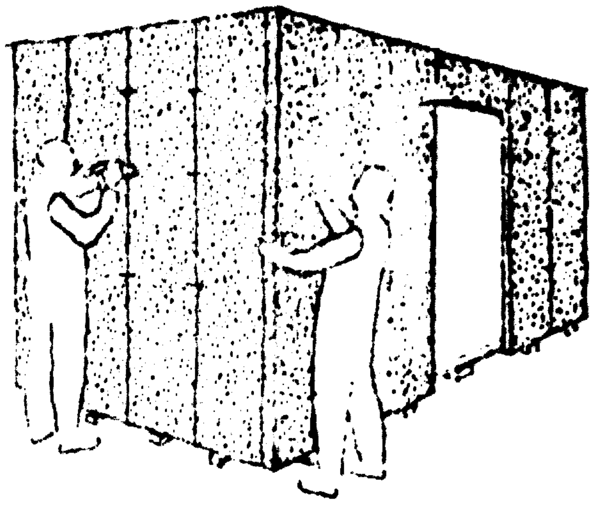
These panels are delivered to the building site in bundles and a two man team carries out the erection. By gluing with special types of inorganic adhesives, unskilled labourers successfully manage this job.



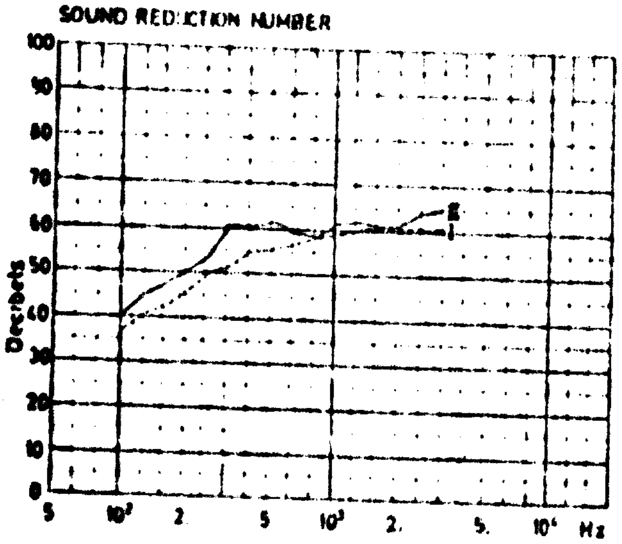


A special cutting process gives smooth panel surface which require no further treatment prior to the application of for example wall papering.

Where specifications call for extraordinary smooth surfaces, the panel can be treated with a thin skim coating.



Wall panels are usually produced with a density of 500 - 200 kg per cubic meter. They are made in widths up to 60 centimeters and lengths up to 3 meters. Sufficient steel reinforcement permits transport, handling and erection without damage.



I Requirement of Danish authorities for main parti
II Aerconcrete acoustical wall (2 x 7,5 cm panels)

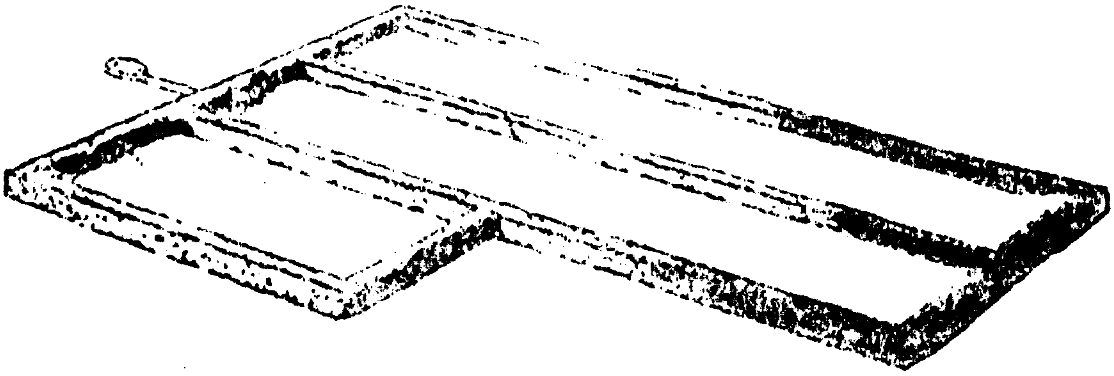
For main partitions between flats, double-leaf walls with low sound transmission has been developed.

A Building System for Aerated Concrete

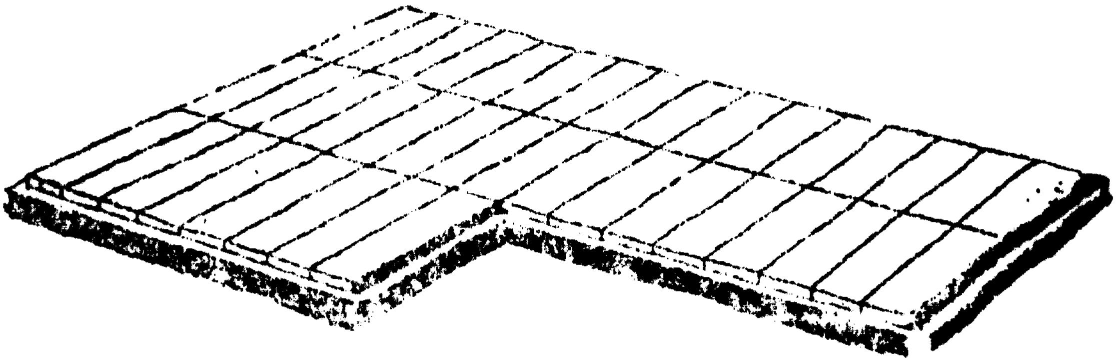
The building system for low rise construction, based on the use of Aerated Concrete slabs and panels, is one of great flexibility and adaptible to local needs and customs. The desire to provide a high rate of low cost housing with unskilled labour and a minimum of machinery and mechanical equipment has guided the principle of its development. It is applied in urban development and renewal as well as in rural areas where local self-help programs are the cause. Heavy cranes and other handling equipment is not required because of the low unit weight of the material.

The following illustrations show the erection of a one family house of 60 square meters with 4 rooms, a kitchen-corner, a bath-room and toilets. This house has been designed in order to be built in series. No mechanical equipment is needed for its construction.

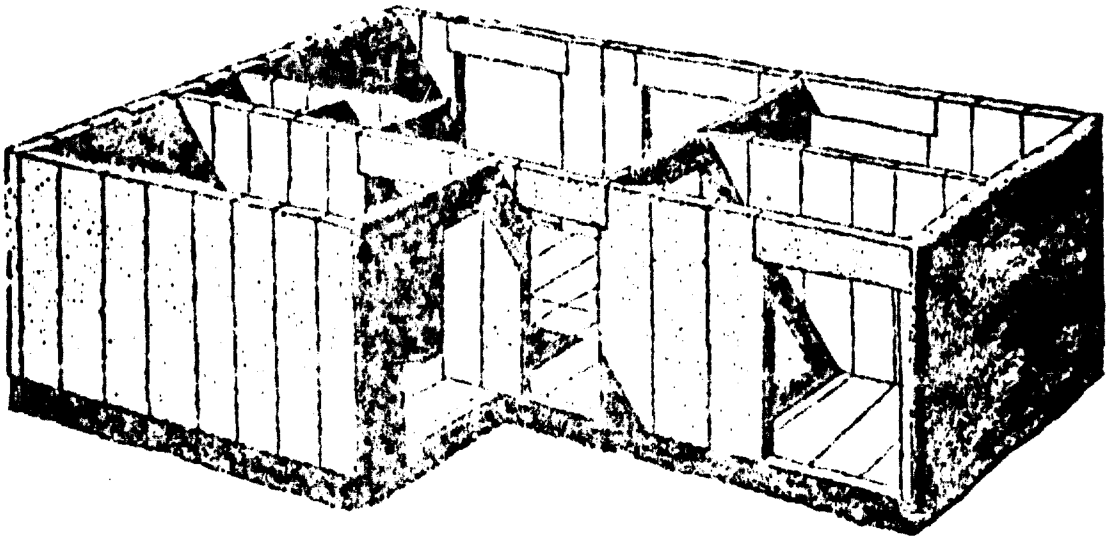
Foundations are made in a traditional way, depending on the nature of the ground. The connections to the various services are gathered at one point.



Floor slabs are then laid with the use of a special cart and the joints filled up with adhesive cement.

