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Focusing on the development of education, the development of educative materials and the training of teachers, with special attention to the fields of mathematics, natural sciences, technology in general and information technology in specific.

(Project no.: TÁMOP-4.1.2.A/1-11/1-2010-0075)

THE STRUCTURES OF: BALCONIES, HANGING CORRIDORS AND LOGGIAS

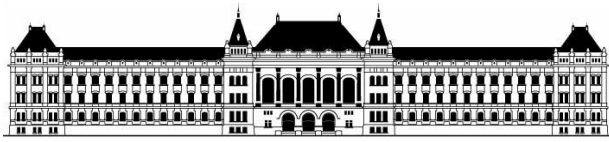
Intended for [Budapest University of Technology and Economics](#), Faculty of Architecture students as a special addition to the Building Constructions 7 and Building Constructions 8 subject material.

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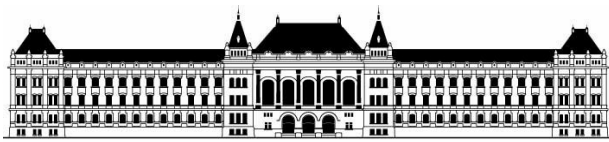
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THE STRUCTURES OF: BALCONIES, HANGING CORRIDORS AND LOGGIAS

A „TÁMOP” Lecture Note

1. INTRODUCTION

Most buildings in Hungary were made before the XXth. century, or at the most at the beginning of this era. The buildings are mostly decorated by balconies. When the lots were built in a bracket format, the inner trafficking was solved by hanging corridors. These solutions are also popular currently. At the construction of new buildings or during the reconstruction of existing ones (of any age) a primary aspect is the creation of long lasting structures that also satisfy contemporary complex requirements. These notes intend to provide help for this professional issues.

In the following notes we deal exclusively with external traffic (corridors) and leisure (balconies, loggias) space horizontal slab structures that have external spaces underneath. Terraces – which enclose heated or non-heated spaces underneath – do not compose the scope of our investigation.

2. LOADS, EFFECTS, REQUIREMENTS AND EXPECTED VALUES

Most reliable is the conscious design of building constructions both when designing new structures or when considering existing ones. The base principle is that technical adequacy is decided by the comparison of the expected loads and effects to the capabilities. We must acknowledge that before us some structures were built according to practical knowledge. Today this is not permissible while building materials are abundant. As the requirements become more complex, all decisions must be made consciously.

In the followings we will introduce, in a table format, the loads and effects on balconies and hanging corridors, also illustrating the requirements and expectations. We will not elaborate on standards and technical rules, as these may change in time. From a teaching perspective, we find it more relevant to provide a kind of view, a way of thinking that – with due practice – will allow creative independent design or technical expert work.



The table may be expanded or contracted when considering a concrete task. Numerical loads and requirements may be added according to the actual level of technical advancement. The capabilities of the structures must always satisfy legal requirements.

Loads and effects	Intensity	Requirements and expectations
Self-weight and useful loads	The amount and type of loads to be considered are defined by standards on building structures	The structure must be stable, must carry the regulated load and deformations are to be limited to the standard allowance (7)
Fire		The structure is to be grouped in the appropriate fire hazard and resistance category given by the fire protection regulations and must satisfy these.
Precipitation in various forms	Its quantity and intensity depends on the corridor's exposure or the locally applied protection	Water draining must be made possible: in case of a free edge line: drip edges, in case of parapets: drain pipe or internal drain lines Gutters or eaves are preferred solutions; however, these are not used frequently for corridor edges.
		Surfaces are to be constructed in a slope towards the collection device (1,5-2 % depending on the slip danger of the finished surface)
		The surface must resist freezing
		The surface must be of a non-slip nature, at least: R11e V, or R10 V4
		The layer designated waterproofing level is to be adhered to (5)



		A lasting finish must be created by anti-corrosion surface and/or through waterproofing insulations.
Thermal deviations on a daily and yearly scale	The value depends on the exposure of the surface, its shading, color and absorption qualities	Heat expansions must be accommodated; keeping in mind that slabs will be prone to faster temperature changes. (6)
		Structural heat expansion is to be allowed according to the current structural regulations.
The structure - as a thermal bridge - will contribute to the heat loss of the interior and to the cooling of the interior surfaces. (1)	The value depends on the material and structural nature of the corridor as well as on the layer composition of the external wall. (2)	Heat loss level is to be kept to a minimum, as defined by the relevant regulations. (3)
		Thermal bridge internal surface minimum temperatures must be defined and after a structural integrity check a decision is to be made whether intervention is needed. (4)
Pedestrian traffic	Its intensity depends on the quantity of the corridor traffic	The surface must be resistant to wear, PEI IV or PEI V
	Dropped objects	The finish must be hard, impact resistant
During proper use (depending on the type of walking) vibrations will appear in the structure.	The standard to be considered is normal, general use	Step-noise transmitted to neighboring noise-protected spaces (beside, below) by the structure must be limited to the allowance, in other words, the surface finish and all connecting structures must have adequate step-noise protection (8)

table 1.: loads-requirements system

Comments on the table above:



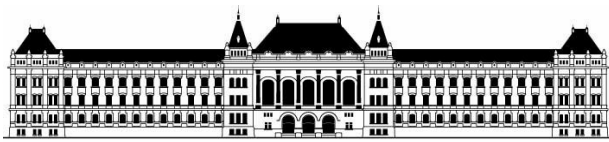
- (1) Corridor structure materials and construction will result with greatly differing thermal bridge properties. Hung corridors that are supported by steel beams usually do not use overhanging slab beams, but instead cantilever consoles. As a result, they are usually not the source of extreme heat loss. As a contradiction, a non-insulated cantilever slab section will be a source of considerable heat loss.
- (2) In the case of external walls that are well insulated, the issue of thermal bridges become increasingly relevant.
- (3) When building anew, we may use thermal bridge gaps both for cantilever consoles and beams. Another option is to replace heavy gravel concrete with light weight concrete. During reconstructions the option is limited to the enveloping thermal insulation of the building.
- (4) During construction integrity check, the vapor load must be compared to the lowest surface temperature. With the reduction of ventilation, the chances of mildew will greatly increase.
- (5) The waterproofing insulation material and technology may vary on the basis of the layer structure:

In case of a structure without step-noise or thermal insulation: surface waterproofing insulation (cement or plastic based flexible layer of a minimum of 2 mm thickness) and directly applied tiled surface finish affixed with flexible external glue.

Only sheet-type waterproofing insulation (typically plastics) may be used when the base is thermal insulation or step-noise insulation.

In case of renewal work, some altogether question the necessity of waterproofing insulation insertion, quoting the fact that there was no waterproofing insulation in the original structure. We today know that all tiled surface finishes leak thru, this in turn will cause corrosion damage in the underlying structure. In order to protect the structure, we must insert waterproofing insulations. The only exceptions are watertight concretes, pre-fabricated balcony units, solid stone balconies and hanging corridors.

- (6) Thin, sunlight and rain exposed surface finish temperature deviations will happen much faster than structural heat changes. It is, therefore, not recommended to glue the finish material directly on to the structure. When the surface finish is glued on, thermal heat expansion gaps are to be positioned with thermal movements of the structure in mind. In case of large corridor surfaces, the heat movements of the surface may be separated from those of the structure by slipping or floating layer structures.
- (7) Generally speaking, existing structures are usually not compatible with current standards (EUROCODE). According to practical experience, however, - if not damaged thru time e.g. due to leakage or mechanical effects - they are still adequately safe for use. According to the MMK Tartószerkezeti Tagozat technical directive (reference) it is permissible that those structures which were built according to previous regulations valid at the time of construction are to be re-checked and renewed according to the rules of these regulations. If no such regulations exist (pre XXth. Century buildings) the engineer is to personally consider all circumstances. Naturally,



for all of the above, the used materials, technical solutions and calculation standards of the time are to be known.

- (8) The necessary level of structure borne (step) noise insulation is determined by the factors of surface material, connections of the structural elements and the overall dimensions of the structure in combination. In terms of sound insulation, some heat-bridge breaks may be useful, as an example. Balconies, hanging corridors, during daily use will experience vibrations limited to the structure due to various kinds of traffic (walking, running). The vibrations will be transmitted thru rigid or flexible joints in the structure to neighboring walls and slabs and will result in noise in the enclosed rooms. The overall quality of this process is simulated by the standard weighed structure transmitted noise level index (L'_{nw}). The intensity of the vibrations depends on the activity, but this cannot be pre-considered. Therefore, the insulation requirements are set for the typical functional loads. The requirement for the L'_{nw} transmission insulation is a resulting maximum 55 dB noise level which is valid for most residential buildings (hotels, family homes etc.).

