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PHILOSOPHY OF DESIGN AND ADAPTATION TO PRODUCTION IN INDUSTRIALIZED HOUSING

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SUMMARY

The development of industrialized building, with its increasing use of precast components rather than in situ concrete, is a natural consequence of labour scarcity and rising wages. The administrative organization of the building industry is undergoing a similar development, leading to the situation in which everything to do with the construction of a building, from the preliminary design to the final tenancy, will be covered by a single organization.

Statics is a small part of structural design which is itself a small part of the planning of an industrial product. Structural components represent a small, but most important part of all the factory products which go into the completed building.

The design philosophy of structural components must be geared to the production and again geared to the overall design philosophy.

Standardization, dimensional co-ordination, modules, uniform building codes, elimination of unnecessary local or individual deviations from logical, optimal solutions - these are means of achieving better and cheaper production; but there must be a reasonable compromise between absolute economy and the variation a country can afford.

The gearing of design to production also means a thorough knowledge, of, and collaboration with, the discipline of "system philosophy". Different types of system are defined in the paper; these are based upon the relationship between the planning organization, the designers, the suppliers and the contractors.

Among the necessary conditions for industrialization are continuity of production (basically a political problem) and ease of repetition (basically a design problem relating to the employment of existing manufacturing techniques, control of the number of variants within one type of component, special components, etc.).

Finally, functional and structural requirements are briefly dealt with, in so far as the new techniques bring them into prominence or offer new possibilities for their development. From the viewpoint of statics, precast structures raise special problems by reason of the joints and other factors affecting continuity.

/THE GENERAL

THE GENERAL PHILOSOPHY

The Basic Philosophy

A philosophy of design for precast concrete structures has no value when considered in isolation. Concrete is only one of several means of achieving a defined aim, the completed home.

A designer must work as a member of a team in building a home, a complete dwelling, as the best compromise between apparently conflicting interests - price, quality, materials, man-hours, speed of erection, functional requirements, useful space, sociological requirements, maintenance, rent, aesthetics, etc. All these interests overlap, and are sometines even indentical.

From some of these requirements the conclusion (or at least the assumption) may be drawn that the basic philosophy must be an appreciation of the world-wide outcry for more housing and of the relatively decreasing and unskilled nature of the labour force.

Homes must be constructed by mechanized processes and with the maximum utilization of industrial methods, prefabrication and highly organized and well-planned schedules, and with a high degree of industrialization based upon continuity and repetition.

Continuity is basically a political problem, whereas repetition is basically one of design philosophy.

The opposite may be the case, however, when a territory is the battle-ground of narrow-minded, uncoordinated local authorities interfering with the opportunities for repetitive, continuous production by an established company.

The structure of precast floors and walls, although representing only perhaps 20 per cent of the total expenditure, is the basis for the industrialization of the complete home, and it is this complete home that must govern the philosophy of its structural design. Dry, fast, accurate and well-timed erection methods create opportunities for manufacture, delivery and installation of pre-finished components, such as bathrooms, facades, fitted kitchens, doors, floors, and units of every kind.

/We must

We must not forget that the precast structure itself seldom competes very convincingly against the traditional structure in cost - although it does in speed and ease of erection - owing to the investment behind the manufacture. But the built-in services, the joinery, the facades and the finish save money which is traditionally accounted for under sub-contracts. Therefore, a convincing overall economy is the result.

The most important requirements for industrialization are detailed planning and organization and a deliberate standardization and co-ordination of orders for building components. This can be achieved by voluntary liaison between clients, establishing the big schemes and the continuity - if not the Government is forced to use its economical power to achieve the co-ordination.

Savings

This point is illustrated by a few examples from Danish experience:

The building cost of the completed dwelling (excluding roads, land and financing) is in Denmark in 1967 15 per cent less for industrialized than for traditionally built blocks.

Man-hours for all factories plus all site operations are 50 per cent of the man-hours spend on a traditional block as constructed by 1950-methods (bricks). The figure is 25 per cent for site-labour - and the man-hours for skilled labour has been reduced to 12 per cent within a decade. (These figures have been adjusted for price index, size and quality.)

Future schemes will probably be evaluated by man-hours rather than cost per flat.

Traditional pre-cut kitchen furniture, delivered, installed, adjusted, cut to size, furnished with cover strips and painted three times on site, was substituted by pre-finished, factory-made furniture, mechanically sprayed to give a finish of far higher quality and better value. The furniture was delivered and installed (the latter being a simple moving-in or hanging on a wall) at the original delivery cost - a total saving of all the traditional site expenditure, to say nothing of the saving in labour (90 per cent with improved quality into the bargain).

/Structure and

Structure and Finishing, Conflicting Functions

The general trend is the transfer of the labour force from site to factory.

Components tend to separate into two groups:

Firstly, rather simple, highly industrialized components, delivered either to assembly factories (examples: standard reinforcement, etc) or directly to the site (examples: simple precast components such as floors and walls - see figures 4 and 5 - pre-finished doors, joinery, etc.); they fullfil one (two) functions;

Secondly, sophisticated components manufactured perhaps by less highly mechanized methods, but nevertheless well-planned and designed for repetitive use on many schemes (examples: complete bathrooms, precast facades); they fullfil a number of funcions.

Figures 8 and 9 show examples of how a separation of functions, and of the corresponding components, allows each contractor to provide a variety of layouts even though he has only a limited range of component to choose from.

Standardization

My remarks so far apply to any component, not just to precast concrete components. The actual work of construction must be matched by public and private efforts to achieve demensional co-ordination and standardization, by a country, a group of customers, a builder or within a scheme.

The degree of standardization found in European countries (the term includes dimensional co-ordination, the use of modules and the private efforts of a factory) ranges from virtually nothing to projects for building millions of indentical flats; this is particularly noticeable as one travels from west to east. The best solution may well lie somewhere in between these extremes.

Standardization may be based upon a combination of the desire for efficiency and the wish for independence between design and manufacture, so that a given scheme when designed may be offered for tender (and/or execution) to several contractors. The reasons for this include a belief in the value of competitive building and a realization that a simplified design will simultaneously be valid for more than one site, as well as that components for different schemes may be manufactured on the same production line.

/Alternatively, standardization

Alternatively, standardization may try to achieve the basis for a limited variation in manufacture, so that factories can rationalize by concentrating on a few layouts.

Standardization may be based upon a national standard, or may be the result of private initiative within a group or groups of companies. Possible means of achieving standardization are listed below:

Dimensional co-ordination, of which

Modular co-ordination is a sub-division.

Preferred dimensions and modules which may apply to co-ordination of components of the same kind (usually on a 10 cm module). Examples are: kitchen joinery, cookers and refrigerators (see figure 9). Another type of modular system is one based on a planning grid, usually on a larger scale. Figure 3 shows a structural grid for floor and wall components.

Standards (including specifications, quality gradings and codes) for preferred dimensions, qualities, requirements of specified units (stairs, refrigerators, electrical switches, etc.) or for materials.

Functional requirements in building codes, etc. These are far more useful than conservative specifications of approved elements.

