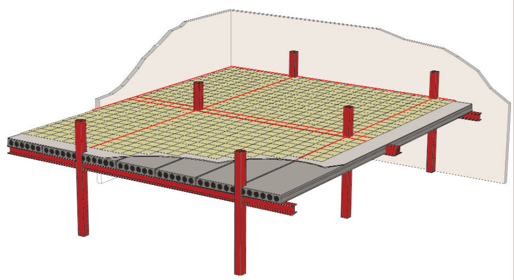
THE MASONRY CATALOGUE 2003 Guidelines **P14**

Tiled precast concrete floor slabs



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1 Introduction

Figure 1.1 Cracked ceramic tiles in concrete element buildings.

Precast prestressed concrete floor elements are often used in the supporting structure of new building projects. They have high strength and high quality. They allow for larger areas without columns, and save space and time at the building site, and they reduce the danger of enclosed moisture.

Therefore floor slabs like hollow core slabs, light-weight concrete-slabs and double T-slabs often become the base for ceramic tiles, terrazzo tiles or natural stone, which can sometimes result in cracks. Such cracks can be seen in office buildings, hotels and shopping centres with large tiled areas. Descriptions in Norwegian standards like NS 3420 and in dimensioning guides from the concrete industry, have not covered the issue of the connection between the supporting structure and the layer of tiles or natural stone. This guide will therefore describe how to plan the construction so that you can provide surfaces that will not be damaged and that require little maintenance.

The recommendations made here are valid primarily indoors, although the main principles are also valid outdoors.

2 Construction methods

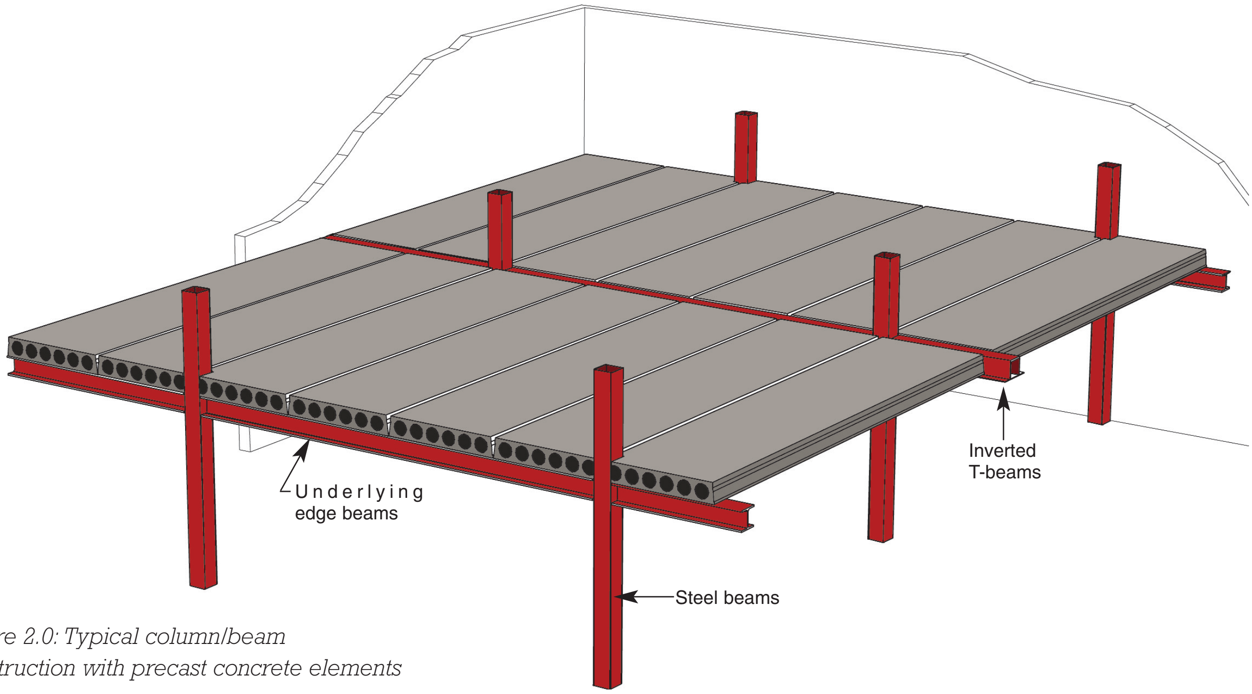


Figure 2.0: Typical column/beam construction with precast concrete elements

2.1 Floor slabs

Hollow core slab constructions in buildings normally have a free span of between 6 and 12 metres. The most common thicknesses of floor slabs are between 200 and 320 millimetres. Thicker floor slabs give correspondingly longer free spans. The distance between the columns are normally from 6 to 8.4 metres. (Figure 2.0)

When extra high loads and long spans are needed, double T-slabs are most often used. These elements span up to 18-20 metres with an element thickness of 500 and 600 mm. In addition double T-slabs that are being used as flooring always have a 50-100 mm concrete topping. If floor slabs made of light expanded clay aggregate (LECA) or porous concrete are used, the spans are rarely longer than 6-7 metres.

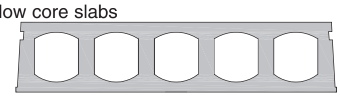
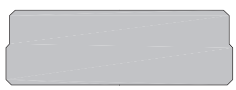
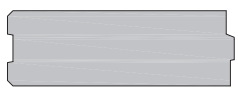
Types of floor slabs	Width mm	Most common thicknesses mm	Common free span metres	Cross-section
Hollow core slabs	1200	200–320	5–14	Hollow core slabs 
Double T-slabs	2400	500–600	12–18	DT 
Leca planks	600	150–300	3–7	Leca 
H+H Celcon Floor slabs	600	150–300	3–6	H+H Celcon 

Table 2.1 Common types of concrete floor slabs

2.2 Beams and connections

Beams in concrete element buildings are either made of steel or of concrete supported by columns of concrete or steel. Precast concrete elements can be prestressed or reinforced. Prestressed slabs are produced with a camber.

The load capacity, span and stiffness are provided according to the specific demands of the construction. Typical connections for slab construction are shown in figures 2.3.1, 2.3.2, and 2.3.3

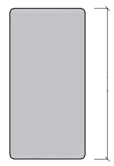
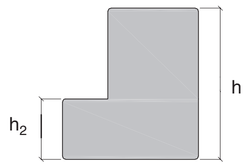
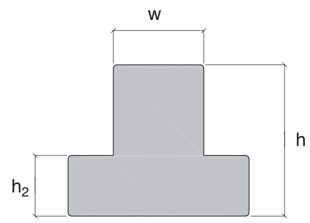
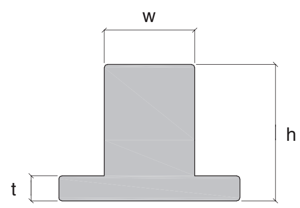
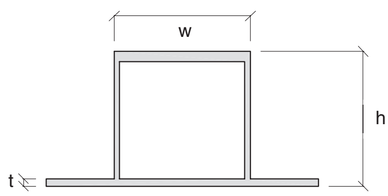
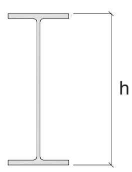
Description	Cross-section
Rectangular concrete beam (RB) Used for underlying bearing of floor slabs in middle axis = 400–600mm	
Concrete flange beam (LB). LB-beams have a one-sided support along the edge of the slab. h = 400–600 mm h_2 = 150–300 mm	
Concrete flange beam (DLB). DLB-beams are double LB beams for two-sided slab support h = 400–600 mm h_2 = 150–300 mm w = width of column	
Inverted concrete T-beam (HB) w = width of column h = 250–400 t = 50–100	
Steel T-beam (HSQ) Used for two sided slab support h = thickness of slab t = 10–15 mm w = 200–300 mm	
I- steel beam (IPE/ISQ) Normally used along the outer axis h = 300–500 mm	

Table 2.2: The most commonly used supporting beams and their typical dimensions

2.3 Deflection and rotation of elements

Beams and floor slabs will deform due to their own weight and the supported load. We also know from experience that shrinkage, creep and relaxation in the prestressed slabs after the tiles have been placed can make significant differences over time. Prestressed slabs can also have an increased camber over time. The deformation of the deck construction after the tiles have been laid, results in rotation of the connections. This rotation may lead to cracks in the tiles. Rotation of connections is seen as the most serious deformation for tile constructions on concrete slabs. A typical column/beam construction can be seen on figure 2.0.

Traditionally, beams and concrete slabs are dimensioned according to the recommended maximum deformation allowable in the appropriate design code. This is done without necessarily bearing in mind whether the finishes are stiff or elastic, and whether they can tolerate the deformations that will occur.

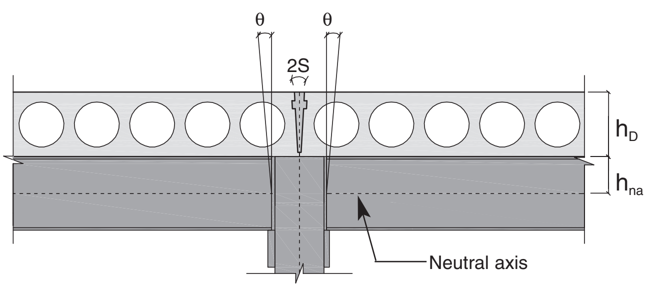


Figure 2.3.1: Element rotation at the beam support

2.3.1 Rotation movement at beam support and column axis

Deflection of beams as in figure 2.3.1 results in rotation deformation θ at the support zone, which again results in a crack in the longitudinal joints between the hollow core slabs as in [2S].

$S = \theta(h_D + h_{na})$
$\theta = 16\,d / 5L$
d = expected deflection
L = span

The beams will rotate about the neutral axis. The supporting construction together with the beam and the depth of the floor slab determine the total rotation [2S] at the top of the slabs in the longitudinal joints of the deck at the columns axis.