The needed structure borne noise insulation may be compiled from the following technical insulators:

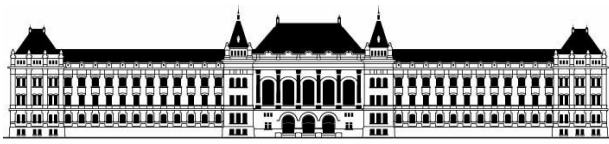
- surface material (in the field of balconies and hanging corridors there is usually little insulation supplied by the surface material as it is normally hard, due to weather exposure)
- the insulation properties of the complex layer structure underneath the trafficked surface (in case of renewal work, there is a limitation in the thickness in which flexible sound absorption sheets could be inserted)
- elastic connection elements between the slab of the corridor and the surrounding walls, slabs (may be useful in case of new buildings, in case of renewal only when the complete structure is replaced)
- internal wall coverings (crust sheet, crust wall, false ceilings, dry constructions).

According to OTÉK, the national building code, the minimum width of a corridor is 110 cm, but in cases of handicapped access the minimum is 120 cm. For community buildings where a large number of people is expected, the width is to exceed 165 cm. Escape route width calculations may need to further expand the available space.

Corridor barrier height, according to OTÉK, is a minimum of 95 cm. In cases where the width of the attic or parapet is at least 30 cm, the height of the barrier may be reduced to 80 cm. The barrier and the parapet are both life preserving protection devices, their satisfactory structural nature must be proven according to national standards. The barrier must be of a solid surface, or at least its slits must be vertical, the maximum space between slits is limited to 12 cm.

3. STRUCTURE VARIATIONS IN EXISTING BUILDINGS

In terms of structural play, balconies or the continued (long) balcony-like hanging corridors may be one of two main types:



- they may be of rigid cantilevers (consoles) which support the horizontally laid superstructure or
- they may be constructed as a singular, cantilever slab (consoled slab).

In case of historical architecture (therefore, in the majority of existing buildings), we find the first solution as absolutely typical. The centerline distance of the consoles is around 2.00-2.50 meters, the typical width of the superstructure being under 1.50 meters. The consoles themselves may be of wood, stone, cast iron, steel or reinforced concrete. In between the consoles we may find stone slabs, brick vaults and various concrete (e.g. slag-concrete) arches or reinforced concrete slabs.

The second variation is practically made solely as a reinforced concrete slab structure (we may consider the rarely found, pre-fabricated consoled slab plank elements as second type).

Terraces, loggias and circular corridors which are (also) supported by external pillars have an inherently different structural play, however, as their exposure and wear is also great and the construction is somewhat similar, their discussion under hanging corridors and balconies is justifiable.

3.1. Wood balconies and hanging corridors

Perhaps this group is the one that is easiest to separate from the others. Other than in wood frame and log houses of heavily forested areas, we seldom encounter wooden balconies. We will not discuss here this structural variation.

3.2. Stone balconies and hanging corridors

Stone balconies were mostly built from the beginning of the Middle Ages on, while hanging stone corridors typically appeared in the XIXth. and XX. centuries.

3.2.1. Purely stone structure balconies (stone slabs on stone supports)

The purely stone structured balconies are composed of stone supports (cantilevers, consoles) usually rigidly built into the wall – often held in place by iron clasps – that are adequately weighed down and of stone slabs laid onto these supports. The slabs are typically also walled in to a quarter brick depth (5-7 cm). The slabs therefore function as a dual support surface where one of the non-supporting edges has additional load bearing capacity. The supports themselves penetrate the wall to a one, or more typically one-and-half brick depth (approx. 30 to 45 cm depending on the size of the brick), the thickness of the stone slab is around 11-12 (15) cm.

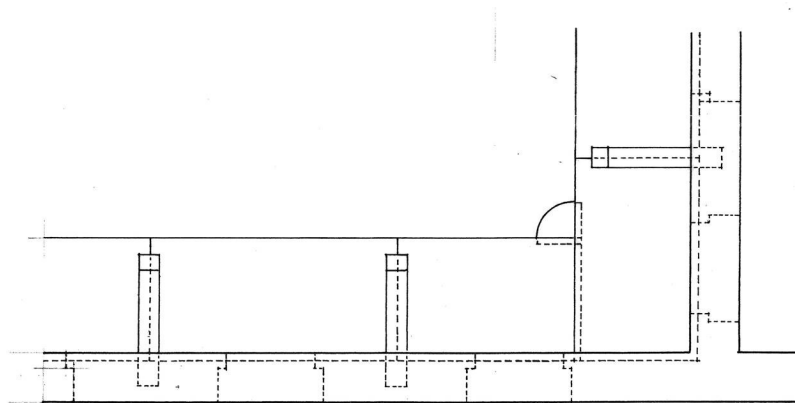
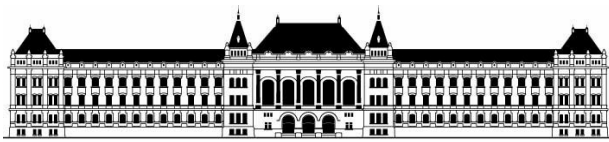


figure 1. Stone structure balconies

3.2.2. Vaults set onto stone supports

There are two variations to the partially stone made balcony, either the support or the resting slab on it is made of stone.

The previous was popular in the architecture of older buildings, when the stone supports held up brick vaults (the foundation stone of the vault was cut to allow an angular joint). We also find this situation in cases where the superstructure was refurbished, or reinforced, but the original structural stone supports remained in place.

The second variation became widely used in the second half of the XIXth. century, when the stone supports were in the beginning replaced by intricate cast iron consoles and later by simple rolled I beams. (for more see section 3.3.).

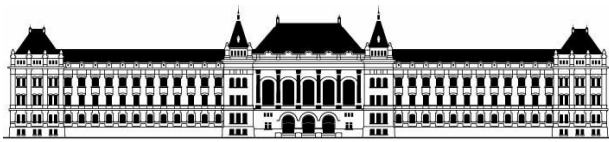
3.3. Cast iron console balconies and hanging corridors

In the second half of the XIXth. century, with the incline of iron and steel production, at first cast iron then (from 1880 on) rolled steel products gained popularity in the construction industry. This well-known tendency may also be observed in the structures under investigation.

The first step was the utilization of intricate cast iron consoles. Afterwards, on the basis of the particular application, some similarly well and some less well decorated wrought iron and in the end (mostly) triangular consoles made of rolled steel elements took over. The later were also made available as ready-made products by the steel factories.

3.3.1. Consoles that are built-in during and consoles that are built-in after construction

The pre-fabricated triangular consoles could have been inserted either during or after the construction of the building. In the first scenario, the upper, horizontal rolled steel bar was anchored with an iron rod into the wall. In the second case, the anchor was led thru a hole in the wall onto the other side where it was either affixed to the slab or to a disk-like anchoring



on the wall. The inclined rolled steel bar rested on a “spur”, typically also made of rolled steel, that assured the desired static play (the transfer of adequate vertical loads onto the wall).

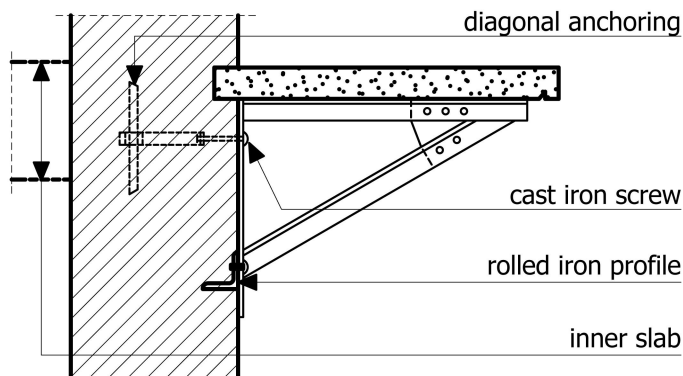


figure 2. Steel reinforced structure

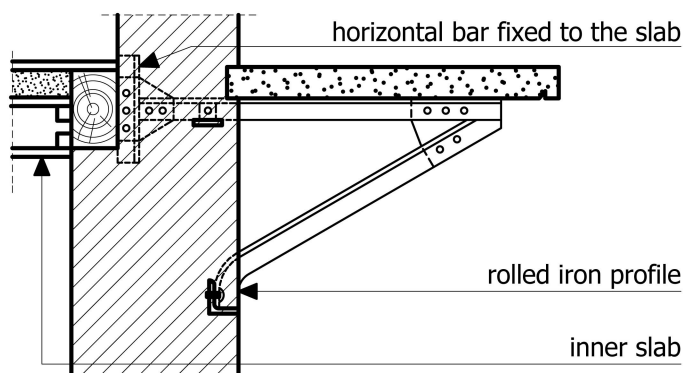
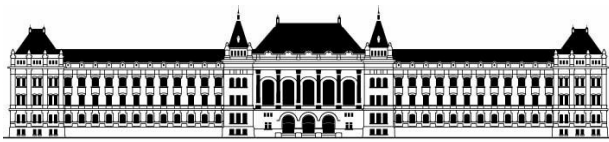


figure 3. Steel reinforced structure

3.3.2. Cast iron and steel console supported slabs

With the wide use of the steel beam slabs, it was an obvious choice to use the excellent and proven I beam as a console for balconies. The I beam was manufactured in a reliable quality from the 1880s on. From a statics stand point, it could have been very advantageous to lead the beams on, through the walls onto the façade, however, because of the heavy filling used in the slab layering of the interior, this would have caused a great elevation change between the interior and the exterior. In the case of balconies and hanging corridors the typical use became the consoled I beam with anchoring going thru onto the other side of the wall. According to the architectural preferences of the historical era, the I beams were then “stuccoed” over, with elaborate coverings that imitated the stone supports of previous times. To the untrained eye these stuccoes may be quite misleading, consequentially, we need to be careful at the determination of the material of the console.

