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JOHS. F. MUNCH-PETERSEN

# COMPONENTS AND JOINTS IN DANISH HOUSING

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# COMPONENTS AND JOINTS IN DANISH HOUSING

Johs. F. Munch-Petersen
Professor, M.Sc.Struct.Eng.,
The Institute of Building Design
The Technical University of Denmark

In the following it is intended to give a brief illustration of the Danish design-principles for prefabricated floors, walls, and facades, exemplified by details of structural joints between precast floor- and wallcomponents, and of facade-joints between exterior walls such as precast sandwich facades, and light (wooden frame) facades.

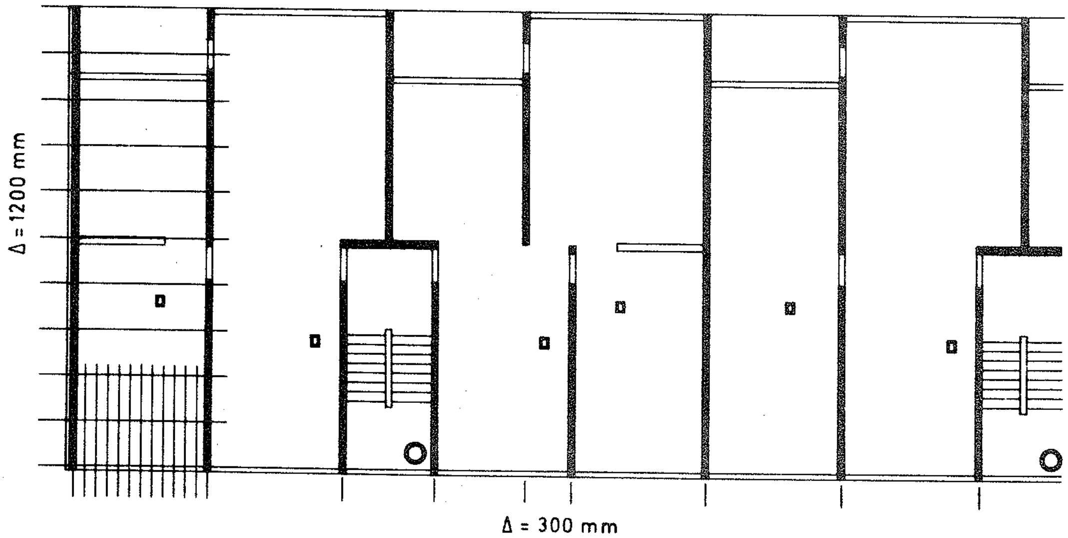



Figure 1. Load-bearing cross walls. Simply supported floors. Planning grid 300 mm x 1200 mm for structural components.

## THE STRUCTURAL SYSTEM IN PRINCIPLE

Originally, a block of flats had precast floor components simply supported on load-bearing cross walls, as shown above (Figure 1). To-day, we have added spans across the building, spine walls, external and re-entrant corners (angles $90^0$ or more, e.g. $135^0$) etc., all mixed within the same building, to allow for more flexibility.

The structural system has a few additional components, viz. the load-bearing concrete sandwich facades (gables), the balcony components, and the longitudinal wind-bracing walls (usually at the stairwell). Facade components are not necessarily part of the structural system. The floor components may support light facade components. The concrete sandwich components may be load-bearing (and/or bracing) or just suspended on brackets at the ends of the cross walls. This permits movements due to shrinkage and due to thermal expansion and concentration, of the external leave of concrete.

Typically, the erection tempo is two flats per day per crane, and the erection of the structure proceeds as follows: The floor elements are laid on the walls (the joint being dry); the joint reinforcement is placed in position; the facades are erected. In spite of the open joints the building is then sufficiently closed to permit its being temporarily heated in winter, so that the joints can be grouted.

## STANDARDS AND DIMENSIONAL COORDINATION

Design on a modular basis is statutory under Danish legislation for block of flats. Furthermore, some standards are statutory, some are (possibly) only recommended but in practice compulsory.

Some of the (statutory) provisions and standards are:

1. Living rooms and balconies must face south or west.
2. A flat (2-rooms or more) should face opposite directions (i.e. south and north or west and east), enabling the tenant to cross-ventilate the flat.
3. The sound-insulation requirements between flats, and between flat and stairwell, make the use of heavy walls around the stairwell and across the block between flats almost statutory, as insulating light elements usually are more expensive.

1-2-3 result in the basic Danish lay-out: Two flats around a stairwell in a cross-wall block. This type of lay-out was analyzed in the late 50's and was the basis for the development of a set of rules for dimensional coordination, later backed up by legislation, standards and recommendations, comprising among other things the following standards or general practice:

4. The basic module: M = 100 mm.
5. The structural grid: 300 mm × 300 mm (3M × 3M)
6. The storey height: 2800 mm (28M)
7. The structural planning grid: 300 mm × 1200 mm (3M × 12M) for blocks of flats with load-bearing cross walls (300 mm parallel to, 1200 mm orthogonal to the facade), figure 1.
8. Several series of sizes for various components, e.g. windows, doors, kitchen-joinery, refrigerators, cookers, light partitions, stairwells.
9. Spans for floor components: Multiples of 300 mm (3M)
10. Width of floor components: 1200 or 2400 mm (or 600, 1800 mm)
11. Width of wall components: Multiples of 1200 mm (600 mm)
12. Several details of floor and wall components, e.g. floor-thickness, wall-thickness (150 or 180 mm), placing of door openings within the wall, principal geometry of structural joints, etc.

Today the precast structural components (and their joints) from most Danish factories are based on the same principles, and usually are so alike that the products from various factories may be used simultaneously on a given project. One may talk of an open, Danish system.

However, the system has been further developed, with spans in both directions, larger balconies, sculptural facades, etc. The rich variety and great flexibility of the system is illustrated by comtemporary blocks of flats, by low-rise housing etc.

DS 1049, the Danish Standard on Positioning of Structural Building Components in Modular Grids (April 1980), illustrates not only Danish Modular Coordination, but also joints identical to and similar to the joints illustrated in this report, see also page 46.

FLOORS AND WALLS, COMPONENTS AND JOINTS, IN PRINCIPLE

Floors are hollow core slabs, simply supported on the load-bearing cross walls. The walls are solid and unreinforced (except for reinforcement around doors, and except for a light transport-reinforcement along the edges) (figures 6, 7, 8).

All joints are designed so that the entire floor or the entire wall can act as a plate transmitting in-plane forces only. The individual components have transverse loading as well (viz. wind on facades, dead and live load on floors, etc.). All horizontal joints (longitudinal and transverse) are reinforced (sometimes even posttensioned in high-rise blocks), but the components are not welded together. The co-action of the components is based upon the shear-keys on the edges of floors and walls together with reinforcement in the joints. Compression, and in certain cases friction will also contribute to the structural stability.

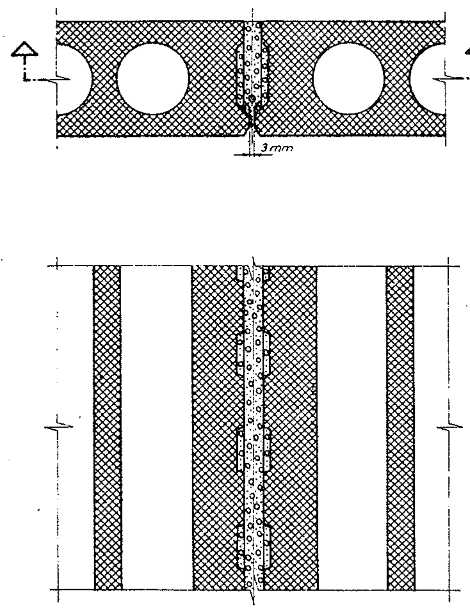



Figure 2. Floor Joint

The floor joint (figure 2) requires no formwork, and the chamfered edges of the components enable differences of up to 3 mm between the undersides of the slabs to be camouflaged.

The tolerance for component width ± 3 mm is small, and the edges must be straight and smooth.

The entire floor is assumed to act as a plate for the transfer of wind forces to the bearing cross walls. For this purpose the edges of the slabs are toothed. The teeth act as shear-keys in the cast joint.

The finished floor consists of beech-wood parquet boards mounted on bearers which rest on soft pads (e.g. wood-fibre) on the concrete slab, the under-side of which is painted.

The beech flooring is (with traditional Danish wage rates) the cheapest on the Danish market. This "floating floor" has excellent sound-insulation capacity, and provides a space very suitable for placing electrical wiring. A flooring involving less labour will be developed in view of the probable future wage and price levels of an industrialized economy.

See also pages 24, 25.

The wall joint (figure 3) likewise requires no formwork, and the edges of the elements are also toothed, so that the entire wall acts as a plate for resisting the wind forces. See also pages 26, 27 (and 31).

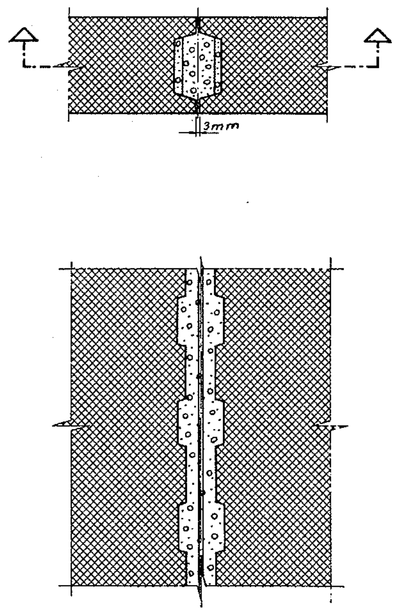



Figure 3. Wall joint

The joint beween floor and wall (figures 4 and 5). The load on the floor slabs must be transferred to the wall on which they rest. The load from the wall above the joint must be carried downwards. Regard must be paid to production and erection tolerances.

Figure 4 shows the reinforcement which ensures the coaction of the floor and wall elements ( See also pages 22-27, 30, 31, 35-37).

Further reinforcement is needed in high-rise blocks and (especially) in earth-quake areas, horizontally as well as vertically as illustrated by Danish systems operating abroad.

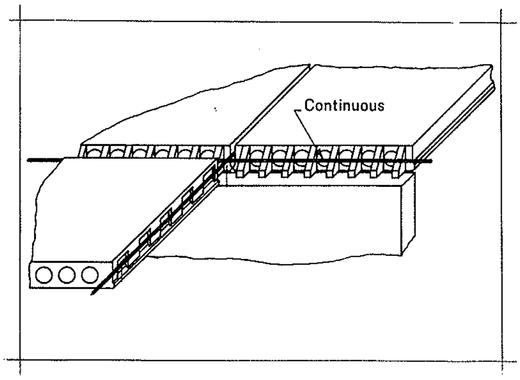



Figure 4. Reinforcement in Joints

The vertical forces in the walls cannot be carried through the floor slabs: The floor slabs have hollow cores, and the narrow zones between them cannot take the forces from a fully loaded wall. Furthermore, the floor slabs ( to increase speed of erection) rest on a dry joint. Thus the stress distribution is a function of small irregularities in the components' surfaces.

Therefore, the vertical forces must be transmitted directly, i.e. through the cast-in-situ concrete in the joint, the cross-section of which is only slightly less than that of the wall. The load is transmitted centrally and the stress distribution is fairly well known.

Finally, figure 5 shows the lifting bolts and nuts used for handling the components, as well as for securing the tolerances of the structure. The nuts are levelled before erection of the wall above, and the bolt positions are checked by templates. Therefore, inaccuracies do not add up from storey to storey.

The 30 mm gap between the cast-in-situ concrete and the wall component is packed with mortar.

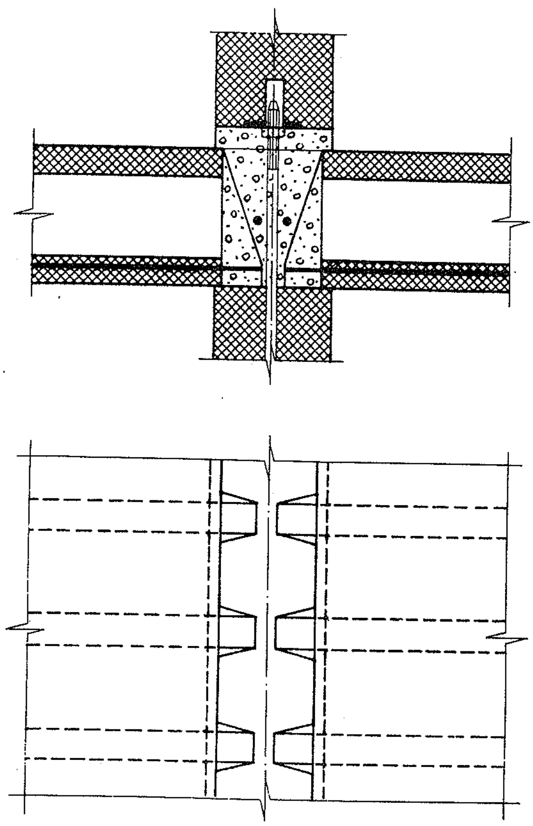


Figure 5. Floor-wall joint

The loads from the floor slabs are transmitted to the wall top by a row of cams at 150 mm intervals. In practice the slabs do not rest on all the cams, and some are useless because of openings in the floor slab. Many experiments have shown that the bearing capacity of a cam is up to 3 tons provided that the reinforcement is carried at least 50 mm in over the wall (the most unfavourable combination of production and erection inaccuracies may reduce this to 40 mm),i.e.carried through to the end of the cam. Such components have been used for most pre-fabricated housing in Denmark for the past 25 years. The end face of the form is quite simple, and there is no projecting reinforcement.

Further details are given in figures 9 and 10, and on pages 22, 23 (and 31, 33, 35).

## DETAILS OF COMPONENTS AND JOINTS

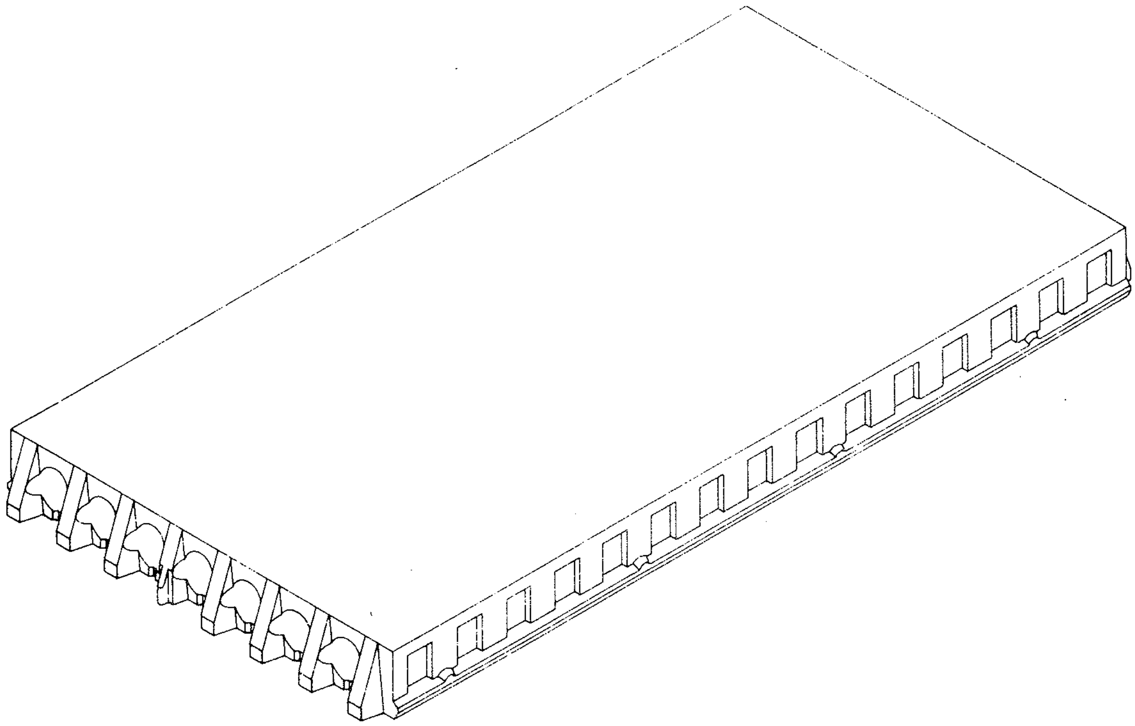


Figure 6

PRECAST FLOOR-COMPONENT, 1:20

Standard width 12M og 24M. Standard length n × 3M (8 ≤ n ≤ 20)

Thickness 180/185 mm (circular cores per 150 mm)
215-240 mm (oval cores per 150 mm).

Reinforcement cold worked, deformed bars per 150 mm (into the cams)

The floor component is simply supported (by the cams) on the walls.

Shear-keys per 150 mm.

Further details, see figure 7 and page 22 ff.

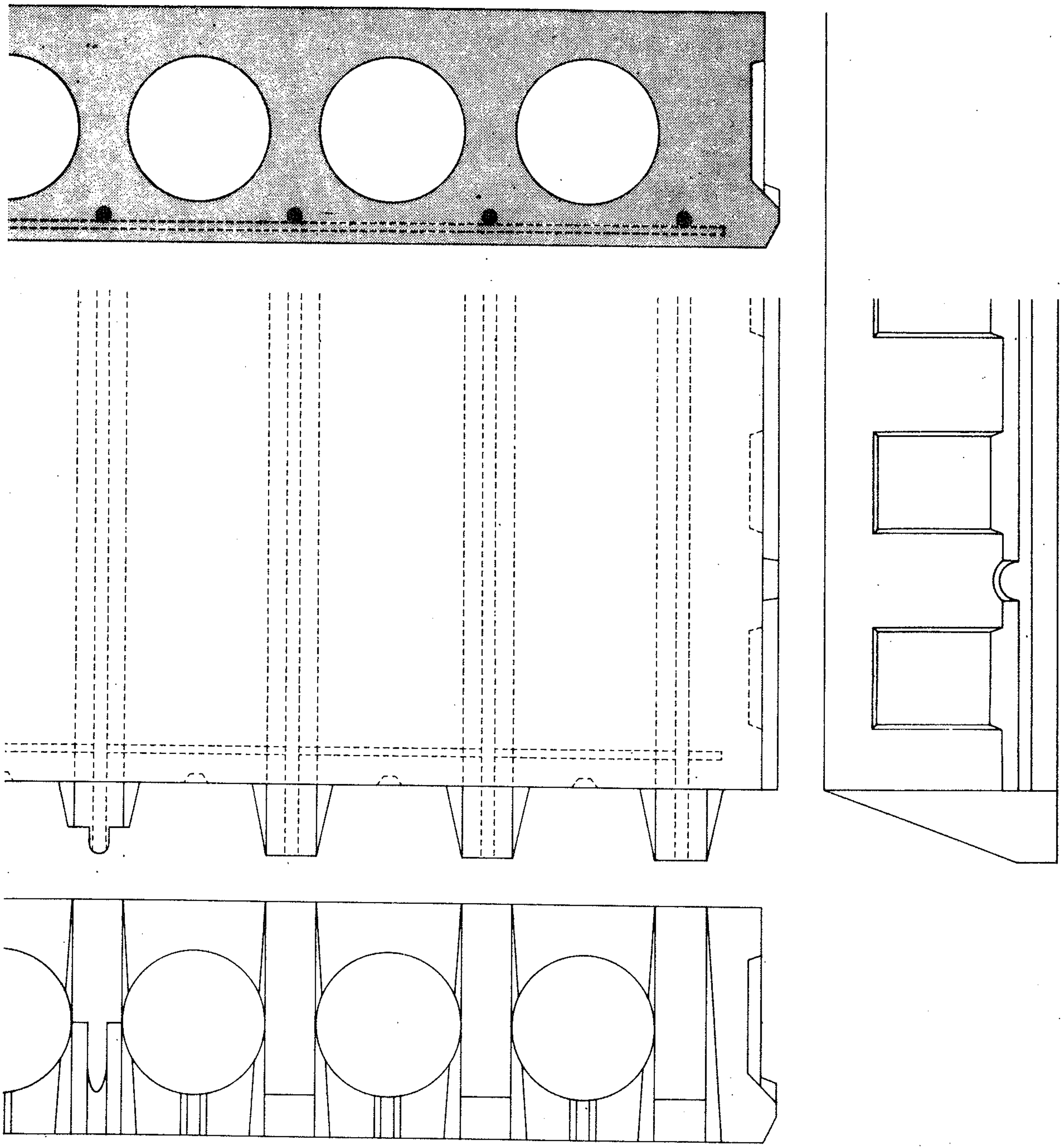


Figure 7. Details 1:5 of floor component

Details of the floor component shown in figure 6.

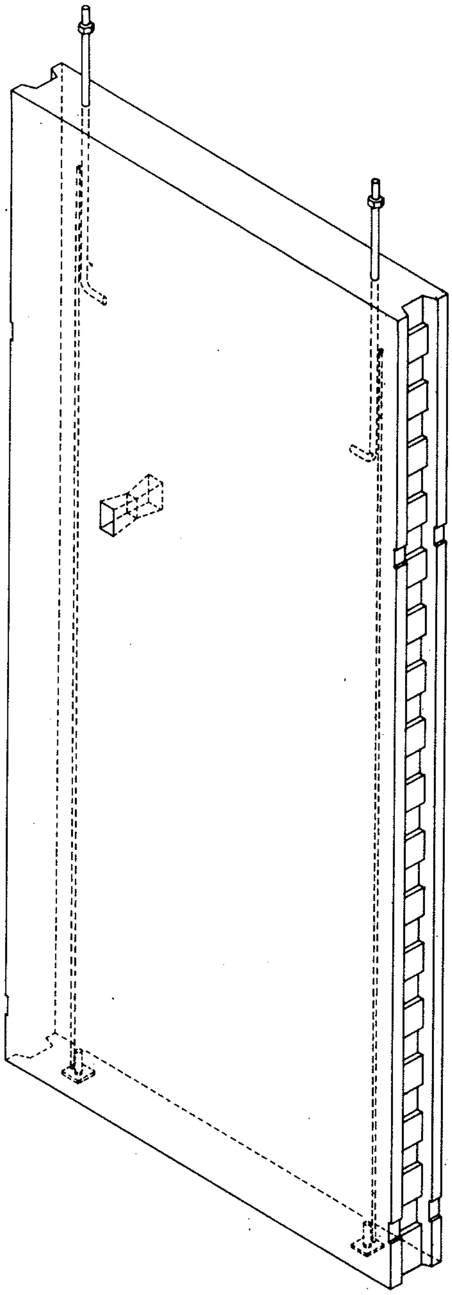
The small recess below the longitudinal cores at the end faces of the component acts as a drain for water which may enter the cores during erection. Before pouring the floor-wall joint the cores are closed by discs, covering also this recess, preventing the grout from entering the cores (and the recess).

Note that one cam (shown as number four from the right) is somewhat shorter, with a projection for keeping the prewelded reinforcement-mesh in position sideways.

Note also the small cam on the longitudinal edge (shown between the first and second shear-key) which carries the reinforcing bar in the floor-floor joint, ensuring a proper embedding of the bar in the jointing grout.