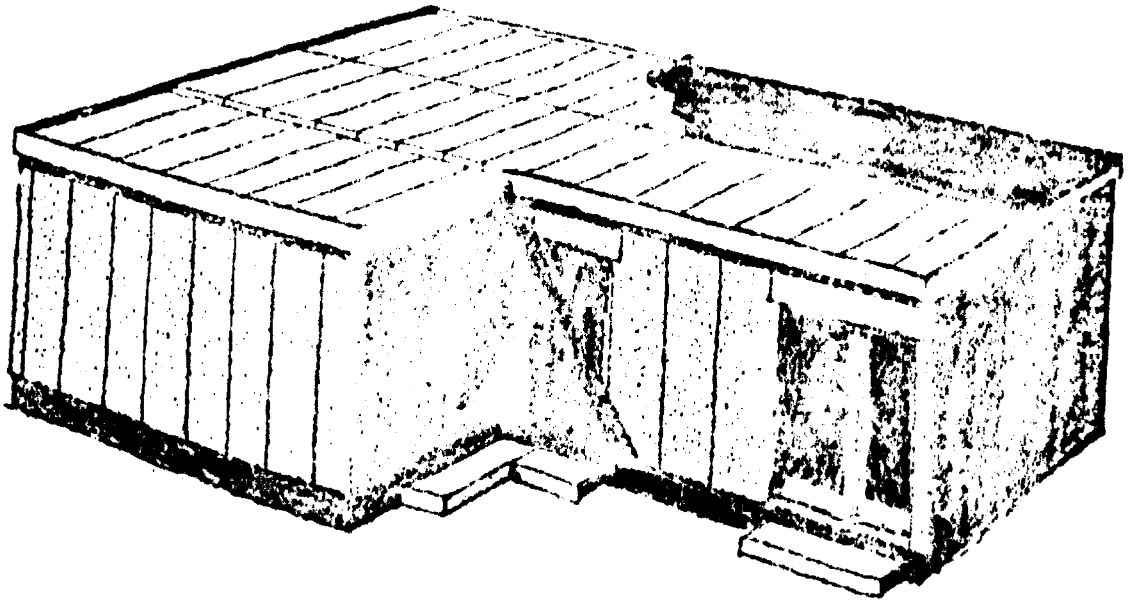


Wall panels are erected with the use of a hand wagon. The exterior panels are provided from the factory with a rended outside finish. All panels are assembled with special adhesives.



The roof is finally laid on the outside panels, the inside load bearing elements and a steel beam which bears over the

living-room. A rain water chenel is provided on the roof which is ready to receive its covering, depending on the local climatical conditions.
Jointing around windows and doors is carried out after the erection of the elements is completed.



This table shows on one side the quantities of material used and on the other the erection times needed by a two man team. The prices will be easy to calculate with help of the "Economy" section.
The shown erection times can be considerably shortened by using using mechanical handling equipment.

	Number of elements	Aer.concrete quantities	Labour in hours for a two men team	Adhesive quantities
FLOOR	40 elem 240x60x12	6,90 m³	25	70 kg
OUTSIDE WALLS	46 elem 240x60x20 6 elem 200x60x20	16,7 m³	110	150 kg
BEARING PART WALLS	6 elem 240x60x20	1,73 m³	16	10 kg
PART WALLS	10 elem. 240x60x7,5 +3 overdoors	1,2 m³	16	13 kg
ROOF	43 elem. 240x60x20	12,4 m³	30	130 kg
TOTAL		37 m³	197 (394 manhours)	373 kg

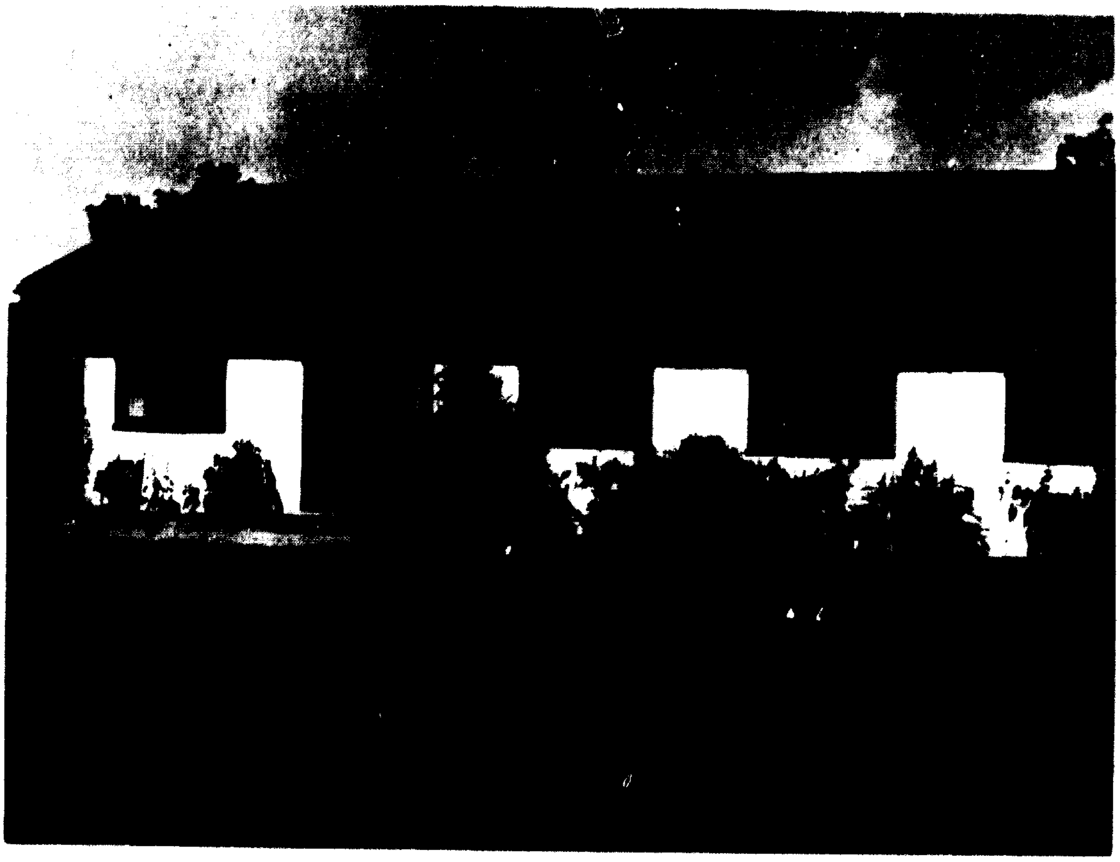
This panel system provides considerable freedom for the architect in the design of ground plans as well as facade elevations. "Fill-in" elements provided either directly from factory or prepared on the site by simple cutting tools permit a horizontal modula for partition walls of as little as 10 cm. However, in order to ensure competitive construction, gross dimensions of the building and sizes of doors and windows should be chosen within the module inherent in the widths of the elements. Door and window lintels are supplied in standardized dimensions.

A short erection time is undoubtedly a major advantage of this building system. The use of large uniform elements of low weight permits rationalized construction at the building site. This rationalization may be accomplished with comparatively inexpensive equipment and is, therefore, applicable not only around cities, but also in rural areas.

The accuracy of the basic house gives further possibilities for cost and time savings in the suosequent steps of the building process. In order to utilize all the advantages provided by the system, prefabricated parts are recommended also in the later stages of the construction process. When as much work as possible is transferred from building site to factory or workshop, the rate of completion for the whole construction is in line with the speed of erection of the raw house.

Wall panels are made with an outside smooth surface whereby further rendering or application of plaster is eliminated. A wide range of paints and other thin layer surface coatings have been developed instead. Basic requirements for good surface coatings are high coverage and good adhesion to Aerated Concrete surfaces. Any such surface coating should be permeable to the diffusion of water vapour through the wall structure.

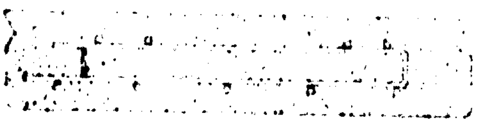
From experience in the field and based on permeability measurements in the laboratory, paint formulas on the basis of emulsified acryllic resins are recommended. Acryllic emulsion paints meet not only the requirement for water vapour permeability, but also the demand for a durable coat for Aerated Concrete. Although the initial cost may be somewhat higher than, for example, a PVA type paint or inorganic coatings on Portland cement basis, acryllic paints are found, in the long run, to be the most economical surface coating because of their greater durability and resistance to darkening and dirt absorption.