3.4. Cantilever steel beam balconies and hanging corridors



The steel supports explained in the previous section, mostly carried horizontal stone slabs. The appearance of the I beam, however, introduced the possibility of various new slab solutions not only for the interior, but also for exterior of the building. This was especially valid for the abundantly utilized exterior corridor function. In between the steel beams – in accord with the development of the slab constructions – firstly flat curve (Prussian) vaults, light weight (hollow brick) vaults, then slag-concrete-vaults and lastly reinforced concrete sheet slabs were built. The end of the I beams were held together by U cross section edge beams, (onto which the cast iron barristrade was usually fixed) and the surface covering was typically made of mortar laid floor tiles. The steel beams of these constructions are, as of now, usually visible (as a rule, there are no face bricks to be found in the exterior) and the original minium-based anti-corrosion paint (if there was any) is long worn away. The structure is often soaked with water which seeps through the deteriorated surface covering and the steel beams are exposed to corrosion. If there is no timely intervention in the deterioration process, the whole structure may become life endangering (in these cases, newly built support consoles holding new, reinforced concrete slabs is the typical solution).

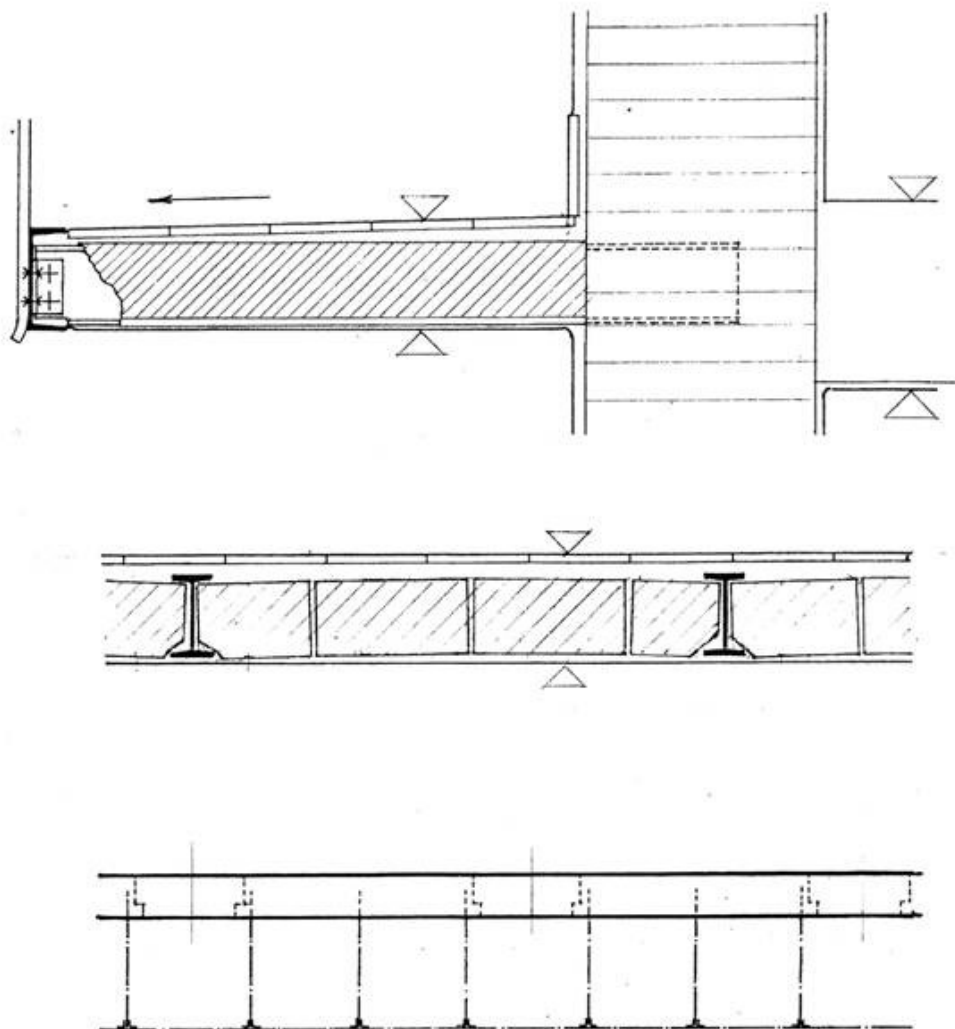


figure 4-6. Steel beam reinforced brick vault hanging corridor example

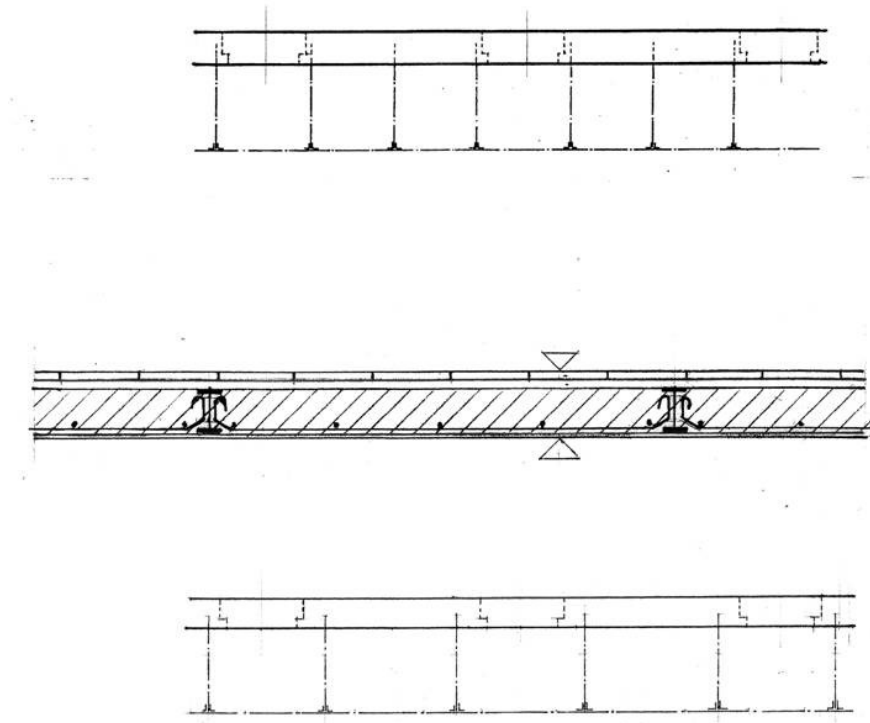
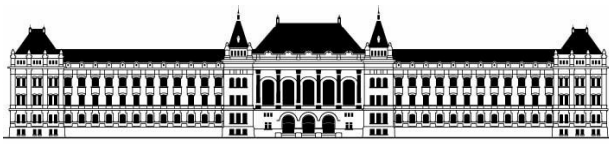


figure 7-9. Steel beam reinforced r.c. slab hanging corridor example

3.5. Site manufactured reinforced concrete balconies and hanging corridors

At the end of the XIXth. and at the beginning of the XXth. centuries, the appearance of (in the beginning almost exclusively site manufactured) reinforced concrete structures, brought about a revolutionary and lasting change in our architecture.

At first, the utilization of the new material was the imitation of traditional forms and structural dispositions, in the case of balconies, this meant horizontal slabs set on consoles. The consoles (which were previously affixed only thru weigh-down now) could now be connected with steel bars laid into the reinforced concrete to the structure of the pillar or the beam using the possibilities allowed by the monolithic technology. Only in later times did the cantilevered, reinforced concrete slab solution become widely popular and abundant.

Early reinforced concrete structures were generally well constructed. Faults and damages are mostly caused by dampness entering the hairline cracks of the concrete and corroding the steel. Corrosion, in turn, will cause volume expansion which breaks off the concrete's surface. Fortunately, in the case of consoles, the real load bearing tension steel elements are located at the top, under the slab and are therefore less exposed to the described damages.

In the case of pre-fabricated reinforced concrete beam slab types abundant after the end of the second world war (typical examples are: soft steel ÉTI beams with brick and concrete tray



inlays, later: tensioned beams with concrete or ceramic block inlays) the consoled balconies (and the consequently less abundantly built hanging corridors) were made of monolithic concrete slabs. The steel of reinforced concrete balconies with a small outcrop were more than often connected only to the ring beam (which causes a torsion load), or alternatively were led into the overlaying concrete of the slab (if there was such). The steel was in better cases anchored down behind a slab beam, or as a less frequent solution, in a reinforcement bar, running across the beams.