To reduce the risk of cracking, the beams must either be made stiffer or the connections must be constructed so that the distance between the beam's neutral axis and the top edge of the slab is minimal.

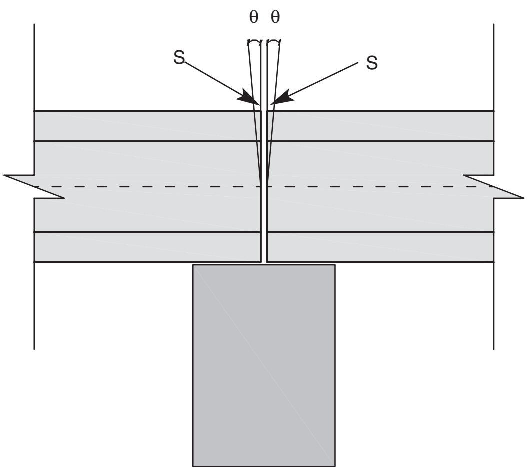


Figure 2.3.2: End rotation over underlying beam

2.3.2 Rotation movement by the support zone

When the hollow core slabs deflect, it leads to a corresponding rotation in the support zone, and this again may lead to cracks [S] at the end joints. Figure 2.3.2 and 2.3.3. This crack will spread through the levelling material, and possibly the concrete topping and tiles if these materials are not separated from the base. This can be done for example with an antifriction layer or a movement joint.

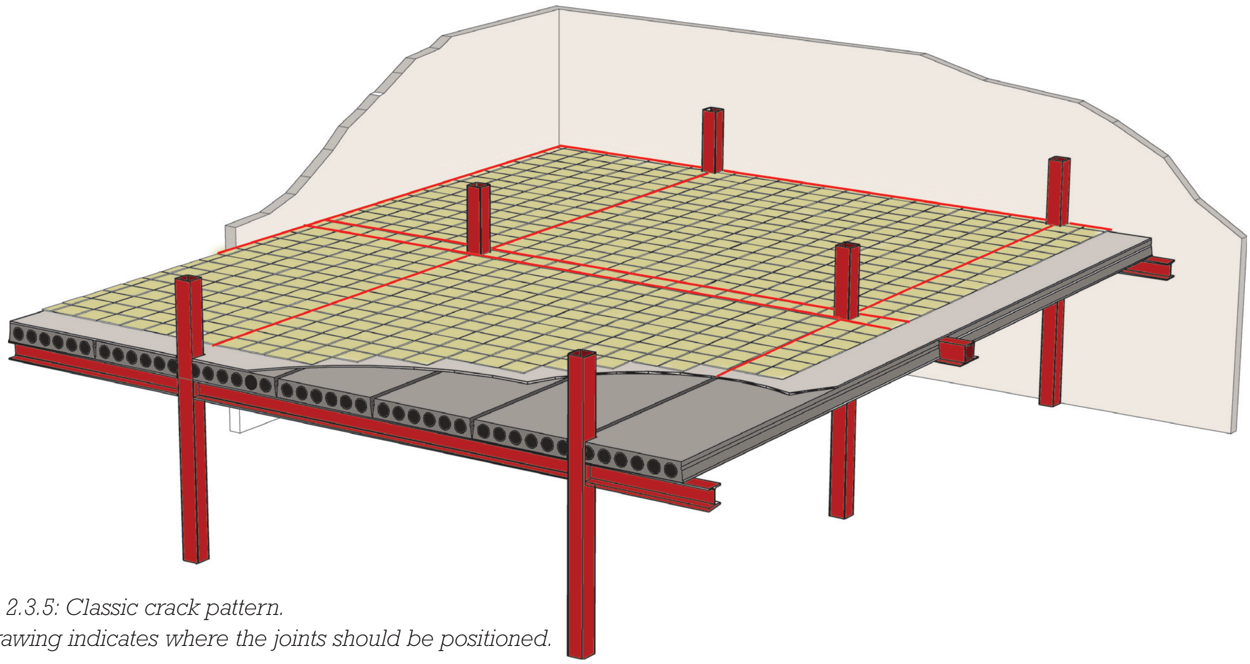


Figure 2.3.5: Classic crack pattern.
The drawing indicates where the joints should be positioned.

When the elements are positioned on top of a beam or a wall as in figure 2.3.2 the total rotation movement is [2S].

When the elements are placed on an inverted T-beam (HSQ-beam), the rotation of the hollow core slabs will lead to two cracks, one either side of the T-beam. See Figure 2.3.3. The rotation movement spreads to the tile layer and this can result in the tiles either cracking or becoming loose. A possible crack pattern is shown on figure 2.3.5. This is a common situation that is often seen on floors with levelling material directly on the elements. Sometimes the beams in the outer axis have a different stiffness to those in the middle axis. This rotation of the whole floor deck may lead to diagonal cracks.

Figure 2.3.4: End rotation results in cracked tiles

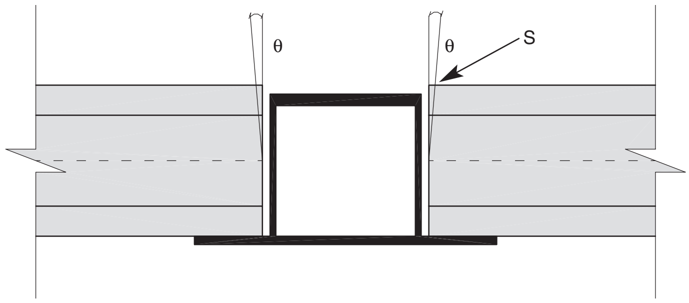


Figure 2.3.3: End rotation on an inverted T-beam

2.3.3 Restricting deflection and camber of the floor slabs

When larger areas are tiled, differences in height will be very visible because of the joints. These irregularities are easily spotted, and makes it important to ensure that people are aware of the most common problems. To ensure that the levelling layer or the concrete topping is not thicker than necessary, the recommendation is that the deflection or camber of the slab should not be more than L/1000 after the levelling layer or concrete topping has been applied. This means that the producer must adjust the prestressing force or put in a top strand in the floor slabs. Alternatively it is also possible to increase the thickness of the slab in order to reduce deflections and camber.

This is a guideline:
$L/h < 38$
L = width of span
h = thickness of slab

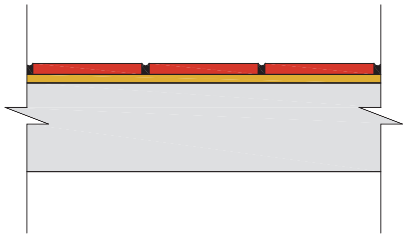
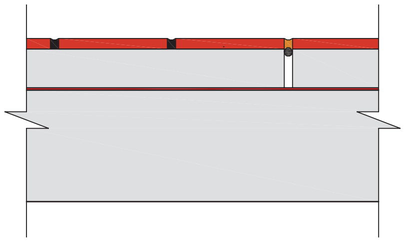
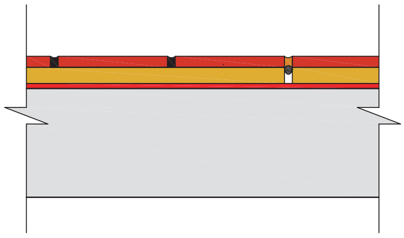
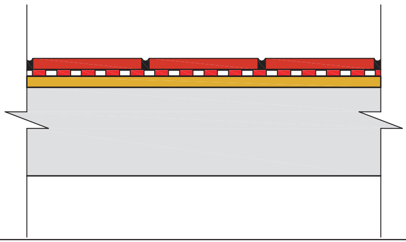
Tiles that are fastened directly onto the floor slabs (firm anchoring).	
Tiles that are on a base that is separated from the slabs with an antifriction layer and concrete topping (antifriction floor).	
Tiles that are on a base that is separated from the slabs with an antifriction layer and concrete topping (floating floor – the LFF-method. A thin antifriction construction.	
Tiles on elastic supports (tension release mats)	

Figure 2.4.1: Alternative floor constructions

2.4 Construction principles for avoiding cracks

Ceramic tiles and natural stone are stiff materials with a high compressive strength but a low tensile strength. The ability to withstand direct clean tension and bending tension is relative to the material, its thickness and not least the way the tiles and the grouting work together. The choice of the floor construction determines whether it can become problem free. There are several types of floor construction available:

- Tiles are fastened directly to the levelled floor, this is also called firm anchoring.
- Tiles on a base that is separated from the floor slabs with an antifriction layer and concrete topping, also called a floating floor.
- LFF-method. A floating construction with a thin antifriction layer.
- Tiles on elastic supports (tension release mats)

2.4.1 Restricting the rotational movement

The rotational movement can be absorbed in three ways to ensure that the tiles will not crack:

- By using movement joints
- By using concrete topping on the antifriction layer
- Combining both methods

When planning to use brittle materials as a finishing material, it is important to keep the total deformation in the tile layer lower than the capacity for tension in the tiles and the glue system. This is done by restricting the end rotation. For tiled concrete flooring it is therefore recommended that the estimated total end rotation from 50% loading and deformation over long time must not exceed 2 mm. This movement can be absorbed by elastic grouting and normal joint profiles. For beams other than inverted T-beams, this means that the total deformations can be kept within the guide figure of approximately L/1200. (Figure 2.4.2)

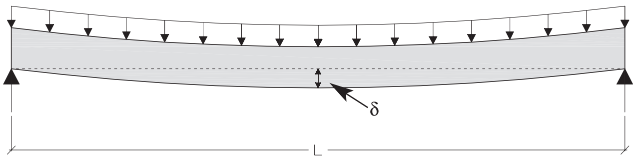


Figure 2.4.2.

Restricting the total deformation means that these slab constructions often have to be made stiffer than the minimum requirements according to building regulations.

For joint free constructions with an antifriction layer, the rotation movement within the tile layer must be restricted to 1 mm. One way of restricting the rotation of the beam ends is to use continuous beams that give a much stiffer beam construction without the concentrated rotational movements. The concrete element producer must be informed of a possible layer of ceramic tiles or natural stone at the tender stage so that they can take this into consideration when calculating and dimensioning the elements. It is therefore important that this is made clear in the drawings and descriptions that the producer is given when providing a tender.