That the storey height should be the same throughout a country is too obvious an example of standardization - or is it?

Benefits of standardization

Easier design, by reason of speed, savings in man-hours, elimination of unnecessary choices and the general application of a sense of discipline which may also simplify the design or items not directly related to the standard system.

Easier manufacture, using simplified manufacturing programme, a limited number of possible variants, an opportunity for rationalization by means of a higher degree of repetition of each operation, although, in the manufacture of a component, each individual operation may be combined with others in different patterns.

Easier erection and completion by the repeated use of specialized equipment and the resulting absence of running-in problems. Also, of course, a saving in human effort or thought (workmanship, speed, understanding, control, making good).

/Standardization must

Standardization must be introduced with care. Local conditions, varying needs for labour economy in relation to available funds, traditions, etc. may impose different requirements. A rich country without a housing shortage, may allow itself the luxury of individual design. But it can only do so for a short while. International competition will enforce the need for savings in an industry that is responsible for up to a third of the national product.

Each country must find its own compromise between the most efficient scheme of construction (all flats identical) and a certain flexibility, allowing individuals the flat they want personally and giving residential areas as distinct character. (Incidentally, do people know what they want? Is not the repetition in older English houses an architectural feature?). Certain types of dwelling, or certain regions of a country, may provide a natural basis for a few standards defining layouts, production schedules or even the completed home.

Generally, a standard system must aim at the simplification of a product, in such a way that mass production is feasible but flexibility is still possible.

Open and Closed Systems

In a closed system a structure of a given geometry allows for a (very) limited number of lay-outs. In an open system, any lay-out within the discipline (usually a structural grid) may be feasible. (Compare standard-layout and multi-layout systems below.)

No contractor yet, as far as I know, is big enough to have a refrigerator manufactured specially for his own system; but a good refrigerator, mass-produced, low-priced, is bought by many builders and installed as part of the house. It follows that the discussion of open versus closed systems is of limited value. Apart from the question of flexible versus rigid layout geometry (upon which depends the amount of variation in the production programme for some, but not all, precast units), the problems and benefits of both systems are the same. Both systems are primarily customers for the same basic materials and both supply the same components, even possibly installing the same mass-produced plastic bathrooms, based upon a public or company standard.

/Both systems

Both systems may have the same efficiency in organizing. A discussion of the advantages of a complete organization covering everything from the preliminary design to the final tenancy is similarly of little value, since we all realize the obvious advantage of complete planning and the value of repetition (if not of the identical layouts then of the organizational pattern).

Finished and Unfinished Systems

A distinction between finished and unfinished systems - that is, between systems that specify and supply every detail of the building and those that do not - is something different. A system based upon a factory making precast units may be unfinished if it does not cover the completion of the house, whereas an organization, not producing anything itself, but conforming to a strict organizational pattern (and to a planned purchase of precast units as part of the total acquisition of all components), may be a finished system.

Teamwork

One may argue that all this has nothing to do with design philosophy. Yet the design must fit in, and the designer must fit in, possibly as a paid employee, possibly as the organizer.

The above reasoning is not an attempt to confuse the issue. We are talking of industrial design where the architect, the consulting engineer and the contractor, in the traditional sense of these works, play relatively minor rôles. Organizers and planners are the key people. The aim is to provide complete homes of optimum quality and quantity, ideal from not only a financial, but a human point of view.

PRECAST COMPONENTS AND SYSTEM BUILDING

How does the above apply to the design of precast components, taking into account the joints, the means of erection, and the relationship between components, possibly under the discipline of some kind of system? What about important problems such as tolerances, demoulding techniques and erection methods? The design must respect these requirements.

/Gearing of

Gearing of Design to Production

Design must be geared to production. This is easier if the client has appointed - before the design begins - one contractor with a well-established technique. If the builder is his own designer, the problem is simplified, becoming one of co-ordination and feedback. (Figures 1 and 2 illustrate how essential it is for a designer to know the techniques of manufacture).

The gearing of design to production is a more complex problem if the result of the design is to be submitted for open tender. The designer must then choose between the following alternatives:

1. He can make a sketchy design and leave the execution of the complete design - by himself or by the choosen contractor - until after the selection among the tendering contractors. In this situation the tender is based upon guesses and uncertainties, and so is the selection.
2. He may design according to the discipline of a system or manufacturing technique known to him. If so, the tendering is unfair to all the other systems.
3. Finally, he may design according to his own ideas which may provoke the industry into creating something new and better (if he is a good designer), but more likely will simply lead to the tendering of too high prices or the submission of alternative designs, whereupon the poor client is again faced with the difficult task of choosing between many uncertain prices and qualities.

Generally, the design is based upon a general knowledge of the possible techniques and aims at something capable of being considered by any of the tendering contractors. If the degree of standardization in the relevant field is high, this may be possible. However, all tenders from any system will be slightly higher than necessary, for the design of certain items will not conform to the production techniques; a revised design, adapted to the selected contractor's methods is necessary. This should slightly reduce the price, especially with very fair contractors, unless the bid was already based upon the assumption that, after selection, the design would be modified to facilitate production.

/The Pre-Selected

The Pre-Selected Contractor

The most efficient design, and the lowest price, gererally occur when the design has been carried out with a particular technique in mind. The client and his technical advisors, using their experience and knowledge of the market, can evaluate the offer made by a contractor. If not satisfied, they may ask another contractor and will certainly do so in the future. Contractors specializing in an industrialized system should compete, on the basic of their reputation, for fair-priced tenders based on their own system. This will give a far more practical market mechanism than open tendering for schemes which do not conform to any one system.

The disadvantage of tying to design to one system - whether or not the designer and the contractor are independent - is the possibility of conservatism. New techniques may be introduced more reluctantly if the conflict of ideas between designers and manufacturers does not take place. On the other hand, competition will generally force the contractor to improve his techniques continuously. So will the public and private exchange of ideas and experience in committees, working groups, etc.

This need for innovation also influences the design philosophy. Even the most closed system must be flexible. Nobody can afford to invest in a technique that is rigid in every detail. Development is so fast that, even if a given system is years ahead of its competitors when established, it will be well behind in five years' time. Such a system may shock and prove unacceptable or expensive, because of the need for investment, when fresh; ten years later it will again prove too expensive or unacceptable because it is outdated. Flexibility, that is the inclusion of opportunities for innovation, must be based upon a clever forecast of the future.

Development, too, is quite often not continuous, but based upon a daring jump ahead. A hard life for designers, manufacturers and investors, but a challenging one.

Types of Organization

It is possible, from the factory's point of view, to distinguish between five different types of organization. They may be defined briefly as follows:

/(a) The

(a) The supplier. A factory produces concrete units for the open market. The factory is a supplier, a sub-contractor, and must base its production either on what is wanted or on a discipline which may be an official standard, a modular co-ordination standard or a factory standard. (A supplier working permanently for one contractor or a group of contractors is classified under one of the headings below.) The supplier must always compete with others. He has no influence on the overall design philosophy, and may not even influence that of his own product. This philosophy is in other, changing hands. The contracts too are in other hands, with the result that he has no decisive influence on the continuity of his own production. An investment in highly mechanized production, involving high depreciation costs, is riskly unless the market is very stable and the supplier very sure of his own capacity for innovation. But this very open type of organization is advantageous for all concerned, so long as there exist bodies well qualified to plan and organize schemes involving a high degree of continuity and repetition. In this case the organizational pattern approaches that of (b). (See also (e).)