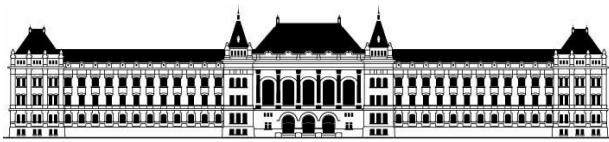
These solutions (especially when the slab is only connected to the ring beam) in many occasions (in family homes, or in small apartment buildings) were made without or regardless of the construction (statics) plans, inconsiderate to the rules and regulations of the time and as a result with inadequate load bearing capacity. This poses serious danger which is especially difficult to judge during renewal or reconstruction work (in these cases, we may only be certain of the applied solution thru exploration or instrumental investigation). The professional solution – the internal, slab high, reinforced concrete cantilever slab section in the pre-fabricated slab – was rarely used, since this solution (would have) required thoughtful design and (pre-fabricated slab based) relative intricate fabrication work. A relatively frequent solution was the outcropping consoled site-fabricated beam that was weighed down by the load bearing wall above, because this did not interfere with the pre-fabricated slab sections of the building. In these cases the balcony slab was resting either directly on the consoled beams, or an edge beam in between the consoled beams and the ring beam of the building itself. From a statical point of view, the latter described two balcony solutions are usually adequately, or even more than adequately safe.

The thermal bridge effects of site manufactured reinforced concrete balconies were not, or only sporadically considered until the 1990s. The new tendencies were slow to enter the design practice, but were even slower to enter the construction field. Thermal bridge gap utilization became usual only at the turn of the millennium, however, even their use was sometimes inconsequential. A total absence of thermal bridges became a practical requirement only in the latest years.

3.6. Pre-fabricated reinforced concrete balconies and hanging corridors

Pre-fabricated reinforced concrete elements in the structural group under investigation were never typical. However, there were some trials. In the early period (the beginning decades of the XXth. century) we may mention pre-fabricated reinforced concrete console elements that were intended to replace the stone consoles in a manner that was identical in use (e.g. inner slab beams as consoles) István Medgyaszay was the designer. In more recent times, we may mention some console ready slab beam or slab plank solutions (e.g. Fk-beams, Ytong, DE planks etc.) or the pre-fabrications used in the panel structures (loggia elements).

3.7. Pillar supported structures (loggias, circular corridors)



For the sake of complete coverage, we need to say a few words about pillar supported structures (upper floor terraces, multi-story loggias, circular corridors) which are commonly – and mistakenly – also called balconies or hanging corridors. These may also be made of wood, stone, cast iron, steel, reinforced concrete, or a mixture of materials. On the basis of the various materials and structural components we may state about the same as before in the case of the previously detailed consoled structures, aside from evident differences inherent to the different statics play. The most important difference is that the more advantageous (dual or multiple support) statics model has greater stability reserve which results with damages causing less frequently life threatening situations.

Iconic examples of the group are (brick or stone) pillar resting beam-, or laid vault supported multi-story loggias, slender cast iron pillar supported courtyard circular corridors which may be observed in several representative XIXth. and early XXth. century buildings.

An evaluation concerning the adequacy for requirements:

- *As discussed above, historical (approx. between 1850 and 1990 built) structures that satisfy the rules and regulations of the time at which they were built are – if not according to today's standards, but on the basis of experience based on use – generally considered safe for use (until the appearance of structural damage). Chances for sudden deterioration is mostly to be expected as the breaking of the stone supports (or sometimes of the stone slabs) or as the braking of slag-concrete slabs.*
- *Although at the time of their building, thermo-dynamical considerations were not important in any of the cases above, the level of thermal bridge effects is by far not the same for all situations: stone consoles laid into the wall pose a relatively small spot-like thermal bridge effect (at least until the wall is insulated), while the monolithic reinforced concrete slab console is a drastic heat loss effect thermal bridge source.*
- *From an acoustic standpoint, we may also state that the spot-like wall connection of the consoled solutions are better, as in these situations only the consoles themselves transmit structure borne noise.*
- *Waterproofing insulation against precipitation was not fabricated in the vast majority of cases until the most recent times. An adequately inclined layer of frost-proof stone slabs or a surface finish that may be considered as homogeneous (e.g. artificial stone) are much better from this aspect than tiles laid in mortar as in the latter case water infiltration and consequent damages are usually only a question of time. It is also important, how the outer edge of the balcony or hanging corridor is made, whether there is a drip edge and whether the water is appropriately led off from the edge. In the absence of a drip edge, the water that reaches the bottom line will not drop freely, but rather will flow back towards the interior, deteriorating the plastering. The most dangerous - from this later aspect - are the U profiled steel edge beam constructions of hanging corridors. Here, in most cases, water will easily reach and infiltrate to under the upper segment of the U beam at the edge of the tiling, causing extensive damage (see picture).*

4. TYPICAL DAMAGES, DIAGNOSTICS, MAINTENANCE



4.1 Structural damages

Weather wears the exposed stone slab a lot more than the support underneath. In addition, there is also considerable frictional wear to be withstood by the upper surface (especially in case of hanging corridors). The result is that the slab is always cut from hard, solid, frost resistant stones – in Budapest, this is usually limestone from the Piszke or Tardos area. The supports were – unfortunately – often made of softer material. We need to note that the long time effect of the detergent based mopping of the corridors may, to a degree that depends on the chemical composition of the detergent, also damage the stone.

Stone structure balcony damages, deteriorations will most often result with the cracking of the slab. The cracks are a visible signal of the deterioration process which calls immediate attention to the analysis of the loads on and the stresses in the stone. The latter naturally may only be investigated after a careful mapping of the crack network and with precise knowledge of the given stone's mechanical properties. From a material-structural standpoint, the stone's resistance may be focused upon. The resistance is the critical stress intensity value of the stone. As a rule, the tensile (pulled) strength K_{IC} value is quoted (break resistance). There is in practice, however, serious limitations to the quantitative calculation based analysis. On one hand, the mentioned mechanical properties change not only from stone type to stone type, but also within a type of stone, on the basis of the location of the mine and furthermore, on the basis of the harvesting location within the mine itself. On the other hand, the conditions for the practical applications of the stone-break mechanical theories are not yet fully available.

The propagation of the cracks may be standstill (instable) or leading to break (stable). The existing crack will at first propagate as stable, then (after reaching the critical crack size) turn into an instable propagation. The process is closed by either breakage or a repeated standstill crack status.

Cracks must always be investigated by an expert, as the on-site visual analysis requires great practice. The simplest method is, however, to simply pour a bucket of water onto the cleaned surface, whereby the cracks will be discolored and apparent. If the water seeps onto the other side, then there is a very serious transcendent crack.

The continuously monitoring and refurbishment of these corridors is of great importance. Usually this means the upkeep of the surface finishing and the repeated anti-corrosion painting of the exposed steel beams. In case of existing rust, the steel surface naturally has to be cleaned and – which is of paramount importance – the reduction of the cross-section size is to be controlled by measurement. When necessary, the adequacy of the remaining load-bearing capacity of the reduced cross-section is to be verified via calculations.

4.2 Damages to the surface materials



The typical deterioration of the upper surface finish is the freezing of the tiles. The cause of the freezing is, without exception, water or dampness that enters the structure underneath the tiling. The water absorption qualities of the tiles vary, however, water will, sooner or later, in all cases, enter through the gaps. Dampness underneath the tiling is indicated well by moss in the gaps, or even by gap fill discoloration (darkening). The freezing of the tiles themselves may be caused by sub-standard materials (non-frost proof) or faulty installation. The later, most frequently, stands for a construction that does not at all, or does not properly lead the water off the surface. For example, if the foundation estrich of the tiles is of a solid, non-water transmitting material, then moisture that finds its way thru the tiling will get stuck in between the layers inevitably freezing during winter.

Frost proof small water absorption quality tiling (e.g. gres tiles) may experience surface or fill discoloration. This happens all the more, if the tiles are laid into the, nowadays popular, flexible thin mortar-glue, directly onto the spread-type waterproofing layer. If the glue does not cover the whole surface (which is a frequent mistake) then the water that seeps through the gaps, since it cannot evaporate or flow out, will collect and pool in the non-filled hollows.

Natural stones, and this surprises most people, in general, will absorb a considerable amount of water. In addition, as in the case of all natural materials, this quality varies greatly within the particular stone as well. If the ongoing way of the water that seeps through the stone is not solved (e.g. non- filtering concrete or mortar is used as foundation) then the discoloration of the surface is to be expected. A frequent side-effect is the appearance of salt deposits which is caused by dampness migrating upwards to the exterior and the evaporation at the surface. The migrating water will inevitably carry some soluble salts with it. The salt deposit will be considered a serious value deteriorating side-effect on the expensive surface finish.