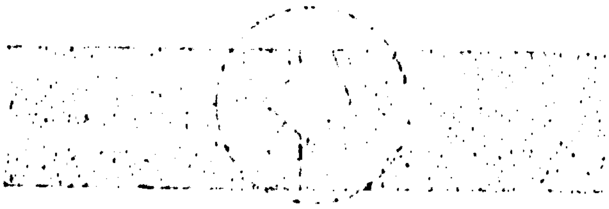
OUTSIDE WALL ELEMENTS PROVIDED WITH THIN LAYER COATING

d- Reinforced Structural Members of Aerated Concrete

This line of production may be taken up where the preexisting industrial development and the availability of basic skills provide possibilities for the more industrialized forms of construction. Besides major investments in equipment and stock, it requires considerable skills for manufacturing these products economically. This is the reason why this line of products only should be put on the market when Aerated Concrete has been well introduced and accepted by the local building contractors.



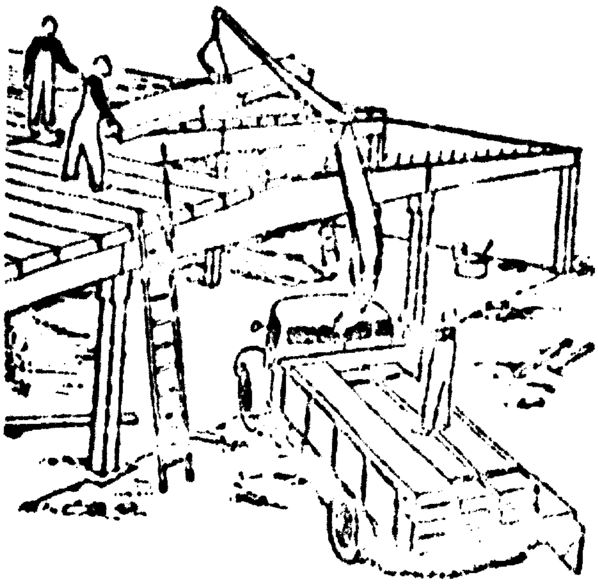
FLOOR SLABS SECTION

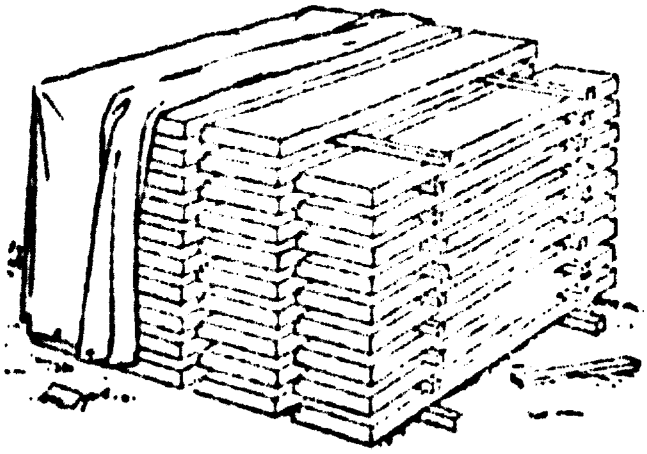


SLABS JOINT

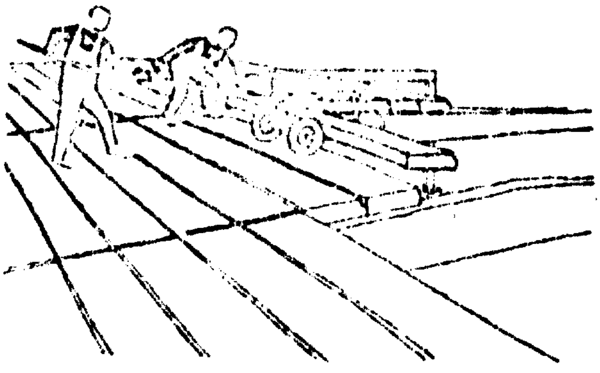
Reinforced slabs for roofs, ceilings, floors and walls are manufactured with densities between 500 and 800 kg per cubic meter and with various types of reinforcements depending on the load bearing ability required.

Standard slabs are 60 cm wide, up to 6 meters long and 10, 15, 20 or 25 cm thick. In addition, a large variety of slabs with special dimensions, edge styles and shapes can be prepared to order for certain specialized applications.

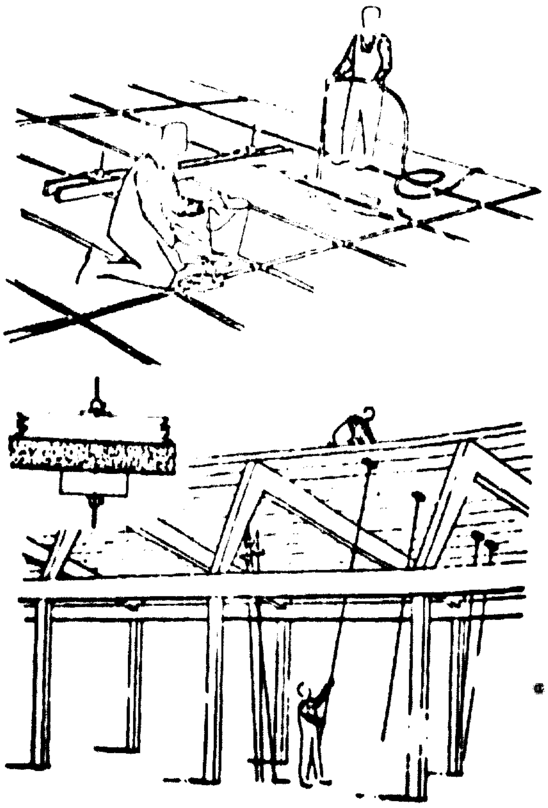




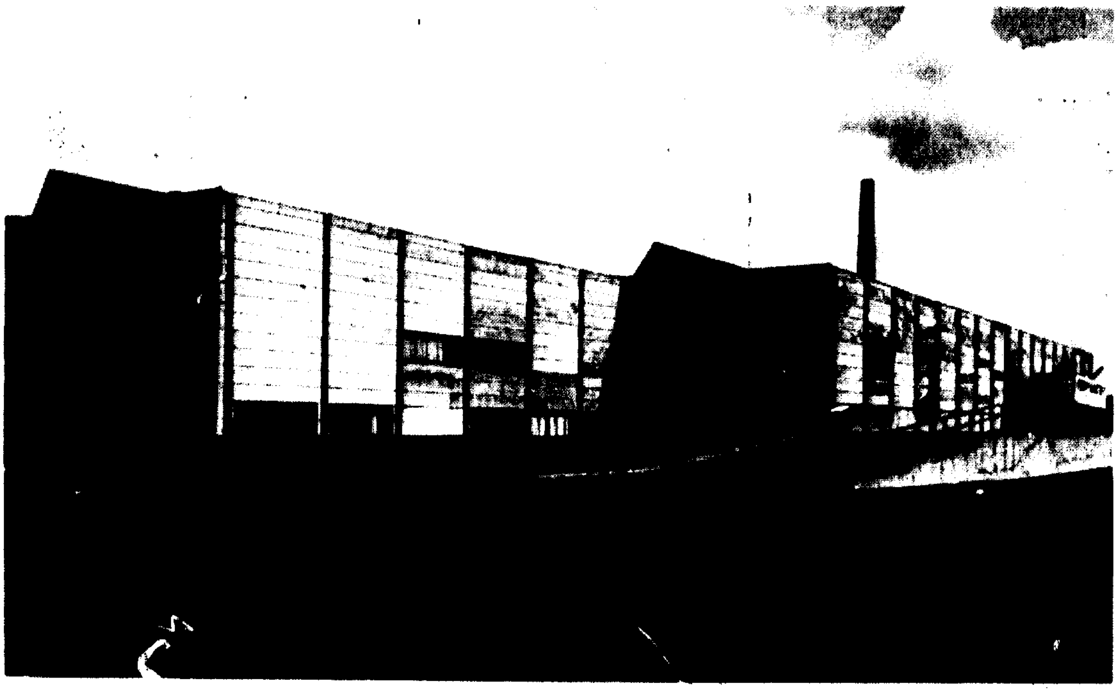
Reinforced slabs are delivered by crane-fitted trucks to the building site. Special carts an clamps have been designed for the efficient handling of the prefabricated elements.
The construction of roof and floor slab is easily managed by unskilled labours.