(b) The multi-layout system. (See figure 4.) Factory production and site erection are carried out by the same company or by a group of more or less formally collaborating companies. The system controls everything from the first manufactured until to the completed structure, including, possibly and preferably, the finishing as well. The system controls design either by the issue of a manual or by the inclusion of the design group in the system. Production is probably based upon dimensional co-ordination, modules and standards and, as in (a), is prepared to deliver to many sites with different layouts. The clients are offered a large variety of layouts - or even any layout within the discipline. This arrangement allows access to more clients, more schemes and a bigger share of the market. On the other hand, in circumstances of simultaneous and rather rapid change in a number of layouts - the change can be too rapid - and adaptable discipline and a sophisticated organization are needed. One risks being forced to accept somewhat undisciplined solutions (the system, after all, advertises its flexibility) which often results in less discipline on the next scheme. Furthermore, the

/repetitive use

repetitive use of standard units, combined flexibly in a variety of layouts, is counteracted by the necessary compromise between the structural units and the services, facades, etc. As layouts vary, the services, joinery and facades vary. Therefore, a certain number, probably a high number, of structural units will be identical from flat to flat, but a small number will vary to accommodate the other components.

The Simple Units

The repetition so vital for mass production may easily be applied to identical or almost identical precast components by means of dimensional co-ordination, possibly using a modular system (see figures 3, 4 and 5). From the remaining precast units, the factory must either face an inefficient production of different components in small numbers or must standardize the possible variations in services, etc. (Figures 8 and 9.)

The Complex Units

From this a conclusion may be drawn which will apply to almost any kind of system: if a certain unit must necessarily be designed as a more complex unit than usual, it may well be taken off the high-efficiency production line and produced by a special technique. This will enable facilities for as many specialized functions as possible to be placed within the geometry of this already complex unit, especially for systems with very large units. With such systems the technique may be based upon the assumption that all components will be equally complex.

The result of this is that the services, like the structural units, have to conform to a system. This is a virtue from the point of view of the suppliers of service units, bathrooms, facades, etc. On the other hand this can, if carried too far, be a hindrance to flexibility of layout. The more one applies discipline and standards to each component, the fewer are the possible layouts. Flexibility itself, however, is a hindrance to the manufacture of ready-to-use multi-purpose units combining many functions. This may not be a disadvantage to the system.

Separation of Functions

A cleverly planned separation of each of the conflicting functions may maintain flexibility and at the same time offer a number of different specializing suppliers an opportunity to mass-produce specialized components,

/such as

such as bathrooms or facades. Mass production of these components could be carried out by several contractors working to several systems, although a clear understanding of the system by the suppliers is essential. Figures 6 and 10 show different aspects of the concept of separation of functions.

The saving in man-hours may be marginally less for a multi-layout system than for a standard layout system.

But the multi-layout system does offer the market a degree of flexibility, thereby ensuring for itself a regular stream of orders and continuity of production. If the market is limited in extent, the multi-layout system may be able to capture a high production of it, again because of its flexibility.

(c) The standard layout system. Basically, this system is not very different from the multi-layout system. Most standard layout systems offer in practice a variety of layouts within a given geometry. Layouts are revised every now and then to meet new requirements. Components for services, facades, joinery, etc., identical to those used in a multi-layout system, are bought from suppliers.

Because of the limited range of layouts, and the geometrical discipline the variations in a standard layout system are limited. The system can provide orders for a continuous production of a number of absolutely identical "specials", or else it can be adapted to the "best buy" from the established range on the market. Its own precast units and erection techniques can be designed with the utmost efficiency in mind. Even complicated units can be repeated, thus making the rationalization of complex components possible. Everything is geared to the limited range of layouts.

The disadvantage may lie in the marketing. How many identical homes can one sell? Slight variations in design, especially in the design of facades, may make the same thing look different in the customer's eyes. The more this is done to please the customers, the more closely does a standard layout system become a multi-layout system.

(d) The box system. This can be regarded as an extension of the standard layout system, but there are certain differences. The layouts are here governed by a strict discipline as all the boxes must fit together and will probably be identical in size; the sizes of rooms are thus strictly

/standardized. The

standardized. The system represents a very logical approach, as the room is completed in the factory. Site labour is at a minimum. The disadvantages are, amongst other things, production costs, factory area (huge components, taking up a great deal of space during the hardening time), transport costs (if the road regulations permit transport at all!); finally, the limited choice of layout may be contrary to the customer's wishes.

(e) Mixed system. The fifth type of building organization may be included in one of the above patterns or may partially incorporate one of them. As overall organization and planning have the top priority, an organizational pattern in which companies organize the schemes without actually manufacturing anything may give a desired degree of variety. Such companies may use existing factories, etc. which may include (a), (b), (c) or (d) above.

Choice of System

Each type of system offers possibilities for continuity and repetition. Market conditions are critical. The more flexibility a country wants, and can afford, the less likely is it to adopt standard layout systems or box systems.

The complete range of building systems is so extensive that it is difficult to file many of them under the above headings. There are all kinds. They all have their advantages and disadvantages. Their common needs are continuity, repetition and discipline. The designer must know the discipline of the system in question. Quite often this information is not available or is incorrect; the contractor's handbook - if indeed there is one - contains errors and anomalies owing to mutual misunderstanding of problems, lack of feedback, or insufficient testing of products. This applies to the relationship between design and manufacture as well. It is not true, of course, for good systems.

/PRINCIPLES OF

PRINCIPLES OF DESIGN PHILOSOPHY

The figures illustrate some basic principles of design philosophy with regard to systems, standards, repetition, reduction of typed, control of variations, modular co-ordination and facilities for services; these are some of the most important aspects. Continuity cannot be illustrated; it must be achieved.

CHOICE OF LAYOUT FROM THE SITE POINT OF VIEW

Basically, design should be geared to erection. The techniques vary from system to system and the design must be based upon a detailed knowledge of each of the operations and their sequence. Figure 11 illustrates a problem frequently encountered in cold climates, and a probable solution.

Repetition in layout is a necessity whichever system is used. Workmen acquire skill in erection techniques only as a result of repetition of effort. Suppliers of plumbing units, not to mention the plumbers, benefit from orders for identical components which can be stacked on top of each other. The list is long and obvious.

The following are, therefore, to be preferred:

- as few layouts as possible;
- each layout repeated, not mixed with others in between;
- each housing block to have layouts which are identical both horizontally and vertically;
- all blocks identical in height;
- all blocks more or less identical in length;
- no special layouts at gable ends, on the ground floor or on the top floor;
- only straight blocks, of course;
- laundries, shops, garages always in separate buildings;
- basements to be avoided;
- maisonettes, if these are necessary, not to be mixed with single-storey flats;

/- services

- services to be designed carefully (preferably vertically);
- access areas kept simple - scissor blocks, etc. are very expensive.