When executed in a binding layer structure, typically on larger surfaces, the different expansion movements of the finish material and the structure underneath will result with damaging cracks and the possible peeling off of the tiles.

Dripstones or deposits may form at the drip edge of the balcony or at the drain point of the inner water collection line. This is mostly caused by water seeping through the filtering concrete or estrich that in turn dilutes free carbonates that are deposited where the water drips.

4.3 Damages due to faulty waterproofing

An improper fabrication of the waterproofing layer is a frequent problem. If at the doorstep the waterproofing is not folded up properly, rainwater will enter into underneath the interior surface layers. This water then will cause dampness and wall mildewing in the inner rooms. As an example, rainwater may travel a considerable distance away from the original fault location especially in the noise insulation layer of the floated floor.

Sometimes the waterproofing is altogether missing behind the footing. Water will also enter the structure at the joint of the wall, when the gap is not properly sealed. Other faults are caused by improperly placed waterproofing (for example, on the outer surface of the thermal



insulation) where the wetness may get behind the line of the insulation and may cause water damage.

At the edge of the balcony, the connection of the handlebar pillar thru the waterproofing is often solved without due consideration, whereupon the waterproofing itself may lead the water into the structure.

5. TECHNICAL SOLUTIONS FOR RENEWALS, RECONSTRUCTION

When preparing the design of hanging corridor renewal work, we must keep in mind that the inhabitants need to constantly be able to access their apartments. Access must be secured during the construction work. In practice, this is realized with an appropriately scaled temporary support structure, placed underneath the corridor. The support structure (forming, scaffolding) may be furnished with a walking upper surface. Both access and renewal work (demolition and construction) may be done standing on this upper surface and in case of site manufactured reinforced concrete, it may also function as the form itself. Naturally, solutions that do not require temporary supporting structures are more advantageous.

Less often, the conversion of buildings may also influence the stability of the hanging corridors. A typical example is the careless re-positioning of the openings, which in turn may remove the required weigh-down of the console elements. (Obviously it is also true for demolition work!)

5.1. Reinforcement of existing structures

5.1.1. The reinforcement of stone supports with steel tension bars

Mostly, when a stone support is eroded, it is replaced by an I beam, or in the case of heritage buildings, by another stone support. Another possibility is, in some cases, the in-place reinforcement of the original stone supports with a special technology. The technology involves the insertion of steel tension bars with dedicated technical apparatus and well trained personnel. (e.g. DIVIDAG)

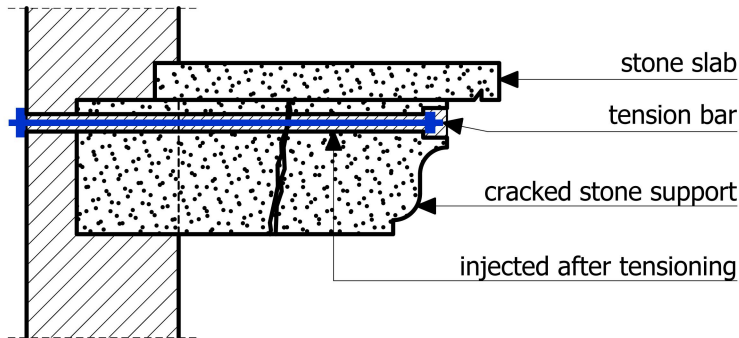
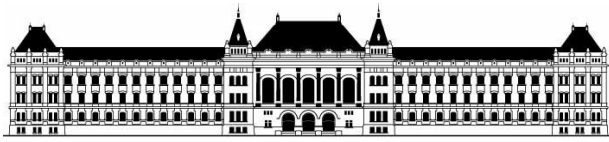


figure 10. The reinforcement of stone supports

5.1.2. The reinforcement of steel consoles and consoled steel beams

The reinforcement of steel elements, as in general, is usually done thru the welding of additional reinforcement components onto the existing structure. Reinforcement may be placed onto the top of the bars (e.g. if the reinforced concrete slab is in between the beams and its top section may be accessed via the removal of the superstructure) or on the bottom and sometimes on the sides.

5.1.3. Stone “sewing”

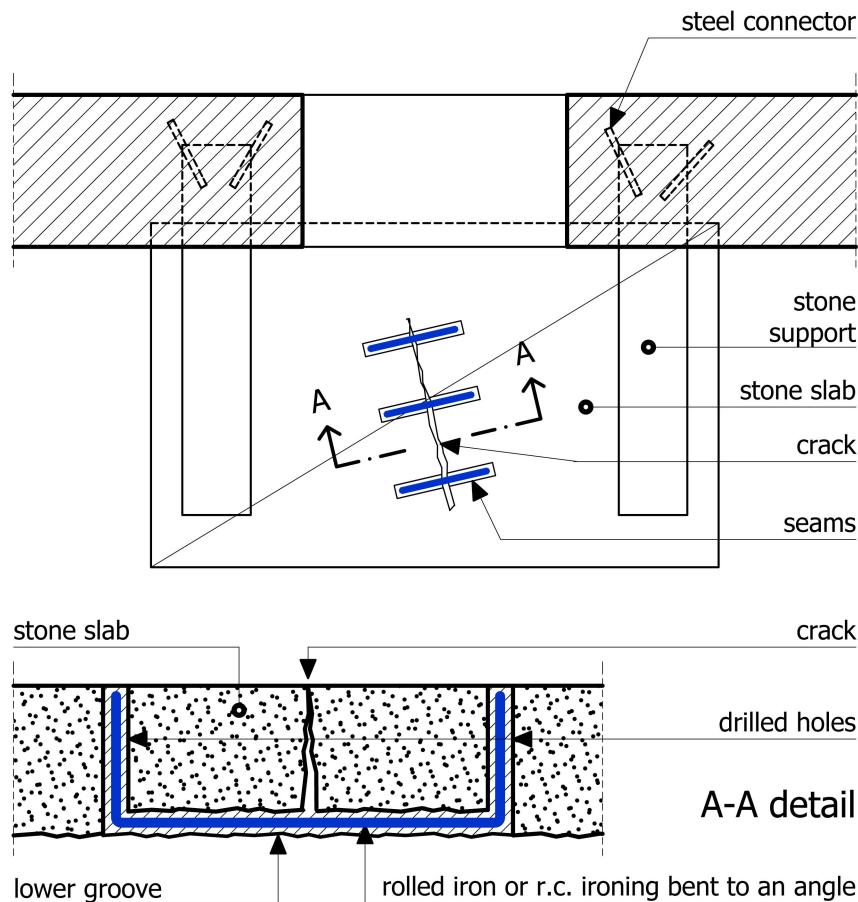


figure 11.-12. Stone slab, viewed from under, section

In case of local stone slab fractures, the so called “stone sewing” is another possibility. In these cases, drilled holes are made on the two sides of the crack and these are connected by a groove on the bottom surface. Afterwards a U shaped steel element (reinforcing steel, soft steel) is placed into the holes and the groove. The groove and the holes are then filled by either an epoxy based mortar, or some kind of high quality stone glue. (Historically, the gap was filled by lead.)

5.1.4. Composite (carbon fiber) reinforcements

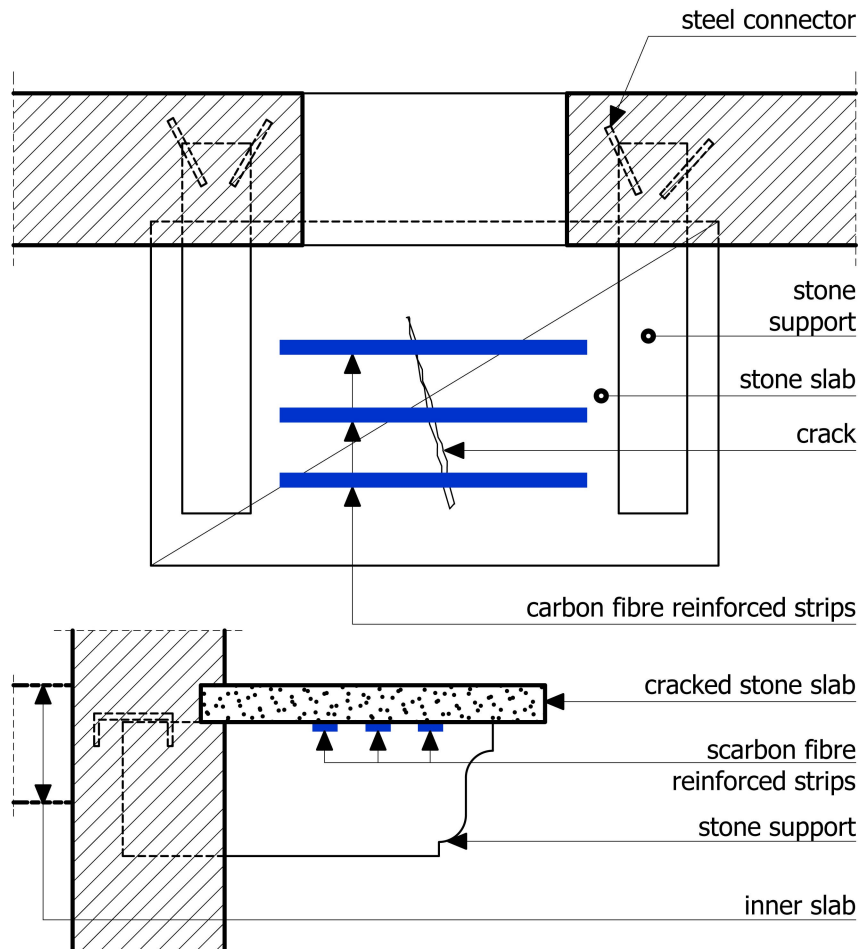
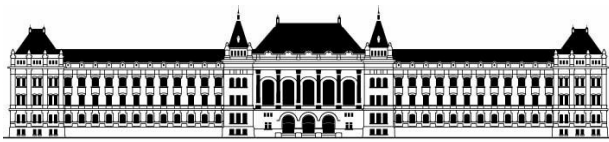