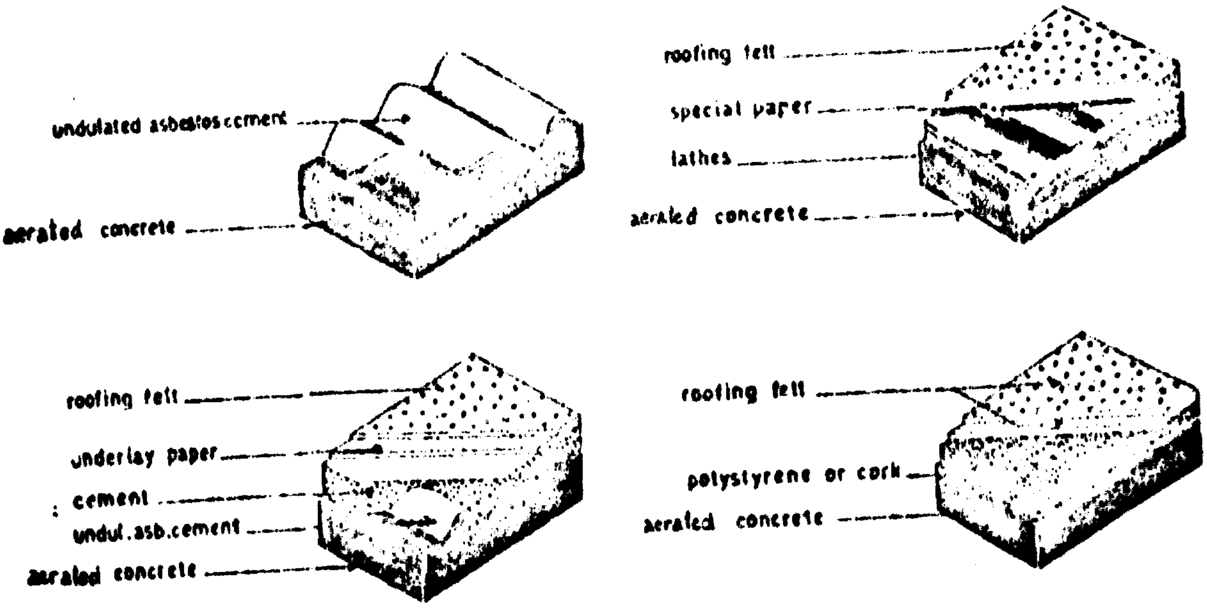
After palcing the slabs on the supports, the specially designed joints are filled with mortar or glued together. The result is a monolithic structure of high strength and stability. Low weight, high insulation value and fire resistance are some of the advantages offered by this type of construction and makes it particularly feasible for factories, warehouses and other industrial buildings. The smooth inner surface may be left untreated or be whitewashed.



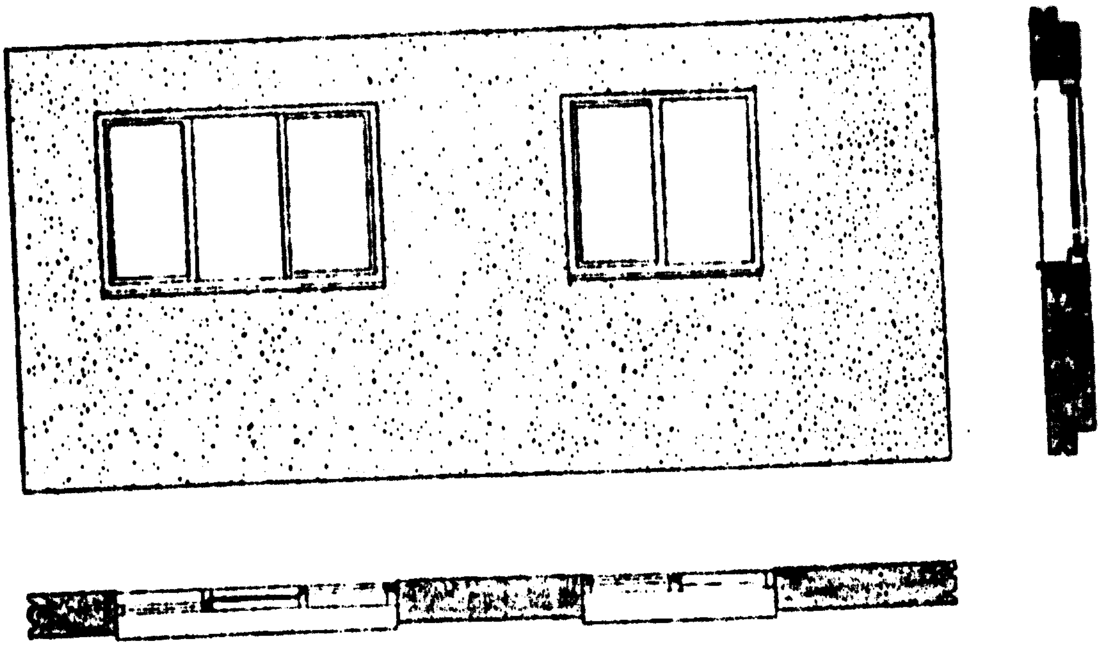
In apartment buildings and smaller houses, slabs have become populer as floor slabs over crawl spaces and in deck constructions. These products have been found to be very competitive, compared to traditional construction methods.



INDUSTRIAL BUILDING WITH HORIZONTAL AERATED CONCRETE PANELS



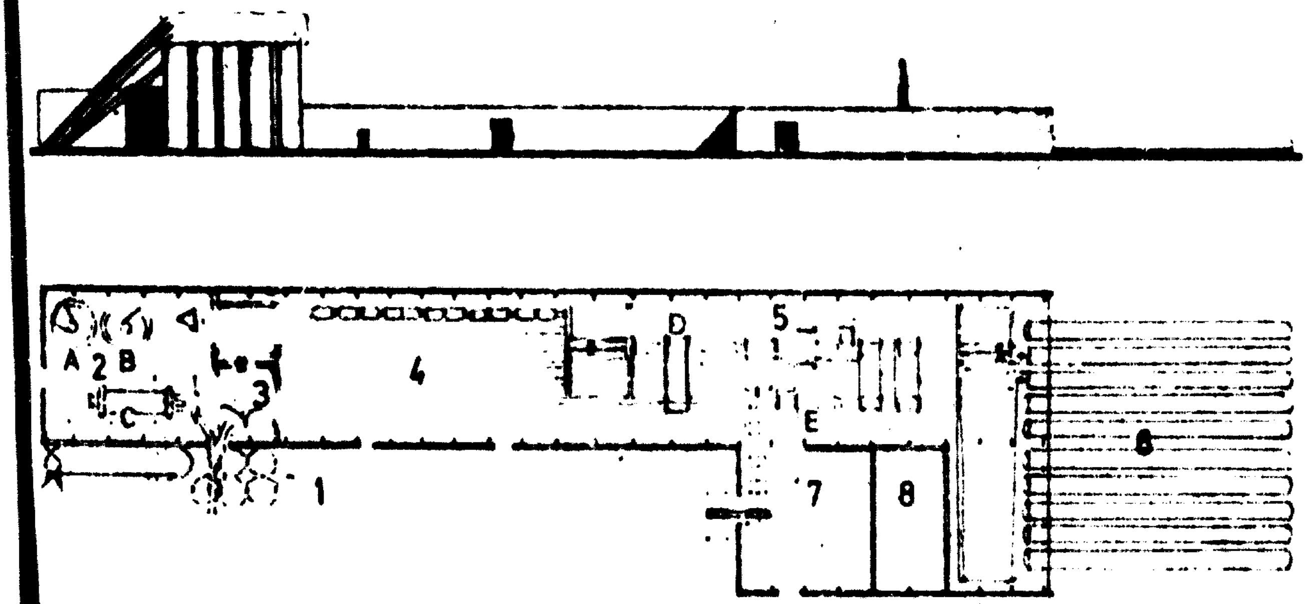
FOUR DIFFERENT EXAMPLES OF ROOF COVERING



WHOLE WALL ELEMENT ASSEMBLED AND SURFACE-TREATED AT THE FAC
TORY FOR USE IN PREFABRICATED MULTISTORY APARTMENT CONSTRUC
TION.

A PRINCIPAL PLANT LAY-OUT

The drawing represents a production unit for Aerated Concrete blocks with an annual capacity of 50,000 cubic meters or approximately 200 cubic meters per day, at one shift operation and a six day work week. A plant of this size will in many cases be quite suitable as the initial stage of an Aerated Concrete industry. The plant lay-out and design are made with due consideration to future plant expansions to increase block production as well as for the incorporation of reinforced wall panels and slabs in the manufacturing program. In the latter case, moulds and cutting equipment have to be installed and the production area expanded to include a workshop for the preparation of steel reinforcement.