Figure 8

PRECAST WALL-COMPONENT, 1:20

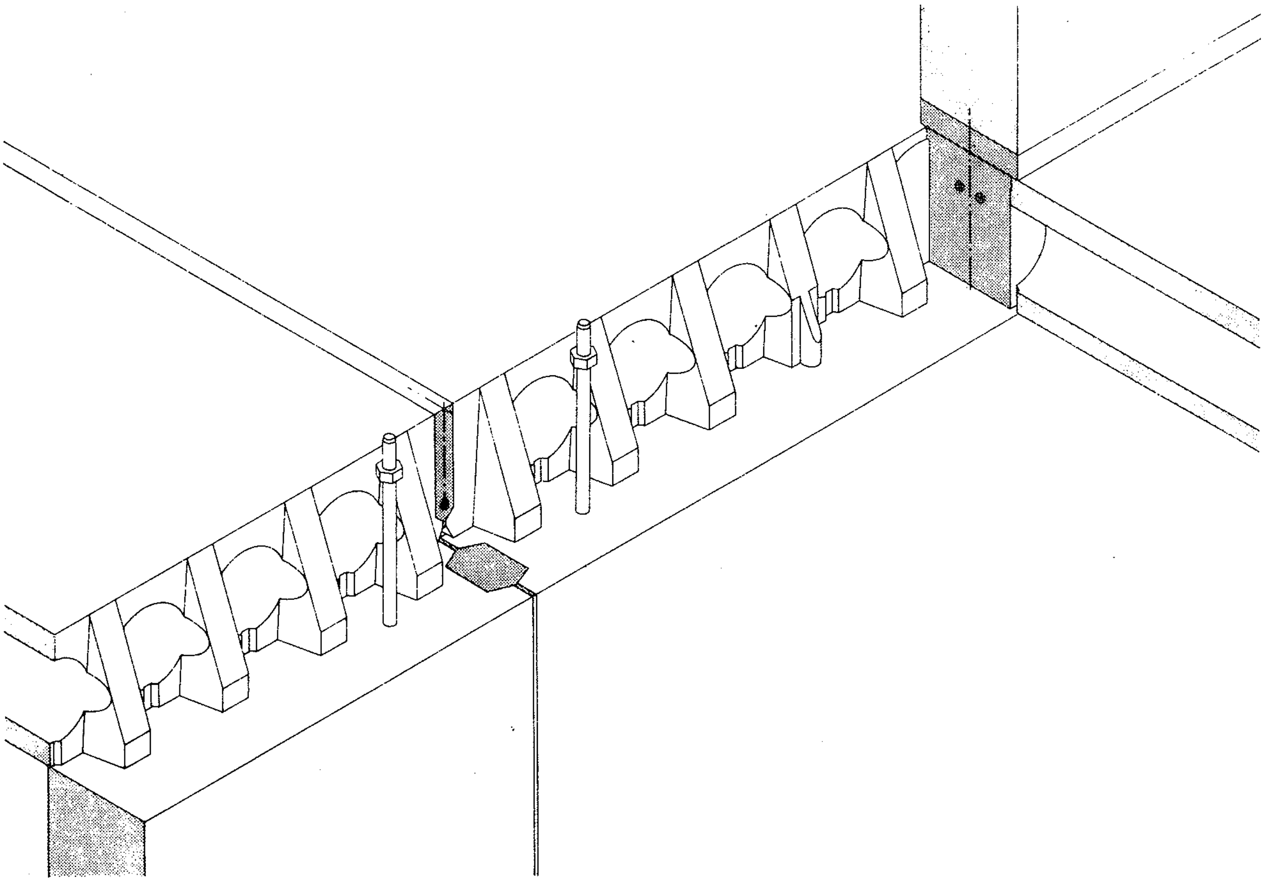


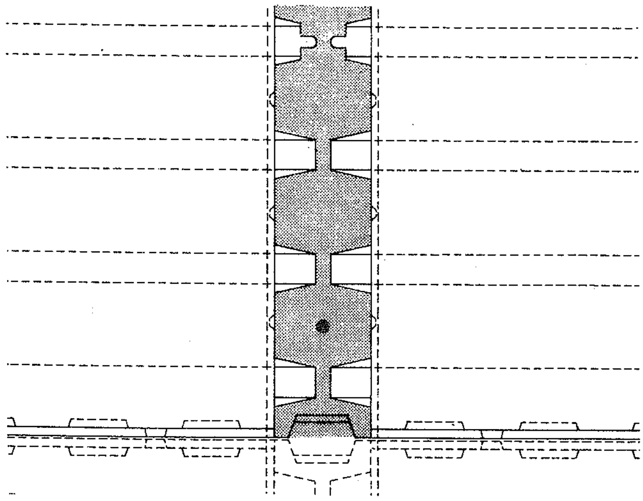
Standard width: n × 12M.

Standard height: The height corresponds to the standard storey height (28M in blocks of flats, 26M in single houses), minus floor thickness (figure 6) and minus 28-33 mm for the joint to be packed with mortar (figure 5).

Standard thickness: 150 mm, 180 mm (and up to 220 mm).
150 mm is minimum for a loadbearing wall due to requirements for support of cams and for sound-insulation.

Note shear-keys along the vertical edges (compare figure 3).





Figures 9 and 10 (1:10)

Further details of the floor-wall joint are shown in figure 5.

The 150 mm spacing of the cams leads to simple principles for placing of lifting bolts, vertical piping and wiring etc. through the floor-wall joint.
The cams on floors of different widths will always correspond and the vertical wall-wall joint is always free for grouting.

## FACADE COMPONENTS

In most blocks of flats the facade panels are concrete sandwich components and/or wood framed facades (see page 12).

Concrete sandwich components consist of an exterior skin of concrete with a ready-made finish (profiled or exposed aggregates), a layer of insulation (mineral wool or expanded polystyrene), and an internal layer of concrete.

The internal leaf is usually the statically active layer, taking up the deadload of the components and the windload, and sometimes loads from the floor. Facades on cross wall blocks will transmit their windload to the floors and their deadload to brackets at the ends of the cross walls (a hanging facade), or the deadload will be transmitted from one component to the next below (a self-bearing facade). The floors are supported at the cross-walls. The gable components are statically cross walls, constructed as concrete sandwich panels. Their internal layer transmits the windload to the floors, and takes up deadload of gables and floors above the component in question, as well as the live load on the floors. Finally, the internal layer, together with the other cross walls, acts as windbracing walls for wind orthogonal to the facade. (A gable is a loadbearing facade, and usually also a bracing wall.)

Examples of concrete sandwich panels and their joints are shown on pages 30, 31 (and 29).

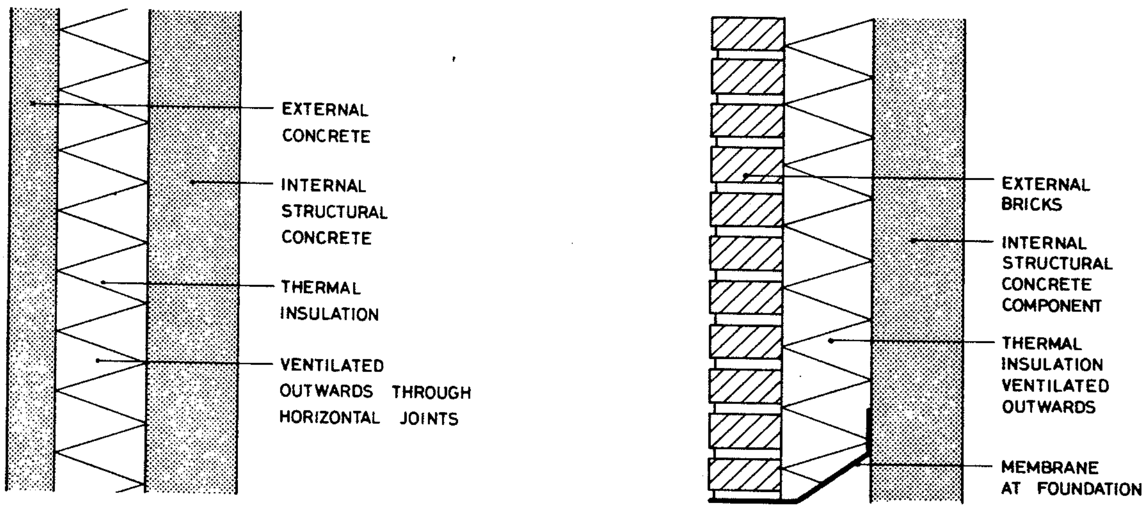



Figure 11A. Examples of heavy (sandwich panel) facades.

Today, heavy facades are of sandwich type with 100, up to 300, mm mineral wool as thermal insulation. The inner leaf of concrete is, in principle, a wall component. If the component is erected as a sandwich component (above, left), the outer leaf is made of concrete with a variety of textures, colours, exposed aggregates - or thin bricks. Figure 11B illustrates the ties between the leaves. Above, right, is shown an alternative. An inner leaf of ordinary wall-components, an added insulation, and an outer leaf of bricks. Brick cladding is quite popular, but not exactly cheap.

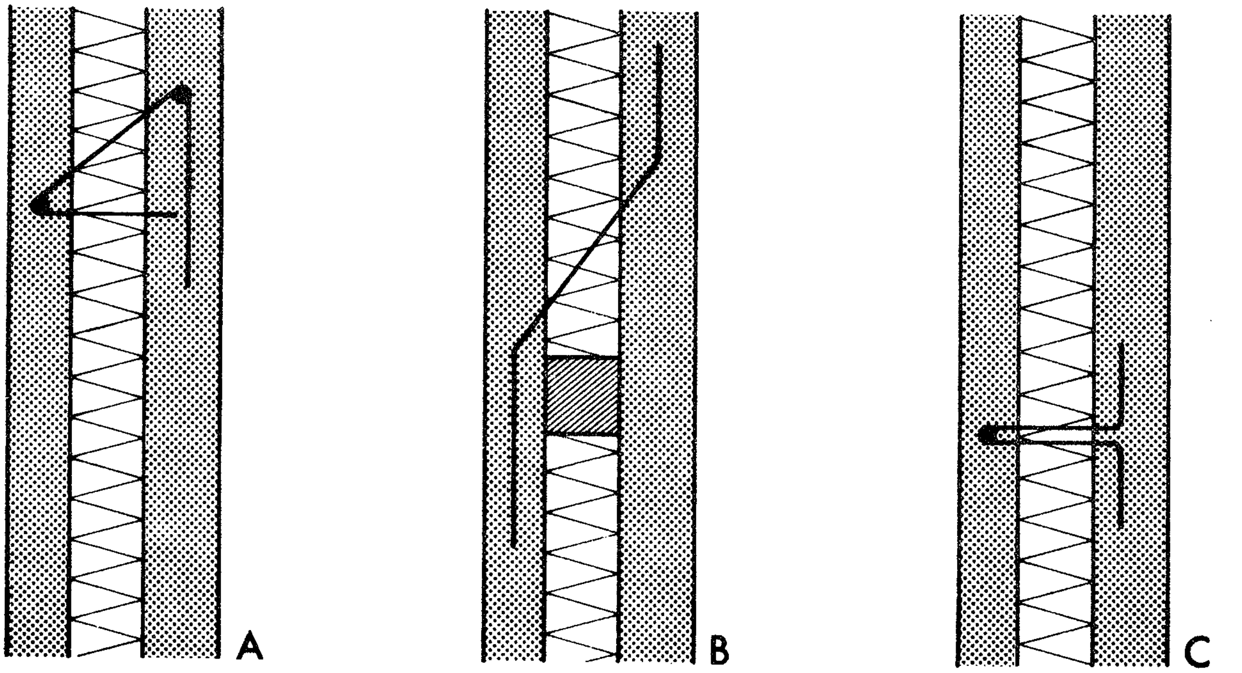


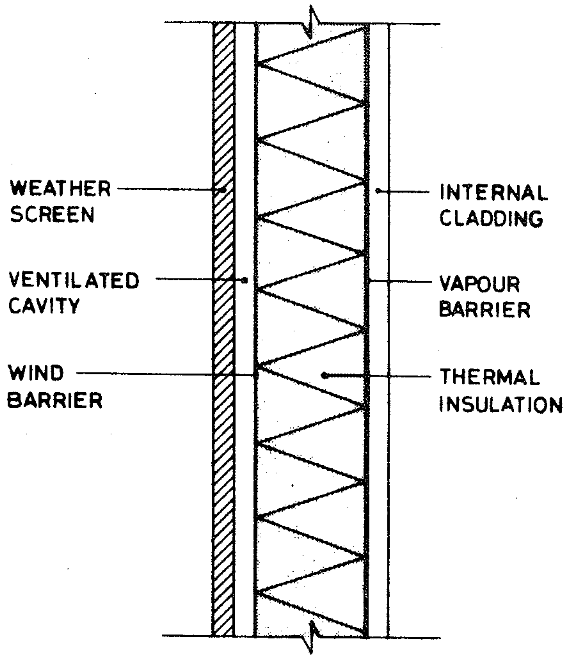

Figure 11B. Ties between Concrete Leaves in Sandwich Panels

The two concrete layers in a sandwich panel have relative movements. The dimensions of the interior leaf vary a little annually due to minor alterations of the inside temperature, whereas the exterior skin will have considerable thermal variations in dimensions, diurnal and annual, due to the climate. Therefore, a longish, rigid connection between layers will cause cracks in the tie if not in the exterior skin and/or deflections (which may open up joints).

Figure 11A illustrates a stainless steel (or alloy) tie suitable for a panel without a window (a gable). The exterior skin, to the left, is hanging in the tie (or ties all located close together above the center of gravity of the exterior skin).

Figure B illustrates a tie suitable for use in panels with windows. The outer skin hangs in two ties, one on each side of the window, the ties being long enough to take up thermal movements with low stresses.

Figure 11C illustrates 3 mm galvanized ties used as a supplement throughout the panel, tying the two layers together during demoulding, and hindering warp etc. of the outer layer. The ties reduce the cold-bridge between the layers to an acceptable minimum.



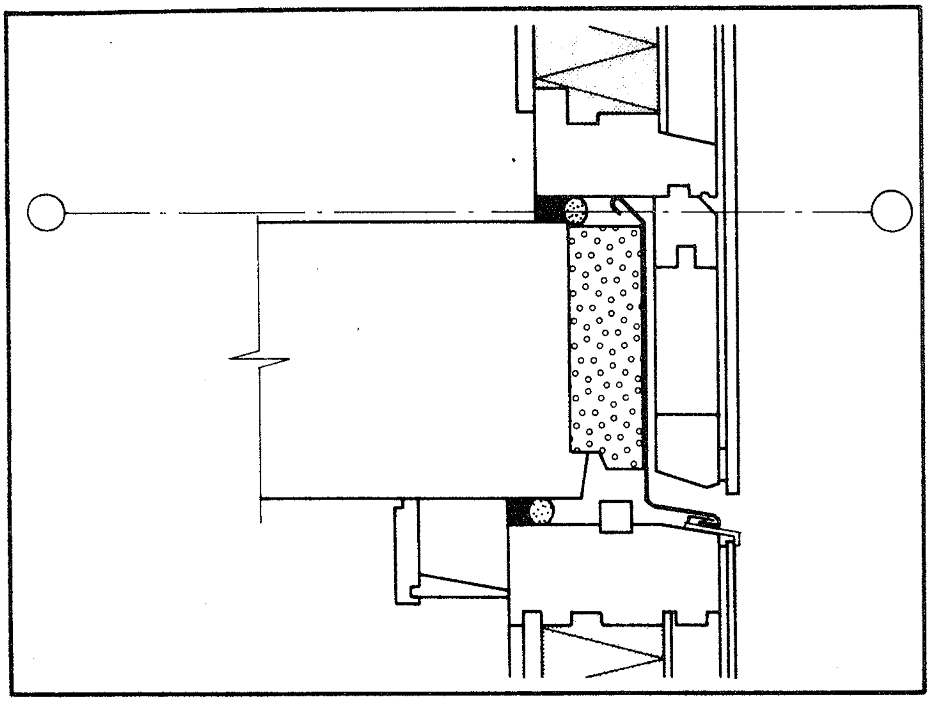

(Compare with figure 11A.)

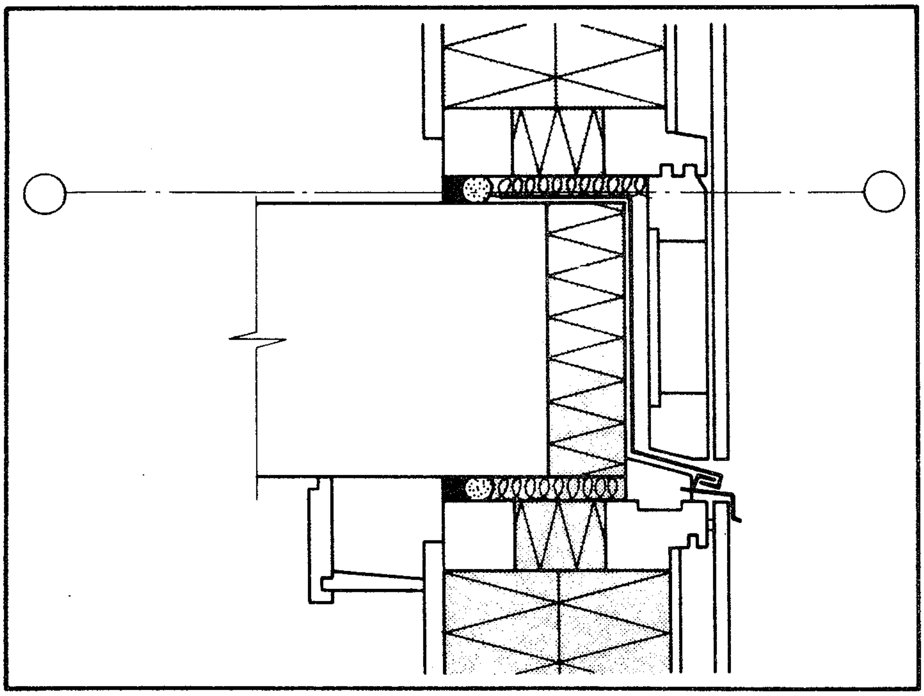
Figure 12. The Principles of a Light Facade Component

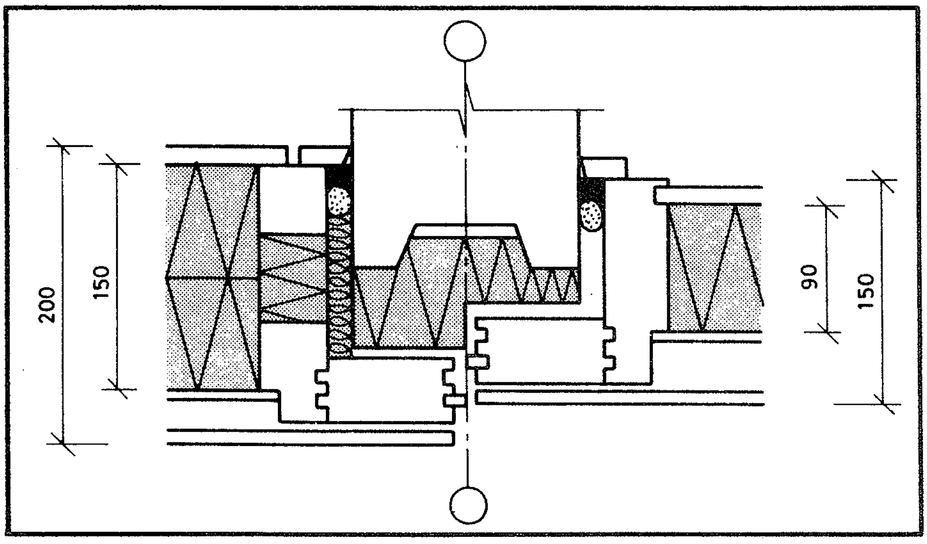
The component consists of a structural frame of wood (steel, aluminium), insulated by mineral wool. The thermal insulation is on the inside protected by, say, a 10 mm plasterboard with aluminium foil as vapour barrier. The insulation is held in place by fire resistant asbestos-cement (3.5 mm D.E.F. 90) on the outside. This layer is relatively air-tight, but not vapour-tight, so that the insulation is ventilated with no risk of condensation. (The aluminium-foil will cause a considerable drop in vapour pressure, compared with the small drop caused by the asbestos sheet. Little moisture will migrate, and it is easily ventilated out). Between the fire resistant asbestos cement sheet and the exterior, decorative skin (any sheet material) the space is ventilated. Driving rain cannot enter the cavity but water may pass through open joints between cladding sheets and run down the back. It is drained out at horizontal, open joints. See the two-stage-jointing principle page 14.

A light facade is prefinished with glass, paint, etc.

Examples of light facades and their joints are shown on pages 13, 28, 29, 32, 33.








<u>Figures 13, 14, 15</u>

Comparison between a light facade from 1960-70 and a prototype of a modern, better insulated, light facade.

Figure 13 and the right part of figure 15 illustrate a 1965 facade.

Figures 14 and the left part of figure 15 illustrate a modern version.

The principles are alike, but for one feature: The frame is divided into an outer frame and an inner one, saving timber, and increasing the thermal insulation.

The frames may be connected by dense mineral wool, glued to the frames, or the frames may be connected by hardboard sheets.

(Reference: Henrik Nissen, DIA-B, Denmark)

## ONE- AND TWO-STAGE JOINTS

Some of the early prefab houses had one-stage vertical facade-joints, and most of them leaked. In a one-stage joint the water-seal and the air-seal is combined. Although some vertical one-stage facade joints, sealed with a good sealant, do not leak, it is very unlikely that a completed building with one-stage joints should not have a number of leaks (some are unnoticed as the joint-details often provide some kind of drainage). One-stage joints sealed under laboratory conditions have much better performance than the joints sealed on a building-site.

All sealants will ultimately fail. Some may serve for a long period of time, but probably none will serve for the life time of a building. Therefore, a seal must be placed so that maintenance is easy.

Shrinkage, creep, temperature, warp, etc., in adjoining components will deform the sealant, and the permissible deformation will decrease with the aging of the sealant. It is wise to say, that a plastic sealant should never be used on the outer side of a building, and on the inner side only where cracks are acceptable.

The adhesion to the joint surfaces is often doubtful, as wet, cold, humid, dusty, painted, impregnated, asphalted, etc., etc. surfaces are unsuited for sealing with most types of sealants. Most surfaces on a site are certainly either wet or cold or something else.

If the surface is profiled, rough or have exposed aggregates, the application of a sealant is difficult.

Furthermore, a guarantee will quite often cover the material only, not the labour, and is nullified, if the priming is wrong (priming is often wrong). No firms give a guarantee for a reasonable period of time (10 years or more).

Finally, application and supervision are rather difficult.

Even small gaps can give unacceptable leakage, when the full air pressure difference acts on a facade covered with a water film.

Conclusion A: It is wise to use specialists for sealing, to use elastic sealants only, to avoid the use of sealants on the outer faces of a building, and to avoid one-stage joints.

Conclusion B: A two-stage seal is better, consisting of a baffle (seal, strip or the like) as the outer, almost water-tight stage, and of an air-tight seal as the inner stage, with a ventilated, drained cavity between the two seals (the outer seal does leak a bit, but leaks less if no air pressure difference acts across the baffle, seal, strip, or the like).