figure 13. -14. Carbon fiber reinforcements

Carbon fiber strips as reinforcements have appeared in the past few years as a new technical possibility for the construction industry. In the discussed field, their utilization is not limited to the reinforcement of cracked reinforced concrete balconies, the technology may also be used to reinforce cracked stone slabs (for this later application, the first use in Hungary is dated back to 1997). The main concept of the technology is to insert carbon reinforcement fibers into resins (usually epoxy resins) thru a plustrusion process and to create a strip that when hardened, may be glued onto the adequately prepared surface of reinforced concrete or stone slabs as new, additional reinforcements. As the strips will increase tensional strength, and thereby will generally increase resistance against bending, they are placed onto the pulled side of the structure (the bottom surface of dual, or multiple support stone slabs and the top surface of site manufactured consoled slabs). The possible use of the application is to be evaluated on a case-to-case basis.



5.1.5. Special technologies for the fixing and remodeling of stone and concrete structures

Lately, more special technologies have become available in the local market, such as dedicated stone filling or concrete fixing materials that allow the completion of missing or damaged stone elements or on-site manufactured reinforced concrete structures, in a way that is enduring and of an acceptable standard. These, by definition, may be used in the area under discussion, however, it must be emphasized, that these materials are not suitable for the reconstruction of load bearing elements as they are designed for solely aesthetic or further deterioration prevention purposes.

5.2. Newly inserted supports as supplemental reinforcements

If the reinforcement of the existing structure is for some reason not possible (or at least not economical) and its replacement is not feasible due to monetary or other limitations, the only remaining option is the insertion of new, secondary support structures.

5.2.1. The insertion of additional consoles

Consoles that are placed as supplements beside existing ones (typically on the side, in an area where the wall is appropriately weighed down) may serve as simple replacements for the old consoles, or for the increasing of the frequency of the number of supports.

5.2.2. The changing of the linear console support to a surface like support

In case of many cracks, or when the hanging corridor's slabs are deteriorated in mass, the only safe option is the surface-like supporting of the existing slab structure. There is a number of options (technologies) available – a common trait being that all of these utilize consoled steel beams placed into the wall cavity (in a manner described above). When constructing the supplemental consoled steel beams, it is of paramount importance to check for the appropriate weigh-down of the inner part of the beams.

A The fabrication of secondary, sprayed-concrete reinforced slabs in-between existing steel beams

Cavities that are chiseled into the wall may hold consoled steel beams that can, with this technology, support (in the bottom section) steel reinforcements that are sprayed with concrete, creating a secondary slab support structure. In order to allow a small structural height and also to secure an appropriate resting of the steel reinforcements on the steel beam,

it is more practical to use steel more densely inserted beams with a profile that has a wider top and bottom section, with less height. (e.g. HEA 80-100).

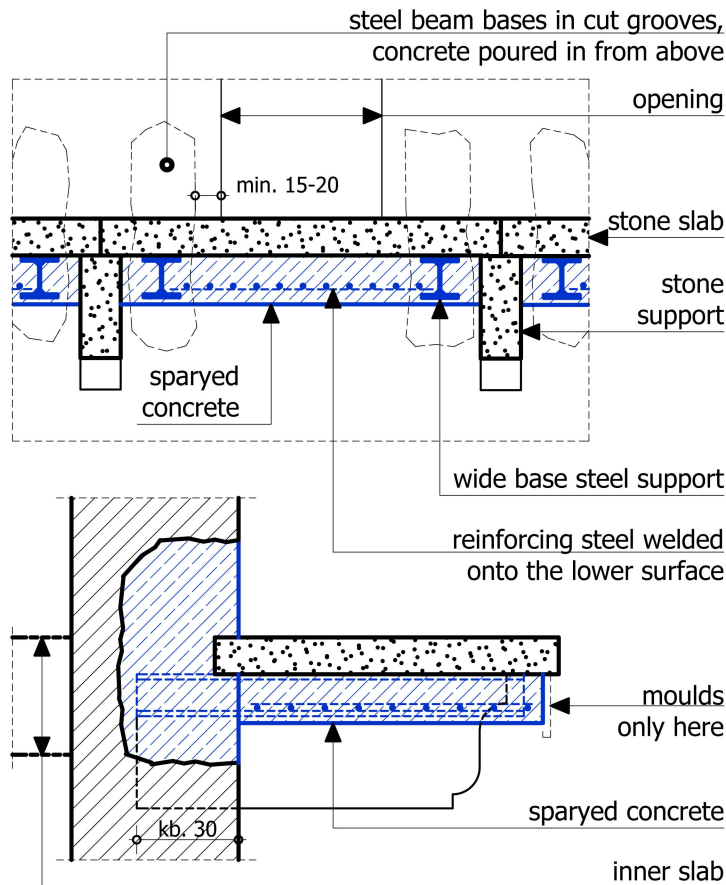


figure 15. - 16. Sprayed concrete reinforcement

B Trapezoid sheets placed onto steel beams

The most popular reinforcement technique of our days is perhaps the use of consoled I beams inserted into the façade wall near (or at) existing consoles of the hanging corridor (or balcony) whereupon trapezoid steel sheets are laid. Generally, the trapezoid sheet is wedged in place underneath the existing slab from a temporary scaffold, then the supplemental I beams are inserted into the previously carved-out wall cavity. The beams are held in place by temporary supports while the concrete is poured into the cavity holding the beam. It is also possible to perform the process described for pre-fabricated reinforced concrete slabs, whereas the trapezoid sheets are welded to the top of the I beams before insertion. In the latter case, only the I beams need to be temporarily supported.

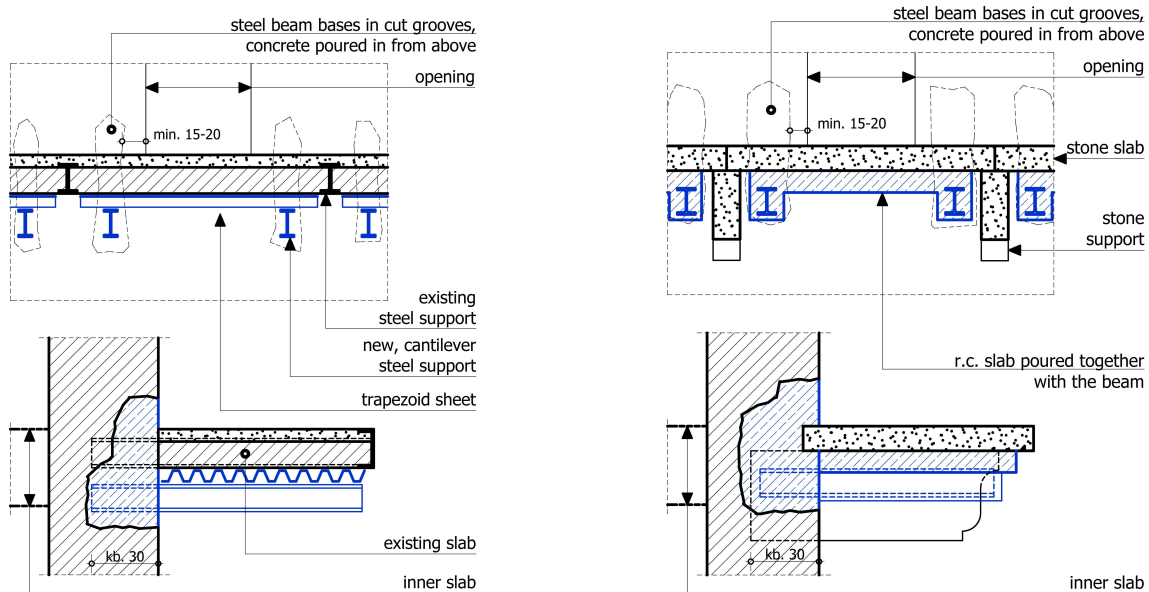
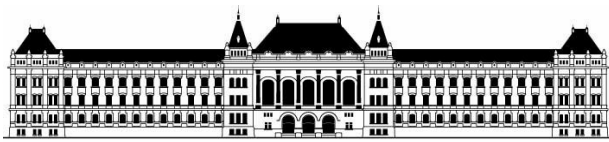


figure 17-20. Reinforcement using trapezoid sheets

5.2.3. Supplemental support using pillars

The using of pillars (and pillar supported beams) is naturally a simple and evident method that may be used for the reinforcement of consoled structures, as this was often in practice in the past. Careful consideration is to be given, however, when deciding the possible use this solution, as it may be damaging, due to the changing of the static model. In addition, this application is architecturally generally not permissible since the historical console forms are alien to the pillar motif. As a final solution, pillars would give the look of the temporary support left in place forever.