Type of beam	L [mm]	h_{beam} [mm]	Crack in dimension [mm] (2S in fig. 2.3.1)
IPE	7000	500	2
HSQ	7000	270	1
RB	7000	600	2
LB/DLB	7000	600	1,5
HB	7000	365	1

Table 2.4.2: Theoretical crack dimension in a longitudinal slab joint as a result of beam rotation from the deflection of a 50% imposed load and from the deformation over long time of 6mm, (L/1200)

3 Constructions fixed directly to the base

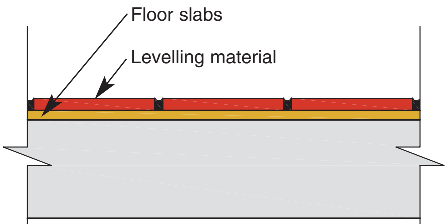


Figure 3.1
Position of joints on precast floors

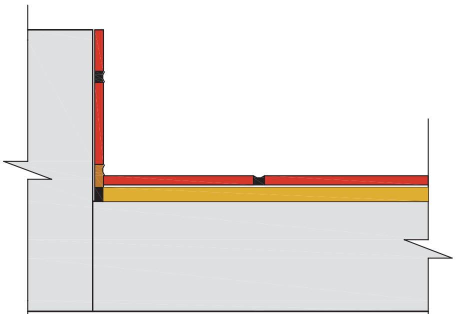


Figure 3.1.1 Edge joint

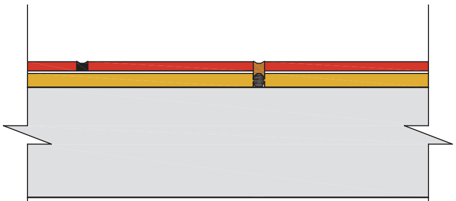


Figure 3.1.2 Section joint

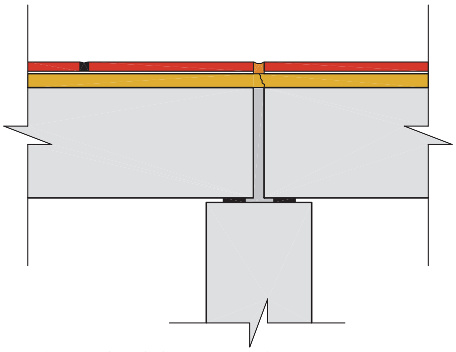


Figure 3.1.3 Support joint

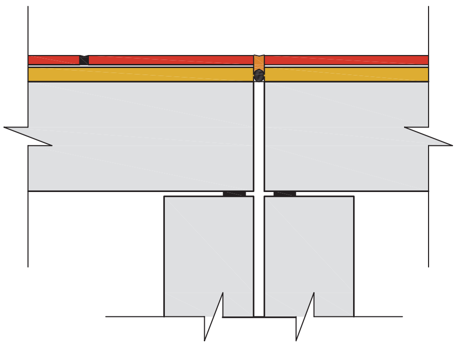


Figure 3.1.4 Construction joint

Today floor slabs are often levelled with 10-15mm self-levelling material. This ensures that the building works are fast, it lowers costs and building height is saved compared to building up a construction with an antifriction layer and concrete topping. The levelling material has little ability to absorb and transfer movement. However deformation and any rotation coming from the supporting construction, will be transferred to the tile layer.

This is also the case for reinforced concrete toppings that have been fixed directly to the base. In addition this concrete layer creates a problem with shrinkage that needs to be taken into account, therefore movement joints are recommended in the concrete topping. To avoid cracks, the tiles should be arranged so that joints occur in the positions where structural movement may be expected. (i.e. on column grids). Where the tiles are laid on a thin self levelling layer the movement may be taken up in the tile thickness without the need to provide a joint in the levelling layer itself. Where concrete topping is used it is important that a movement joint is provided through the tile joint and into the concrete topping. The joints should be put directly over the element joints, as long as you are not following the instructions in chapter 3.2.

Positioning the joints is dependant on the distances between the columns, and the respective lengths of the elements and columns. Using an axis distance of 6-7 metres between columns is favourable when using brittle surfaces.

To ensure that the movement joints are put in the correct places, the critical concrete element joints (support joints, longitudinal joints) should be marked clearly both on the joint plan drawings and at the building site before the tiling begins.

Joints should be a specified item on a quotation. If the placement of the joints and the type of joints is assumed to be part of the quotation per square metre without specifying it, the result is often that the problems with joints are not taken seriously.

3.1 Movement joints and sectioning requirements

The necessary movement joints are the following:
- Edge joints
- Section joints
- Support joints
- Construction joints

3.1.1 Edge joints along walls and columns

Edge joints should always be put along through-going walls and columns, to ensure that the support construction does not put pressure on the tile layer when shrinkage, creep and deflection etc. occurs (Figure 3.1.1)

It is advisable to ensure that the edge joints along the walls coincide with the end supports or the longitudinal joints at the beam supports.

3.1.2 Section joints

By a section joint, we mean a joint which is taken down through the tiles, covering layers and concrete topping. Using these joints is most common for floors with concrete topping. Figure 3.1.2

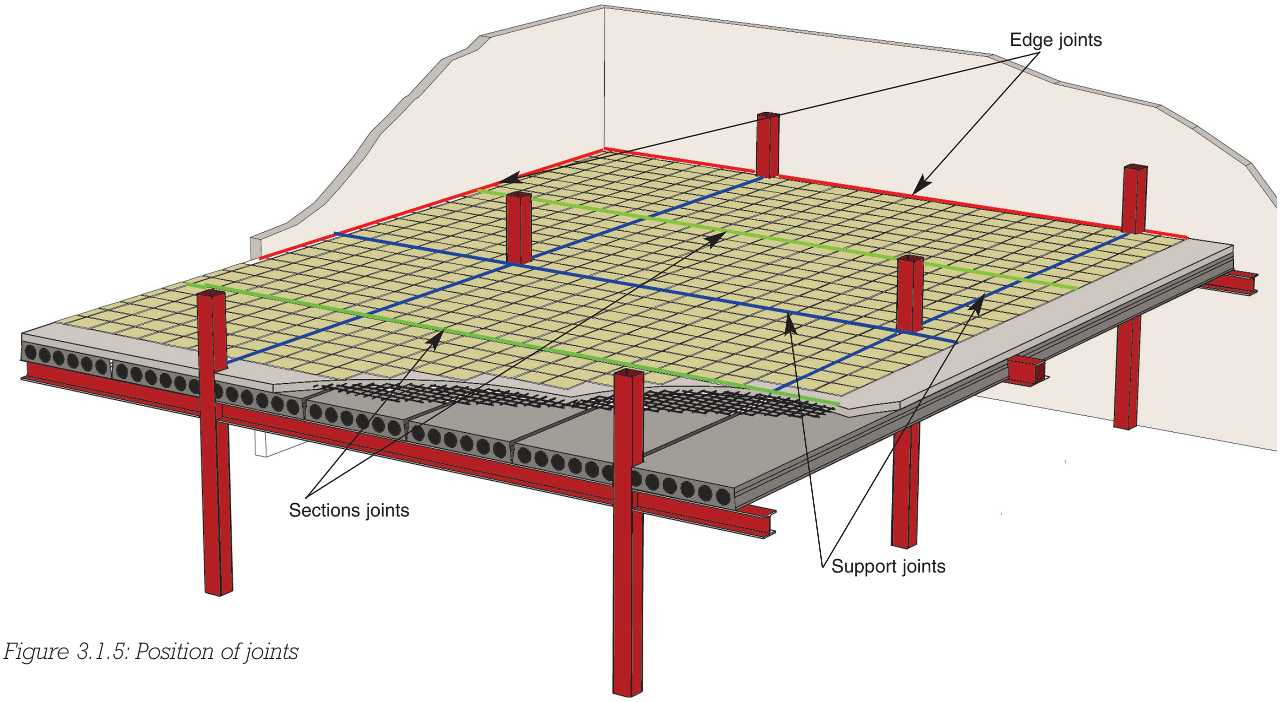


Figure 3.1.5: Position of joints

The tile layer should be separated into areas that can absorb the shrinking movements from the topping/levelling layer. The joints can also absorb cambering and temperature movements. The greatest need for through-going support joints are by the floor slab's end supports and along the side of the slabs in the columns axis. There should ideally not be any areas without a joint larger than 40-50 m2. If so, consider putting in more section joints. The areas should be square if possible, and the proportion between the side lengths should never be larger than 1: 1.5. This means that the greatest distance between the joints in both span directions should not be larger than 6-8 metres. There should also be section joints where the floor changes shape due to e.g. stair cases.

3.1.3 Support joints

A support joint is a through-going joint in the continuation of the element edges, or a joint that lies along the element where there can be edge rotation because of the deflection of the slab. (Figure 3.1.3)

3.1.4 Construction joints

Larger building constructions are often separated into sections that move independently of each other. Between these sections are the construction joints. (Figure 3.1.4) The construction joints run along the whole slab construction and should be able to absorb quite large movements. (5–20 mm dependant on the construction and its size). The joint profiles therefore need to be dimensioned to absorb the movements that can occur.

3.2 Layout and position of joints at support

The movement joints should correspond with the tile joints when the construction is fixed directly to the base. The only way to achieve this is with thorough planning and by fitting in the width of the joints and the tile format between the movement joints. Some movement can be absorbed by using this principle as shown in figure 3.2.2 and figure 3.2.4. When using different tile formats, for example a narrower row of tiles along a joint, the movement joint can be adjusted without upsetting the pattern or the combination for the rest of the areas. It is recommended that the tile pattern is laid in the same direction as the elements, so that the joints can be located at the support zone and the element edges. A diagonal tile pattern can result in cracks, or the movement joint will have to be located so that it breaks with the pattern of the tile joints.