Figure 16 illustrates the two principles, the one-stage and the two-stage vertical joint. The two-stage joint is often called "the open joint" or "the ventilated joint" ("rain-screen-principle", "pressure-equalization", etc.). It was developed and successfully used in Denmark 20 years ago. Its functioning was checked by experiments in the Norwegian, and later the British and Canadian, Building Research Institutes. The two-stage joint is the only recommended principle to-day in prefab construction. (See also reports from CIB, working group 61. Joints in Exterior Walls.)

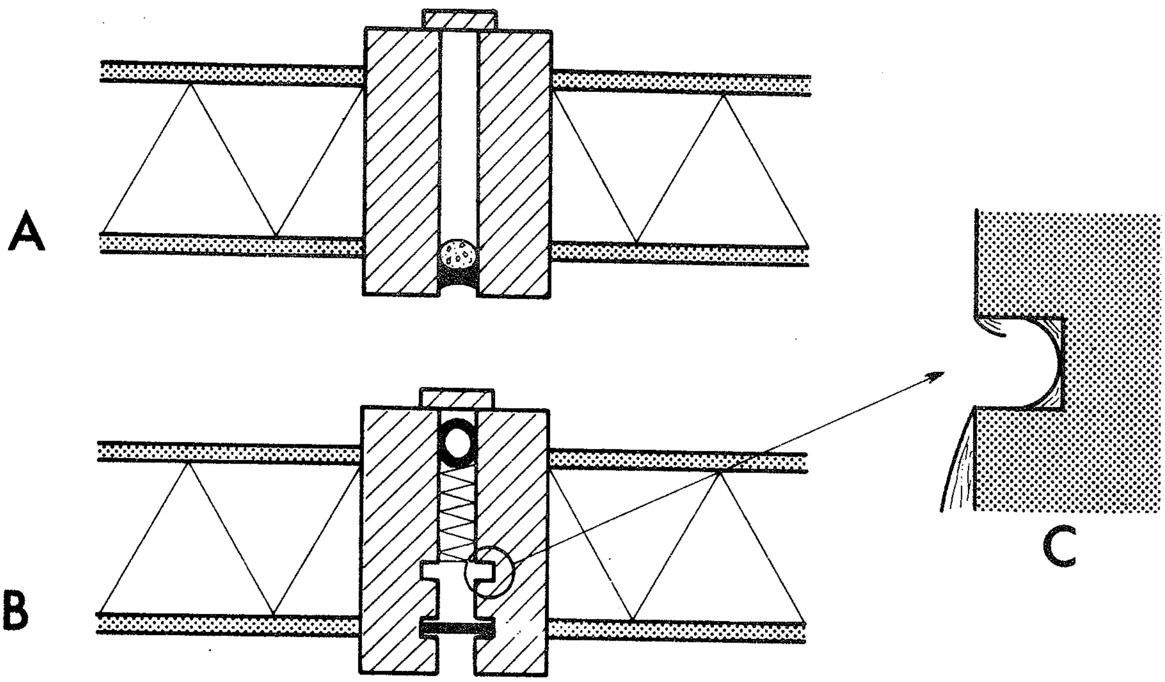



Figure 16. One- and Two-Stage Joints in Wood-Framed Facades.

Figure 16 A illustrates the one-stage joint. A sealant acts as combined water- and air-seal. A crack in the sealant due to ageing or deformation, or a gap between the sealant and the component due to failing adhesion, or any other small opening will primarily give an (possibly) acceptable air-leak. During rain, especially driving - rain on multi-storey facades, a water film will cover the facade and the air pressure difference will press the water through the leak. Quite often cover strips (as in figure 16 A), profiled edges or the like will lead the water, making the tracing of the actual outer leak difficult.

Figure 16 B illustrates the two-stage vertical joint in a wood-framed facade. Near the outside (down in figure 16 B) a baffle is slid down in grooves in the adjoining components. The baffle may be of neoprene, PVC, impregnated wood, metal, etc. The baffle will stop driving rain, but some water may seep through at the grooves. The cavity behind the baffle is ventilated (through the horizontal, overlapping joint) so that no static air pressure difference (but possibly a minor dynamic difference) will press water across the grooves. Water intruding into the cavity will stop at the next groove and run down along the groove, probably due to surface tension hindering the passage of sharp edges (figure 16 C). The cavity, with the vertical, draining groove is ventilated and drained outwards at the horizontal joints. Behind the cavity is a strip of rockwool (fire protection) and the second stage, the air-seal, consisting of a neoprene tube under compression. Rockwool, pointed into the joint, against a stop, may form an equally good air-seal. The cover strip on the inside is not taken into account.

See also pages 28, 29, 32, 33.

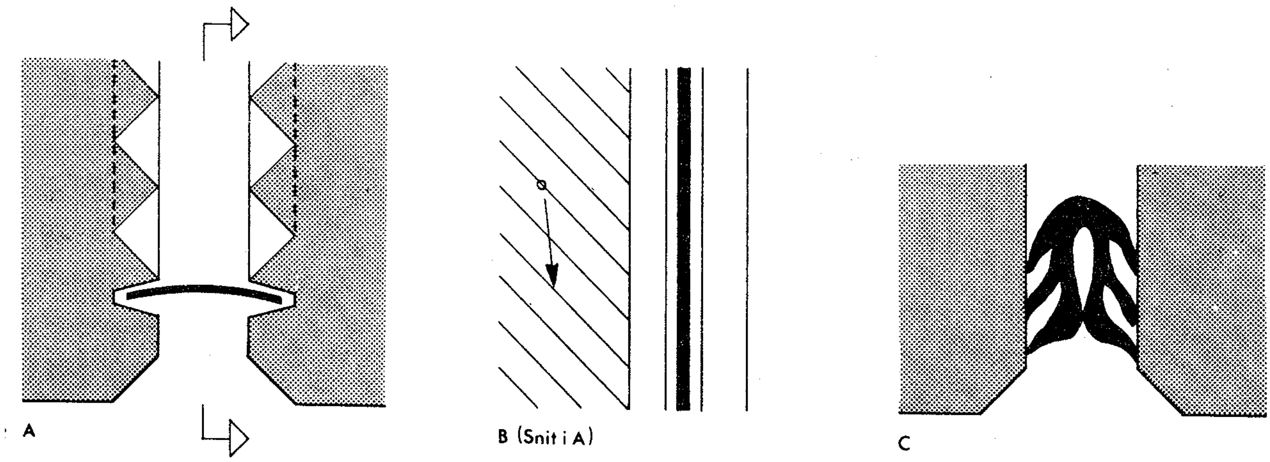



Figure 17. Baffles in Two-Stage, Open, Ventilated, Vertical Joints between Concrete Facade Components.

Figure 17 illustrates similar baffles in two-stage vertical joints between concrete panels. Again the cavity is ventilated and drained at the horizontal, overlapping joints. The baffle in figure 17 A consists of a 3 mm neoprene gasket, slid into grooves. Behind the baffle is a "washboard", i.e. inclined grooves, leading the water down, outwards, see figure 17 B (a section through 17 A).

Figure 17 B shows a combined baffle and drain of extruded neoprene. The small cavities between the fins act as vertical drains (Vari-lock).

The width of the joint is 16 - 20 mm so that dimensional deviations can be taken up, so that variations in width of the joint should not be too visible, and so that a sufficient gap for placing the neoprene is obtained.

See also pages 29-31.

Figures 16, 17, and 18 illustrate the two-stage principle:

Outside: a driving rain barrier (stage one).
Behind the barrier a ventilated, drained cavity.
Inside: an air-seal (stage two).

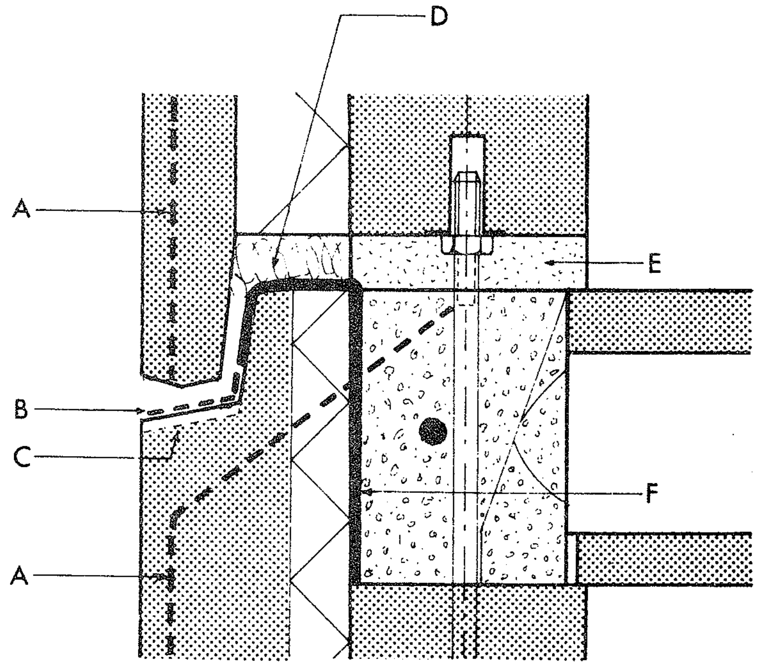



Figure 18. Overlapping, Horizontal Joint in Concrete Facade.

Figure 18 illustrates a typical, horizontal, overlapping joint. The downwards projecting part of the component above covers the threshold of the component below the joint, and makes the joint water-tight. The casting and the pointed mortar (E) form the air-seal. A two-stage joint.

D is a rockwool strip forming a stop for the mortar.

(A) indicates the neoprene gasket in the vertical joint. The neoprene follows the overlapping, ventilated joint and ends up inside where it is fastened in the casting of the floor-wall joint.

C is a groove stopping horizontal waterflow from entering the vertical joint. B is an alternative, a PVC foil covering the vertical joint. A foil (F) is anyway glued to the top of the component, protecting the insulation against rain during erection.

The minimum height of the threshold is 40 - 50 mm. The width of the joint is approx. 18 mm so that dimensional deviations can be taken up, and so that the variation in width shall not be too visible.

The horizontal joints drain the vertical joint, and ventilate the joints as well as the insulation.

See also pages 30-31.

The air-seals in the vertical and horizontal joints must meet at the joint-intersections if a sufficient air-tightness shall be obtained. This simple fact is quite often ignored. The resulting air-leak may transport water into the building.

## BUILDING SYSTEM KEY

Further details of components and joints (normal and variants) are shown in "Building System Key" - an example of systematic presentation of design details in building systems.

Also these details are from the 1960-70 period, when the "Danish System" was developed. As may be seen, the details above and the following ones correspond neatly. Most modern precast housing structures have still these basic details, although components generally are larger, and further (advanced) variants of the details are developed, see page 46.

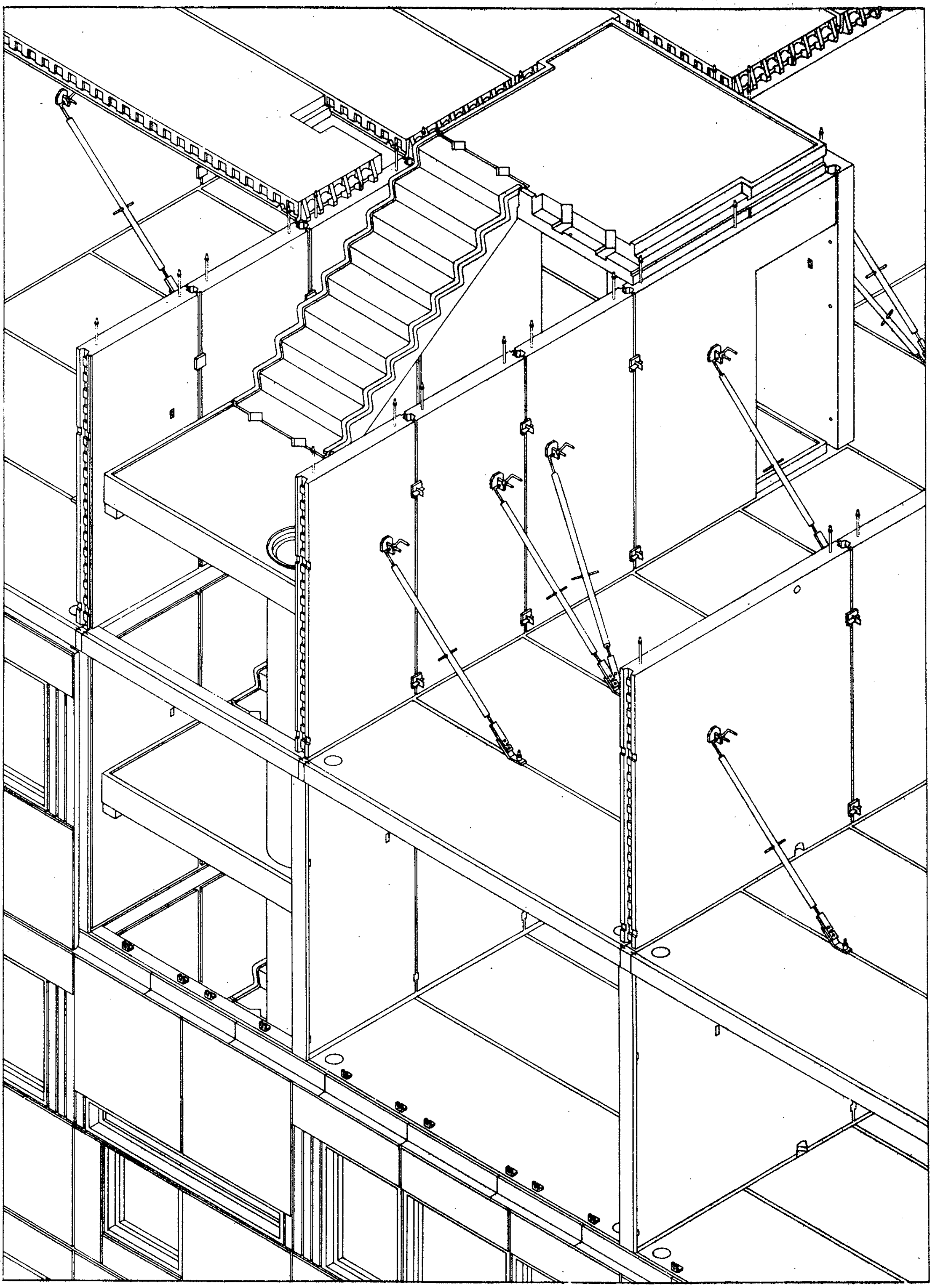
Examples of recent details may be found in Marius Kjeldsen, "Industrialized Housing in Denmark", (Danish Building Centre, Copenhagen 1967) in "Byggeindustrien" (published monthly by Teknisk Forlag, Copenhagen). Reference is also made to "Systematic Survey of Key Joints" (CIB W24, 1980, Danish Building Research Institute) to "Geometry of Joints" (CIB W24/IMG, 1980, Danish Building Research Institute) and to Munch-Petersen "Typical Danish Building Systems" (The Institute of Building Design, The Technical University of Denmark, 1980).

The Building System Key was made by Messrs. Klaus Blach and Filip Wanning (Danish Building Research Institute) as a result of registration of the details from a housing scheme (Hedegaarden) in Copenhagen.

I am most grateful to Messrs. Blach and Wanning as well as to Lemming & Eriksson, Consulting Engineers, Copenhagen, who kindly allowed me to use the following in this report, "Building System Key" (Translated by me) and, respectively, "The Erection Procedure".

The housing scheme illustrated on the following pages, Hedegaarden, had P.E. Malmstrøm as consulting (structural) engineer and used precast components from Modulbeton (The Jespersen System), see also Marius Kjeldsen "Industrialized Housing in Denmark", page 60 (Danish Building Centre, Copenhagen, 1976).

KLAUS BLACH OG FILIP WANNING 1980



# BUILDING-SYSTEM-KEY

-AN EXAMPLE OF SYSTEMATIC PRESENTATION OF DESIGN DETAILS IN BUILDING SYSTEMS.

BUILDING - SYSTEM - KEY

- an example of systematic presentation of design details in building systems.

The building system, which has been chosen to illustrate that a systematic approach is necessary both during development and presentation of a building system, is the loadbearing cross wall system which has been widely used in many countries.

This system can be used for more complicated building designs than the simple, rectangular block design illustrated in this presentation, and several details among those shown have been further developed and refined in recent designs. This presentation should not, therefore, be taken as guidance in solving building technique problems.

The main aim of the presentation is:

A. To show that in connection with development of a new building system - or at extention of existing ones - it is necessary to have a clear comprehension of the magnitude of the job in hand. It is thus not enough to design a few principle details and then postulate that thereby a building system has been created.
The survey will illustrate that even when a clear and simple structural principle is applied to a straightforward building form - a rectangular block of flats - then it is necessary to develop more than fifty design details before the system is really ready for being implemented.

B. To show how to avoid the too common mistake which is to believe that development work is finished, if the system itself has been finished. The success of any building system itself has been finished. The success of any building system depends very much upon how compatible it is when it comes to the question of combining it with components from other systems.
The survey illustrates how the components of the system in question have been prepared for being assembled also with components from other systems being marketed, viz. curtain wall components and partition components.

C. To show it is necessary, in trade catalogues and information sheets, to explain about the design configurations for which the system has been developed. Also in this case a single "normal detail" will not suffice.
Even in connection with very simple design jobs, the architect will meet with at least the design details shown in the survey. If the information material clearly shows that these details have been developed, this may in many cases be decisive for the final choice of the building system to be applied.

Klaus Blach Filip Wanning

Remarks to the following presentation:

## Drawing technique

The main aim has been a visually clear and easily comprehensible presentation. The drawing technique is, therefore, not the same as should be used for working drawings. Thus there are, on all sections, shown modular lines which are not to be used on working drawings.
In principle, all drawings are made with thin lines. The exception is that on details in scale 1:10 the contours of prefabricated components are shown with thicker lines. At the same time the components are in this case shown less detailed than on the principle details, which are in scale 1:5.

## Dimensions and texts

All dimensions and texts have been omitted to underline that the systematic way in which the details are presented is more important than the actual design.
The illustrations are shown in a sequence which relates to a coding system, in which each component and detail has an unambigous number. For ease of understanding these coding numbers are in this presentation substituted by simple key-words.

## Scales

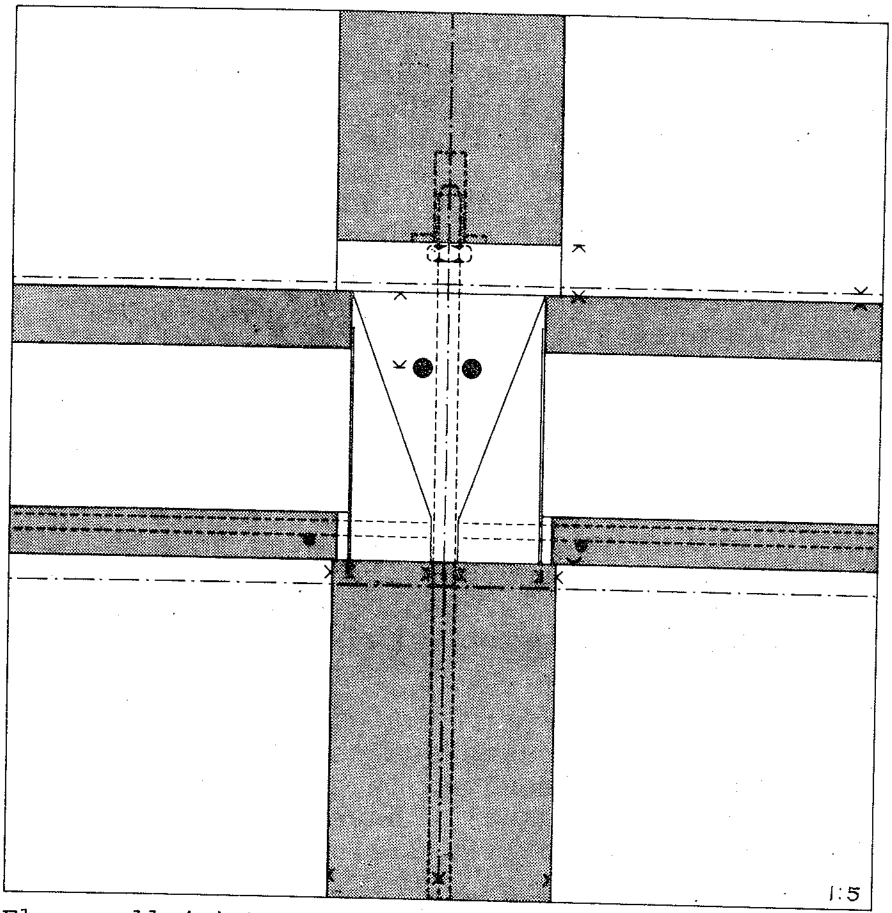
All illustrations are shown in commonly used scales. For each type of assembly the principle detail is shown in scale 1:5. The components used in system building usually have so fine details that only illustrations in scale 1:5, 1:2.5 or 1:1 will be really informative.
Isometric drawings and supplementary details, which do not have to contain quite so much information about design details, have been shown in scale 1:10.

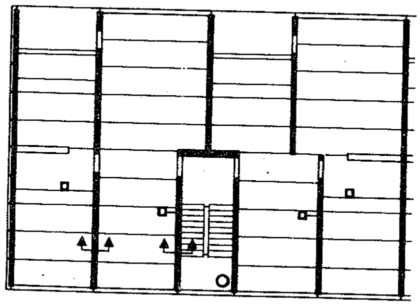
## Isometric drawings

Many design details are easier to understand if they are also illustrated in isometric drawings. Such drawings may also in quite many cases make the order of erection or positioning more clear.
The isometric drawings shown all "turn the same way", that is, they are all viewed from the right towards the left. They may, therefore, be pieced together to form an entity as indicated on the front page. This way of presentation has been chosen in an attempt to facilitate comprehension of the spatial built-up of the building system.