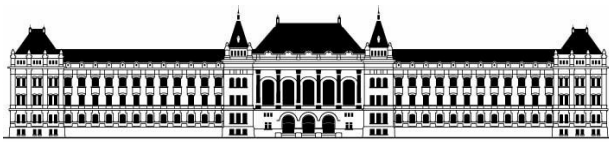
5.3. Partial- or full replacement of the structure

The replacement of the console supports, support stones is in all cases performed with the temporary supporting of the slab sections above (except, of course, when the slab is also removed before the console is replaced).

When only the slabs are replaced, the consoles which are in good condition, may stay in place, whether carrying loads, whether if only for aesthetic purposes.

If the original steel consoles are in good shape, the forms of the newly made reinforced concrete slab may even be hung upon the steel beams. Alternatively, built-in forms (e.g. trapezoid sheets), that are left in location may be used.

5.4. Special or composite structural solutions



Real life, as we find, often produces situations, where various aspects work against each other and none of the above techniques may be used as an exclusive option. As often as not, the existing structure is already the result of some kind of combination of the construction techniques of the time, instead of known, or for all purposes and intentions, in this note demonstrated clear archetypes. In these cases, dedicated evaluation and the use of engineering creativity may be the only solutions.

5.5 Variations for follow-up waterproofing

In multi-layer constructions, the support structure material is different from the surface covering, therefore, it is possible to insert some kind of waterproofing in-between. A case-to-case investigation is necessary to decide what particular solution is feasible. Corridor or balcony connection thresholds and internal level heights are defining characteristics when considering the alternatives. The least layer thickness is achieved by spread waterproofing on the structure with flexible thin mortar glue onto which frost proof ceramic tiles may be laid. In this case the limited movement tolerance of the surface is to be paid attention to. If there is enough space to create a sliding or even floating floor, the layer structure will reliably tolerate the different motions of the structure and the superstructure. When using a floating solution, the enveloping thermal insulation can also be easily inserted, thus cold bridges are reduced. An additional benefit is the reduction of transmitted noise, in effect, floating the floor will result with near-standard levels of noise transmission.

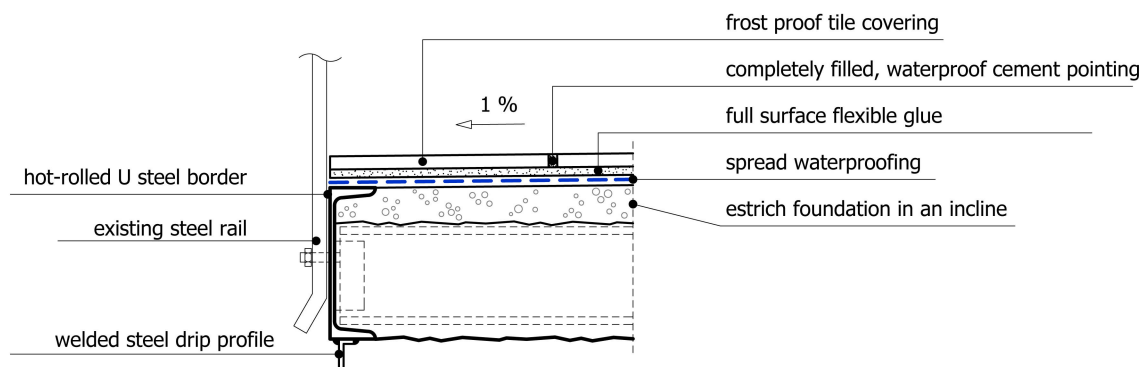
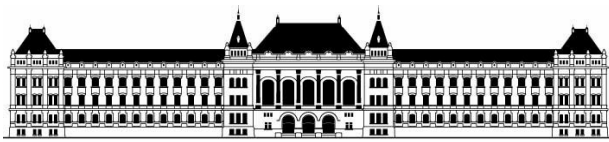


figure 21. Example showing the renewal of a steel beam hanging corridor

The originally different thermal bridges of balconies and hanging gardens need special attention when affixing post construction thermal façade insulations. The building thermodynamics investigation must focus on surface temperature variations, or in other words, the dangers of deterioration due to low temperature zones (mildew). If the cold zones of corners and wall-wall and wall-slab connection lines are reduced - supposing the vapor load of the room is the same - the risk of mildew creation is also lessened. The shown few examples are typical to the one case in focus. Dedicated investigation is required in all cases.

6. DESIGN AND CONSTRUCTION OF NEW STRUCTURES



New hanging corridors and balconies must be designed according to current standards and regulations, adhering to the generally accepted level of technical advancement. The most relevant regulations are collected in the enclosed table.

6.1 Structural solutions

Reinforced concrete and steel structure construction must note available thermal bridge gap solutions. The steelwork solutions are provided by qualified manufacturers and the traits of the products are constantly monitored (strength, fire resistance, linear thermal insulation). Thru the utilizing of these solutions, strong thermal bridges may be avoided and consequent deteriorations hindered (mildewing). Thermal gap elements are not only manufactured for reinforced concrete slabs, but also for beams and other structural components. Their use allows us the construction of floating floors with waterproofing layers in a thickness that corresponds to the thickness of the interior floor layer structures (see picture).

Newly constructed balcony and hanging corridor structure schemes (cutaway, detail, bottom view)

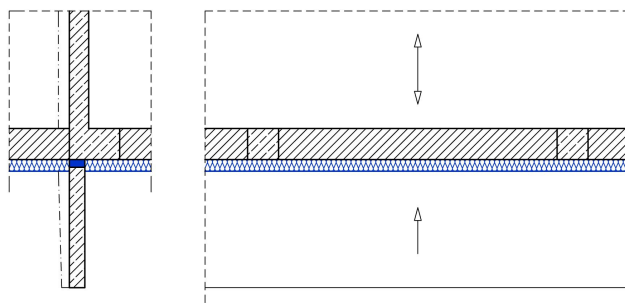


figure 22-23. consoled slab with thermal gap

In the case of beam supported slab structures, the recurring question is, whether it is enough to cut the slab thus removing it from the building and saving a considerable amount of cold bridge gap fixtures. The double support slab, however, will experience thermal expansions that are by far greater than the movements of the triple or four times supported slab. These expansions will result with leaks, dampness in the most delicate area, at the wall (since the waterproofing will rip apart exactly at the wall-slab joint). Due to the above, generally it is not advisable to completely neglect the insertion of gap elements in the wall-slab joint line, even if statically otherwise this is not necessary. This rule does not apply to very small structures and loads where the calculated expansions are minimal. The practical solution is to insert the gap elements not as a continuous line, but rather in sections: alternating with insulation-only lines. This structural solution need to be considered by the architect with the aid of the statics engineer (see picture).

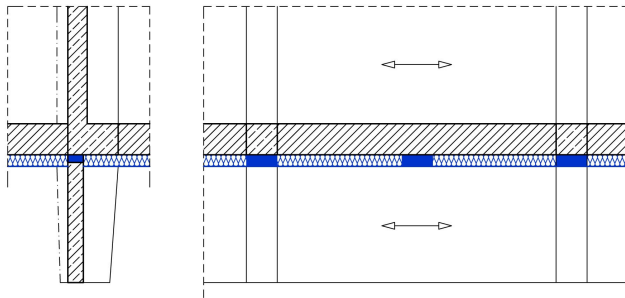
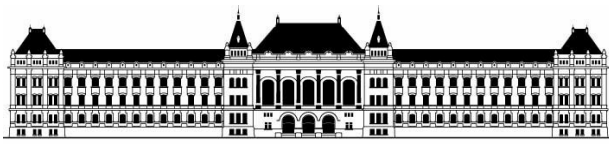


figure 24-25. consoled beam with thermal gap

In order to reduce the cold bridges of the balcony and the hanging corridor (as there is no structure without a cold bridge) a frequent option is the enveloping thermal insulation of the whole structure. An alternative is the use of lightweight concrete (e.g. liapor concrete), the latter is not often used in Hungary.