The most economical block is that with the maximum number of storeys permitted in the following situations:

- without lifts;
- without lifts, but below the height at which special fire regulations come into force;
- with lifts and governed by special fire regulations, but below a height at which structural problems necessitate costly additional reinforcement.

Crane Capacity

Furthermore, it sould not be forgotten that a well-organized site uses the crane at top capacity. Quite a number of flats may be erected, at least two every day using one crane. Short blocks, therefore, require very special erection techniques, as more than one storey is erected before the grout in the joints can take the load of the units above. An alternative is, of course, to use welded connexions for all necessary load transmission. This technique may be seen in the USSR, but it has never been popular in Western Europe or elsewhere. The moral is, therefore, to build not tower blocks but good, long, straight blocks. A tower-crane on rails makes 120-130 lifts in eight hours.

It is quite essential to use the lifting capacity of the crane as much as possible. All units should ideally have the same weight. A single, very heavy unit is decisive for the choise of an expensive crane. Many, light, small units cost the same to lift per unit as one bigger unit.

Preliminaries

Finally, access to the site, transport roads, storage space, water supply and sewers are matters of the utmost importance and must be available before the transport and erection of components begin. This problem is quite often insoluble because of inadequate town planning, or because public funds are scarce for roads and sewers at the time. It is obviously preferable to use the final roads and parking areas during the erection period, but there are many conflicting interests to be considered.

/FUNCTIONAL REQUIREMENTS

FUNCTIONAL REQUIREMENTS

The list of functional requirements, and their influence on layout and on the design of precast components and joints, is very long. A few of the more obvious ones, though not necessarily the most important ones, are outlined below.

Insulation from sound, airborne or impact. If windows were much more efficient and were always kept closed, we should not have to burden our town planners with problems of sound insulation. The noise from roads, car parks and playgrounds is generally a big problem, one that usually remains unsolved. (Windows, incidentally, if wrongly designed, can often serve as a means of spying on neighbours.) We all know that services, too, are a most irritating sound source, but considerations of economy tie our hands. Still, the arrangement and positioning of bathrooms, WCs and kitchens within a flat and in relation to other flats must be given a lot of thought.

That we today use heavy precast components as the sound barrier between flats does not mean that we will in the future. Double floors and walls may be the only way to satisfy increasing requirements. Box systems and column beam systems may then be economical, but today we must rely upon floating floors and heavy walls.

Finally, the joints are important. Grout should be vibrated to eliminate voids. Transmission of sound along walls must be avoided. Lightweight facades should never continue past the floor or wall between two flats. (See figure 12.) Light partitions, acting as identical, coupled membranes quite often transmit sound between two flats (vertically or horizontally).

The advantage of using precasting techniques is that they provide a means of introducing new solutions that are unthinkable for in situ operations. This is a challenge for the designer.

Thermal insulation. Most of us think of this problem as one of keeping the heat inside, but the situation may be reversed in the tropics, where the thermal expansion of roofs and the lack of ventilation are big problems for countries with a limited economy.

/In Europe,

In Europe, most of us must heat our flats at the lowest cost. The indoor climate is quite often unsatisfactory. In the summer the windows are too big and we cannot afford the necessary air conditioning. The ventilation is poor, even though the windows do not fit tightly enough. The thermal capacity is often not considered.

In short, we are unable to control our indoor climate. New techniques and materials should give us better possibilities, but so far our experience is limited. The problem is brought into prominence by a higher standard of living.

Condensation is also a problem. The vapour barrier on the inside prevents the dispersal of humid air. We may escape condensation, but we still have a humid atmosphere, again due to the lack of ventilation. Insulation of structural components to avoid cold bridges costs money. The necessity of allowing for thermal movements and avoiding cold bridges increases the complexity of concrete sandwich panels.

Rain. This problem is worst in tall buildings. The water flowing downwards forms a thick film which makes the design of joints critical. Even with the many kinds of mastic now available, it is sometimes difficult to find one suitable for the given surfaces, or to rely on the quality of the mastic or the workmanship. The Danish ventilated joint* is the one we rely upon. We first applied it to conditions of heavy driving rain in Bergen; since then, I and many other Danes have used it successfully in many countries and for many projects.

Wind protection. This is also a problem for the facade designer. Generally, this should be solved independently of the rain problem, in order to avoid a water leak being aggravated by wind pressure.

Wind, rain and condensation, in different combinations, are the source of corrosion, discolouring, etc.; to discuss this problem would require a special paper.

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* See Report N°38: Problems of Joining Room-Sized Building Units, published 1963, by the Danish National Institute of Building Research.

/Fire protection

Fire protection. This problem is so complex, and the means of solution so varied from one country to another, that it is difficult to draw any conclusions. In general, the means of escape from a burning flat should be safe and the adjoining flat should be unaffected. Spreading of the fire should be prevented. Most problems are well known, but many of the new materials in use, especially plastics, create fresh problems. Insulating material in facades may spread the fire. Plastic water pipes may give the fire access to the flat above. The material may not burn, but may give off toxic fumes.

Structural Requirements

The structural requirements like the functional requirements, raise so many problems that only a few brief examples can be given. In this paper I am not concerned with problems of structural stability except where they stem from the use of precast components and the associated materials.

The special problem of precast structures is the general lack of continuity due to the joints. The joints themselves, therefore, and the influence of the joint on the shape of the edges of the components - and vice versa - are the main problem. Furthermore, the influence of dynamic loads (earthquake, for example) on precast structures is almost unknown. Although a series of theories does exist, they are uncertain to apply to structures, especially to precast structures. Little experience has been gained on earthquake loads on high quality precast structures.

Floors are usually simply supported and give few new problems.

Walls do not usually need additional strengthening. Their strength is mostly well defined, although new techniques for rapid casting and demoulding, for example high-temperature curing, must be critically examined.

Joints* raise problems. The inclusion of a joint in a wall lowers the effective cross-section, thus directly reducing the bearing capacity of the wall; reduction also occurs indirectly as a result of the concentration of forces, resulting in splitting effects.

* See Report N°38: Problems of Joining Room-Sized Building Units, published 1963, by the Danish National Institute of Building Research.

/Anchorages. When

Anchorages. When post-tensioning is applied, the anchorage problems may demand specially reinforced units.

Concentrated loads. Finally, it quite often happens that certain areas subject to concentrated loading need special attention and possibly special detailing. A related problem is the effect of the deflexion of, for example, a floor component, which concentrates the load on the edge of the wall.

Problems relating to the structure as a whole

The problem of overall stability in a prefabricated block of flats is that of the interaction of all components. Compression is no problem, unless shrinkage allows relative movements between components. Shear and tension, however, raise problems which may be solved by welding the joints or strengthening them by other means. Shear keys may be effective if the cracks formed by shrinkage are not too wide.