1 SILOS
2 SAND MILL AND SLURRY MIXERS
3 MIXING UNIT
4 WAITING ROOM
5 CUTTING EQUIPMENT
6 AUTOCLAVES
7 STORAGE AND SHIPPING
8 STEAM GENERATING PLANT

A SAND SLURRY
B FLY ASH SLURRY
C SAND MILL
D REMOVAL OF TOP
E CLEANING AND OIL TREATMENT OF MOULDS

LAY-OUT FOR A PRODUCTION UNIT FOR MANUFACTURE OF AERATED CONCRETE CAPACITY: 50.000 cubic meters of blocks per annum

This plant requires an investment of the order of 1,8 million US dollars including design, equipment, shipping charges, erection and start-up, but excluding buildings and site.
The table lists the space requirements for the various factory components:

- Main factory building	approx.	2.400 m^2
- Boiler room	"	250 m^2
- Workshop and spare parts room	"	300 m^2
- Cloak-room and canteen	"	150 m^2
- Office building	"	250 m^2
	approx.	3.350 m^2
- Storage area for finished product	"	4.000 m^2
- Total area suggested, excl. sand quarry	"	25.000 m^2

Normally, production units smaller than 50.000 cubic meters per annum is not recommended, but the minimum, and still economically feasible, size depends a great deal on local circumstances. For more details on this question, please refer to the section on "Economics'.

For countries with an abundant supply of manual labour and low wage rates, low cost unit with a capacity of about 25.000 cubic meters per year in a one shift operation can be designed. The plant components are designed for a two shift operation whereby a yearly production of 50.000 cubic meters is possible.
The initial investment for this plant is reduced to 1.3 million US dollars.

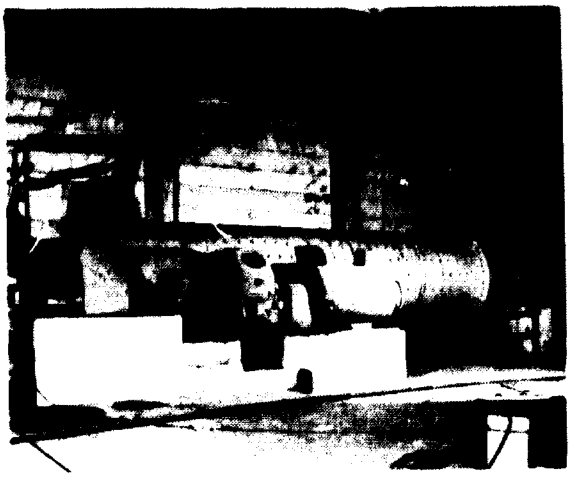
Basic raw materials

In the above presented principal plant lay-out, Aerated Concrete production is based on sand and fly ash as the silica raw materials and Portland cement and quicklime as binders.
A number of modifications are possible however, depending on the raw material situation in the vicinity of the selected production site.

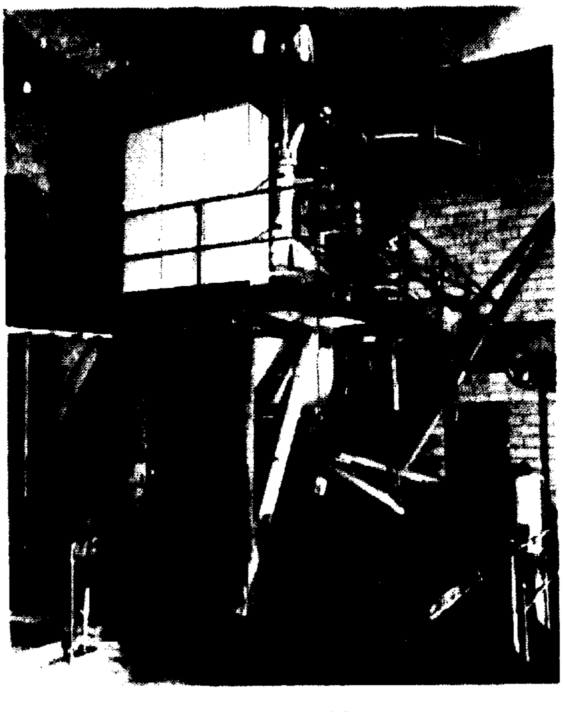
The sand/ash combination can be replaced by either straight sand or straight ash, provided the selected material is free of detrimental agents.
Where lime is not available in sufficient quantity or in suitable quality, it may be replaced by Portland cement, in which case the amount of binder required may increase somewhat.

Cement and powdered quicklime are normally received in bulk shipments and stored in silos in the raw materials area, shown on the left side of the lay-out.
In certain instances quicklime is available only in "lumps" and a lime mill of suitable capacity must then be installed at the plant.

Sand is received by truck from the pit and ground to cement fineness in a ball mill, whereas fly-ash is usually of sufficient fineness for direct use in the process.
The grinding of sand in the ball mills may be done as a wet or dry process. Wet grinding is normally the most economical of the two.



SAND MILL



MIXING UNIT

Mixing and aeration (drying aera)

After preparation of the raw materials follows the mixing and aeration processes. Sand and ash, in slurry-form, are pumped to the mixing units in metered quantities, while Portland cement and quicklime are drawn directly from the storage silos, via suitable weighing units. Towards the end of the mixing process, aluminium powder suspended in water is added.

The finished mix is then cast into moveable moulds, placed below the mixer.

The moulds are now transferred to the waiting room where the aeration process takes place. The mass will rise to a predetermined height and the setting reactions simultaneously develop the stiffness required for the subsequent cutting process.

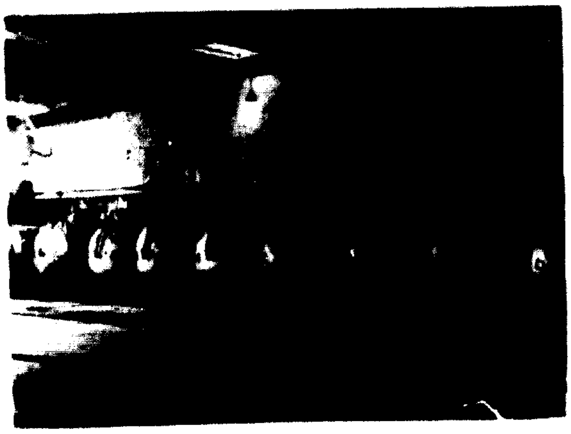
WAITING ROOM

Cutting - Autoclave Curing - Storage

After removel of the mould sides, the mass is devided into the desired sizes by moving wires, which also produce the characteristic zig-zag pattern on the block surfaces. For cutting panels, special wires are used in order to obtain a smooth surface.

CUTTING EQUIPMENT

Finally, the rounded top section is removed by a vacuum-operated top lift, and recirculated into the slurry silos.



AUTOCLAVES

With a transfer trolley, the moulds now enter the various autoclaves for curing in saturated steam at 180°C. - 10 atmos.

Upon completion of the curing process, the moulds are removed from the autoclaves and the finished product, (blocks or panels), are lifted from the mould bottoms and banded into packs of suitable size with steel bands.

The plant production equipment are designed with emphasis upon reliability, a reasonable degree of automation and low maintenance cost. This design is at the same time flexible enough to be adjustible to local conditions.

A production of 50.000 cubic meters of Aerated Concrete blocks per year, in a one shift operation, will normally demand a labour-force of 42 workers, 12 supervisors and office personnal. The actual numbers depend, of course, a great deal on the degree of automation and the industrial training and experience of the workers available.
For a plant producing a similar volume of panels, about twice as much process labour is needed.

Labour, raw material and power consumption of the Aerated Concrete manufacturing process is summarized in the table below. The data are based on conditions prevailing in Denmark, but considering local conditions, it is believed that the figures provide useful guidance in estimating the variable cost of Aerated Concrete production.

Raw materials per m^3 Aerated Concrete:

- Sand and fly ash	500 kg
- Quicklime	90 kg
- Portland cement	60 kg
- Aluminium powder	0.4 kg
- Steel reinforcement	7.5 kg (for wall panels)
- Fuel oil	15 kg
- Water	0.4 m^3
- Power	20 KWH
- Mould oil	0.8 kg
- Grinding media	0.8 kg
- Various expenses	5% of total cost

Labour per m^3 :

- Block production	0,6 to 2,0 man-hours	depending on training
- Panel production	2.0 to 6.0 man-hours	depending on training and products.

ECONOMY

According to the discussion in the preceeding sections, it is assumed that the introduction of Aerated Concrete on new markets is best accomplished by an initial production of blocks. The manufacture of this product requires a minimum of technical skills; equipment and the process are rather simple and the manufacturing program can be tailored to the established pattern of the local market.
Furthermore, Aerated Concrete block construction is commensurate with traditional application techniques and should, therefore be readily accepted by local contractors and bricklayers.