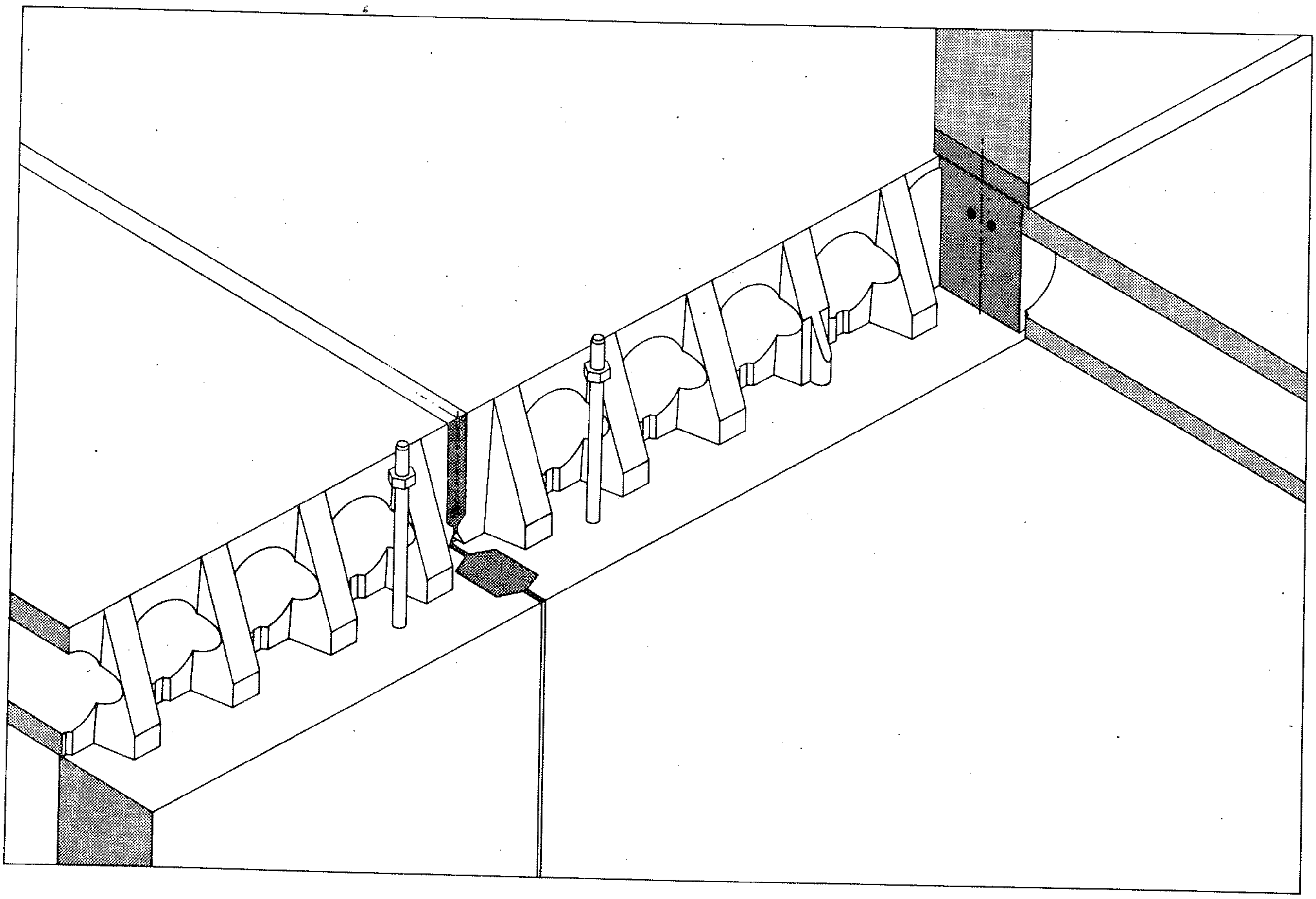
## Sections from top to bottom

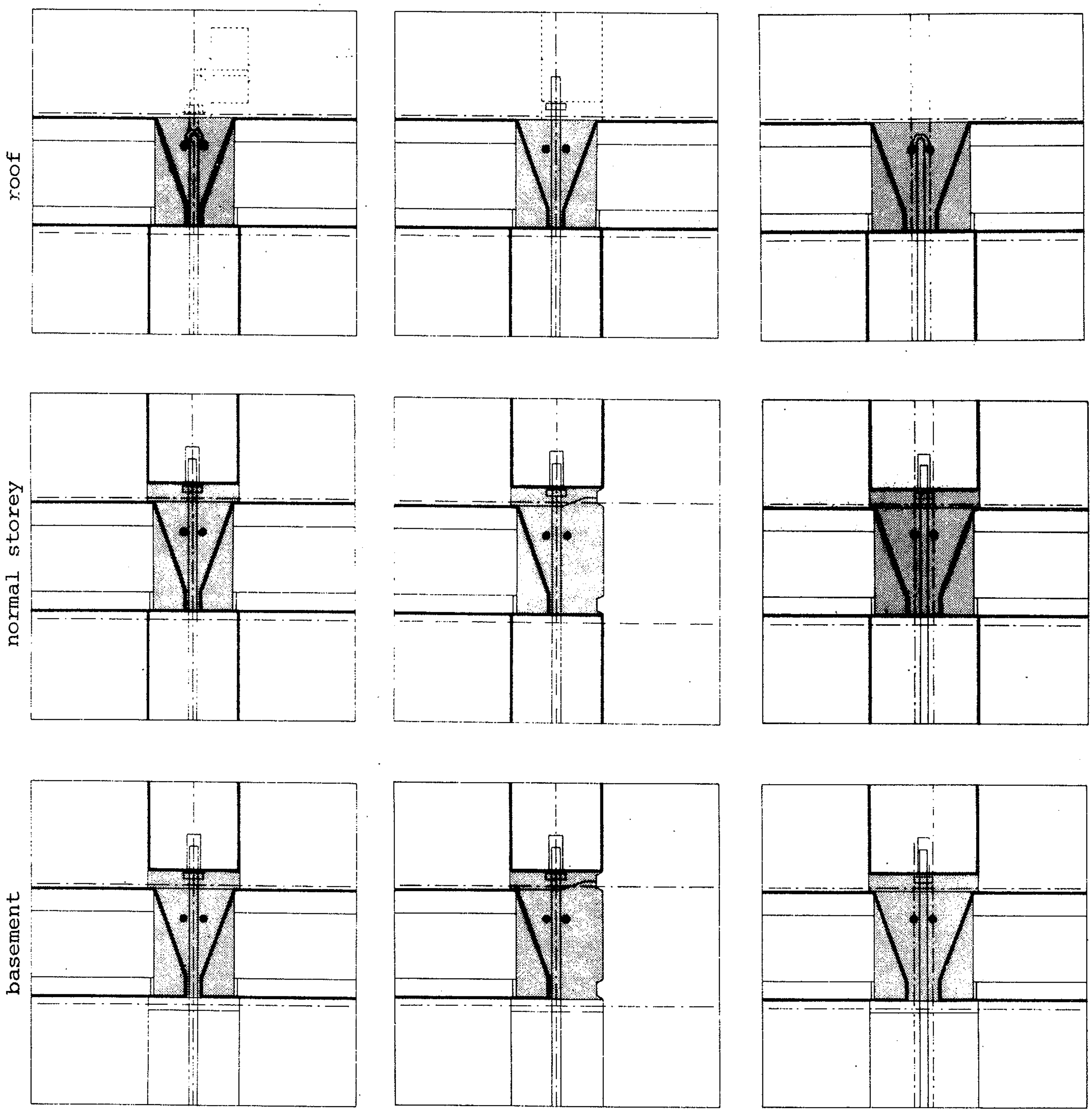
The principle details, shown in scale 1:5, are those found at a normal storey. But further to this are shown also the details where the system "assembles" with the roof, with facades and with the basement.
Especially the details at the roof and at the basement are often "forgotten" even in good trade literature and in information sheets !
Vertical sections at the roof, the normal storey and basements are indicated on small key-plans by arrows. Horizontal sections are in the same way indicated on the key-plans by circles.



Floor-wall joint

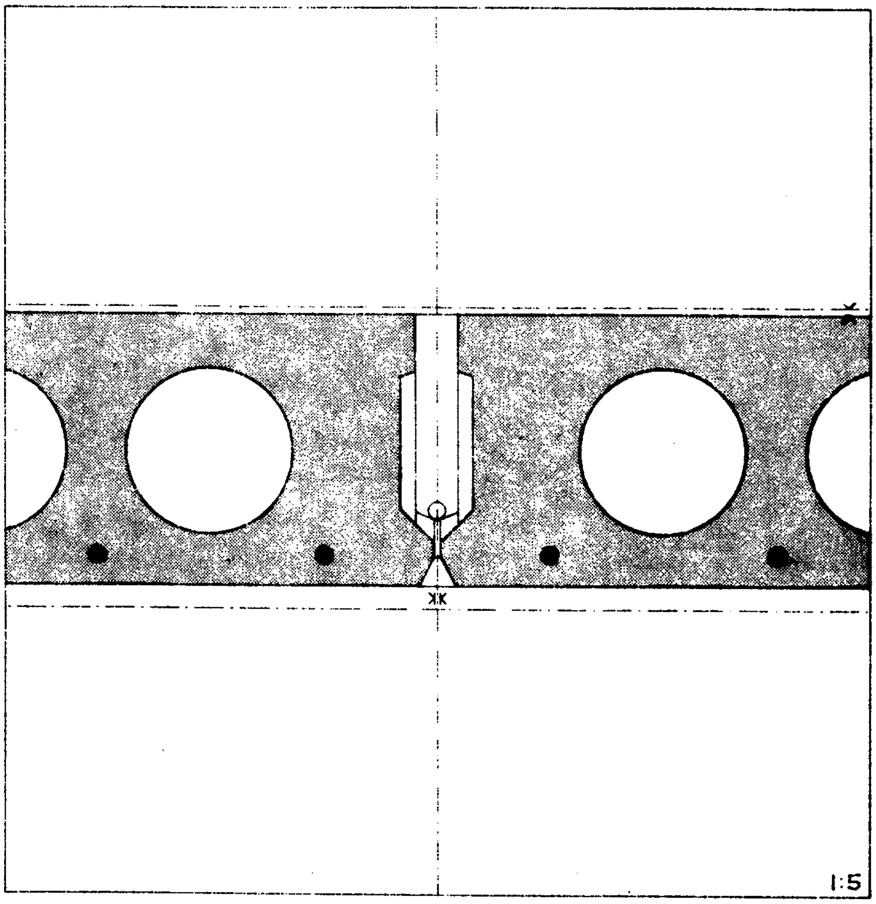


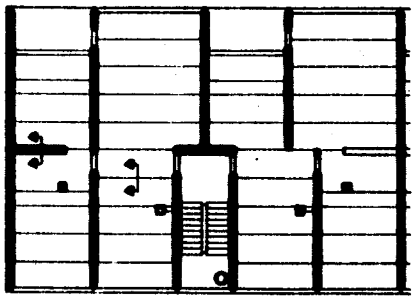



Floor-wall joint

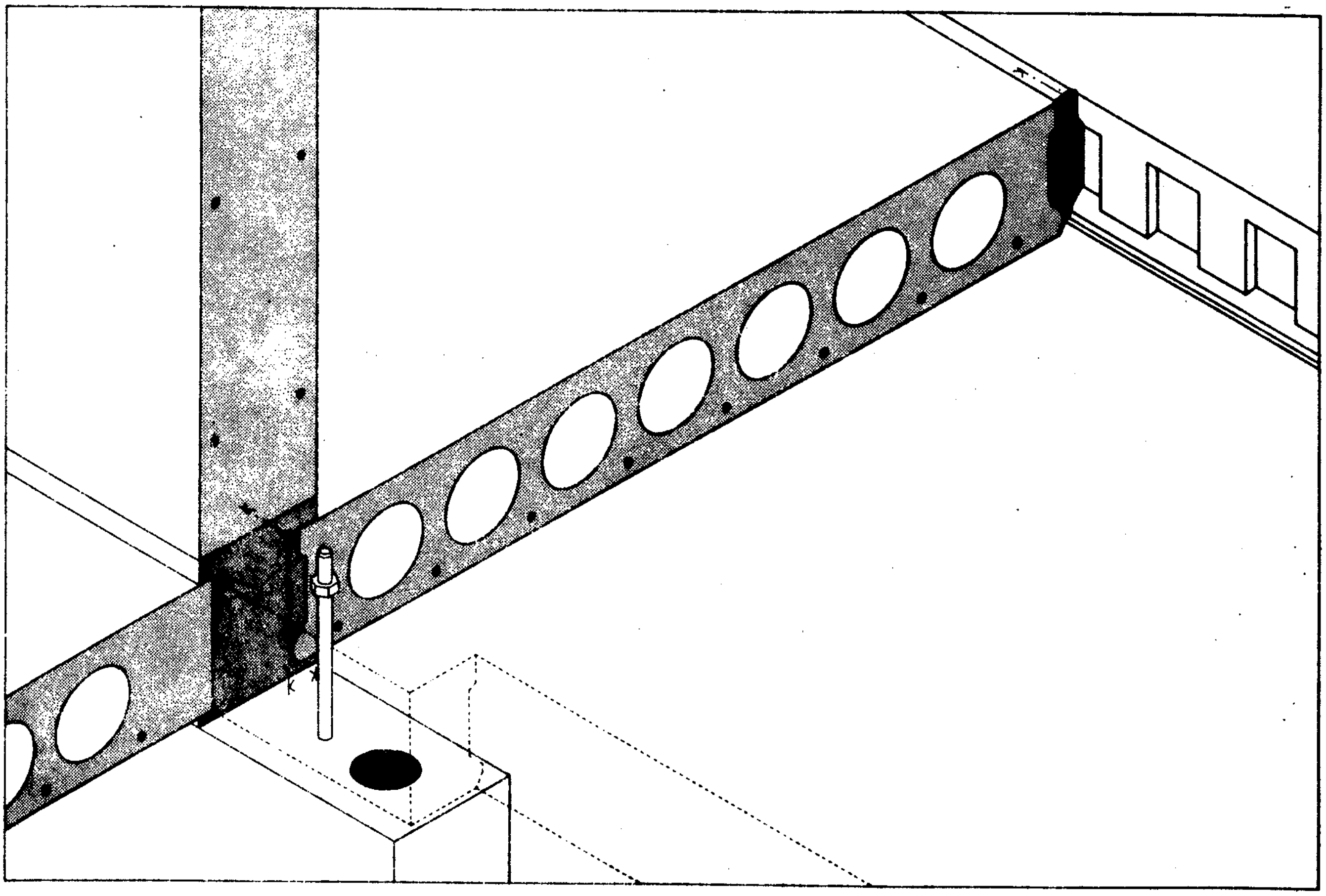
Stairwell

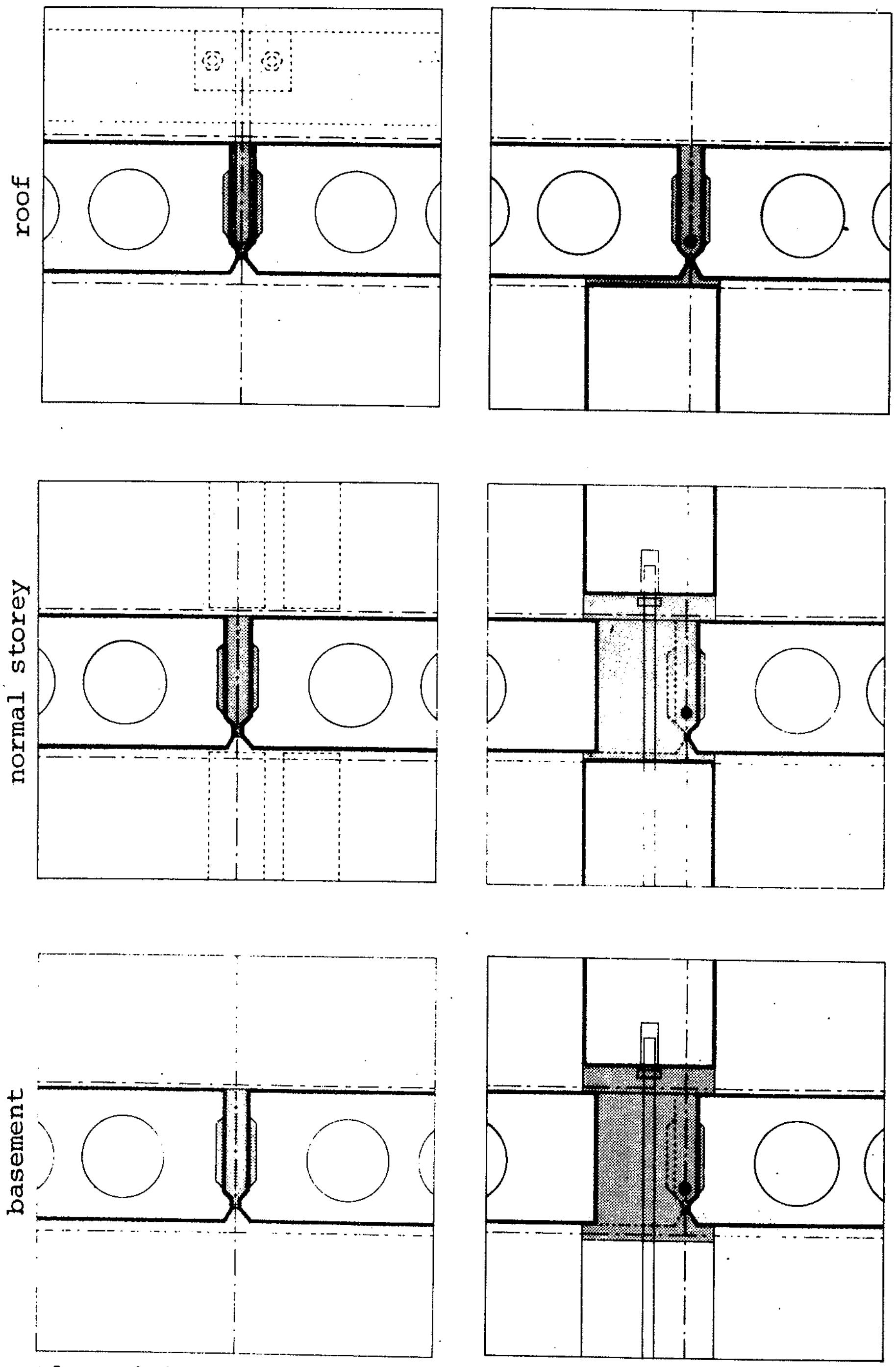
Alternative joint
at 180 mm wall



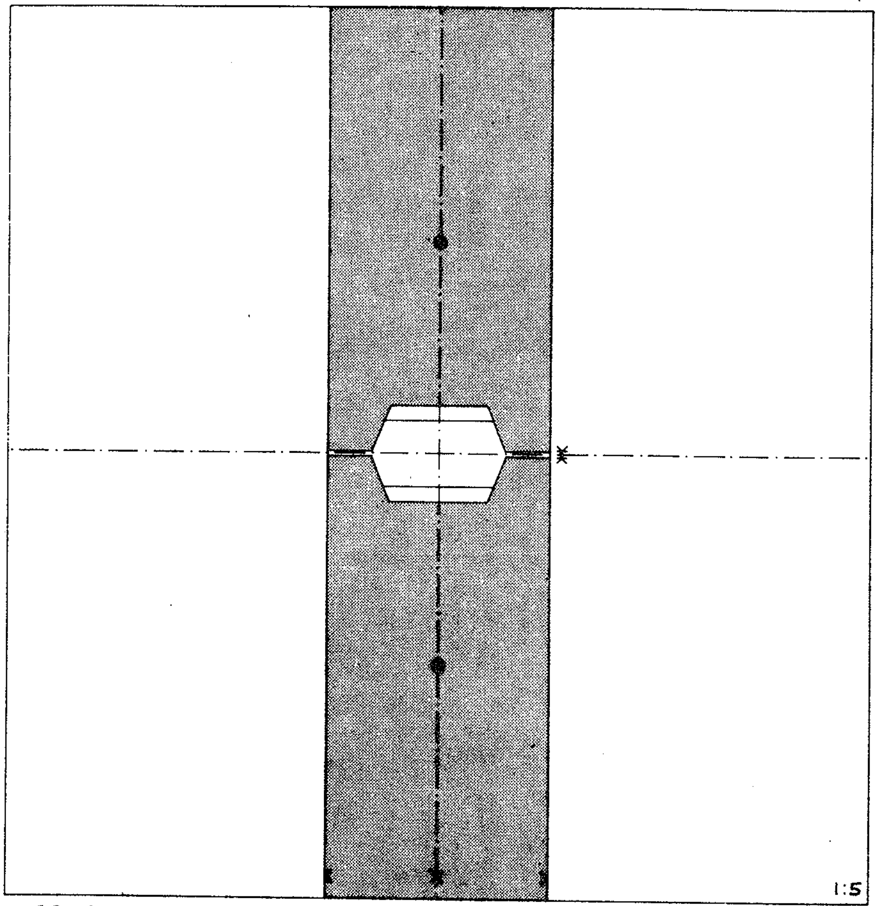
Floor joint

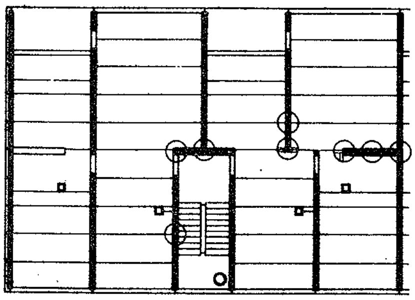




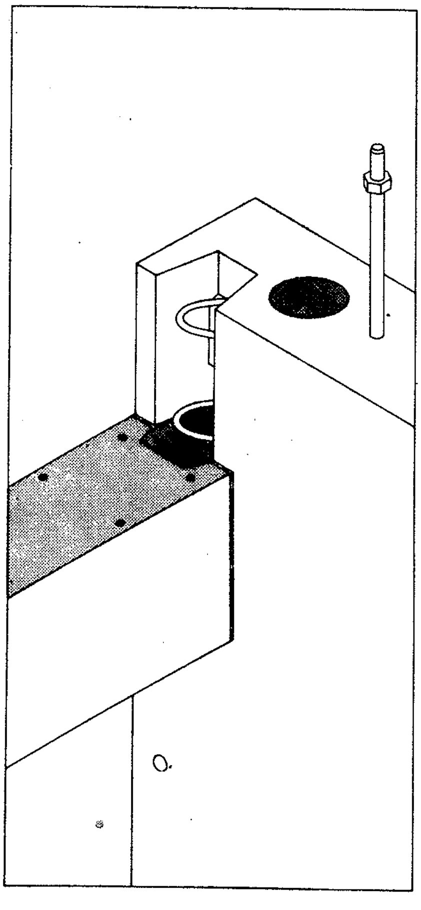

Floor joint

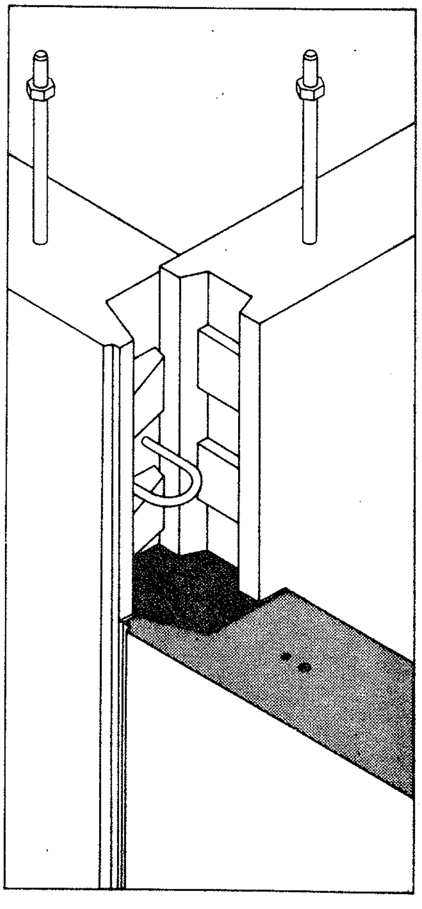
Floor(-wall)joint at longitudinal bracing wall