Post-tensioning may increase the allowable shear-strength in wall-joints due to the established friction (instead of shear-keys).

Tensile stresses can be taken up in many ways. Generally, they are concentrated round wind-bracing walls, where the continuity in the tensile reinforcement can be established by welds, splices, sleeves (muffs), laps, U loops, bolts, cables, etc. The problem is to find a solution which allows easy production, easy erection, easy jointing, easy finishing and easy control. The lack of space, and the close tolerances, make the obvious solutions complex. Very few good laboratory tests on solutions of this problem have been carried out.

Finally, the problems of stability during erection are of interest. Cases of collaps are known. The loading of materials and components may exceed the calculated load. Stability must be ensured for each component during erection, when the forces acting on it are usually different from the final ones.

The low early strength of fresh units, low temperatures and high winds are other examples of factors affecting strength and stability. The failure of equipment, the collapse of faulty components and other mishaps create dynamic loads whose influence on the partly finished structure is little known. These accidental full-scale experiments are unfortunately seldom publicized, which is understandable, but short-sighted.

/Annex I

Annex I

ADAPTATION OF A SYSTEM IN ANOTHER COUNTRY

The above paper was prepared as a general report of the AIPC-Symposium on Design Philosophy and its Application to Precast Concrete Structures in London, May 1967. It has been redrafted and adapted for the purpose of the present Seminar.

The paper deals with a Scandinavian approach to design, which may not apply to other countries, although the philosophy as such is of a general nature, valid for all approaches to innovation in building.

The necessity of industrialization is in Scandinavia due to a housing shortage that cannot be overcome by traditional methods, as the necessary labour is not available. An outer sign of this labour shortage is sharply rising wages.

Other countries have developed high productive construction methods for other reasons. Countries in Latin America, Asia and Africa are, at present, developing prefabrication of housing, as production in factories gives far better quality and control with the product. If the labour has little training, is unskilled, without a background of rational handcraft, industrialization gives a faster way of recruiting building workers. Each man shall be trained to repeat simple processes, there is no need to teach him a trade.

Some countries are taking up industrialization for political reasons. Machinery is the only way, if the Government wants homes fast as part of the transition into a modern state.

The general reason - in all countries - for industrialization is the speed of erection thus achieved.

This did not say that industrialization always means precast concrete or organizational patterns like the Scandinavian ones described in the paper. The thinking - the philosophy - of the paper may be adopted. The methods must be adapted.

Furthermore, the Scandinavian countries have a well-developed, long established, high quality industry for many building parts as prefinished windows, doors, kitchens, etc.

Thus, the process of industrializing the building industry concentrated on setting up factories for prefabricated structures as precast concrete elements (for timber-framed room-sized units for single-storey houses),

/whereas the

whereas the completion of the home was regarded as the organizational problem of using the fast, dry, accurate structure as the basis for well-planned and well-timed delivery and installation of prefinished parts.

Steel and aluminium, quite obvious materials for fast erection in other countries, were always too expensive. Plastics are coming, but it is a new field, still with dubious features and little experience.

The best compromise based upon local conditions can only be found by careful analysis of available labour, investments, traditions, needs and requirements.

Therefore, the choice of system must be made in team-work with participation of clients, architects, engineers, the Government, etc. Analogous conclusions can be drawn from the experience stated in the paper - and much know-how and experience can be transferred and adjusted.

Most systems with thousands of names, are so much alike for a number of processes that it is impossible to define them. They are - if good - based upon know-how and experience and brains capable of finding the optimum under given circumstances, a cocktail which has no boundaries, although the local variant may taste a bit different.

It may as an example be said that Danish systems now operate in more than 20 countries in all parts of the world. And how different are these systems from French or Russian systems? or from any other system?

Heat-insulation and double glazing as well as bracing-wall for seismic forces are simple, outer signs of a particular local condition and of an adaptable process to a system.

/Annex II

Annex II

CHOICE OF SYSTEM, BASIC FACTORS

No specific approach can be defined. A few of the main (basic) factors in the analysis are:

Labour	Shortage? Unemployment?
	Wages? (Rising, steady)
	Skill, education, tradition, trades
	Trade Unions?
Materials	Concrete/Timber/Steel
Supplies	Are components (which?) available?
Structural requirements	Seismic forces?
	Soil conditions
	Low-medium-high-structure
Qualities	Houses - maisonettes - flats?
	Size
	Standard
Climate	Rain?
	Hot, cold climate?
	Wind?
Market	Shortage of homes?
	Flexibility or standard-layouts
	Continuity
	Financing, governmental support?
	Small or big settlements?
	Transport distance

/Annex III

Annex III

PRINCIPLES OF THE DESIGN PROCESS

(Basis for the Building Process)

1.0 The introduction from the client

- 1.1 What shall be built?
- 1.2 How shall it be built?
- 1.3 Who shall build it?
  (Pre-selected contractor ensures design geared to production)
- 1.4 Economy
- 1.5 Time limit

2.0 Initial drawings from the architect

- 2.1 Suggested town-plan, etc.
- 2.2 Suggested layouts

3.0 General principles

- 3.1 Structure
- 3.2 Services
- 3.3 Prefab- and to what extent (suppliers?)
- 3.4 Initial planning

4.0 The construction programme made out to the client

- 4.1 Decision on 2.0 and 3.0
- 4.2 Constracts with advisors
  (Architects, consulting engineers, etc.)
- 4.3 Time table
  (Limits for the different stages of design and construction)
- 4.4 Design schedule
  (Time limits, principles, relations, decisions, etc.)
- 4.5 Authorities
- 4.6 Division between the contracts with suppliers and contractors
  (Definitions etc. apply also, if general contractor for everything is appointed, but most of 4.0 is simplified with regard to responsibilities, but not to specifications)

/5.0 Initial

5.0 Initial design

- 5.1 Suggested solutions from architect, landscape architect
- 5.5 Structural engineer, M & E services engineer, planning engineer (contractor)
- 5.6 Information from authorities
- 5.7 Information from chartered surveyor

6.0 Decision on principles

Subdivided as the case may be. Examples:

In situ concrete, precast components, gable ends, facades, stairs, roof, basement, foundation, services, electricity, gas, sewers, drains, light partitions, flooring, surface of walls, of ceilings, joinery, bathroom (floor and wall), etc.

Decisions on materials, qualities (specifications), tolerances, manufacture, delivery, erection, technique, finish

7.0 Detailed design

- 7.1 Final drawings, all details (any detail) and specifications and quantities
- 7.2 Work planning

  (See enclosed paper on the building process)

8.0 Applications

- 8.1 Technical applications (Authorities)
- 8.2 Financial applications

  (8.0 simultaneously with design whenever possible)

9.0 Pricing (tender maybe)

10.0 Contract

11.0 Start

- 11.1 Supervisors
- 11.2 Main supplies
- 11.3 Roads

/Annex IV

Annex IV

FIGURES

Figure 1: Floor component with recess for plumbing unit. (Example of simplification.) In the standard layout system floor components are purpose-made for a specific location with correctly sized recesses. In the multi-layout system a single unit may be used in any position, the recess being large enough to accomodate the services in any flat. This simplifies manufacture and administration of delivery and erection, but the over-size hole must be filled. Perhaps a better solution would be to rearrange the services to fit into a single, smaller recess.