Aerated Concrete blocks will, however, be marketed in direct competition with clay bricks and cement blocks. The latter can be produced with rather inexpensive equipment and, if necessary, at very low cost if the local market is not quality conscious.

The successful introduction of Aerated Concrete blocks will depend on the extent to which the local market is able to utilize the superior quality of this material.
The high insulation value of the material is a valuable asset in areas where heating or air conditioning is applied.
Lower weight of Aerated Concrete masonry can lead to savings through smaller foundations and load bearing members if this advantage is incorporated in the initial design.

The cost comparison for various types of masonry work in Denmark, shown on page e7 , may give some idea of the relative labour and shipping costs. The cost of an Aerated Concrete wall is, for eample, about two thirds of that for a comparable wall made of bricks and additionally, for high insulation requirements, the brick wall would have to be combined with mineral wool, lightweight aggregate blocks or a similar material.

In the following graphs, the profitability of an Aerated Concrete block factory has been evaluated for various levels of sales prices. The evaluation is based on the following assumptions:

- Annual sales	50.000 m^3 of blocks
- Total Cost of plant (depreciated over 10 years)	2.000.000 US $
- Royalties	3 % of sales revenue
- Overhead expenses	100.000 US $
- Production expenses	7 US $ per m^3 of blocks

Overhead expenses include management, sale, supervision, plant maintenance and office expenses. The stated figure may be too high for countries with low wage rates, but it is believed to be realistic in most cases, since the advantage of low wage rates often will be offset by the need for expatriate assistance in the initial stages.

The fixed expenses for this plant will be the sum of overhead expenses plus depreciation costs, and will total 300.000 US $ per annum.
The variable expenses consist of production costs and royalty fee.

The calculation presented in the graphs clearly indicate that, to maintain a reasonable return on investments, the sales price should be between 15-18 US $ per m^3. This may, however, exceed the price a highly competitive market is willing to pay. In such cases, a larger plant may be tho answer, provided the potential market is big enough for the higher production.

A plant producing 100.000 m^3 of Aerated Concrete will not cost substandially more than one producing 50.000 m^3, and the fixed expenses per produced cubic meter Aerated Concrete will thus be reduced.
Such a plant may show a comfortable profit margin even at much lower sales prices, as indicated in the following figures:

- Production capacity	100.000 m^3 per year
- Sales price	15 US $ per m^3
- Break-even point at sales volume of	40.000 m^3 per year
- Pre-tax return at annual sales of 100.000 m^3	450.000 US $ or 23 % of invested capital

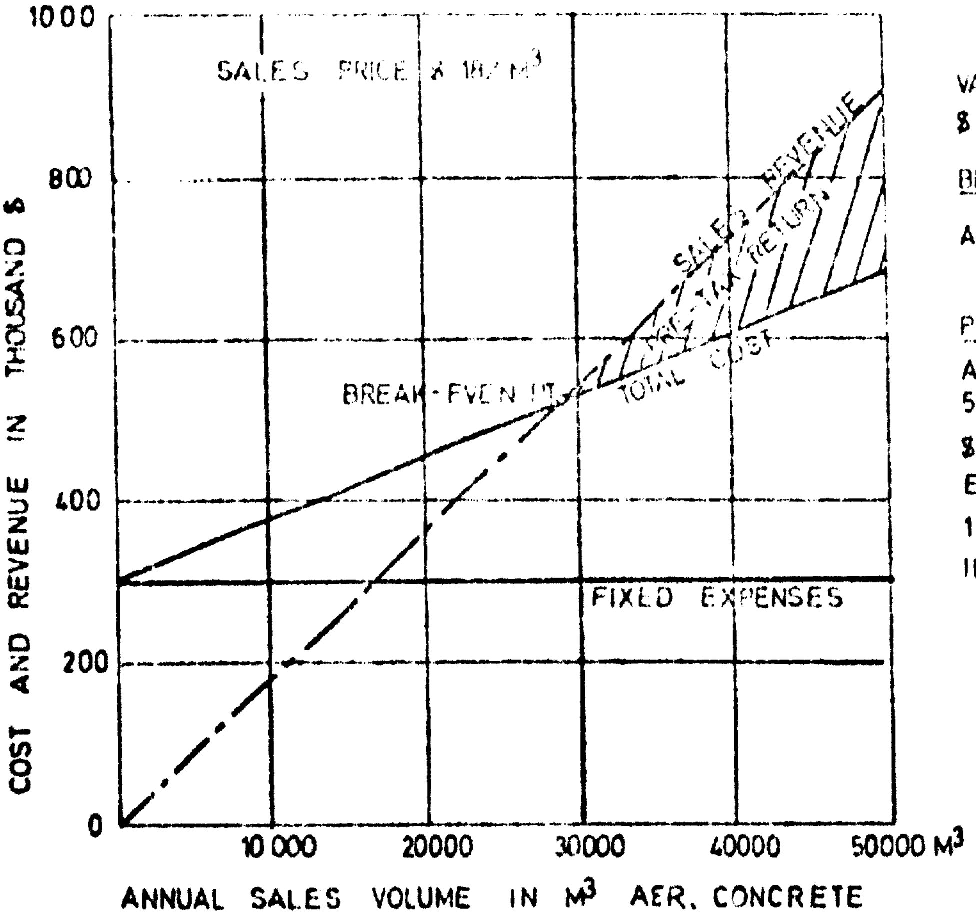
If the local market does not permit the introduction of Aerated Concrete blocks at a reasonable level of profit, the possibilities of marketing wall panels and elements should be investigated. The products will command a higher sales price due to the higher degree of finish, the short erection time and the elimination of plastering work.
Aerated Concrete panels will compete with ordinary reinforced concrete elements, plaster bonds and other large size elements, rather than with low cost items such as concrete blocks or clay bricks. In this competition, Aerated Concrete panels have an appreciable advantage because of low weight, ease of erection and dimensional stability.

In comparison with brick and block masonry, a somewhat different erection technique is used and some efforts should be made to train local workers for this type of work.
In many companies a contracting division for erection of panel walls has been established. This arrangement has assisted in introducing the material at a reasonable cost and made it easier to keep in touch with the requirements of the market with regard to proper design of products.

The break-even charts presented here are based on Aerated Concrete plant producing 50.000 m^3 of panels annually or 500.000 m^2, if average wall thickness is assumed to be 10 cm.

The calculation is based on the following data:

- Annual sales	500.000 m^2 of panels
- Total cost of plant	2.200.000 US $ to be depreciated over 10 years
- Royalties	3 % of sales revenue
- Overhead expenses	125.000 US $
- Production expenses	11 US $ per m^3 or 1,10 US $ per m^2 of panel