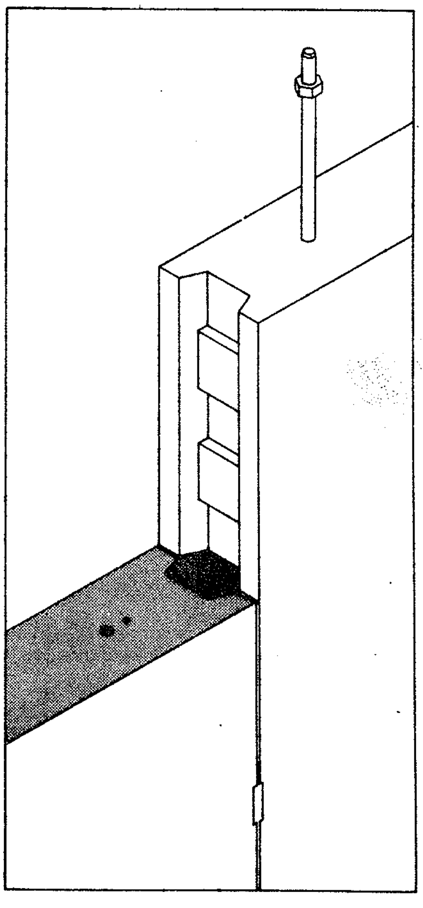


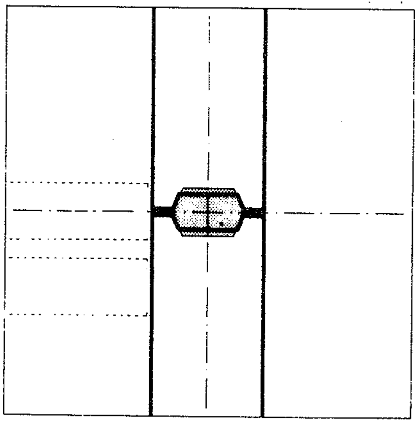



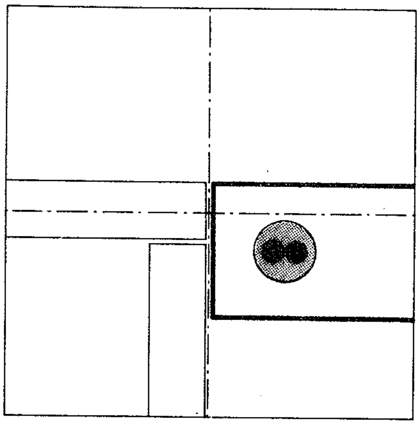
Wall joint

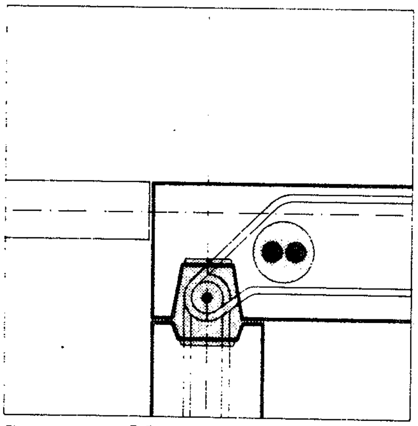


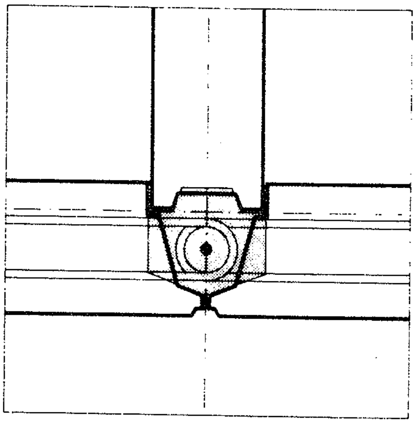


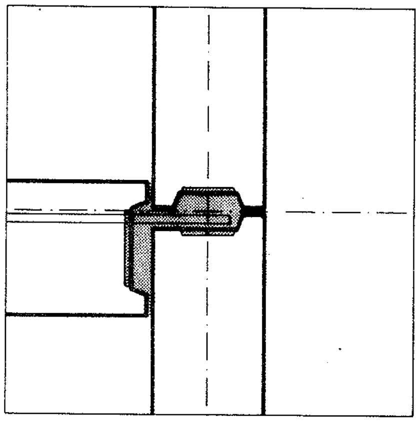


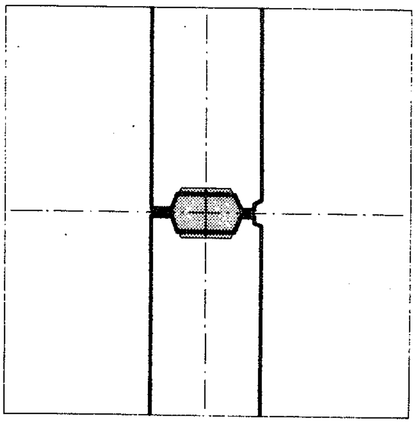

Wall joint

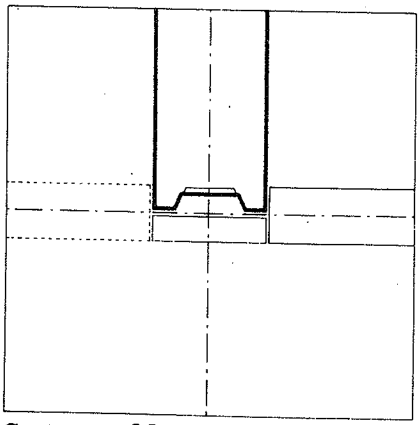

Bracing wall,
light partition

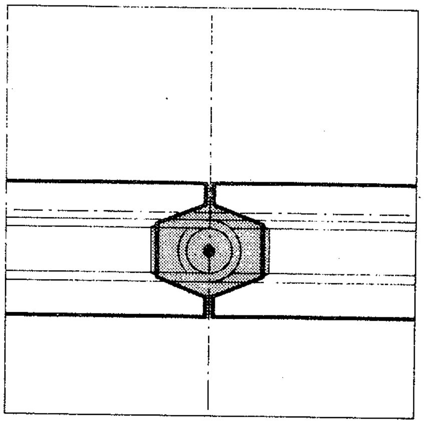

Cross wall - bracing wall
at stairwell

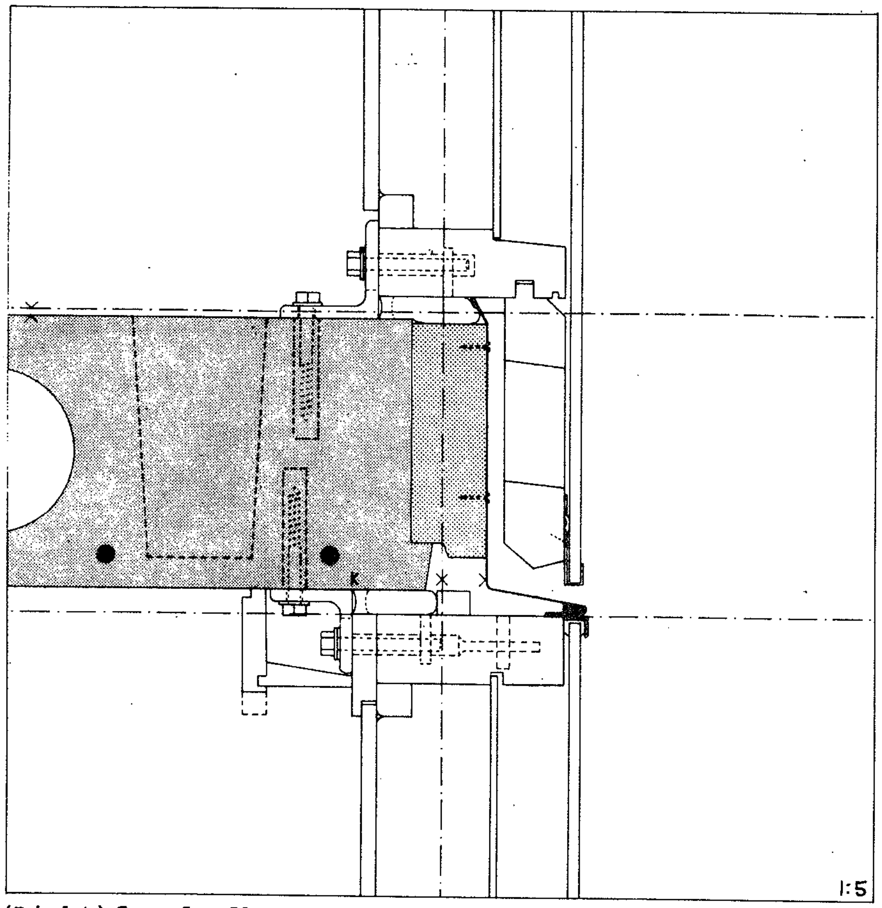

Cross wall - bracing wall
at stairwell

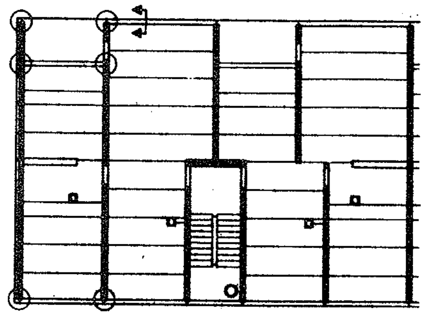

Cross wall - bracing wall


Wall joint, stairwell

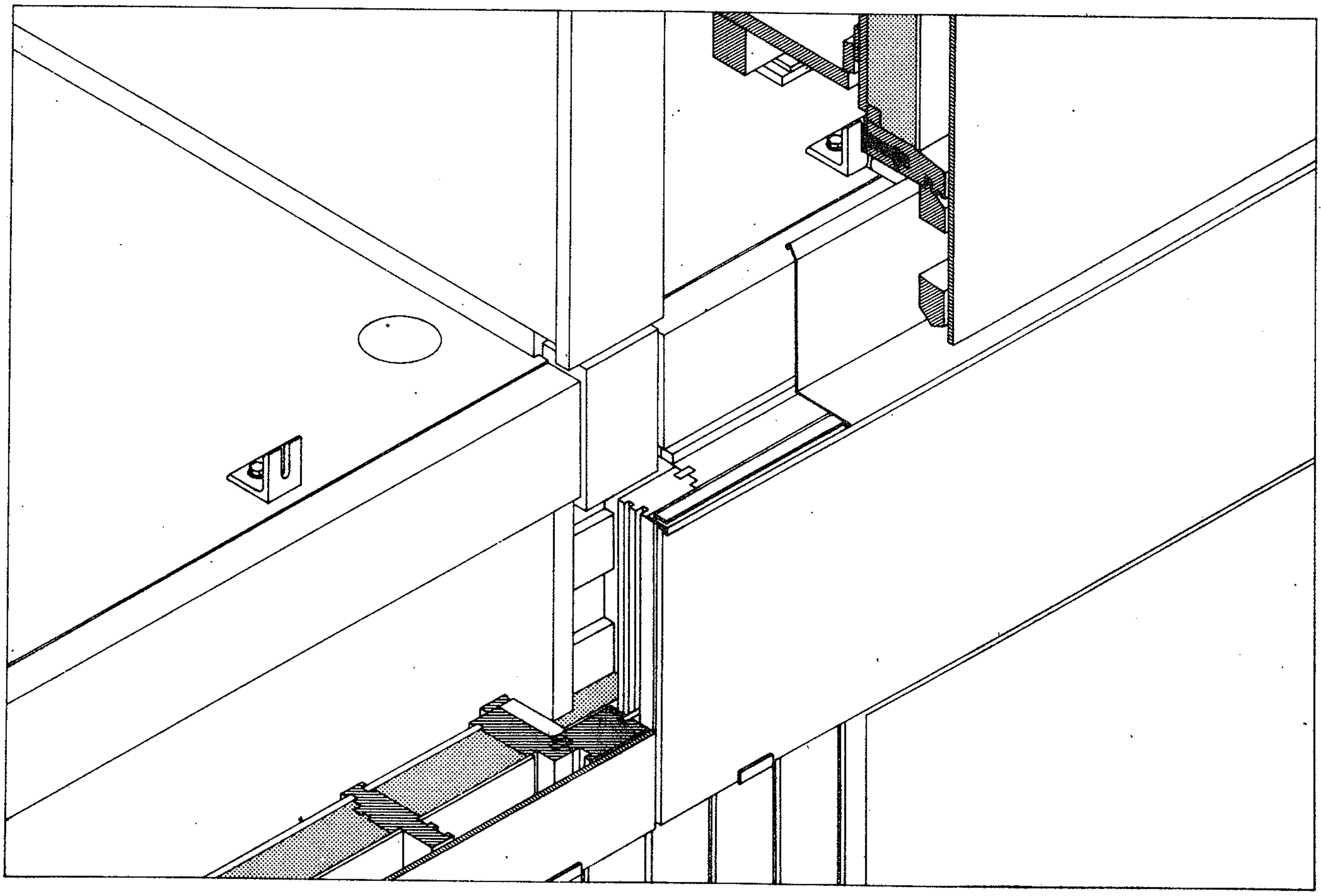

Cross wall,
light partition

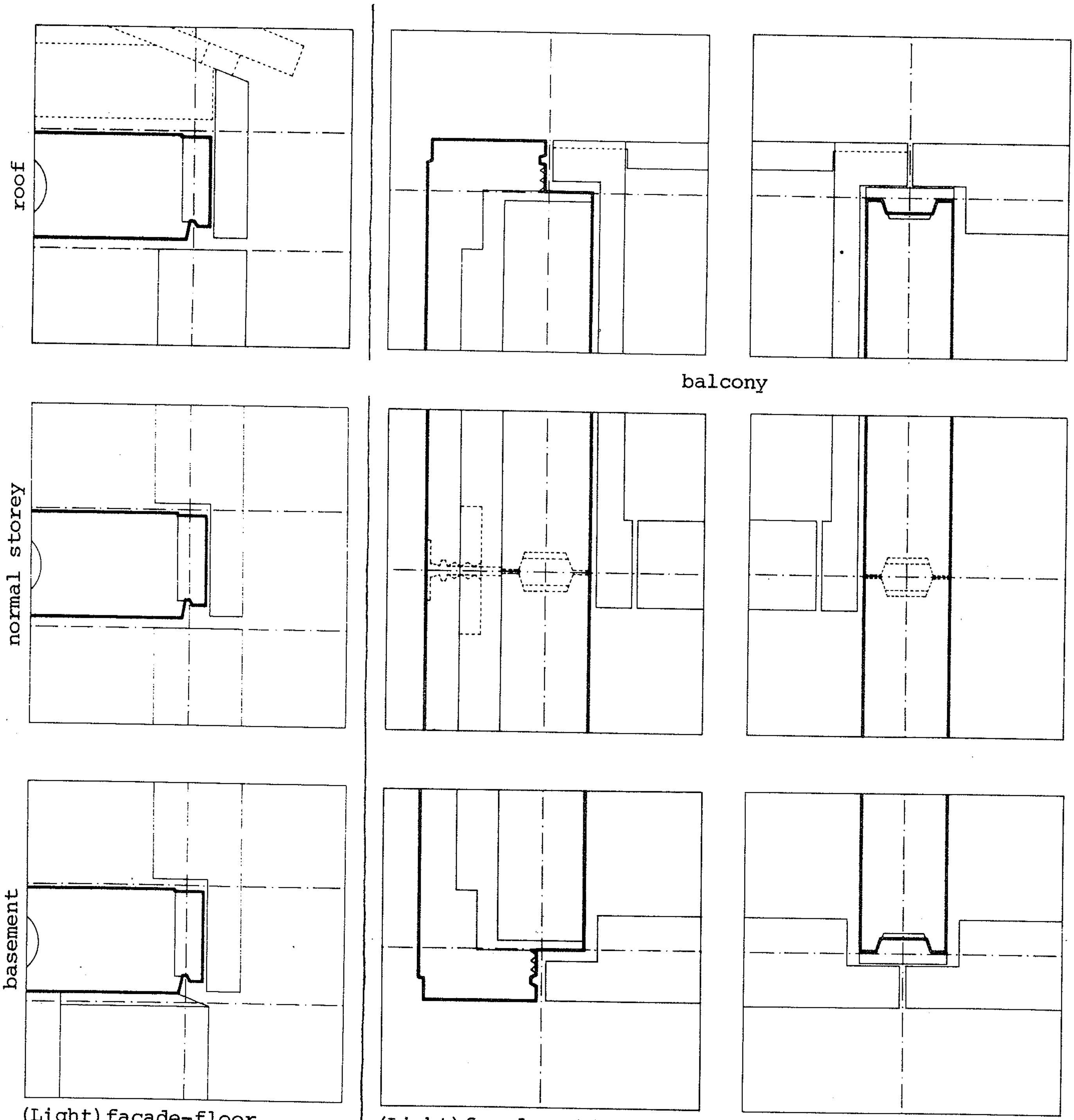

Wall joint
in bracing wall



(Light) facade-floor joint

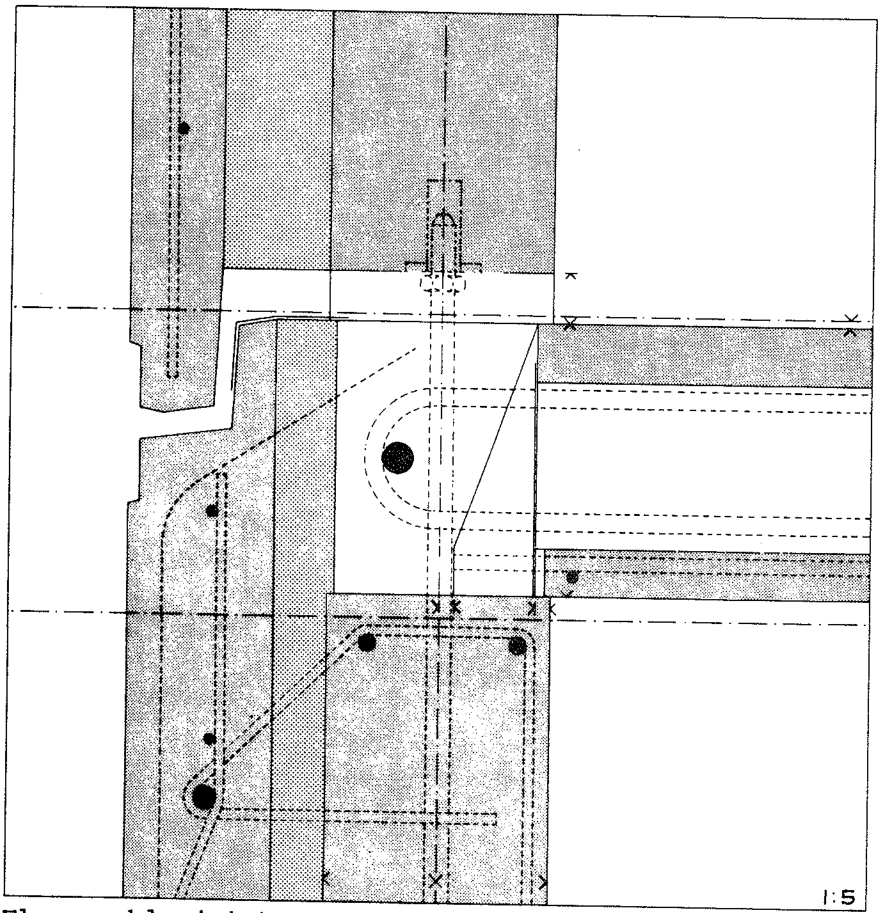


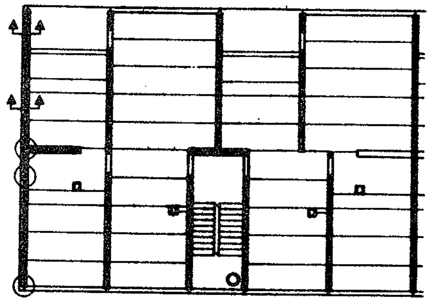



(Light) facade-floor

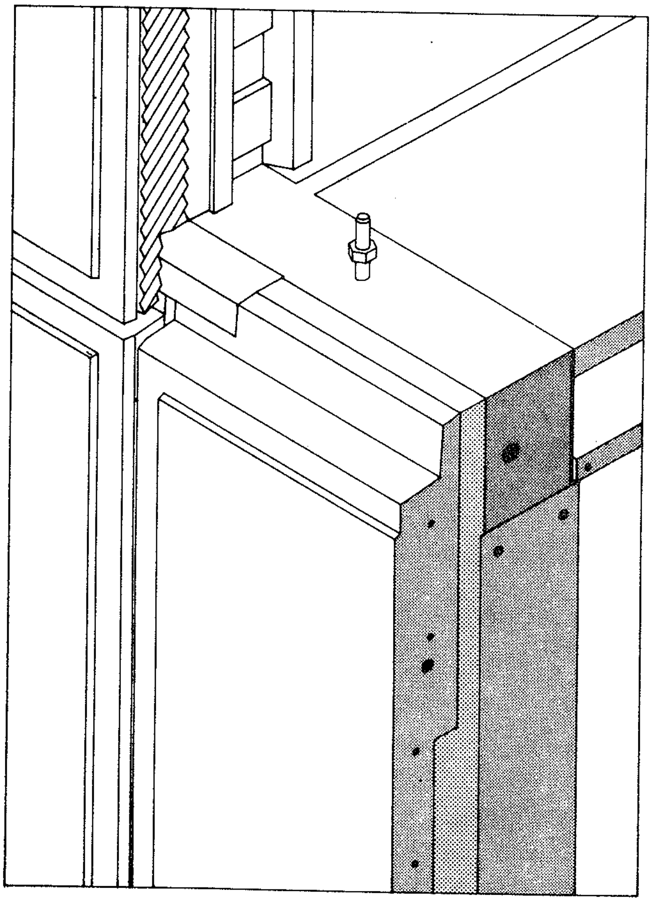
(Light) facade-gable

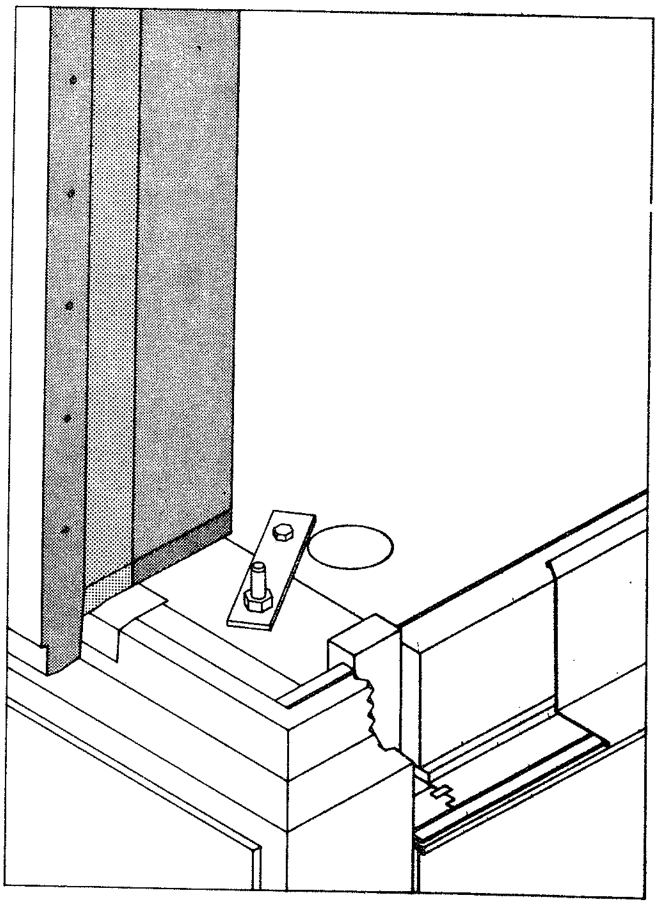
(Light) facade-cross wall

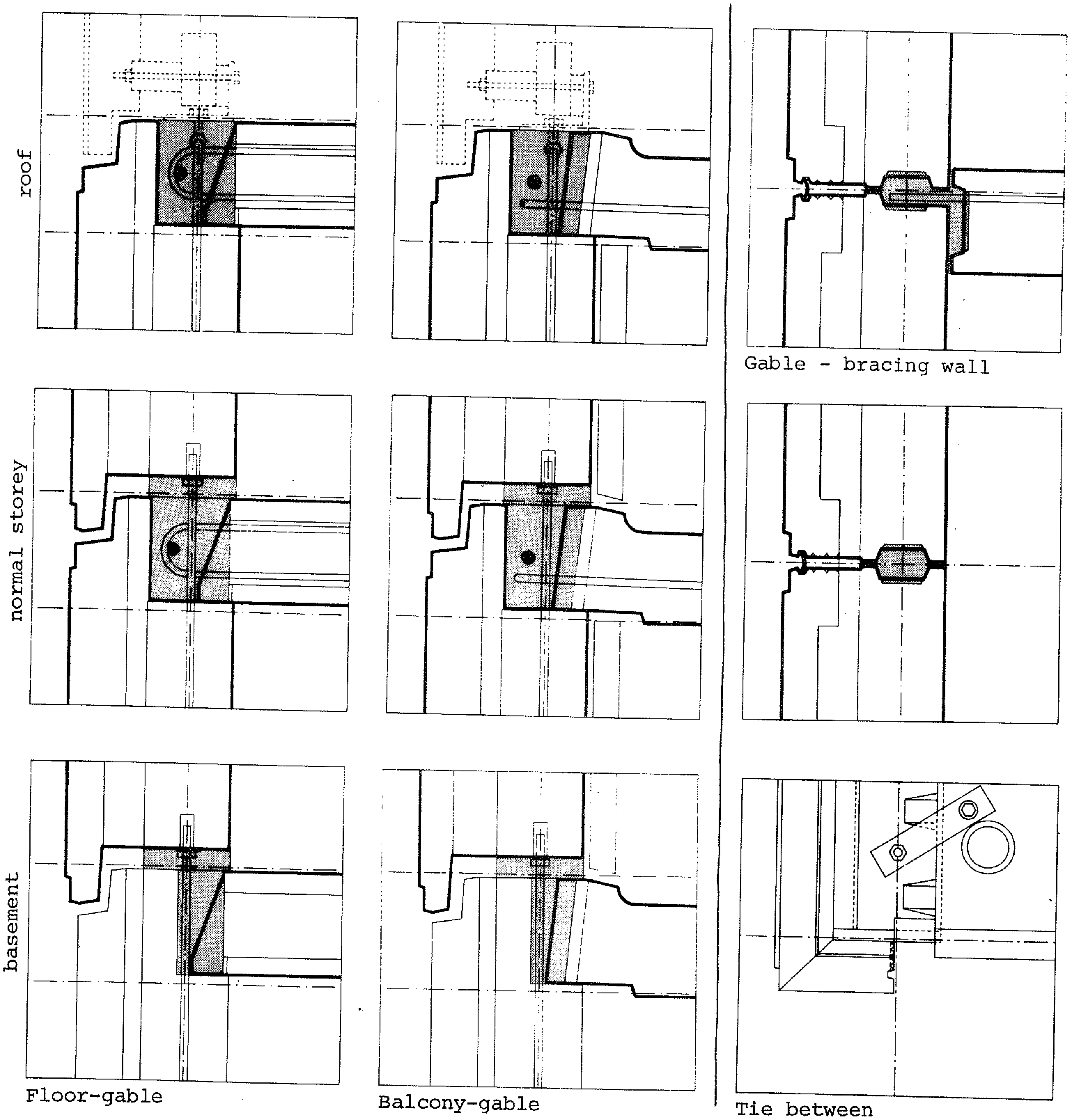