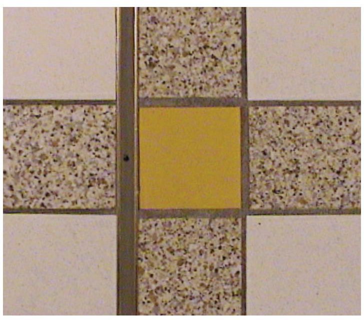


Figure 3.2.1 Adapting smaller tiles at the movement joints. Shown here is also the use of a joint profile.

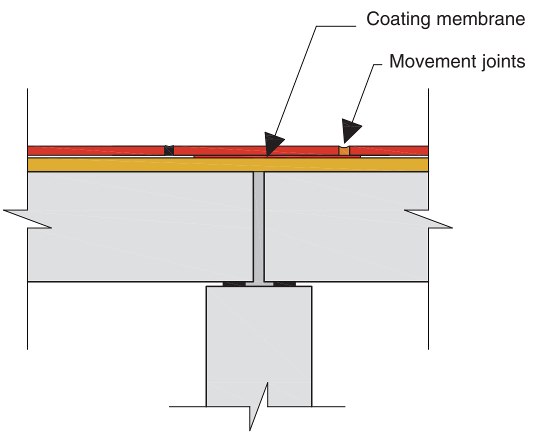


Figure 3.2.2: Side-shifted joint solution

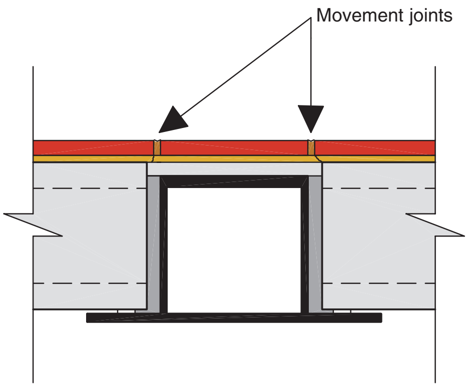


Figure 3.2.3: Double joints at inverted T-beam'

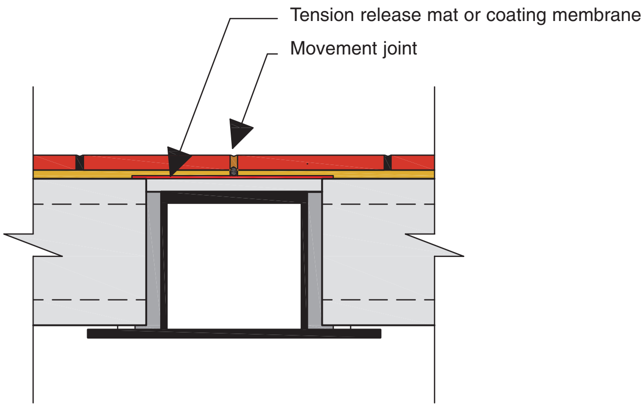


Figure 3.2.4: Joint solution with an antifriction layer against the beam

3.2.1 Side-shifted joint solution

If the distance between the edge of the element and the location of the movement joint is less than 50 mm, a minimum 1.5 mm thick coating membrane or a similar flexible surfacing can be applied in this zone. The membrane is very flexible and can transfer some movement to the joint sideways. The method must not be used where large loads can result in broken tiles because of the flexible construction. The method is also not recommended if the slab constructions are not sufficiently stiff.

3.2.2 Double joint method

For hollow core slabs with HSQ, DLB and HB slabs supports, there is a risk of a crack at each end joint at the beam. The best thing to do would be to put a movement joint at each end joint, as shown in 3.2.3. This is important if the beam is wide or the deflection is large. The movement joint should be taken through the tile layer and the levelling layer. By applying a coating membrane or a similar elastic material on the beam top, the flexible material can transfer the movement to a joint approximately in the middle over the beam. The placement of the joints can then largely be adapted to the tile format. This method depends on the rotation movements not becoming too large for the tiles, glue and the levelling material or concrete topping to absorb, and that heavy loads are avoided in that area for example from pallet trucks and similar equipment. An alternative, and much safer method is to use tension release mats over the connections. (Chapter. 5.1)

3.3 Levelling materials

Levelling materials are normally applied in a thickness of 10–50 mm depending on the needs for correction. Self levelling materials are most often used. When more than 20-25 mm is applied, the levelling materials should be put on in two applications to ensure that the surface is level. The levelling material is put down with a good grip to the base. A good grip is important to ensure that shrinkage in the levelling material is transferred as micro cracks in the surface rather than the material de-laminating from the base. The levelling material's grip to the base should be more than 1,0 MPa, and with a total shrinkage of less than 0,06 % (0,6 mm/m). The levelling material should be primed before tiles are laid.

4 Constructions separated from the base with an antifriction layer

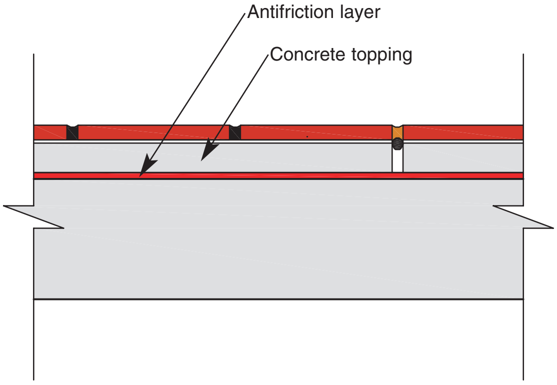


Figure 4.1: Construction with an antifriction layer is also called a floating floor.

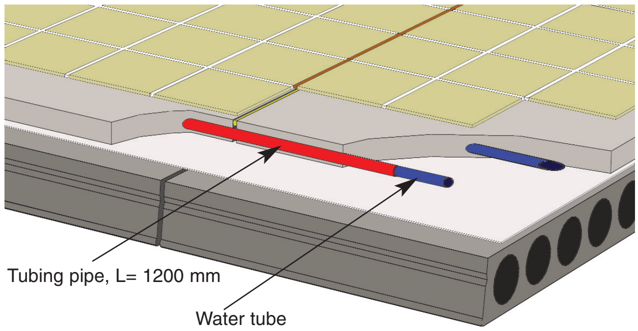


Figure 4.1.2: Tubing pipe should be used where there is a need for movement joints.

Norwegian Standards NS 3420 chapter T describes tiled constructions. Separated tile layers attached directly to the base and constructions with an antifriction layer are called floating floors. The standard describes how both the tile layer and the concrete topping should be constructed with sufficient movement joints to ensure that cracks and other damage is avoided. A floor construction with a reinforced topping on an antifriction layer has the benefit that the base and the tile layer including the concrete topping will be able to move independently of each other. A reinforced concrete topping on plastic foil, a tension release mat, a sound proofing mat or sand will to a certain degree insulate movements from the base. For example end rotation and shrinkage will be transferred to the tile layer. This type of construction is used for example where under-floor heating is to be laid.

If heating elements (water pipes or electric cables) are to be laid in the concrete topping, then these should be covered by a minimum of 30 mm including the tiles. This ensures that the temperature distribution is even throughout the floor, and the installation also has the necessary mechanical protection. Where water pipes pass a movement joint an insulating sleeve should be put on the pipe. This should extend 0.6 m to each side of the joint. This gives enough freedom of movement for the pipe to move in proportion to the joint.

4.1 Antifriction layer

The antifriction layer ensures that the reinforced concrete topping is less likely to have cracks because of end rotation than a topping with a fixed anchoring. The antifriction layer consists of two layers of 0.15 mm plastic foil, or a combination of the foil and a fibre material. Large floor areas still need to have the tile layer separated into smaller areas. The surface should be able to absorb movement from shrinkage and temperature changes. A fresh concrete topping of 50-100 mm thickness has a shrinkage which creates tension between the grouting and the tiles. In addition the end rotation from the floor slab construction will create movement in the topping. Support joints and section joints combined with a flexible glue can absorb such movements.

4.2 Concrete topping

On floors with normal loading conditions, concrete qualities of C25 or C35, are most often used where there are good curing conditions. Local cracking can be significantly reduced by the use of fibre reinforcement which adds to the tensile strength of the concrete.

Where fibre reinforcement is not used, concrete topping over 50 mm should be reinforced with a steel mesh, which is placed in the middle of the layer. Mesh which is typically used is K131 (5 mm dia.). Deflection and large spans are factors that result in end rotation in the support zone and will therefore have to be considered separately when considering the danger of cracks.

Necessary curing time in 24 hour segments after 4 weeks aftercare (18°C and 60 % RH in the air.)						
Thickness of slab	Curing-conditions	Aftercare (4 weeks)	C35 (v/c=0,60)		C55 (v/c=0,40)	
			RF 85%	RF 90%	RF 85%	RF 90%
100	One sided	Water/rain	197	88	56	16
	"	Plastic	140	47	40	8
100	Double sided	Water/rain	76	34	28	8
	"	Plastic	54	18	20	4
50	One sided	Water/rain	98	44	28	8
	"	Plastic	70	24	20	4
50	Double sided	Water/rain	38	17	14	4
	"	Plastic	27	9	10	2

Table 4.2.1: Necessary dehydration time and curing time in 24 hour segments before tile laying, depending on the thickness of the slab and the conditions.