Figure 2: Formation of boxes, recesses and grooves. (Example of design geared to production.) The designer must know the techniques of manufacture. For example, a comparison between horizontal and vertical casting of wall panels will show that it is more difficult to ensure full compaction of concrete around a recess in a vertical mould. Similarly, junction boxes and grooves are difficult to cast in the top surface of a horizontal mould, but they may readily be located in position by the mould itself. A further point is that positioning of reinforcement is easier in horizontal moulds.

Note also the shapes of the recesses. A slope of at least 1 in 7 is necessary to ensure satisfactory demoulding if the recess former is attached to the mould.

Figure 3: Modular system for a 2.5 ton multi-layout system. (Danish standard-recommendation.) The system uses a 30 x 120 cm structural grid, load-bearing cross-walls and a structurally independent facade. Maximum use is made of simple components with standardization of "specials". Bathrooms are identical in all flats. Kitchens are fitted with standard joinery and include a standard plumbing-ventilation unit housed in a standard recess.

The standard bathroom and kitchen are separated to allow maximum freedom in planning. If they were combined, a third standard would be created. This would increase the overall costs and is not economically justifiable on a limited market.

/Figure 4

Figure 4: Standard floors for a 2.5 ton multi-layout system. (16 per flat as figure 3.) Bathroom floors, stairs and balconies are special units. (4 per flat.) (Example of reduction of types, variants, etc..)

Figure 5: Standard walls for a 2.5 ton multi-layout system. (11 per flat.) Electrical outlets and door openings are shown. Wind-bracing walls are special units. (1/2 per flat.) A similar 5 ton system could be based upon 240 and 360 cm walls with the same flexibility in planning.

Figure 6: Basic facade units for a 30 cm modular system. (Figures 6 and 7 exemplify reduction of types, variants, etc..) The first unit can be hinged on the right or the left side.

Figure 7: Combined facade units for a 30 cm modular system. Production is simplified by attaching corner units or down-stand edges to standard units.

Figure 8: Wall unit with single door opening. (Example of separation of functions.) In a multi-layout system the components are supplied to the site separately and can be combined in nearly 200 possible ways. In a standard system the unit is supplied in a pre-selected combination.

Figure 9: Kitchen units and fittings. (Example of separation of functions.) Each of the three units at the top of the figure can be either right- or left-handed. The ventilation and plumbing unit can be combined with the floor unit to give four different positions for the sink unit around each floor joint.

The fittings in the lower half of the figure are co-ordinated dimensionally, yet separated functionally. This enables them to be arranged in an almost unlimited number of different ways. (Example of a 10 cm module used in Scandinavia.)

Figure 10: Floor component for a multi-layout system. A hole can be made where necessary by punching through the recess; this gives four possible arrangements for pipe runs. A standard layout system produces the component actually needed.

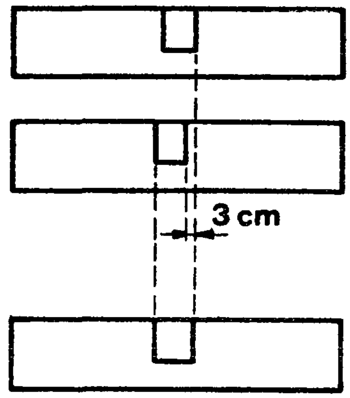
Figure 11: Sandwich panel facade. (Erection must be independent of climate.) The arrangement on the left is difficult to erect in winter since the walls to which the facade is attached cannot be positioned until the in situ concrete joints in the floor and room below have

/been filled

been filled. This cannot take place when the temperature is low. However, if the facade could be installed, it would be possible to provide temporary heating to enable the joints to be concreted. The arrangement on the right allows erection to proceed.

Figure 12: Alternative arrangements of facade panels passing adjacent flats. (Flank-transmission of sound.) The arrangement shown on the left allows flank-transmission of sound along the facade unit passing the cross-wall. The other arrangement provides a gap between the facade panels which reduces sound transmission. The latter is also easier to joint adequately.

(Annex IV cont'd)



Standard-lay-out-system

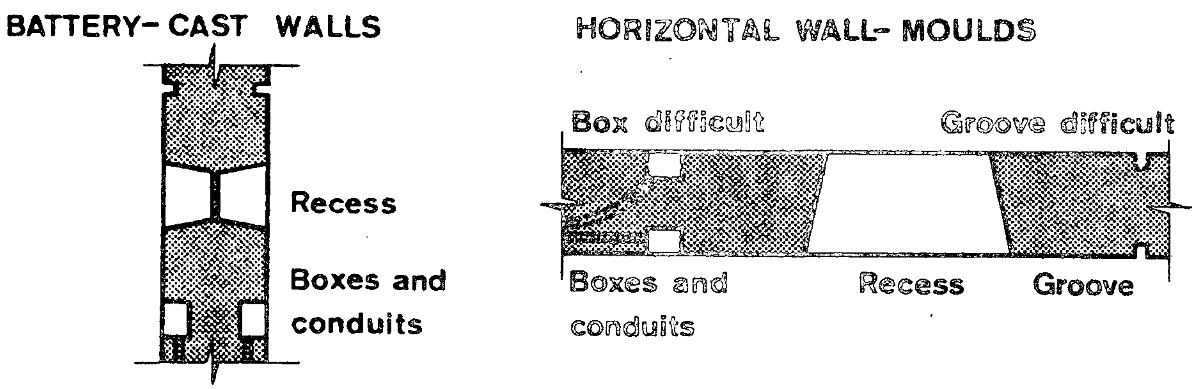
Exact fit around recess saves on site (each component supposed to have its own mould).

Multi-lay-out-system

Wider recess reduce number of variants Saving in factory counter-acted by expenditure on site. What is optimal? (each mould supposed to be used for a number of variants).

Optimal solution is probably to move services to fit into a single, smaller recess.