Floor-gable joint





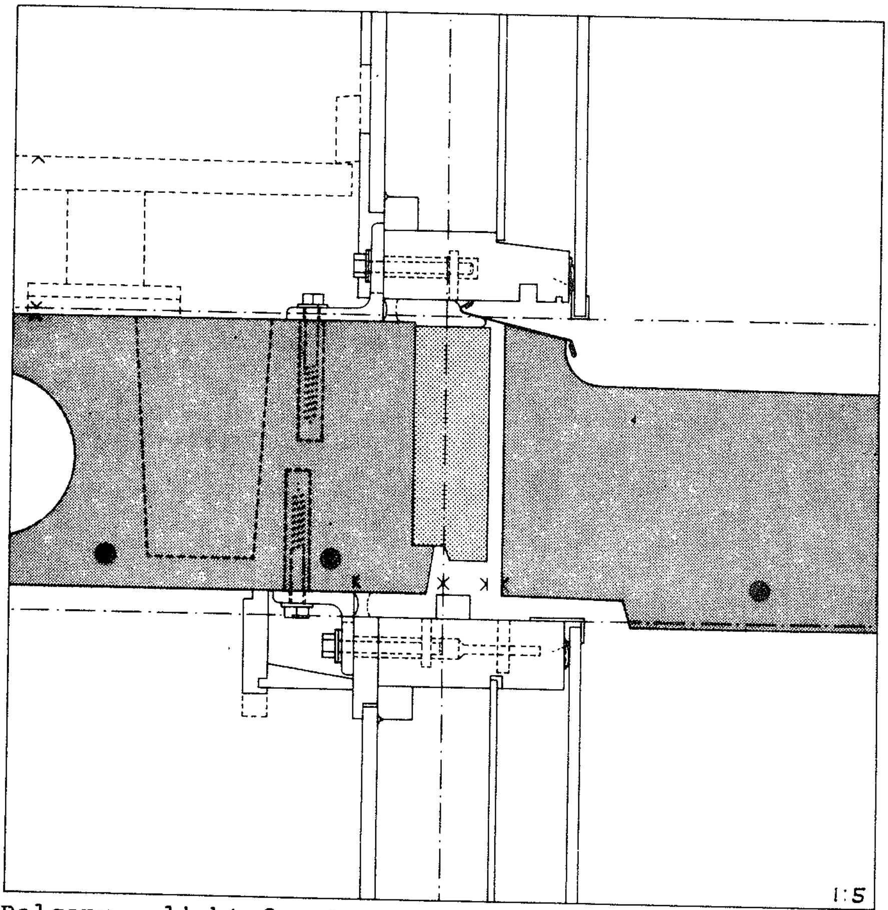


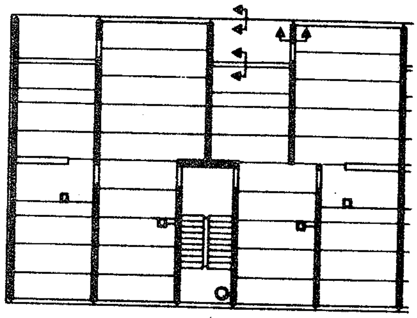

Floor-gable

Balcony-gable

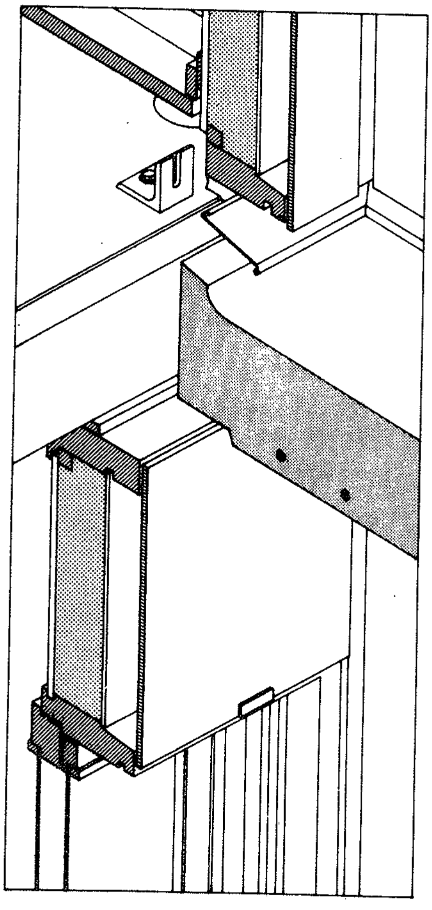
Gable - bracing wall

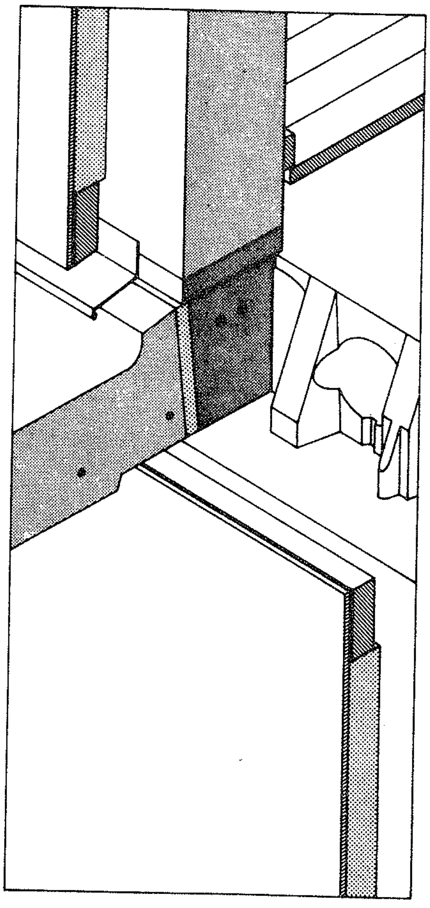
Tie between floor and gable

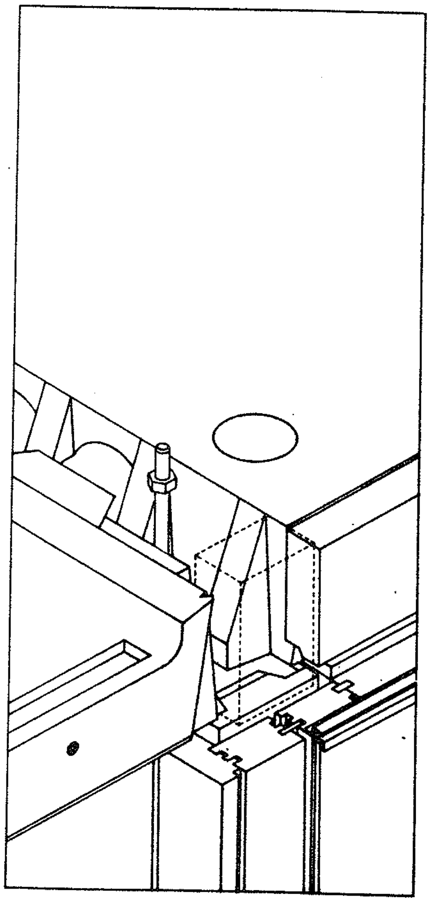


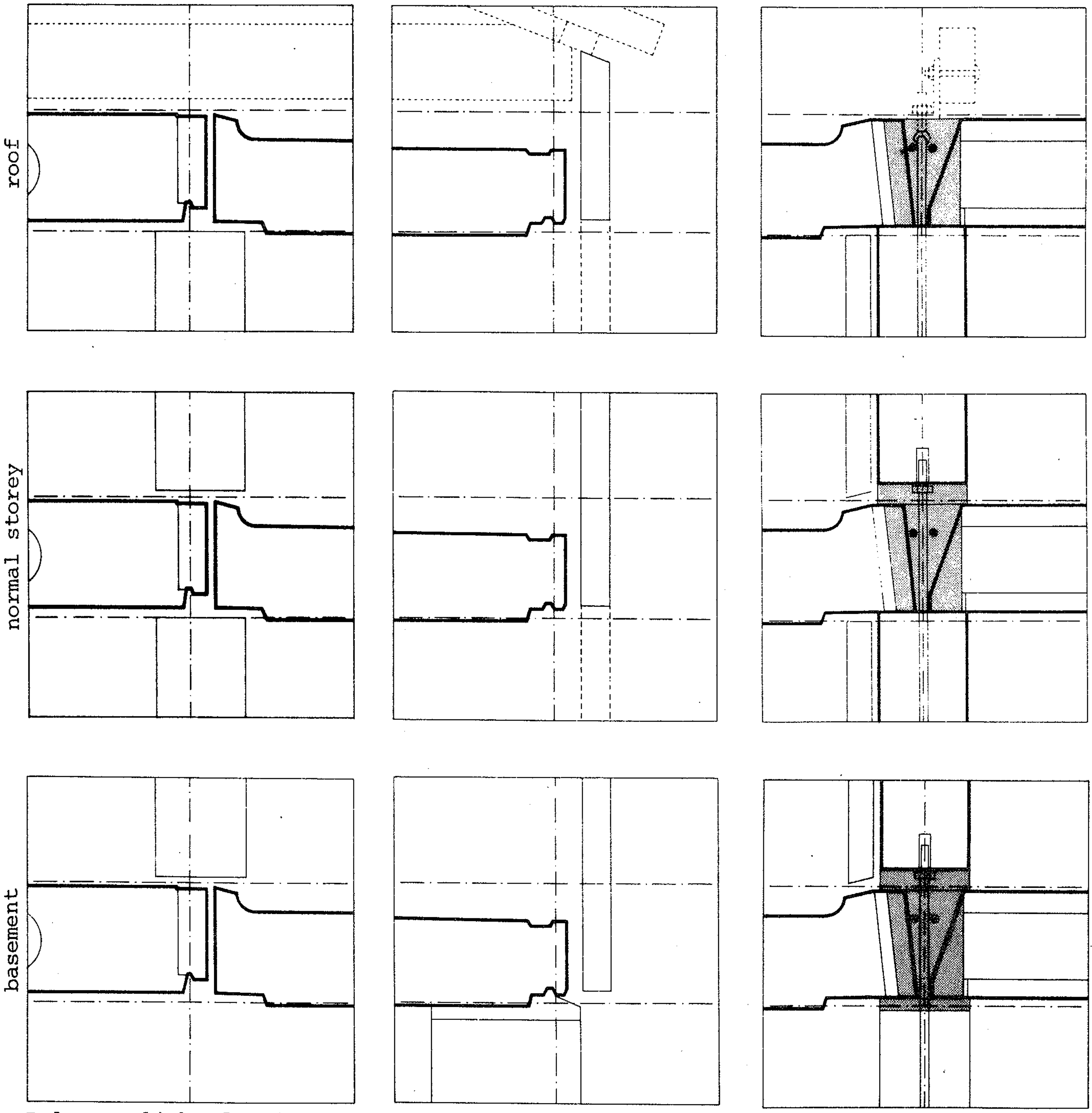



Balcony - light facade





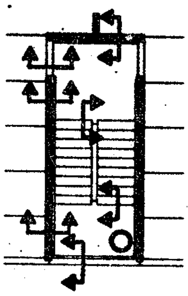
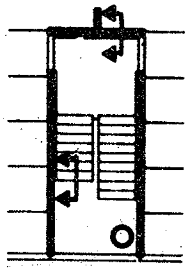
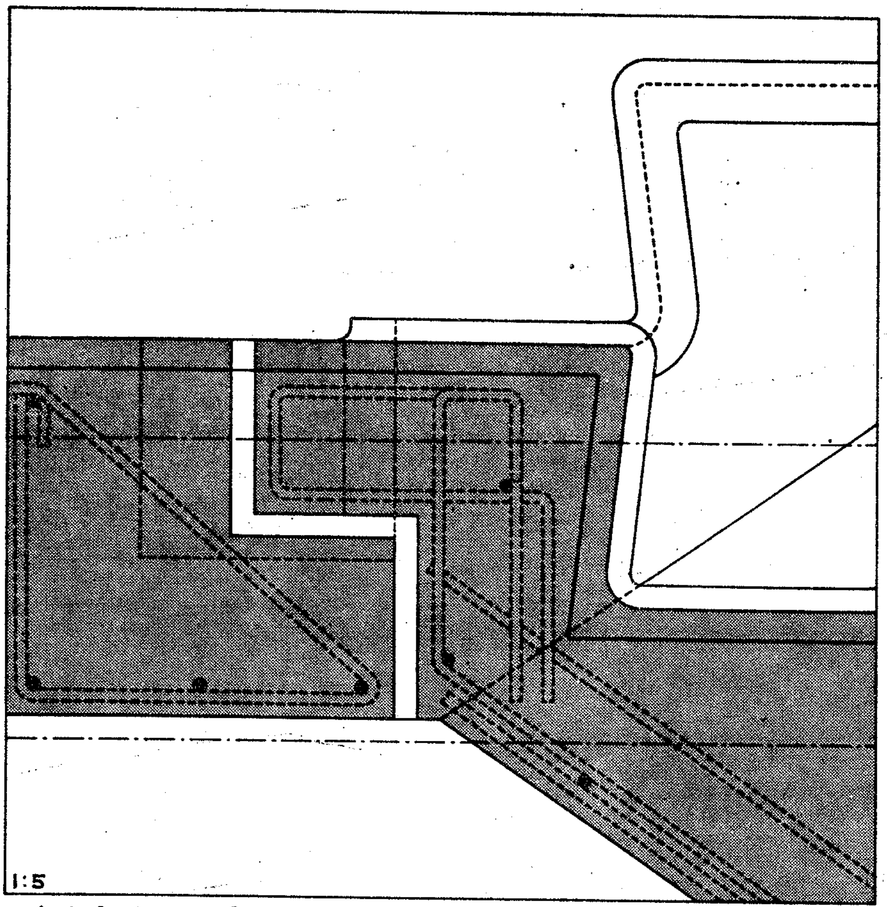




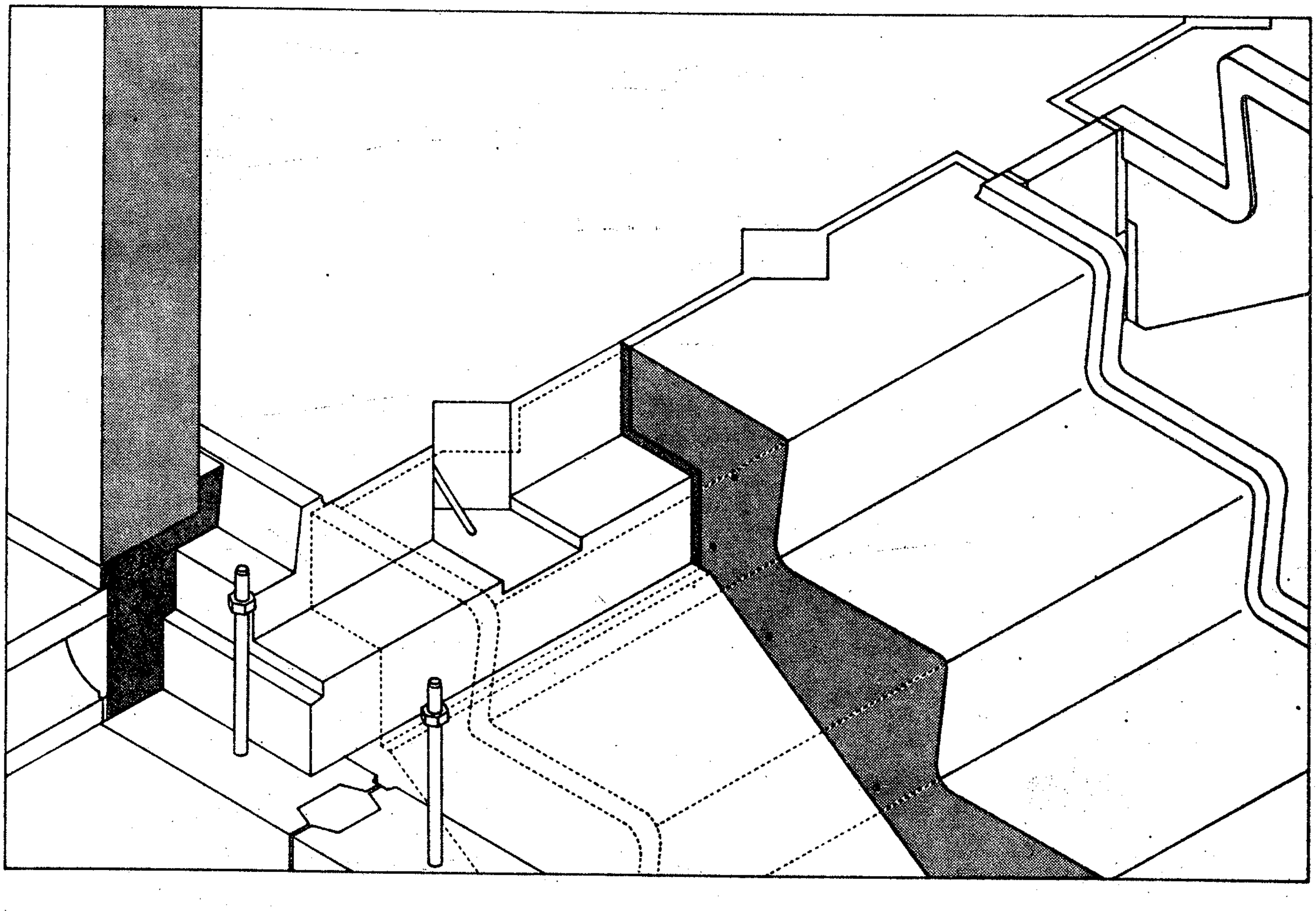

Balcony - light facade

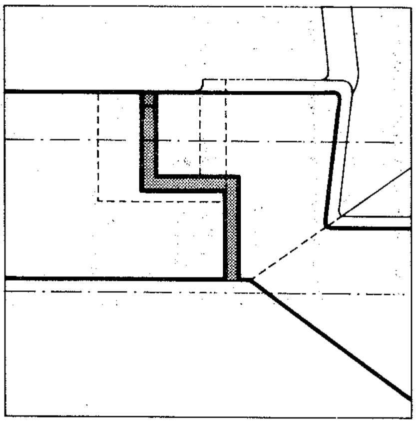
Balcony parapet

Balcony - cross wall

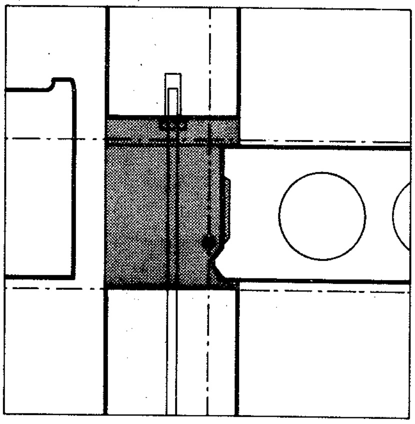





Joint between landing and flight

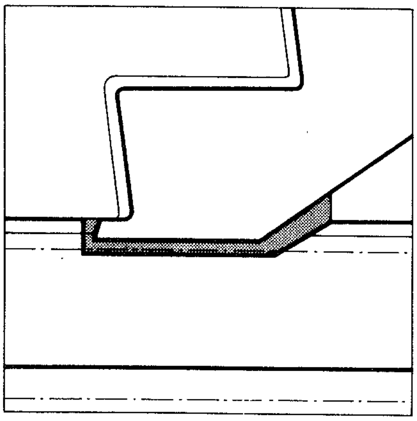




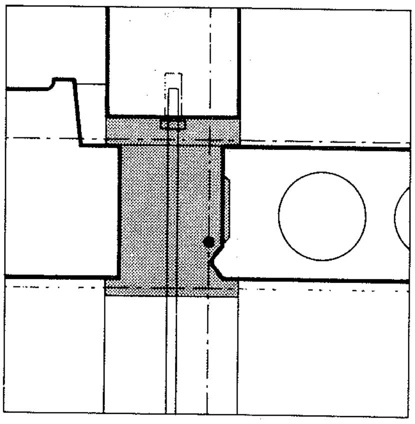
Half landing - flight



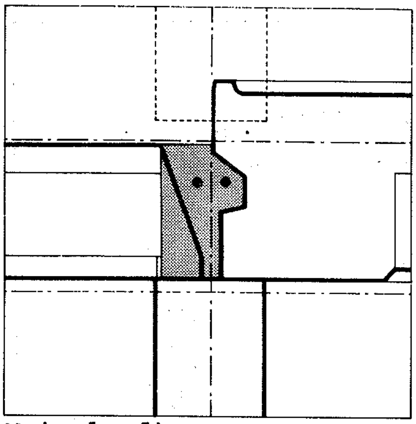
Main landing - cross wall



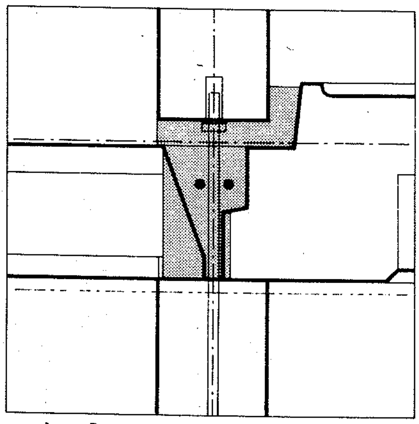
Ground floor - flight



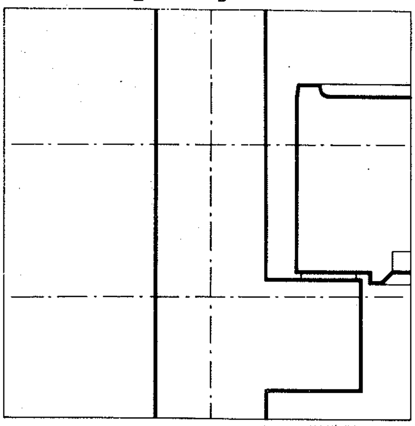
Main landing
- cross wall
(ground floor)