4.2.1 Shrinkage and dehydration of large areas of concrete topping

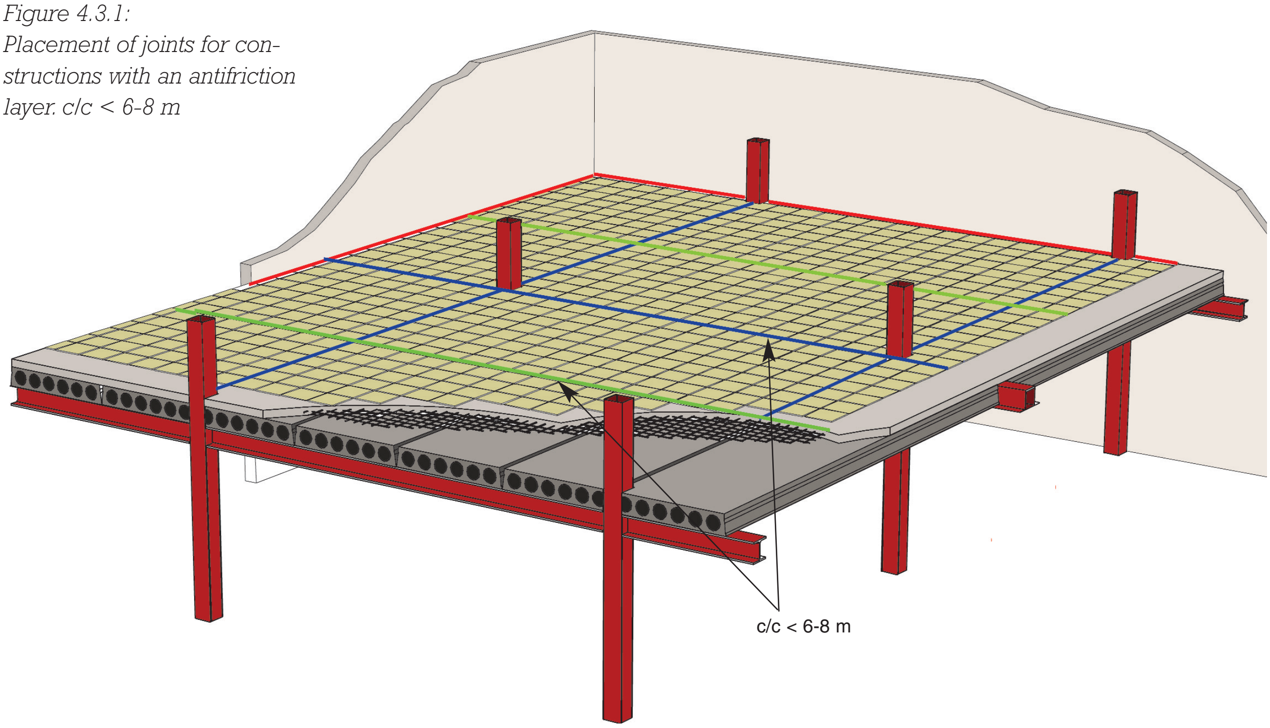
Before tile laying starts there should be little remaining shrinkage and trapped moisture in the concrete topping. This can be achieved by using the types of topping that ensures a quick drying period and with the correct aftercare. For optimal curing the concrete needs an aftercare that ensures the correct amount of moisture, by watering or covering it up with plastic for approximately 4 weeks. After this it is important to let the concrete dry out. Table 4.2.1 shows how long it normally takes for concrete to dry out to 85 or 90 %RH. Covering the concrete with plastic, or using a curing membrane are the most effective ways of ensuring fast and good aftercare. It is recommended that concrete with a low water content is used, this means concrete with ws/c–conditions of less than 0,6, and aftercare with plastic covering minimum 4 weeks. If a curing membrane is used then this must be totally removed before tile laying, unless the producer can guarantee that the curing membrane will not have an affect on the grip between the tiles and the concrete base. The following example shows how it is possible to determine the right starting time for the tile laying if the correct demands for moisture and shrinkage have been met. The dehydration speed is influenced by the choice of concrete quality. The use of different types of additives makes some of these types of concrete somewhat more expensive than the traditional concrete types. It may still be an economical alternative because the building time will be faster, and the floor is not as likely to be damaged.

Examples:
If there is a 100 mm concrete topping of C 35 concrete quality on an antifriction layer, which is covered for 28 days with plastic, it will take an additional 54 days (8 weeks) to reach a relative humidity of 85%. (In total approx 12 weeks after the grouting). If it is sufficient with a maximum of 90% remaining moisture, this can be reached 18 days (approx 3 weeks) after the first curing period (totally approx 7 weeks after the grouting).

For traditional concrete toppings, for example C35, the connection between the drying period and the remaining shrinkage is important. By drying it to 85% most of the shrinkage will have taken place and the necessary strength will have been achieved. When using high strength concrete for example C55, the shrinkage graph deviates from the dehydration graph, which means that it takes longer to get the material shrinkage free, even if the remaining humidity is low.

This example is based on a temparature of 18°C and 60% RH in the air. If the thickness is 75 mm it is possible to interpolate along the lines between the numbers in the table.

Figure 4.3.1: Placement of joints for constructions with an antifriction layer. c/c < 6-8 m



4.2.2 Concrete topping and load bearing capacity

The load bearing capacity of the tiled floor is dependant on the underlying constructions. It is important to consider both vertical and horizontal loads due to shrinkage or temperature changes. Concrete, both when used as a concrete topping and as a levelling material, must have a compressive strength that gives the tiles a stable and firm support. The compressive strength of concrete toppings and levelling materials with normal loads should be more than 20 N/mm2. It is not good if the compressive strength is too high as such a base often produces more tension over time. The grouting compound should be shrinkage compensated, i.e. the shrinkage should be less than 0.06 %. It is also an advantage that most of the shrinkage happens early in the curing phase (80% in the first 14 days), so that the majority of the grout shrinkage occurs before the tiles are laid. Figure 4.2.2 describes how point loads (concentrated loads) normally transfers down through the layers.

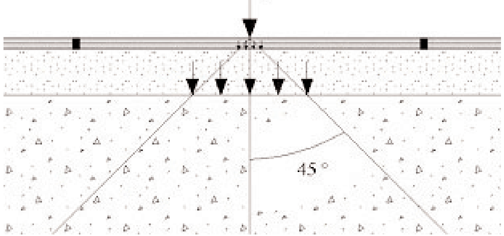


Figure 4.2.2: Normal load distribution for point loads

Since tension from point loads are conical down in the load bearing underlying layers, the tension will decrease with increased distance from the load. The pressure on the levelling material with the same load will be less with thick tiles than thin tiles. The necessary compressive strength of the levelling layer can be reduced if the thickness of the tiles is increased. Inversely the thickness of the tiles can be reduced if the levelling layer has good compressive strength and an adequate coating of glue. Floors that have a high level of traffic will perform better if the tiles are laid on a solid concrete topping than if they are put in earth moist concrete. If an earth-moist concrete is used with a thickness of more than 50 mm, it should be applied in two layers. The first layer must be compressed thoroughly before the next layer is applied. The next layer must then also be compressed and levelled to the right tolerance level.

4.3 Spacing of joints

It is recommended to provide the end- and section joints at maximum central distances apart of 6-8 metres in constructions with antifriction layers. A natural placement is along the column rows and towards the ends of walls. If you use an antifriction layer then the movement joints can be moved up to 100 mm depending on the element joints. The movement joint should go all the way down to the antifriction layer. Alternatively it is possible to make slit markers (crack inducers) in the concrete topping so that later cracks will correspond with the movement joint in the tile layer. It is important to choose the correct materials that will absorb the movement of the compressive and tensile forces.

4.3.1 Shaping of the joints

The risk of edge curling of the concrete topping when using through-going joints can be reduced in the following three ways:

1.When using a continuous topping, the joints may be cut afterwards and the tile layout can be adapted to suit the the position of the support and section joints. This can also be used with construction joints when they are marked off clearly and accurately through the concrete topping. The method cannot be used with floor heating with water or electric cables, unless the placement of the joint is very carefully determined. The joint should reach the antifriction layer. If a long time is allowed between the grouting and the joint cutting, it reduces the danger of edge rising in the concrete topping. To reduce this risk it is possible to cut a slit (crack inducer) to a depth of 40% of the thickness of the concrete topping. If the floor is cracked, the placement of the cracks is predictable. The joint in the tile layer should coincide with this slit.

2. Grouting the floor in sections.
This method is used where it is natural to grout in sections and at the same time combine the size of the sections with joints. The sections can be finished with an adapted end formwork. The joints are established with strips of an elastic joint material. See figure 4.3.1. The joint can easily be adapted to the corresponding joint in the base. The risk of edge curling means that the floor should not be tiled until after any curling has taken place.

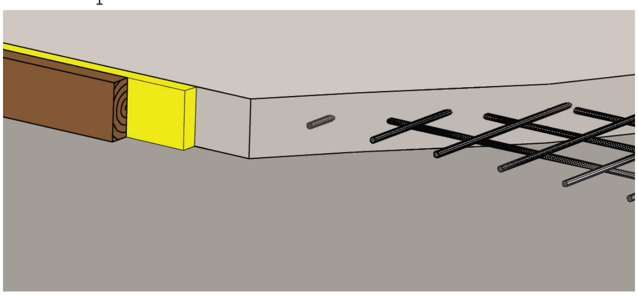


Figure 4.3.1: Sectioning with strips of elastic material

3. Grouting with a joint profile
This method involves placing a joint profile against the edge formwork for the area that the grouting compound is filled towards. (Figure 4.3.2). The joint profile is regulated height wise. Some joint profiles can be used as a guide rail when levelling or height adjusting. The joint profile cannot be combined with the use of a through-going reinforcement mesh. Figure 4.3.2 shows a joint profile that goes down through the concrete topping at the support joint. The rotation in the elements is transmitted via the area separation joint.