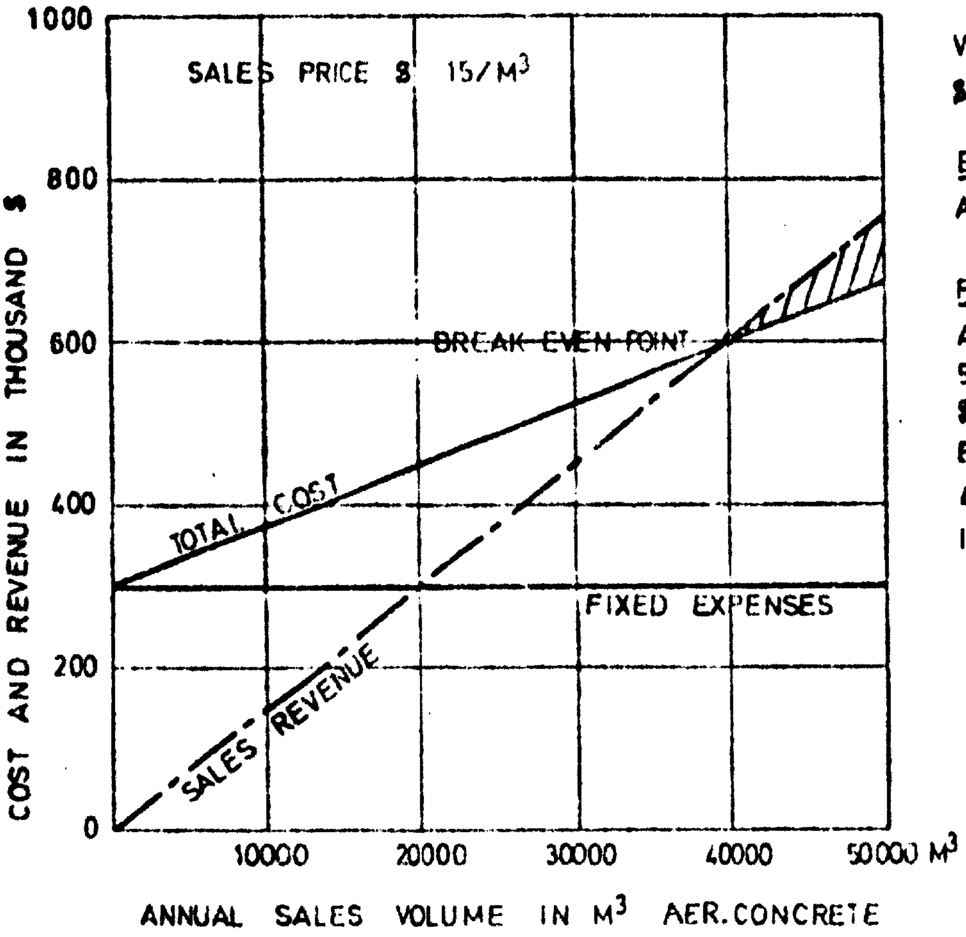


VARIABLE EXPENSES PER M^3
$7 + 0.03 x 18 = 7,54

BREAK-EVEN POINT

AT SALES VOLUME 29000 M^3/ANNUM

PRE-TAX RETURN AT ANNUAL SALES OF 50000 M^3 BLOCKS $ 223000 - EQUIVALENT TO A 11 % RETURN ON INVESTED CAPITAL



VARIABLE EXPENSES PER M^3
$7 + 0,03 x 15 = 7,45

BREAK-EVEN POINT

AT SALES VOLUME 40000 M^3/ANNUM

PRE-TAX RETURN AT ANNUAL SALES OF 50.000 M^3 BLOCKS: $ 77.500 - EQUIVALENT TO A 4 % RETURN ON INVESTED CAPITAL.

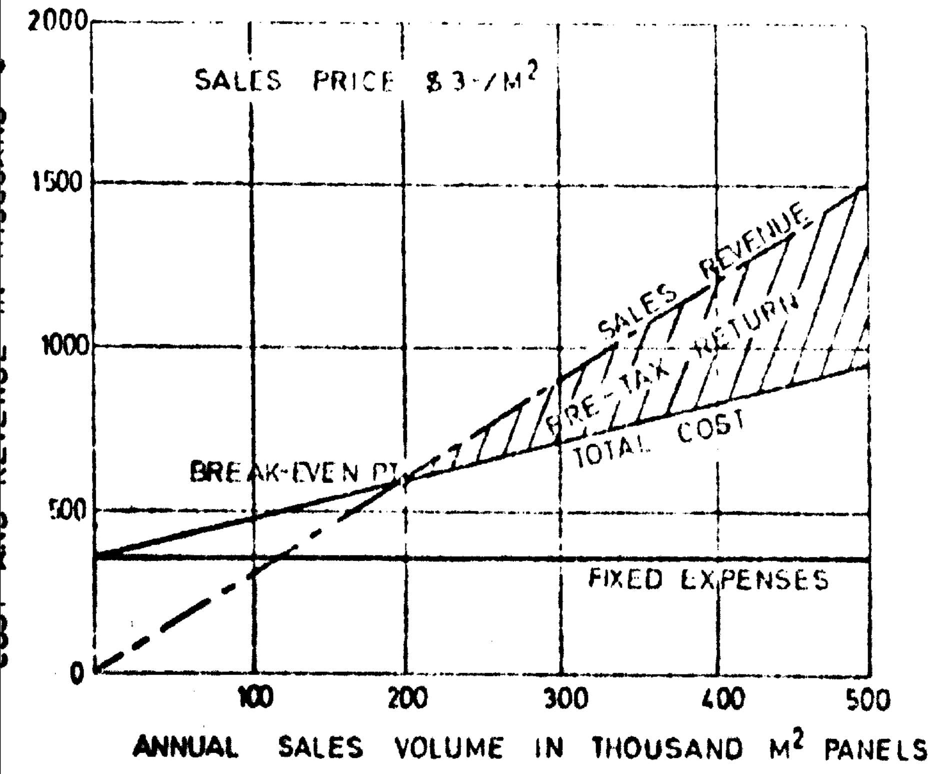
BLOCKS

The fixed expenses for this type of plant will be 345,000 US $ per annum.
The calculation indicates that reasonable profits can be achieved with a sales price per square meter panel, of 2.50-3.00 US $. Larger plants will do considerably better and, for a plant manufacturing 1,000,000 m^2 panels per year, sales prices can drop to 2.00 US $ per m^2 and still give a fair return on invested capital.

- Production capacity	1,000,000 m^2 per annum
- Sales price	2.00 US $ per m^2
- Break-even point	at sales volume 430,000 m^2
- Pre-tax return at annual sales of one million m^2 panels	495,000 US $ or 23 % of invested capital.

In the discussion of project economy, capital and cash flows for the first years have not been covered.
Working capital depends a great deal on local conditions, the manufacturing program, product mix, the rate of turn-over of the stock, allocations for raw materials stock and receivable accounts. These questions must be studied separately in each particular case.

Detailed studies covering these subjects should be carried out for each specific project as a basis for evaluation of project economy.



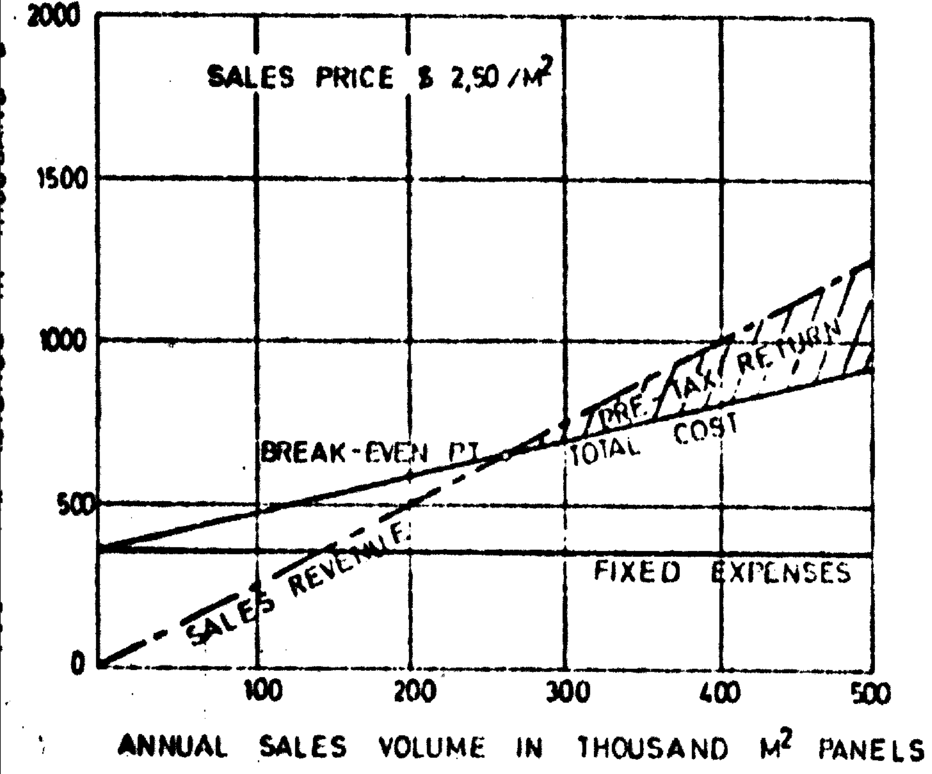
VARIABLE EXPENSES PER M²
$ 1,10 + 0,03 x 3 = 1,19