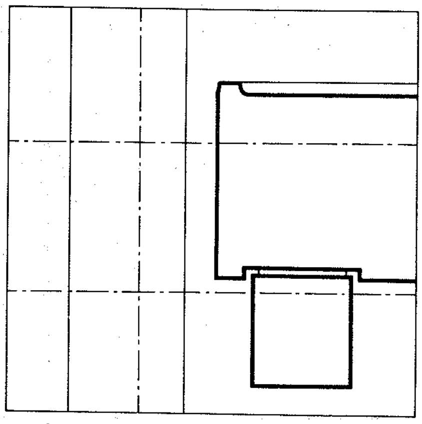
Main landing
- door opening



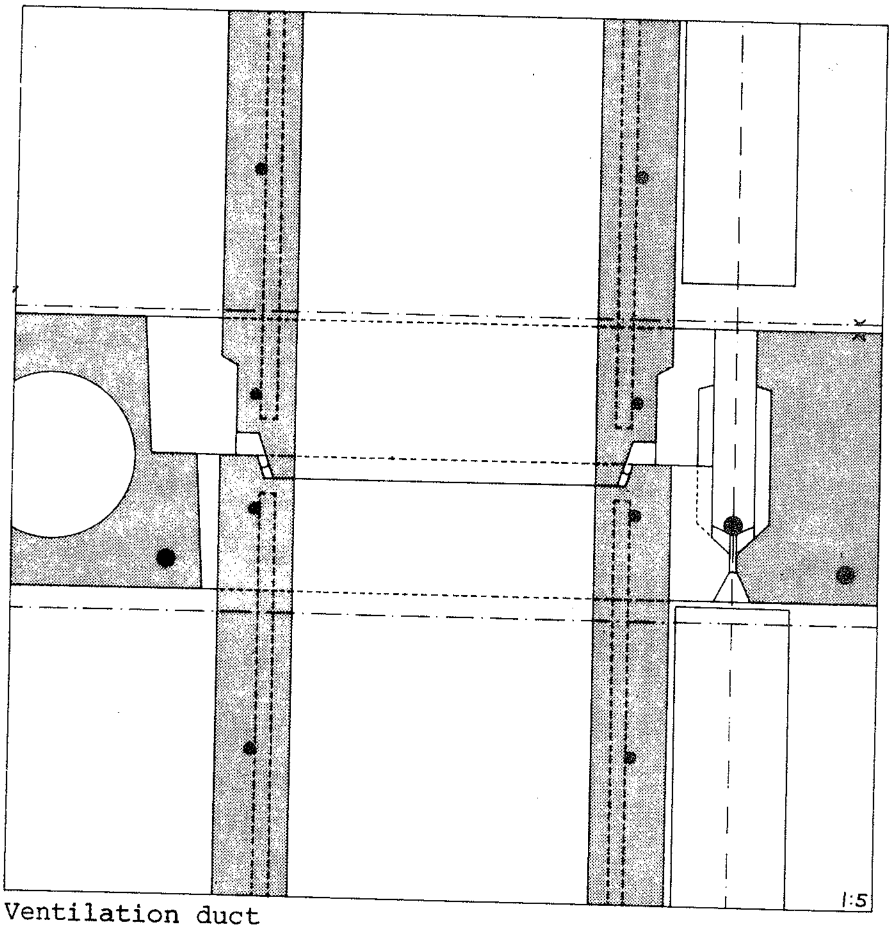
Main landing - cross wall

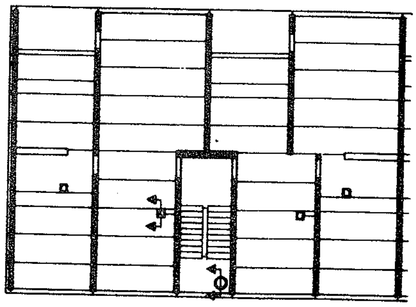


Half landing
- cross wall

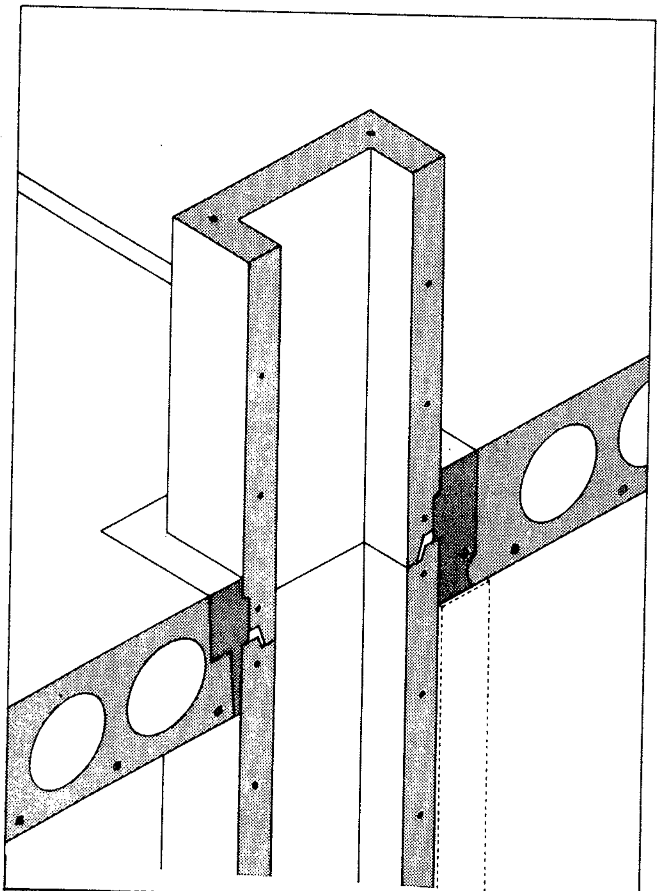


Half landing - facade

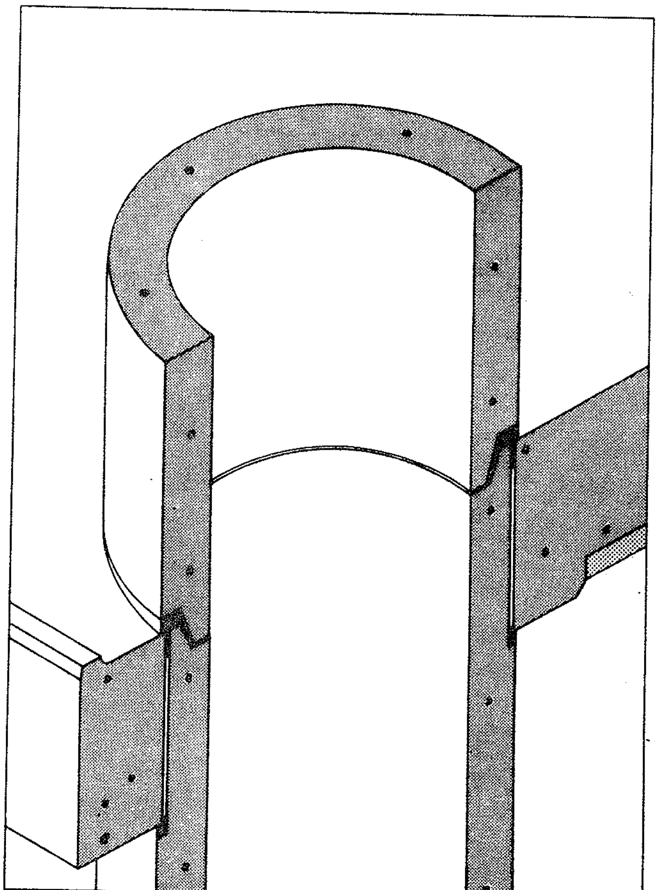


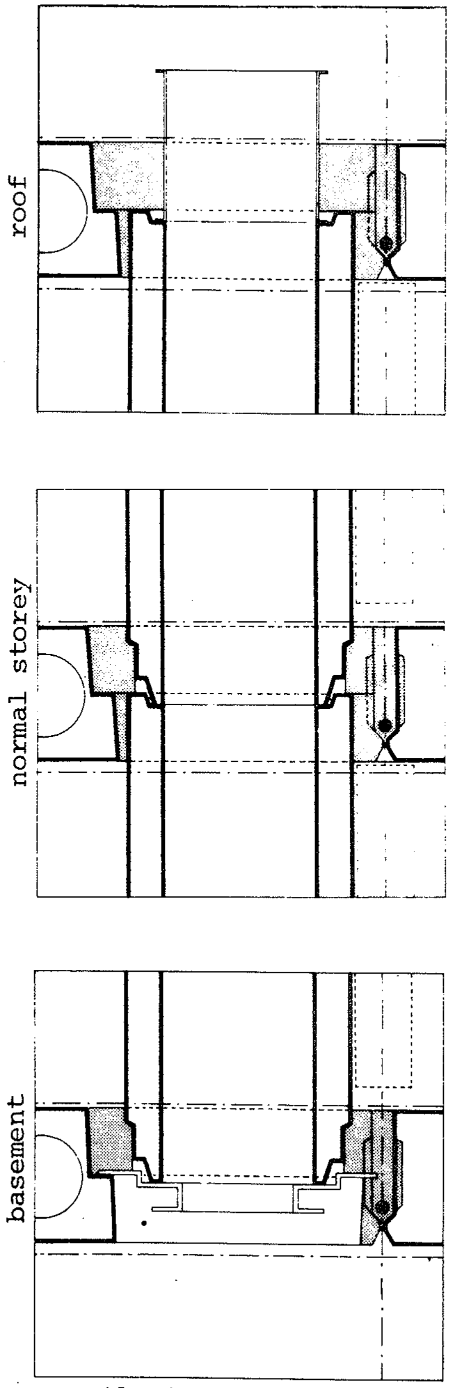
Ventilation duct



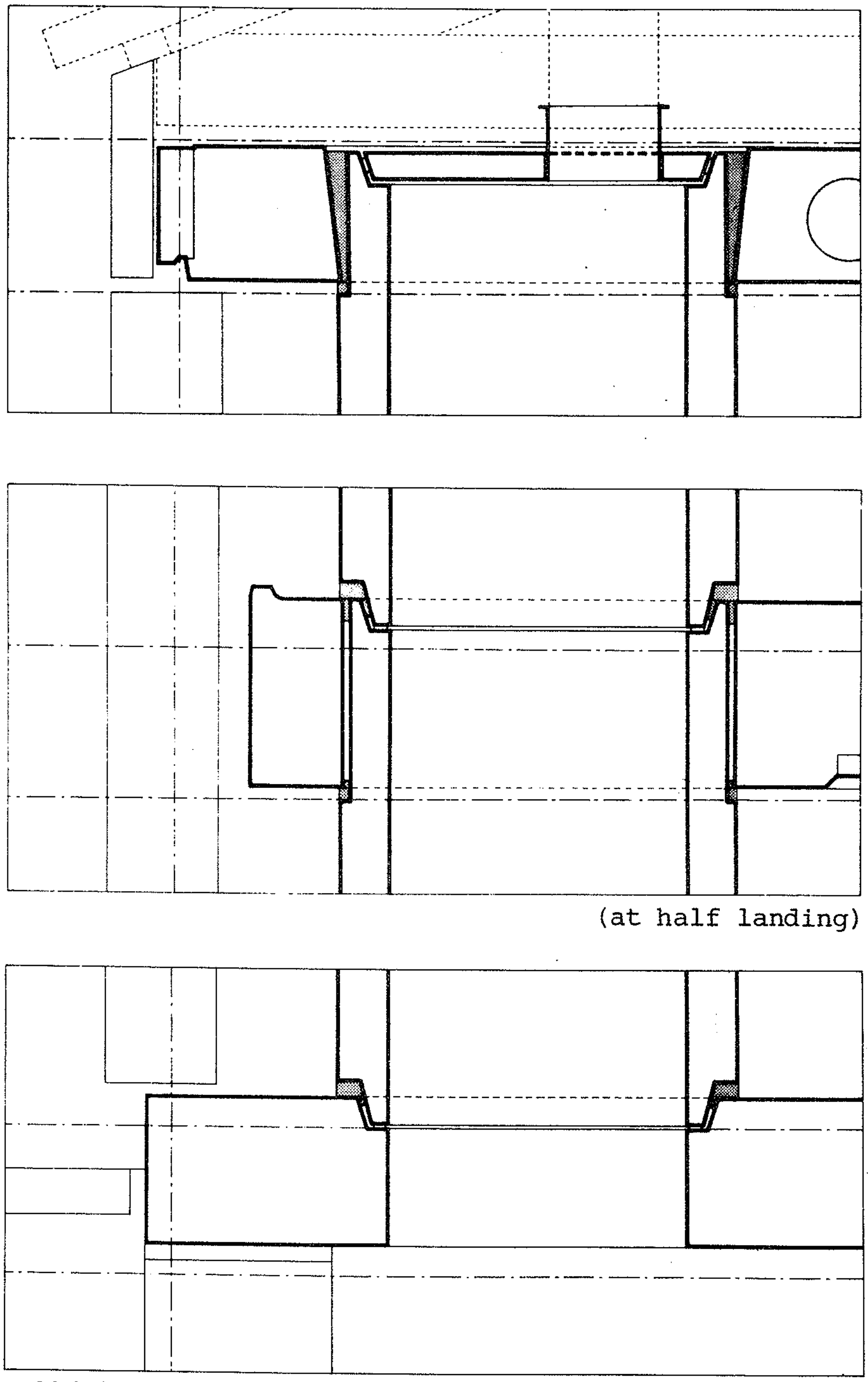
Ventilation duct



Rubbish chute




Ventilation duct




Rubbish chute

(at main landing)

## THE ERECTION PROCEDURE

Lemming & Eriksson, Consulting Engineers, Denmark.

This report illustrates some of the precautions taken to secure a safe execution of the structural joints in precast system buildings, by a typical example taken from the Danish Standard System.

By means of an example of the erection sequence of the Danish Standard System the report illustrates typical steps taken to ensure that the structural joints are made in such a way that the assumptions for the structural calculations and laboratory tests are satisfied.

### INTRODUCTION

Precast concrete units are commonly produced in well-equipped concrete element factories guaranteeing a uniform and well defined product.

Standardization of structural components and joints have stimulated laboratory research on their resistance characteristics.

Greater structural safety should be a result from this approach.

Too often, however, the actual site conditions from making the structural joints are neglected by the designers, although the very execution at the site is of paramount importance for the structural safety.

Danish system building emphazises therefore erection procedures which "automatically" secure a correct execution.

A primary aim of any erection and assembly of structural components is to achieve well defined conditions for the site operations. This will, to a great extend, exclude the need for strict supervision.

Among the site conditions influencing the quality of the structural joints the report will be limited to the following two conditions, i.e.

geometrical conditions and
climatic conditions.

## GEOMETRICAL CONDITIONS

Joints and erection procedures should allow for

a) an easy grouting process of the joints and
b) a stable outer boundary of the joints.

Re a) Joints should be designed with ample space to allow for a proper filling around the reinforcement.

Re b) The erection should be so that no further adjustment of the position of the precast units is needed after the grouting of the joints, as any such motion of the units may harm the hardened joint grout.

## CLIMATIC CONDITIONS

Joints and erection procedures should allow for protection of joint concrete against

c) frost
d) sun and wind (fresh concrete)

Re c) Frost destructs the "skeleton" of the fresh concrete as it leads to the formation of free ice in the concrete.

An uncontrolled reduction of the strength of the joint concrete is the result: Therefore joints and the grouting of the joints are so arranged that a frost free grouting process is ensured during all seasons.

Re d) Sun and wind may dry out the relative small amount of concrete in the joints, if these are left unprotected before the concrete is well cured. Therefore all joints should be protected.

ERECTION STEP 1.

The erectionprocess starts with the erection of the wall units. But before the wall units are put into place, a levelling of the nuts of the correctly positioned erection bolts is taken place. The levelling is done by a simple wheel with a mark indicating the reference level, (fig. 1).

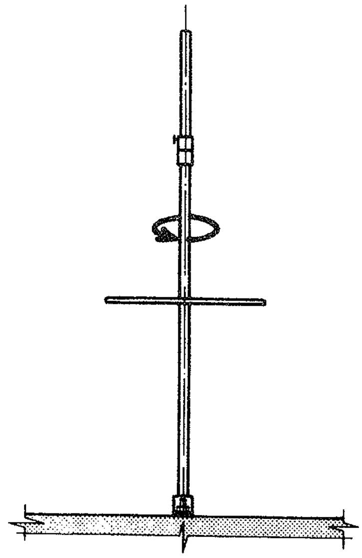


Fig. 1 Levelling

ERECTION STEP 2.

The load-bearing wall units, including exteriour load-bearing walls, are hoisted into place and are preliminarily supported by adjustable props fixed to the floor (fig. 2) and bracing links in the vertical wall joints (fig. 3). These two types of bracings are swiftly applied to allow the crane to leave the wall panel immediately.

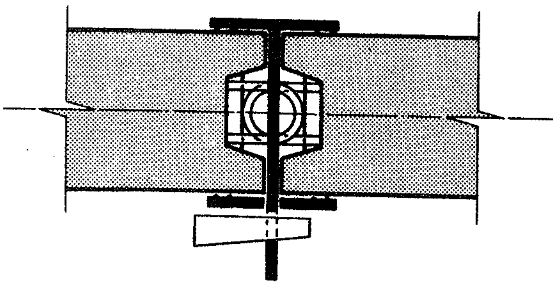


Fig. 3 Prel. Bracing

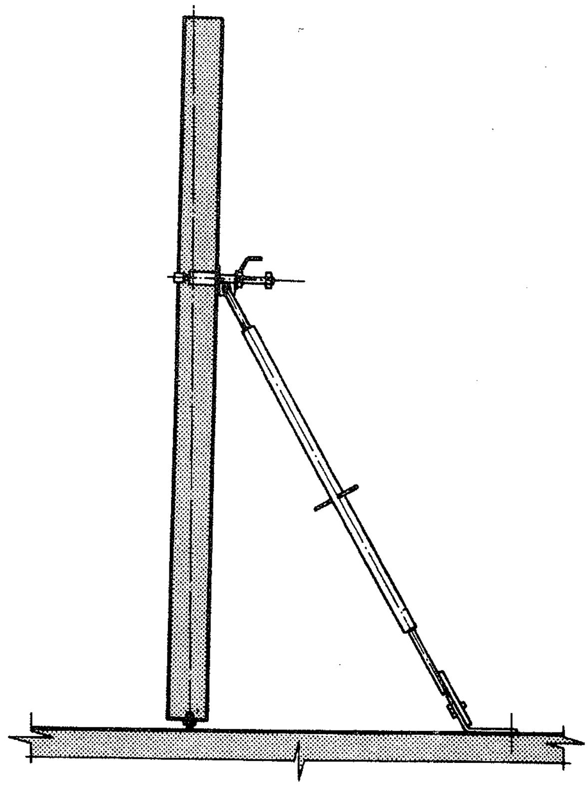


Fig. 2 Erection of wall unit

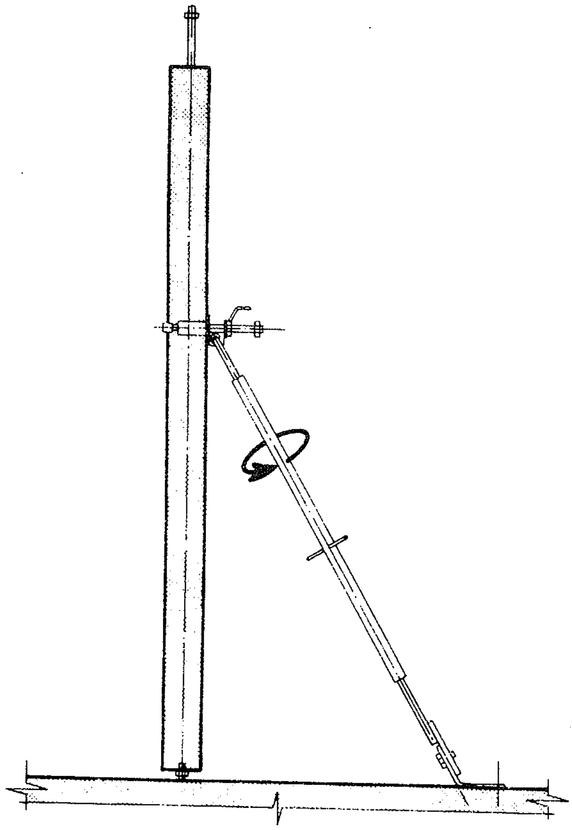


Fig. 4 Adjustment

ERECTION STEP 3.