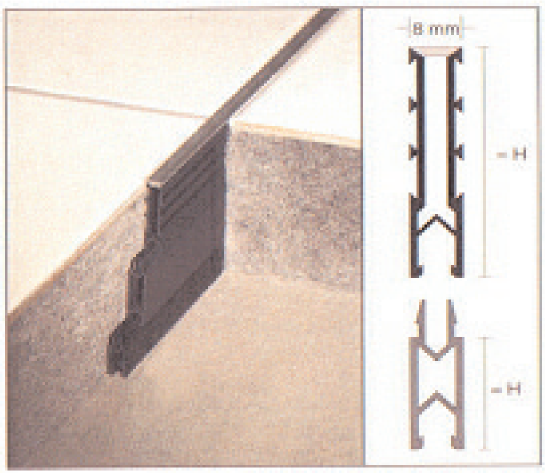
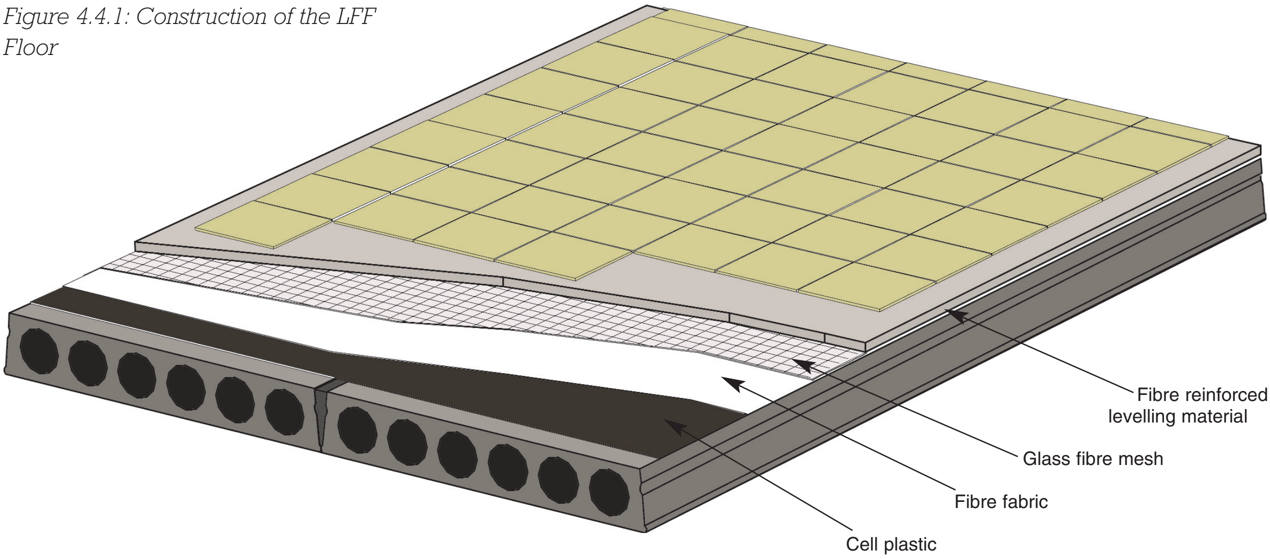


Figure 4.3.2: Joint profile

4.4 Thinly constructed floating floors (LFF – method)

An alternative method for floors with antifriction layers is the LFF- method. (Thinly constructed floating floors). A fibre reinforced levelling layer is applied, 18-30mm thick (see table 4.4.3), on a 5-8 mm thick base layer (See figure 4.4.1). These layers are constructed so that 90% of the shrinkage has taken place after approximately one week at temperatures over 15°C, and they can be considered to be almost shrinkage free after this period. In addition to the fibres of the levelling material, the layer will be reinforced with an alkaline resistant glass fibre net. This is laid with a 200 mm overlap in the joints.

Figure 4.4.1: Construction of the LFF Floor



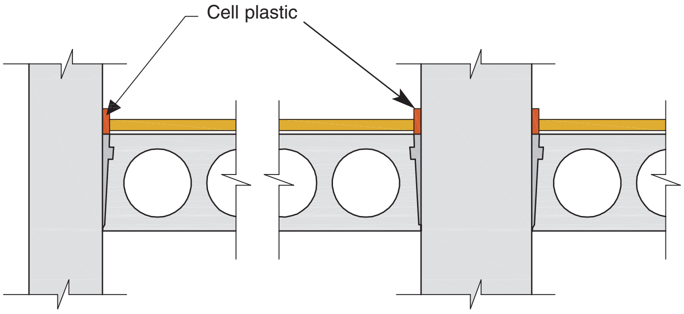


Figure 4.4.2: Strips of cell plastic against firm through-going constructions like beams and walls

To ensure that the top layer is able to move freely during and after the curing period, strips of cell plastic are placed along the through-going walls and columns (figure 4.4.2). To ensure an even drying of the mortar and to avoid edge curling, the floor should be laid according to the suppliers advice. Do not use products that can weaken the grip of the tile glue. With the LFF – method, movement joints do not need to lie directly over the element connections, and the distance between the section joints can be increased. If the rotation movement in the floor construction is limited to 1mm, the tiles can be laid within an area of 20 x 20 metres. It is still recommended that an elastic grouting material is used close to the slabs' end rotation point. The section joints should go down to the glass fibre mesh. The LFF – method works well for floors with moderate loads. For floors with large and permanent loads, as for example in shopping centres, industrial buildings, offices etc, this method is normally not suitable. Areas with large loads must be separated by movement joints. The thickness of the grouting is dependant upon the size of the area and of the load. See table 4.4.3.

4.5 Construction on flexible supports

4.5.1 Tension release mats

This method helps prevent tension between the tile layer and the base by inserting an elastic layer. It is important that the elastic layer fixes both to the tile layer and the base. Figure 4.5.1 shows an elastic tension release mat with tiles glued on top. These products are made from profiled plastic. Spacers create a gap with the base and gives the grouting an opportunity to dry out, so that it is possible to start gluing the tiles before the concrete has reached its final humidity level. This presupposes that the air slots are opened at the ends to ensure air circulation. Some mats will also be waterproof layers for the underlying construction. The mat can absorb some movement sideways, so that the forces in the base are not transferred to the tile layer. The mat is laid in tile glue, with a 4 mm toothed grouting, on a primed surface. Floating glue is recommended. The tension release mat has a moderate ability to absorb point loads, and is not suitable for areas with high loads or rotation movements larger than 1 mm.

Load group	Uses	Surface area m	Thickness levelling layer mm
1	Private houses with load of up to 2 kN/m2	< 5 x 5	20–25
2	Private houses, offices and industrial buildings with a load up to 2 kN/ m^2 Light rubber tyre traffic	< 10 x 10	25–30
3 - 4	Offices, shopping centres, industrial buildings with a load up to 5kN/ m2. *) Traffic with polyamide tyres **)	< 15 x 15	30
3 - 4	Larger areas than 15 x 15 *)	< 20 x 20	30–35

*) Areas with high permanent loads are separated with through-going movement joints.
**) High point loads require stiffer bases

Table 4.4.3
Spacing of areas and the recommended minimum thickness with the LFF- method.

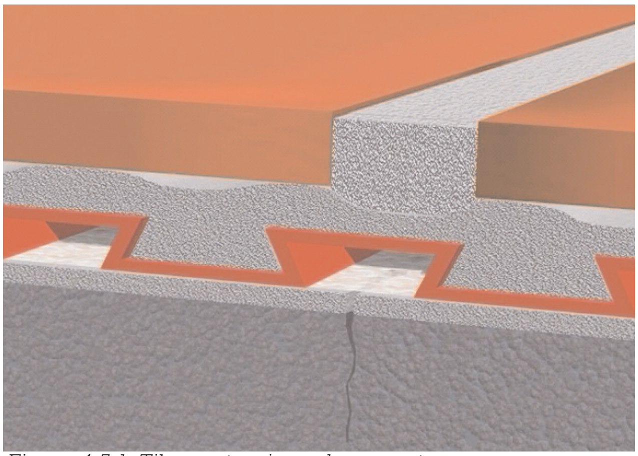


Figure 4.5.1: Tiles on tension release mat

It is also possible to use sound proofing mat supports, similar to the ones that are used in sound proofed floor constructions. When the sound proofing mats are thicker than 10mm, the construction can absorb rotation movements in the base of up to 2 mm without movement joints. Areas with high point loads on these floors must be separated by section joints.

5 Movement joints

To absorb movement in and around the floor slab constructions, it is necessary to use joint profiles and/or elastic sealants. Prefabricated joint profiles are a good choice for constructions that have to absorb heavy rolling traffic or strong sideways movement e.g. from construction joints. Traditionally movement joints have been constructed with elastic compounds like silicone, MS-polymer, polyurethane or similar compounds. The life of these joints is normally lower than the rest of the floor materials. Assuming that the joints are done correctly, a floor with moderate traffic and little chemical exposure will last according to normal expectations. It is not unusual to see that the sealant grip on the edges of the joint is lost over time, or that the material itself disappears. Elastic sealing requires more maintenance than the rest of the jointed areas. Floors that are cleaned with pressure water cleaners or with machines that use chemicals or abrasive methods are especially vulnerable to wear and tear.

Elasticity properties	Group (ISO 11600)	Movement capacity	Note
High elastic	**25 LM** **25 HM**	**+- 25 %** **+- 25 %**	Low elasticity module High elasticity module
Elastic	**20 LM** **20 HM**	**+- 20 %** **+- 20 %**	Low elasticity module High elasticity module
Elastoplastic	**12.5 E**	**+- 12.5 %**	
Plastoelastic	**12.5 P**	**+- 12.5 %**	
Plastic	**7.5 P**	**+- 7.5 %**	

Table 5.1.2: Types and properties of elastic and plastic sealant.

5.1 Flexible grouting – types and specifications

Elastic joints should grip well onto the surrounding materials. In addition the sealant must absorb changing deformations without cracking. If the pressure is removed, then the sealant in the moveable joints should return to their original shape.

The properties of the sticky plastic sealants mean they are something in the middle between the plastic and the more elastic sealants. The ability of the sealant to absorb movement is not constant and depends on the type of movement, temperature and age. The life of the sealant and its ability to absorb movement depends on the size, of mechanical and climatic pressures and of varying chemical influences.