BREAK - EVEN POINT

AT SALES OF 190 000 M² PER ANNUM

PRE - TAX RETURN AT

ANNUAL SALES OF
500 000 M²
$ 560 000 -
EQUIVALENT TO 25 %
RETURN ON INVESTED CAPITAL



VARIABLE EXPENSES PER M²
$ 1.10 + 0,03 x 2,50 = 1,175

BREAK - EVEN POINT

AT SALES OF 260 000 M² PER ANNUM

PRE - TAX RETURN AT

ANNUAL SALES OF
500 000 M²
$ 317 500 -
EQUIVALENT TO 14 %
RETURN ON INVESTED CAPITAL

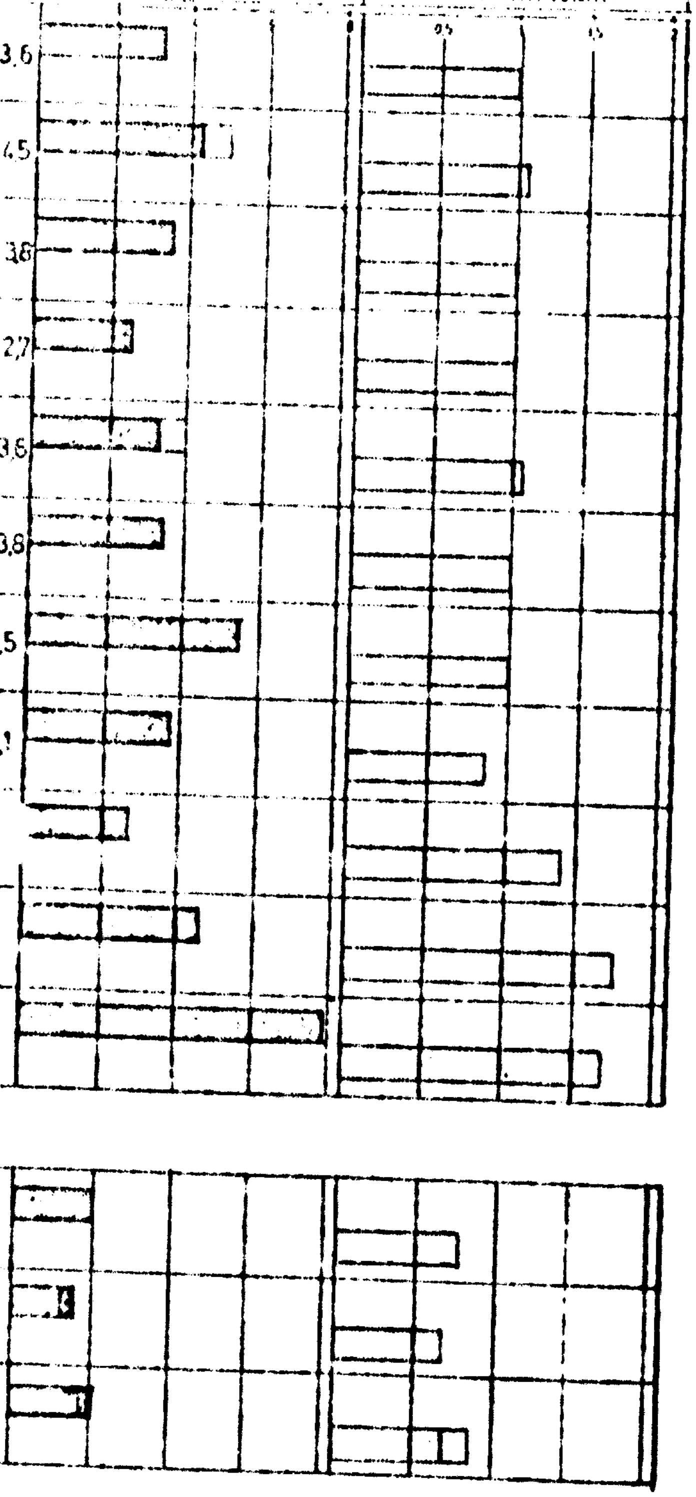
PANELS

COST COMPARISON OF VARIOUS TYPES OF WALLS

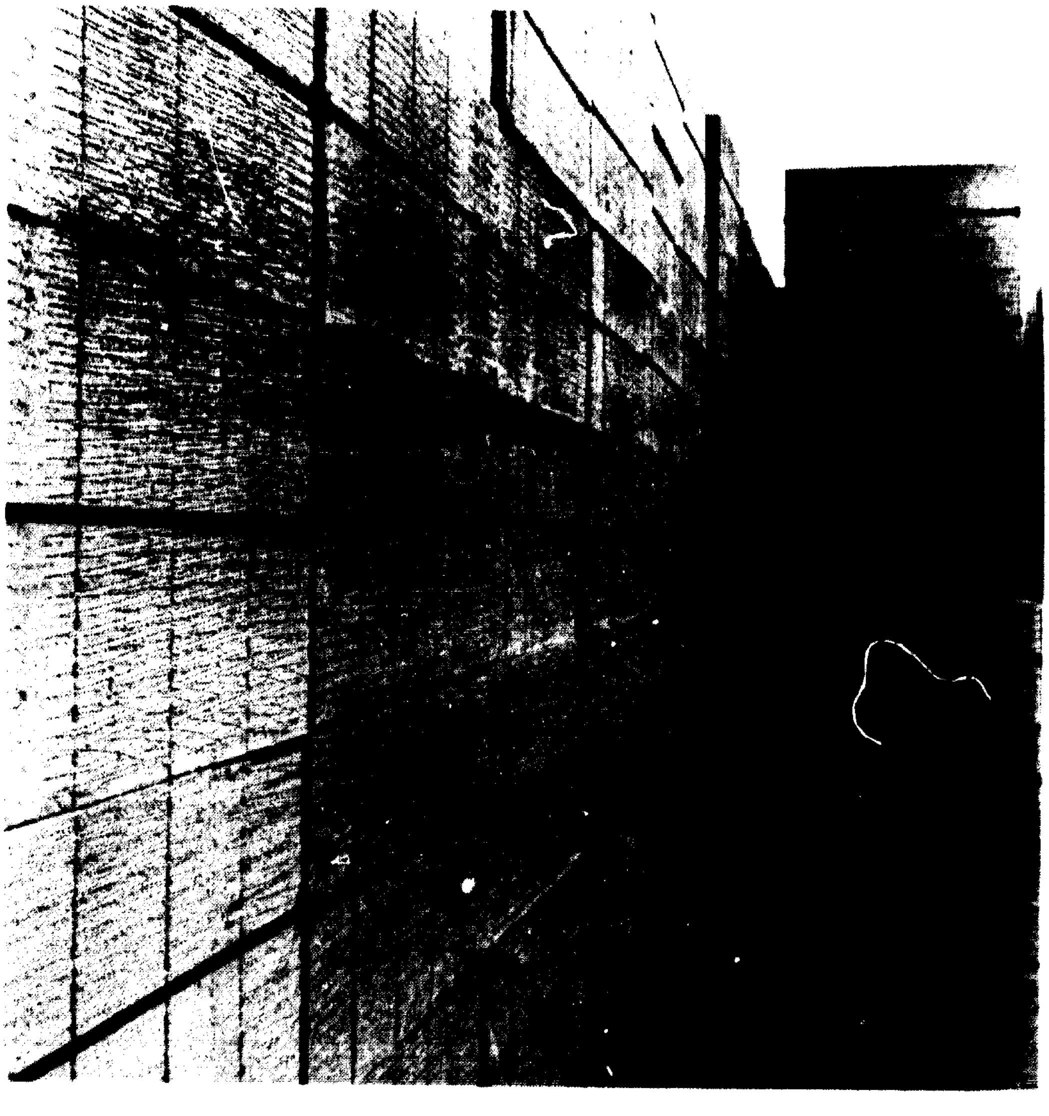
	DESCRIPTION	K val	Material US $/m²	Cost per m² in US $ material only	Labour time in hours/m² for a two-men-team
1	AER. CONCRETE block wall, 20cm thick outside: visible joints, implastered inside: plastering	0,90	3 to 3,6		
2	As n° 1 with acrylic paint outside	0,90	3,9 to 4,5		
3	As n° 1 with plastering on both sides	0,89	3,2 to 3,8		
4	AER. CONCRETE block wall, 15cm thick, outside: visible joints, implastered inside: plastering	1,13	2,3 to 2,7		
5	As n° 4 with acrylic paint outside	1,13	3,2 to 3,6		
6	As n° 4 with plastering on both sides	1,12	3,3 to 3,8		
7	AER. CONCRETE panel wall, 20 cm thick outside: visible joints, implastered inside: jointing	0,67	5 to 5,5		
	As n° 7, 15 cm thick	0,96	3,7 to 4,1		
	hollow concrete block wall, 20cm thick	ab. 1,8	2,5		
	Hollow brick wall 29 cm thick outside: visible joints implastered inside: plastering	1,15	4,5		
11	29 cm cavity wall construction brick 18 cm + 7,5cm Gas concrete panels	1,06	7,85		

DE PARTITION WALL.

12	Brick partition wall, 11 cm thick plastering on both sides	-	2		
13	Aer. concrete panels, 7,5cm thick special skim coat on both sides	-	1,2 to 1,4		
14	As n° 13, 10 cm thick	-	1,5 to 1,8		



▭ wall material
▭ outside material
▭ labour
▨ special skim coat



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