When the very erection is finished a final adjustment is taking place rising the wall unit to plumb (fig. 4) and aligning neighbour units (fig. 5). It is here essential that no grouting along the periphery of the unit has taken place as such gouting might be spoiled during this rectification.

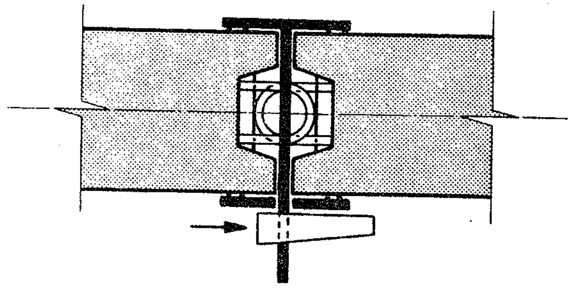


Fig. 5 Alignment of wall panels

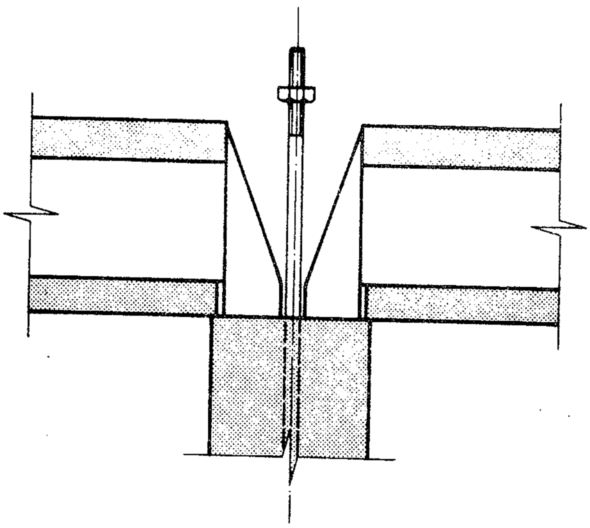


Fig. 6 Erection of floor panels

ERECTION STEP 4.

Now the floor units are erected. These are placed directly on the top of the wall panels (fig. 6). Immediately after establishing the floor the distance between the bolts of the wall units is checked by special prepared gauges (fig. 7). Skew bolts are corrected.

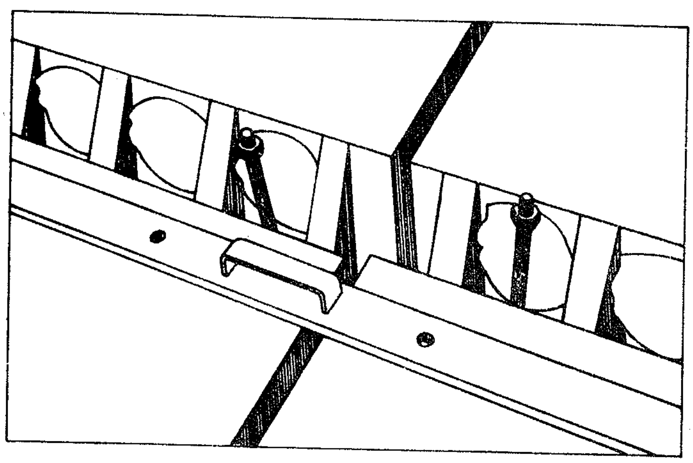


Fig. 7 Checking the bolt distance

ERECTION STEP 5.

Finally the storey under erection is closed:
- : Joints of load-bearing facades are packed with mineral wool (fig. 8) and a neoprene gasket is inserted (fig. 9), resulting in the weather tight ventilated and drained joint (fig. 13).
- : Non-load-bearing facades are erected and the joints are closed (fig. 10),
- : and - in the cold seasons - insulating mats are placed above the open floor joints (fig. 11).

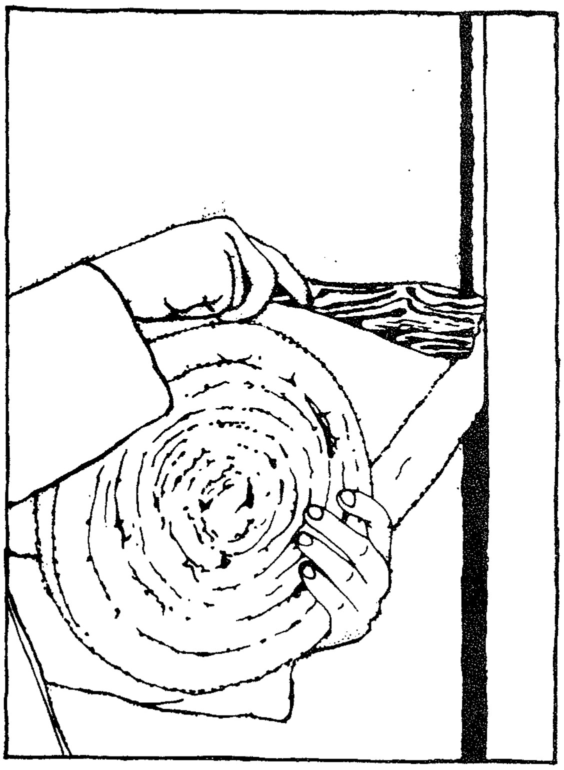


Fig. 8 Packing with mineral wool

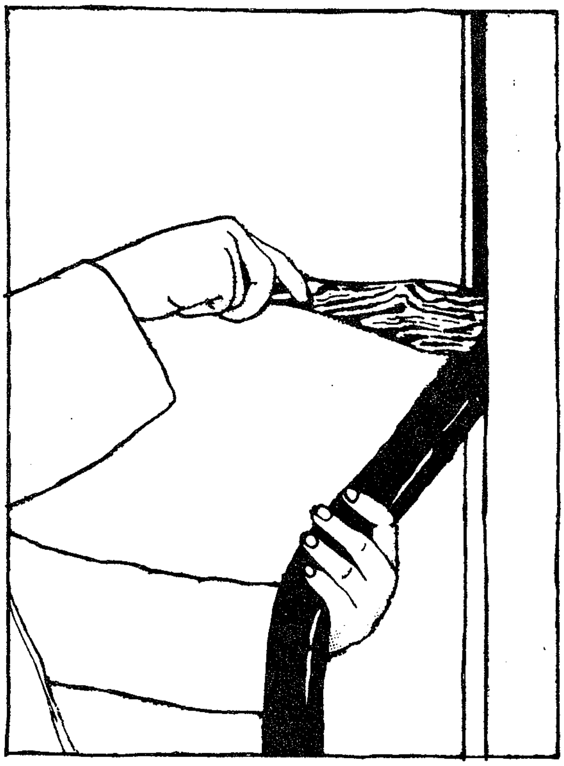


Fig. 9 Insert of neoprene gasket

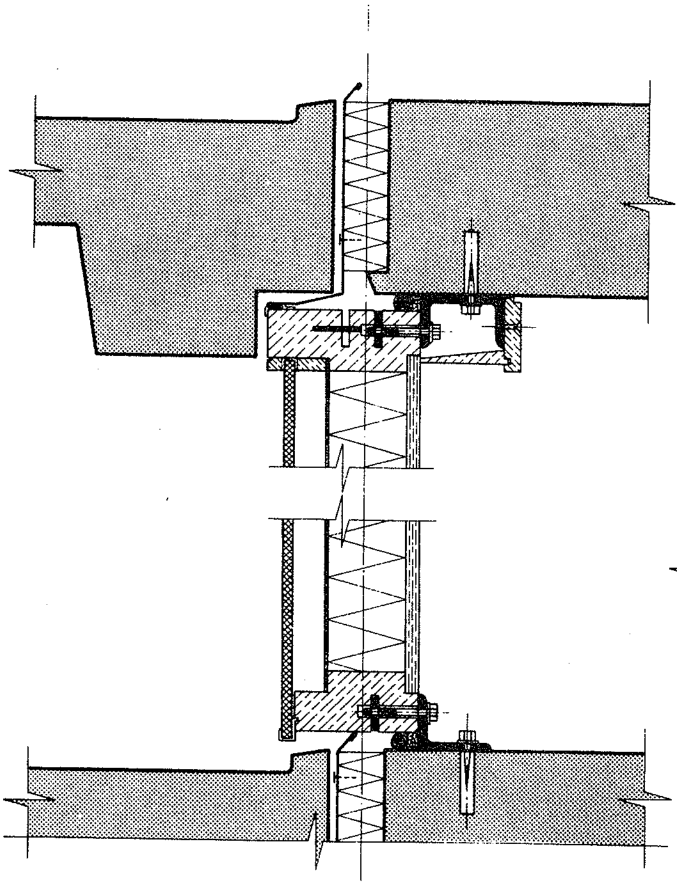


Fig. 10 Facades

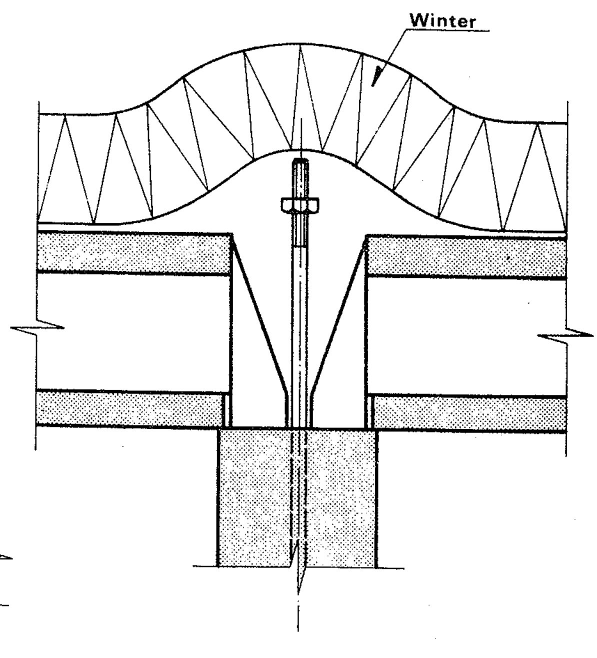
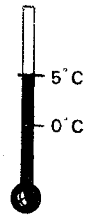



Fig. 11 Insulated joint




ERECTION STEP 6.

Precautions are taken to assure that the air temperature of the now closed storey under erection is not below 5°C. During cold seasons it may be necessary to heat the rooms for instance by blowing hot air into them. This can be done economically as the building is already closed and insulated.

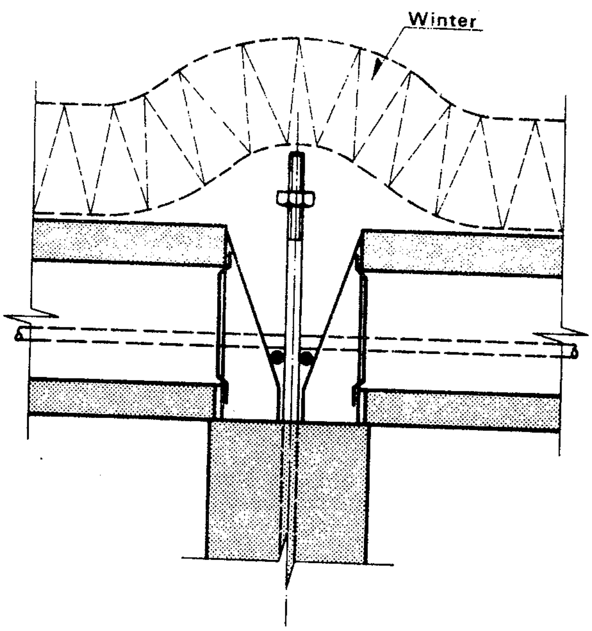



Fig. 12 Preparation of wall/floor joint

ERECTION STEP 7.

Now the joints are being prepared for grouting: reinforcement is placed in all horizontal floor joints (fig. 12) and in some vertical joints (fig. 13 and 14).
If necessary foamnylon strips are inserted in the joints serving as "shuttering" during the later grouting.

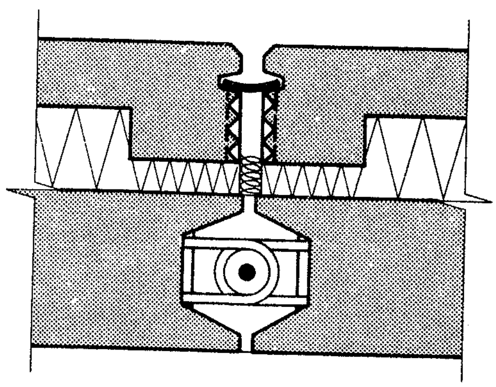


Fig. 13 Preparation of vert. wall joint

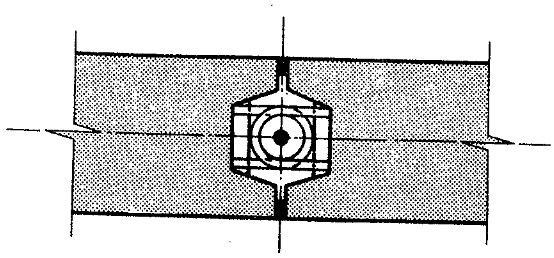


Fig. 14 Preparation of vert. wall joint

ERECTION STEP 8.

Dry mortar is packed under the wall units using an effective tool and packing against a preliminary, well fixed shuttering (fig. 15). Only around the bolts, "pockets" are left open.

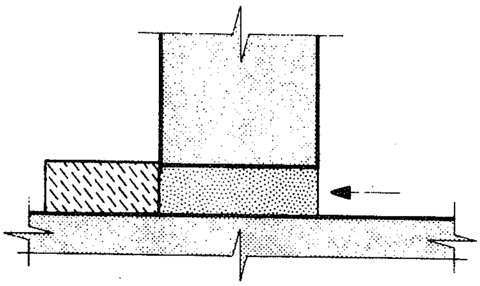


Fig. 15 Packing with mortar

ERECTION STEP 9.

Vertical wall joints are grouted. Ample space provide for proper filling (fig. 16 and 17).

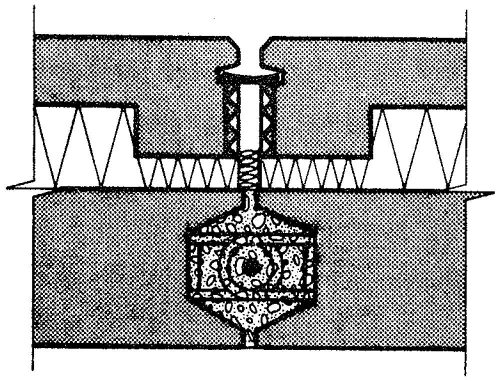


Fig. 16 Grouting the wall joint

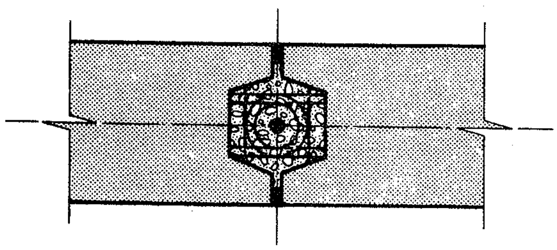


Fig. 17 Grouting the wall joint

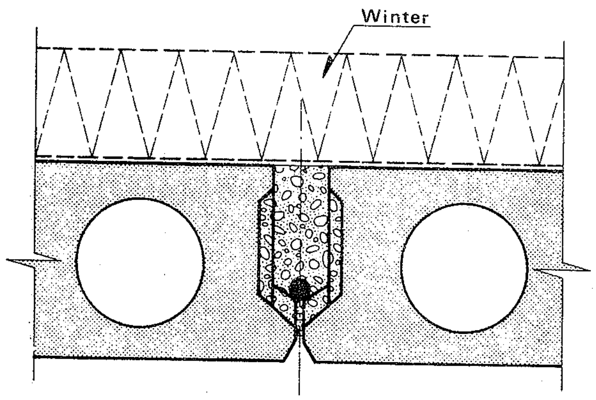



Fig. 18 Grouting

## ERECTION STEP 10.

Horizontal floor joints are grouted. Different joint shapes (fig. 18 and 19) may require different consistencies of the grout.

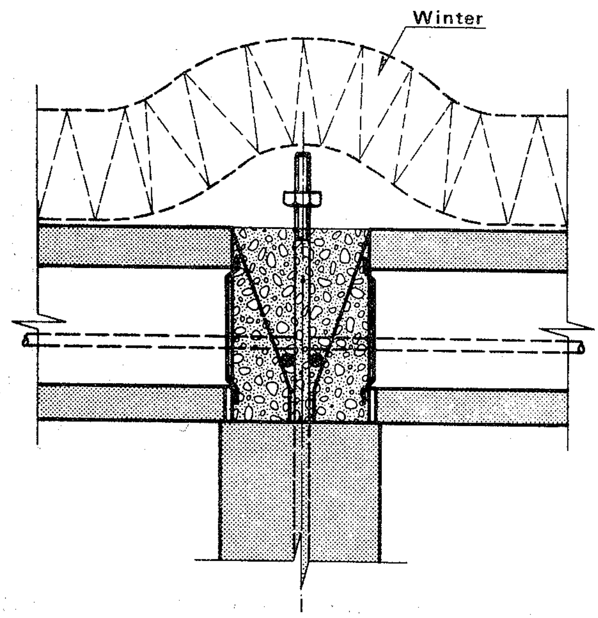



Fig. 19 Grouting

## ERECTION STEP 11.

Finally – when the grout has hardened the bracing props and the bracing links are removed, the erection bolts are loosened (fig. 20) and dry mortar is packed in the "pockets" around the bolts (fig. 21).

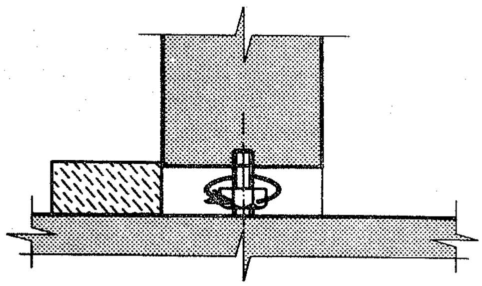


Fig. 20 Loosening the nuts

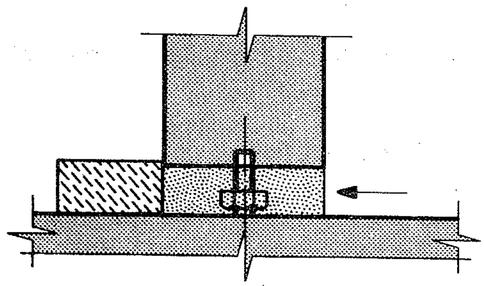
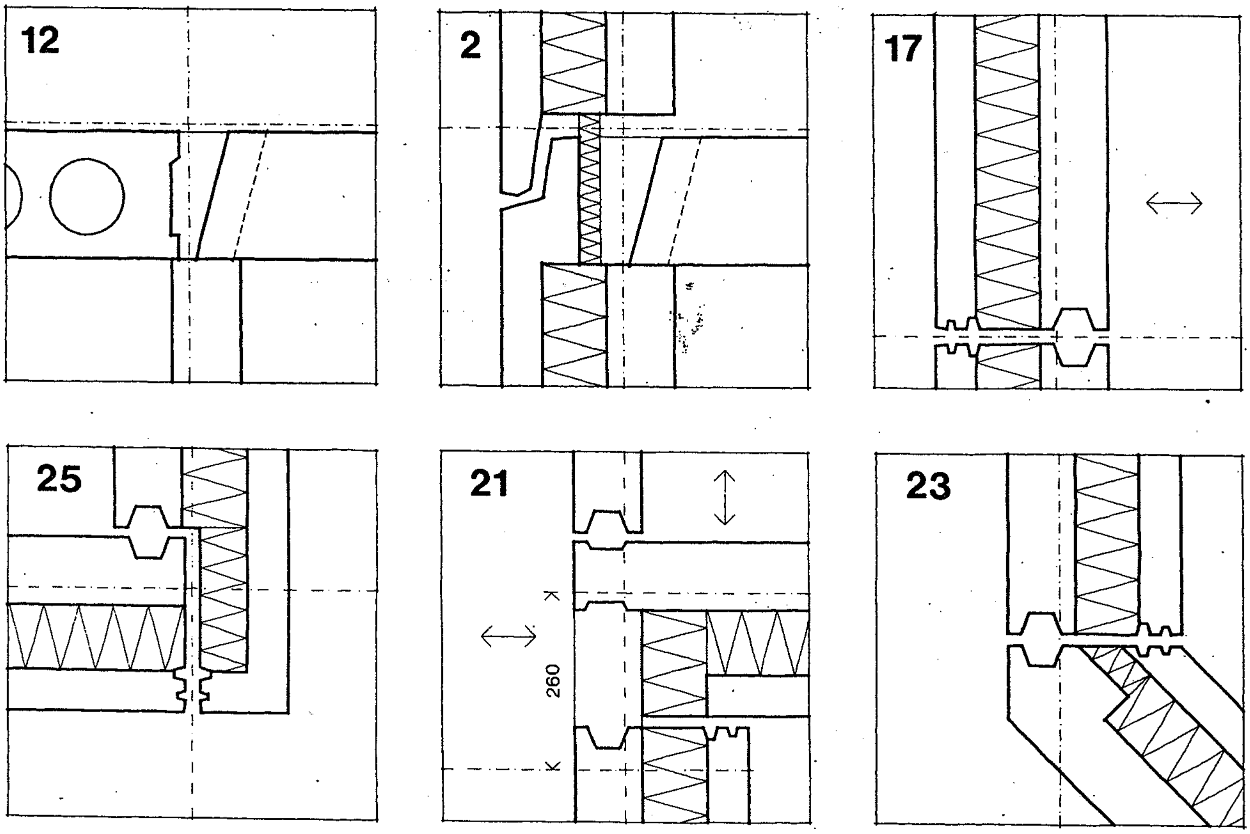


Fig. 21 Packing the "Pockets"




1984-details are like the 1965-ones, but have additional features

From "BYGGETEKNISKE DETALJER", Danish Building Research Institute, SBI-SÆRTRYK 306, 1984, I have taken a few figures which might illustrate that 1984-details are in principle like 1964-details, with slight improvements, and additional features.

Compare 12 with the figures pages 5, 22, 23, 24. Today, a house often have spans in orthogonal directions. 1965-houses had cross-walls (or spinewalls and load-bearing facades). Today, the principles are mixed to allow for a more flexible design.

Compare 2 and 17 with figures pages 17, 30, 31. The only difference is that the thermal insulation today is up to 300 mm thick (mineral wool).

25 is similar to the external corner, page 29, at the bottom. 25 has two concrete sandwich-panels, the figure on page 29 illustrates a corner with a heavy and a light facade.

21 illustrates a re-entrant corner, an innovation in line with the development of low-rise, high density housing.

23 illustrates a $135^{0}$ corner, another innovation.

Finally, the figures on page 13 illustrate the development in light facades and their joints.