Type	Elasticity	Durability	Chemical resistance	Resistance to traffic loads	Typical uses
Silicone	High elastic/ Elastic	Good	Good	Weak/ Medium	Wet rooms Kitchens Pools
MS Polymer	High elastic/ Elastic	Good/ Varying	Good/ Varying	Good/ Medium	Floors Wet rooms Outdoors
Polyurethane	High elastic/ Elastic	Good/ Varying	Varying	Medium	Wet rooms Not swimming pools
Polysulphide	High elastic/ Elastic	Good	Good	Medium	Floors Outdoors (smells)
Acrylic	Plastic	Varying	Poor	Not suitable for trafficked floors	Dry rooms Porous absorbent surface

Table 5.1.2: Types and properties of elastic and plastic sealant.

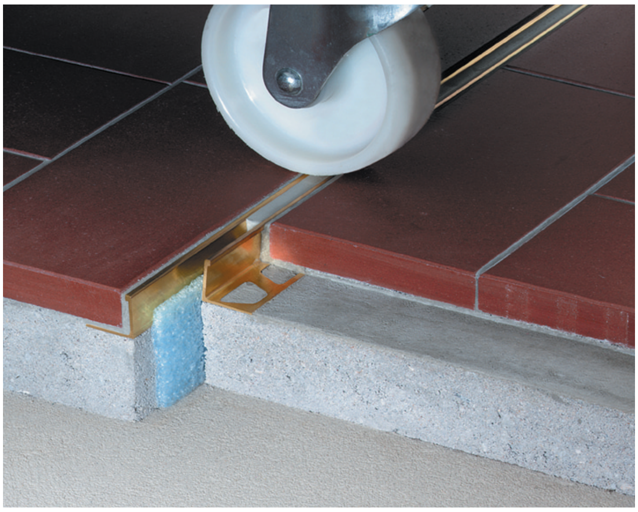


Figure 5.2.1: Construction of joints in areas with edge strengthening where there is rolling traffic

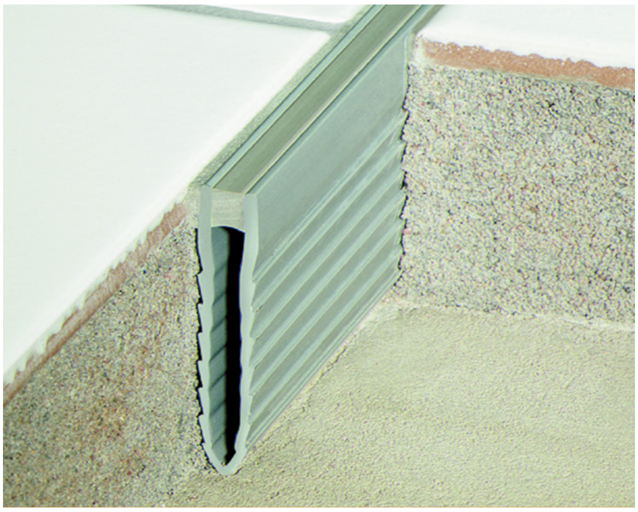


Figure 5.2.3: Profiles for joints in concrete topping.

5.2 Joint profiles

Joint profiles are prefabricated metal or plastic rails that are made to absorb movement and to reinforce defined joints. Joint profiles give a secure solution for floors in e.g. shopping centres, entrances, industrial kitchens, dairies, and similar areas with chemical wear and/or heavy traffic. On floors with rolling traffic and hard wheels, the joints should be made with some means of edge reinforcement. Edge reinforcement of joints is especially important where there are concentrated point loads on the tiles, e.g. where vehicles with hard tyres (nylon tyres or similar) are used. Contrary to a mortar filled joint (which gives the tile an effective sideways support), an elastic joint will be vulnerable to breaking because the pressures are from the sides and this can crack the tiles. Figure 5.2.1 illustrates how metal joint profiles protect the tiles, absorb sideways pressures and stop the tiles from being broken at the edges. The joint must be constructed with bottom fill and an elastic paste between two profiles. If thin tiles with low mechanical strength are used, and will be subject to a large load, the best way to avoid damage at the edges is to use an edge reinforcement. As a rule the profile should be placed directly over the joint in the substructure (element or concrete topping). It is possible to shift the joint profile sideways in relation to the underlying joint as described in point 3.2.1. Figure 5.2.1 shows a track profile that is a movement joint and which is placed corresponding with the end or through-going joint in the elements. A profile type can be installed at the edges as a finisher when the floor is being grouted in smaller areas. Fig 5.2.2. Figure 5.2.3 shows a profile type that creates a joint both in the concrete topping and in the tile layer. It is made of hard plastic and can be adapted to different building heights. They are placed in the continuation of the edges or along the longitudinal joints. Some profile types can be installed into the base after the concrete topping has been applied. This method reduces the possible risk of a edge rising, but can create problems when hitting on element edges and joints. The system requires precise measuring from column rows and reference points.

Figure 5.2.2: Joint profile as edge finisher when grouting the floor in smaller sections.

6 Ceramic tiles, glue and adhesives

Load group	Rupture strength (F) kN	Usage
1	< 1,5	Light use, e.g. in private houses.
2	1,5–3	Light traffic with rubber tyres. E.g. business building.
3	3–5	Floor loads up to 6 N/mm² (60 kilos/cm²). E.g. industrial or business buildings.
4	5–8	Medium to heavily loaded areas between 6–20 N/mm² (60–200 kilos/m²). Shopping centres and industrial floors. Traffic with polyamide tyres.
5	> 8	Heavily loaded areas over N/mm². (>200 kilos/m²). Heavy traffic and storage areas. Traffic with polyamide tyres.

Table 6.1: Usage is based on load group and rupture strength.

For floors and outside areas the important features are strength, resistance to wear and tear, scratch resistance, and that it is non-slippery and resistant to frost. The best surface result is achieved by using calibrated tiles and jointing by machine. Tiles with poor support will experience bending and tensile forces that can lead to breaking or cracking. Weak grouting with a strength of under C15, or self levelling materials with a low compressive strength are not recommended for a floor which will be used with a high pressure load. The area's ability to absorb pressure loads is dependant on the tensile strength, the thickness and the quality of the material. Table 6.1 gives recommendations about using brittle materials according to the load group and the areas of use.

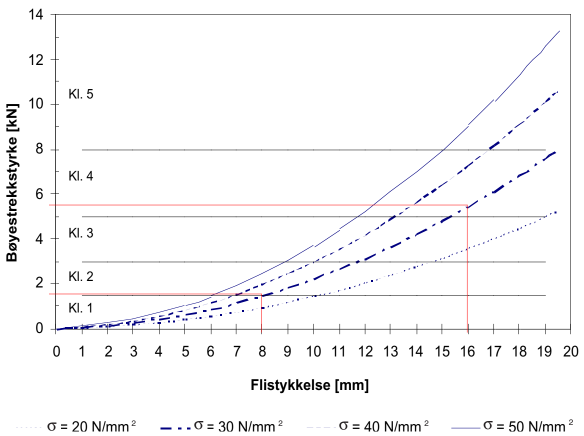
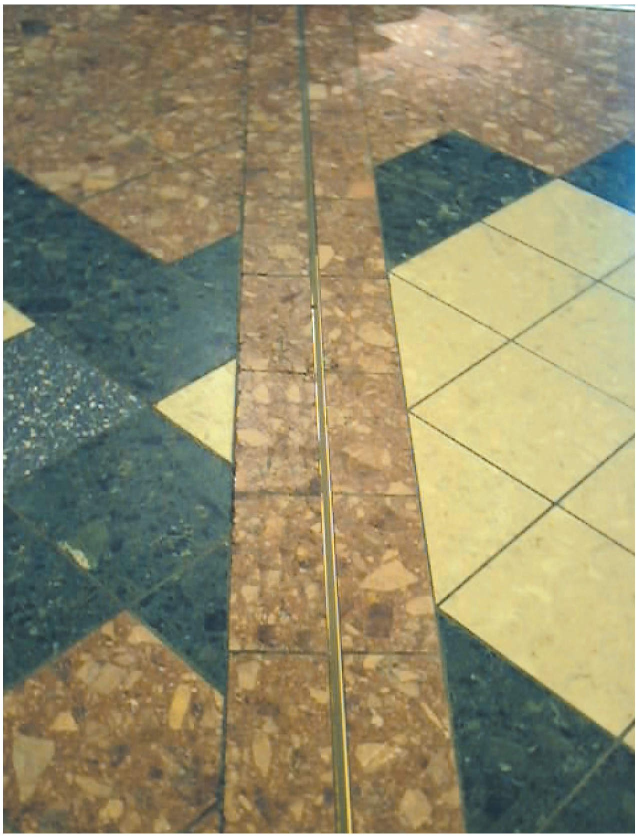


Figure 6.2: The tensile strength of a 30 x 30 cm tile with varying thickness and tensile module. The horizontal lines separate the different load groups.

Figure 6.2 shows the relationship between the thickness of the tile and the tensile strength. If we know the tensile strength of a tile (_) and know what thickness it has, we can determine what load it can normally take. Ceramic tiles in areas with heavy wheel traffic (pallet trucks, heavy floor washing machines, trucks etc) should have a thickness of at least 12/14 mm. Granite tiles laid with floating glue and full glue cover have a very high load capacity even when relatively thin. The type of wheels have to be considered in relation to the load. Hard wheels are not advisable. In areas with only pedestrian traffic and light rolling traffic, tiles with a thickness below 10 mm may be appropriate.

Example:
A 30 x 30 cm tile with a given tensile strength of (_) 30 N/mm2 and a thickness of 8 mm would have a tensile strength of approximately 1,3 kN (= 130 kilos). If the support is not good and tensile force is applied, it will break with a point load of approx 130 kilos. Rotating element ends are typical situations where these types of loads can appear. If a similar tile quality is used, but with a thickness of 16 mm, the tensile strength will increase fourfold, to more than 500 kilos.

Figure 6.1.1: Not like this,



6.1.2: …… Like this.