Fig.1



REINFORCING MUCH EASIER IN HORIZONTAL MOULDS

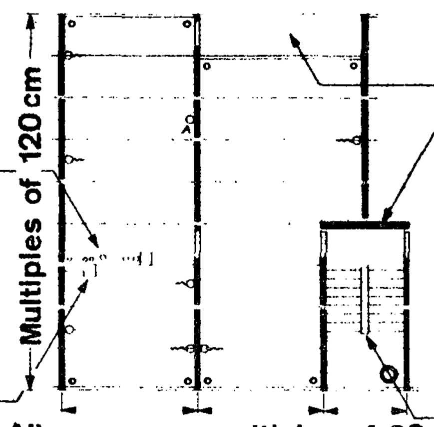
Fig.2

(Annex IV cont'd)

MODULAR SYSTEM 30x120 cm.
for 2,5 ton multi-lay-out-system.
Load-bearing crosswalls, facade independent of system
MAXIMUM OF SIMPLE COMPONENTS + STANDARDISED SPECIAL UNITS

Bathrooms are identical in all flats. Special component with different modular spans

Kitchens based upon standard joinery and standard plumbing-ventilation-unit in standard recess



Balcony
Special component

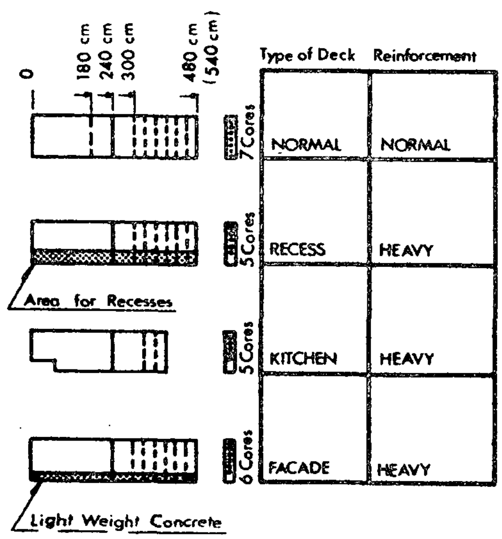
Wind-bracing wall
Special component
including: Wind-bracing
TV-supply
Telephone-supply
Electricity,
Supply and Meters

Stair+refuse chute
are special units

Bathroom-standard and Kitchen-standard separated to allow maximum freedom in planning. Might have been combined in this example. If so a third standard would have been created, giving higher overall prices for all lay-outs.

Fig.3

STANDARD FLOORS
For 2,5 ton multi-lay-out-system



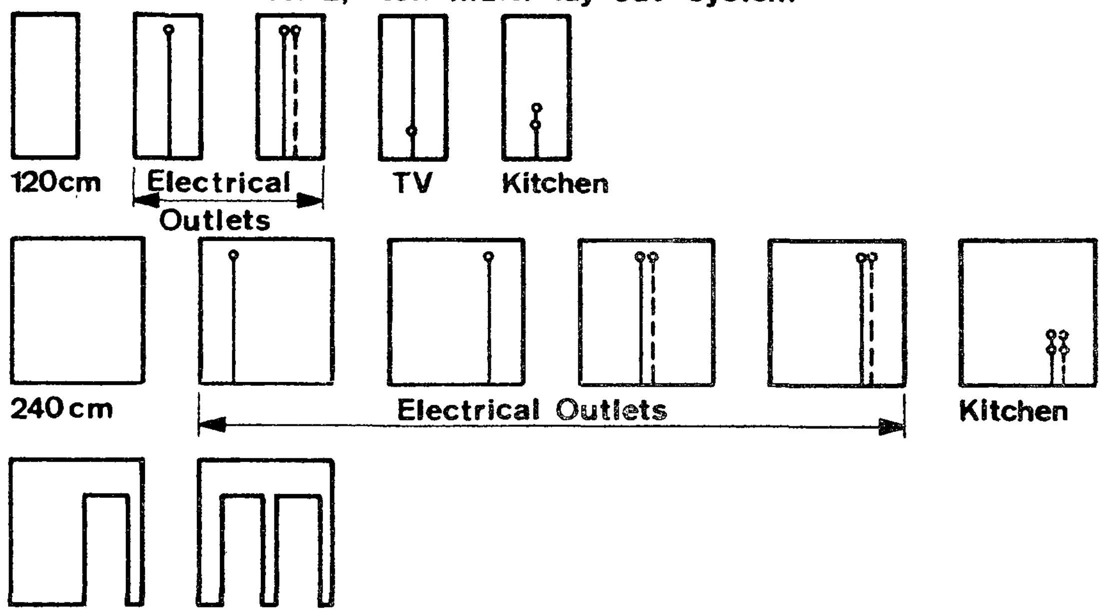
Bath-room floors, stairs and balconies are special units

Fig.4

(Annex IV cont'd)

STANDARD WALLS

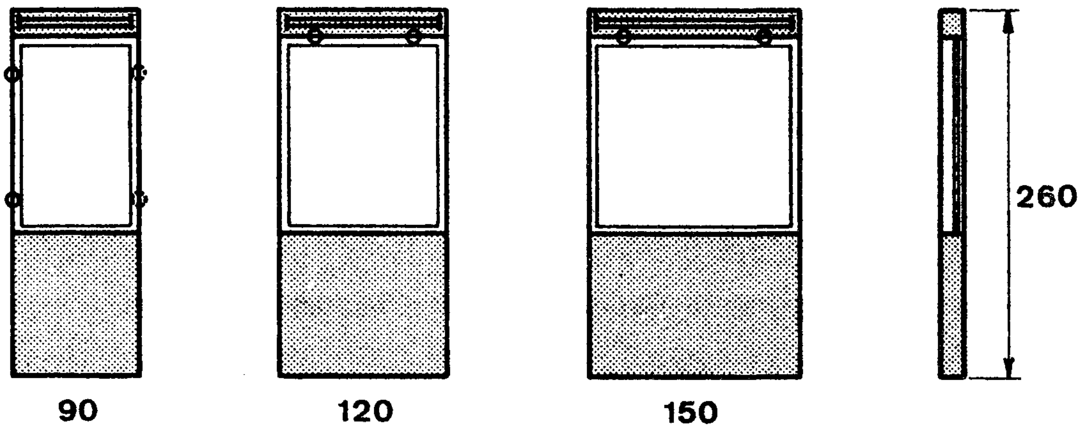
for 2,5 ton multi-lay-out-system



240 cm Wind-bracing walls are Special Units.

A similar 5 ton system might be based upon 240 and 360 cm walls with same planning flexibility.

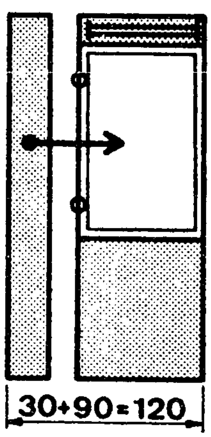
Fig. 5



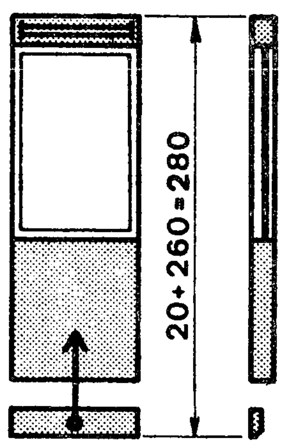
Right – or
left – hinged

BASIC FACADE UNITS
For 30 cm modular system

Fig. 6

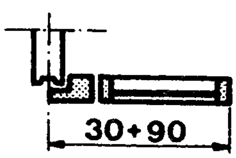


Right or left-handed
at crosswalls



Down-stand
to cover floors

Down-stand at facades
but not behind balconies

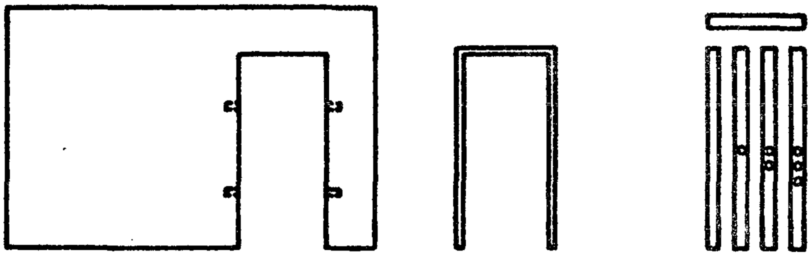


COMBINED FACADE UNITS
Basic facades+special attached
units simplify production

Fig. 7

(Annex IV cont'd)