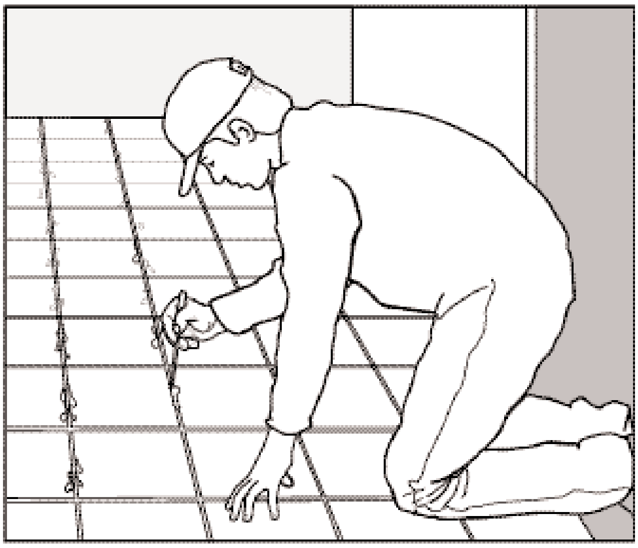
Note:
It is difficult to predict in a calculation what the construction's maximum allowable load will be, according to the tensile strength of the tile and the grouting's ability to withstand pressure. We do not always have precise indications of what stresses the tiles encounter when the strength of the base and the grouting and glue cover may all vary. The load group must be adapted to the usage. Generally we recommend using load group 2 and upwards for floors with rolling traffic and heavy point loads. See table 6.1.

6.1 Tile formats and patterns for laying tiles

It is important to consider the span direction when you decide on the direction of the tiles. If the tiles are put diagonally to the span direction, you will have problems with checked patterns when you put joints at connections and beams. The tile format should be adapted so that whole lengths of tiles are fitted between the movement joints, or use adaptive tiles as described in chapter 3.2.

6.2 Glue and adhesives

Durable methods are achieved with a thick layer of glue, a good glue cover and with a flexible glue with strong grip. A strong grip is important to ensure that the transverse strain between the base, glue and the tiles will not separate the tiles from the base. The thickness of the glue layer decides how large the shifts can be between the tiles and the base before the tile loosens. A tile glue with a low elasticity will give brittle breaks, whilst an increasing elasticity ensures a more ductile break. The thickness of the glue layer should be at least 3–4 mm to ensure that some of the transverse movements can be absorbed and transferred through the glue. Cement based tile glue, or floating glue has the best elastic qualities. The qualities of the floating glue give it good glue coverage combined with a high flexibility. To ensure that you have the necessary grip it is important to clean and prime the base. Remains of floating glue in the joints must be removed soon after laying the tiles to ensure they do not hinder later transversal movement.



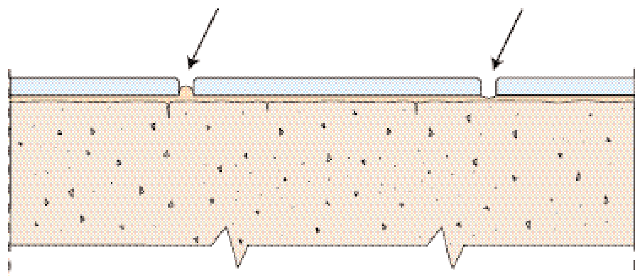


Figure 6.2.1: The joint must be cleaned and glue residue should be removed before laying the tiles.

7 Advice for project planning

If you want a floor with brittle surfaces on concrete elements to have no crack damage, it is important to insert joints in both axis directions to absorb movement due to shrinkage in the concrete topping, the levelling layer and in underlying concrete elements. Rotation, deflection and temperature changes can also result in movement in the elements. The sectioning of the tile layer is necessary both when the layer is firmly anchored to the base and when you use constructions with an antifriction layer. The movement joints in the concrete topping and the tile layer should correspond with the joints between the elements.

If you glue the tiles on the levelling material with a firm anchoring, the movement joints should lie directly over the element joints. The location of the joints should be marked on drawings before the tile laying is started, and preferably marked directly onto the floor construction. When planning the load-bearing system and the floor slabs for tile laying, the limitation of the end rotation must be decided upon. Rotation movements that happen because of a 50% service load, should be limited according to figure 2.4.2. It is also important to allow for the maximum camber and deflection after the levelling material or the concrete topping has been applied. (The recommended maximum: L/1000). It is important to use a flexible adhesive, and to apply it at a thickness of 3-4 mm with a very good cover.

Figure 7.1.1: Edge joints from joint profiles along through-going wall constructions.

Edge joints should be laid along all walls and columns so that the construction does not put pressure on the tile layer. Put in section joints where the floor area changes shape e.g. by stair cases.

Figure 7.1.2: Section joint at the corner of a stair case

7.1 Construction fixed directly to the base

Constructions with brittle surfaces that are attached directly to the bases are the ones that have most problems with cracking. It is therefore only recommended where the allowable construction depth is too small to allow other methods, or when the areas are small and you have control over the stability and deflection of the underlying construction. The total rotation movement at the element connections as mentioned above should not be more than 2 mm. Joints should be inserted at the column axis where there is rotation in the longitudinal floor joints because of the floor slabs deflection and by the element supports where there is end rotation in the element. Section joints are not seen as necessary in stable indoor constructions where the floor slabs are levelled with self levelling material and where the span is less than 10 metres. When constructing floor areas with large temperature variations like for example floors that are in the sun, or with heated floors, the joints should be placed closer together.

7.2 Construction separated from the base with an antifriction layer (floating floor).

Constructions with a reinforced concrete topping on an antifriction layer, can be separated so that they can absorb movement and tension that appear in the topping as well as in the load-bearing construction. As mentioned above, the total rotation movement at the element connections should not be more than 2 mm. Joints should follow column rows when both end rotation and element rotation appear. It is acceptable that the movement joint is shifted up to 100 mm according to the underlying element joint. The distance between the section joints should not exceed 6-8 metres. This gives a maximum area of approx. 40–50m2. The effect of the antifriction layer depends on the levelling of the element surface, so it is important to get the surface as level as possible.

7.3 Thinly constructed floating floors (LFF- method)

The LFF method can be used where there are no permanent high loads and where the floor construction depth is critical. The LFF method decreases the need for joints. The maximum distance between the section joints can be up to approx. 20 metres. This limit presupposes that the maximum end rotation is limited to 1mm.

7.4 Construction with tension release mats

In addition to fixing the layer of brittle material to the levelled base, the tension release mats that are glued to the base will also be able to absorb quite large movements from the underlying constructions. The mats work as moisture barriers that the tiles can be glued directly onto. The method can be used over element connections, without putting movement joints in the tile layer. The rotation movement must be limited to 1 mm. Tiled areas with tension release mats should not be larger than approx 20 x 20 m. The section joints should be as near to the rotation points as possible.

On the next page are some suggestions to additional reading according to NS3420 (Norwegian standards), 3. edition

8 Specifications

8.1 Additional reading for N41.2: Tile construction fixed directly to the base.

8.1.1 Necessary pre-treatment:

- Before grouting, remove all dust, salt and grease.
- If necessary regulate the absorbency level of the base with a primer.

Before gluing, ensure that the tolerance level of the base corresponds with the finished surface. If they do not correspond, ensure that the levelling is done and that the responsibility for end results is assigned.

8.1.2 Construction requirements:

- In constructions where the grip is very important or where it is not possible to have slip areas behind the tiles, it is important to use the double gluing method or other glue techniques that give the same effect.
- The necessary thickness of the glue should be specified. If nothing else is mentioned, floor constructions should have a glue layer of 4–6 kilos/m2, this corresponds with a 3–5 mm finished glue layer.
- The temperature in the laying and setting phase should be between 15–25 degrees (Celsius). Do not apply more glue than you can tile before it sets, according to the open time of the glue and the working environment.
- The joint should be left open for 1 – 3 days before grouting, depending on the curing conditions and the type of glue. The joint should be filled completely unless anything else is specified.
- For floors that should have an exact levelled surface, it is best to use calibrated tiles with straight edges and filled joints with a maximum of 1 mm insertion.

8.1.3 Movement joint (N42.1)

Movement joints are described according to chapter S.

- Joints should be placed on the column axis when there is rotation in the longitudinal floor joint due to deflection of the beams, and also in the element supports when there is end rotation in the element. The location of the joints should be shown on the joint plan that is provided by the producer or the element supplier. This is to ensure that the different layers can be adjusted to fit each other.
- Specify the joint type (type, width, colour, designation (according to ISO 11600)) or the profile type when you describe the product.

See the Masonry Catalogue's Guidelines M8 6.1.2 for information about constructing joints.

Definiions

Levelling layer:	A levelling layer that is constructed using levelling material.
Levelling material:	Material used to even out the sub-base. This is usually made of a cementitious base, but can also be plaster based.
Tension release mat:	Plastic mat with the ability to transfer sideways movements at the same time as it grips both the underlying construction and the glued brittle material.
Tile layer:	Layer of tiles, adhesives and grouting.
Fluid grout:	Self levelling material
Construction joint:	Through-going joints in the underlying construction, as well as through the whole of the tile layer.
Mortar:	Cement based earth-moist concrete in at least 50 mm thickness used for setting tiles.
LFF-method:	Thinly constructed floating floors method.
Support joint:	Through-going joint in the continuation of the edges of the element or alongside the elements where there is edge rotation because of the beam deflection.
Primer:	Liquid that is added to the base before the levelling material or the concrete topping is applied. The primer ensures a better grip to the surface by reducing the dehydrati on process.
Edge joint:	An elastic joint or profile in the transitions of the material and in the outer edges. Its purpose is to separate the tile layer from the adjoining constructions.
Section joint:	A joint in the tile layer and the levelling layer which partitions areas into appropriate parts.
Self levelling material:	Cement based easy flow concrete used for levelling and straightening base floors.
Grouting:	Material for levelling uneven supports. For floors it is most often self levelling and cement based.
Open time:	The longest time after applying the adhesive that the tiles can be laid and comply with the specified demands to the adhesion strength.

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