DOOR WALL

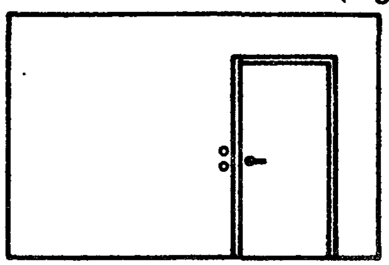


Wall-component
1 variant

Door-frame
2 variants
(right or left)

Architraves
1 horisontal
4 vertical
(0-3 switches)

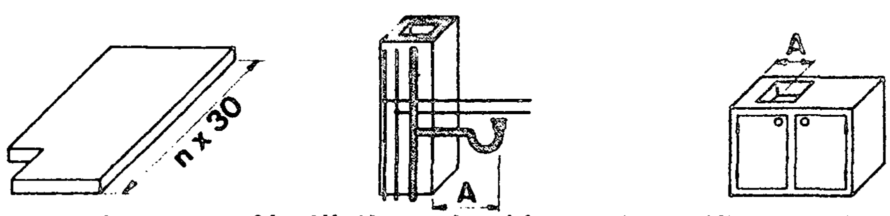
Multi-lay-out-system
Separation of supplies.
200 possible combinations



Standard-lay-out-system
Completed component cast in suppliers pre-selected combination

Fig. 8

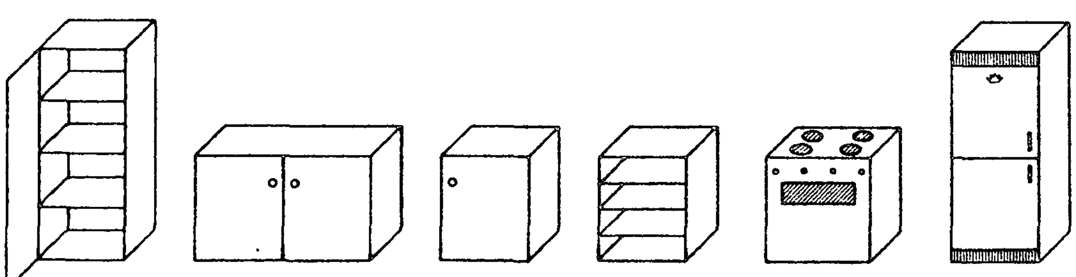
KITCHEN



Floor component
Standard recess,
1 variant (+ handed one) for each span.

Ventilation-plumbing-unit
1 variant (+ handed one) gives 4 alternate positions of sink around each floor joint.

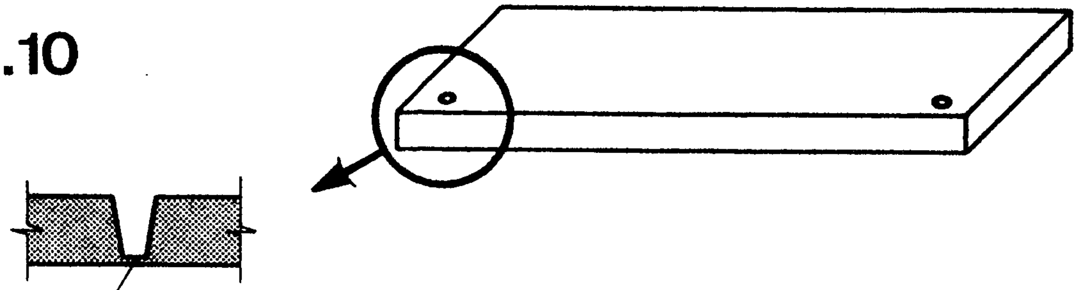
Kitchen-joinery-unit with sink.
1 variant (+ handed one)



Dimensional coordination and separation of supplies allow unlimited kitchen-lay-outs

Fig. 9

Fig.10



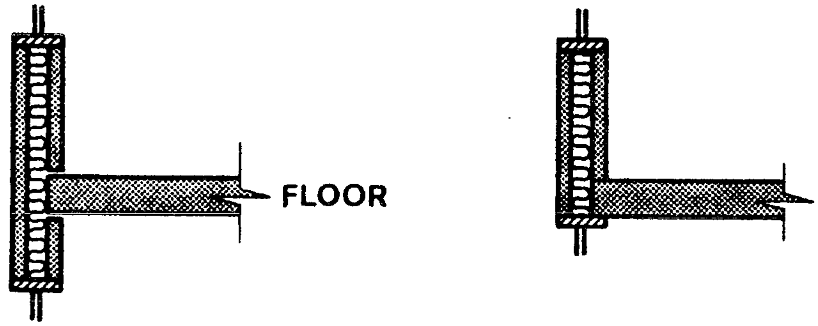
5mm
to be punched
out where
needed

One floor-component (4 variants in one)
Four possible arrangements for pipe runs
(0-0, 0-X, X-0, X-X)

For multi-lay-out-systems. Standard-lay-out-systems produce the actually needed component

CONCRETE SANDWICH FACADE

Fig.11

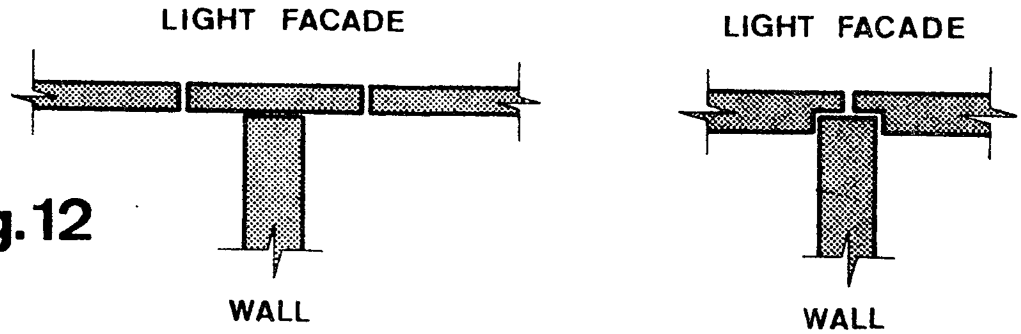


Difficult manufacture.

Winter—erection vicious circle:
Facade should be jointed to
(possibly hung on)
walls whose erection
awaits grouting in flat below
awaiting temporary heating
awaiting facade unit closing room

Preferable solution.

Fig.12



Flank-transmission (sound)
Doubtful jointing between flats.

No flank-transmission (sound)
Easier jointing between flats.