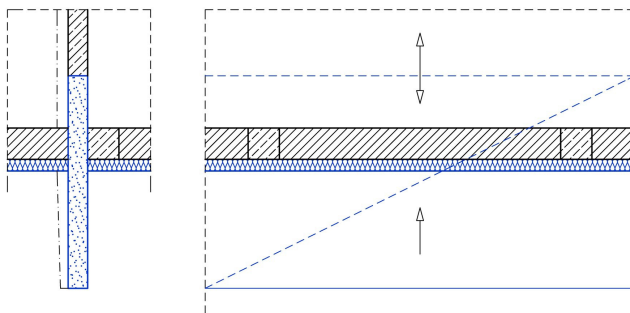


figure 26-27. liapor concrete consoled slab

The thermal insulation enveloping of the reinforced concrete structure requires a relatively thick layer structure that generally is only possible when the upper surface of the external slab is submerged. Even then, the submerged structure will, in effect, continue to behave as a cooling radiator element. Thermal insulation is to be inserted both at the bottom and the top slab surfaces, even more, when a beam is consoled, it must be covered on all sides. When considering that the top layer insulation must be at least “load bearing” quality (dense, hard), it is understandable, that another, floating noise insulation layer is also required. Furthermore, hanging corridors must also have a built-in load distribution layer (estrich or screed) underneath the surface layer, due to the experienced traffic (see picture).

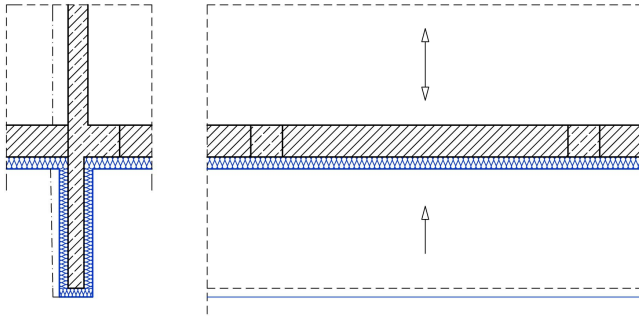


figure 28-29. consoled slab with enveloping thermal insulation

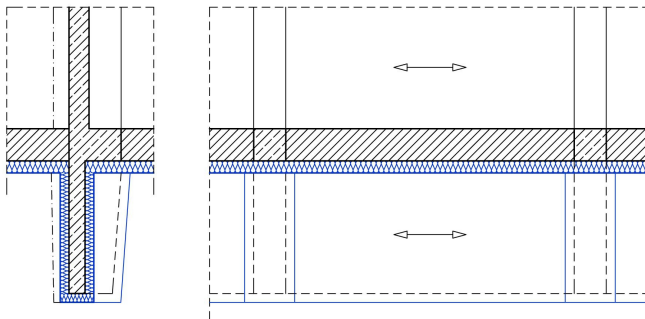


figure 30-31. consoled beam with enveloping thermal insulation

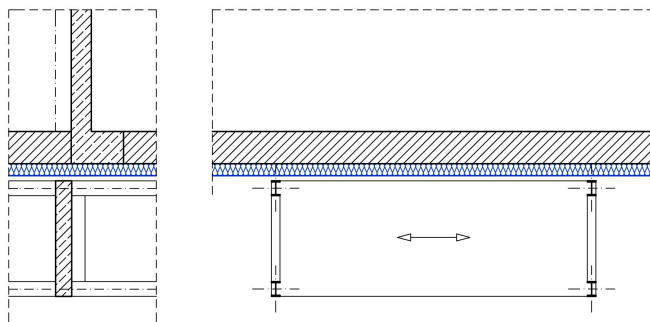


figure 32-33. independently supported balcony

6.2 The surface materials and their foundations

6.2.1 Ceramic floor tiles

Frost proof ceramics, glazed ceramics, stone ceramics (gres) are typically laid into shallow mortar bases, the mortar is a dedicated external flexible glue.

Surface covering and its foundation:

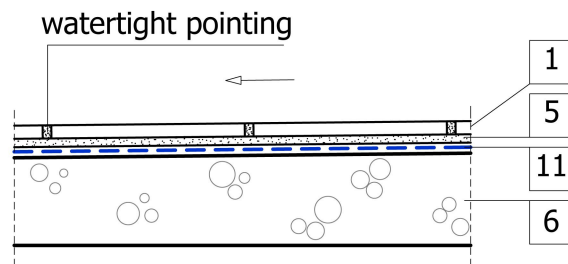
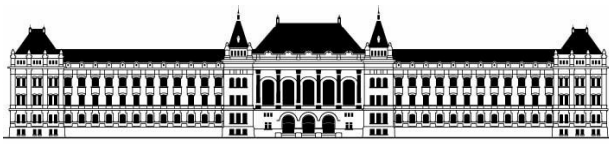


figure 34. Small water absorption tile glued onto spread waterproofing

- | | |
|--|---|
| 1 low water absorber tiling | 7 filtering concrete or mortar |
| 2 natural stone covering | 8 fine concrete gravel as a base |
| 3 fabricated stone covering | 9 drain sheet with plastic filter layer |
| 4 saturated or heat treated wood surface | 10 protection for the waterproofing |
| 5 full surface (no bubble) gluing | 11 waterproofing, min. 2 mm against percipitation |
| 6 lestrich or concrete that provides incline | 12 waterproofing against percipitation |

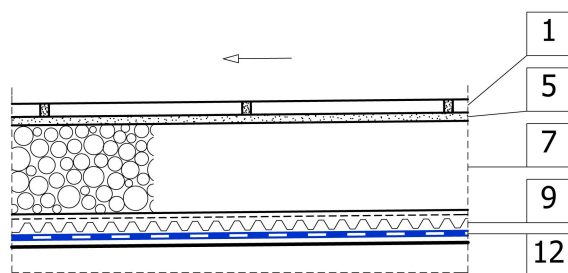


figure 35. Glued tiles on a water transmitting concrete base

6.2.2 Stone blocks

When laying down natural stone blocks, it must be considered that these are porous, in other words they freely transmit water. The water transmission quality – with few exceptions – greatly supersedes the same quality of the ceramic or stone ceramic tile. As a result, water seeping and outlet solutions must be provided.

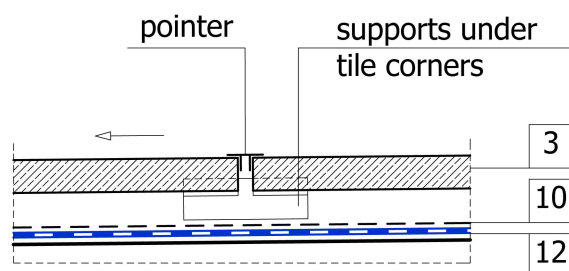


figure 36. Stone blocks with spot-like supports, water flows out at the bottom

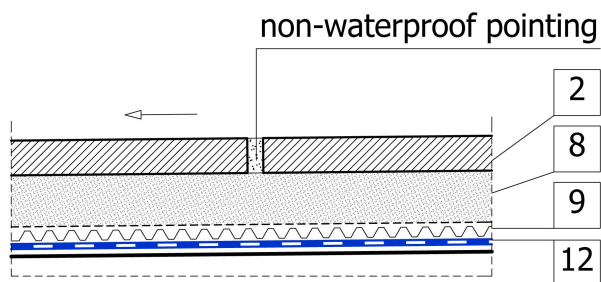


figure 37. Stone blocks in a water transmitting base

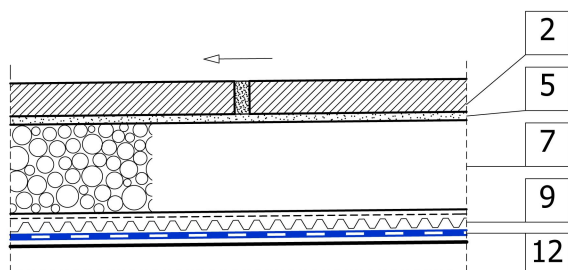


figure 38. Stone blocks over a water transmitting concrete base

- | | |
|--|---|
| 1 low water absorber tiling | 7 filtering concrete or mortar |
| 2 natural stone covering | 8 fine concrete gravel as a base |
| 3 fabricated stone covering | 9 drain sheet with plastic filter layer |
| 4 saturated or heat treated wood surface | 10 protection for the waterproofing |
| 5 full surface (no bubble) gluing | 11 waterproofing, min. 2 mm against percipitation |
| 6 lestrich or concrete that provides incline | 12 waterproofing against percipitation |

6.2.3 Artificial stones

Artificial stones and concrete tiles (terrazzo) coverings must be selected only from frost resistant products. Due to the relative thick nature and high water absorption quality, the solutions for natural stone layers are also suggested for these cases.

6.2.4 Wood coverings

Wood coverings for high traffic areas (corridors) are not recommended. In all other cases (balcony, loggia) an evaluation is to be made weighing the relatively short lifespan and high upkeep costs (1-2 times annually) against other factors. The surface finish itself and the underlying wood blocks, as a rule, must be of heat treated or saturated woods,. The layer composition is to be designed so that trapped water is not to remain under the blocks.

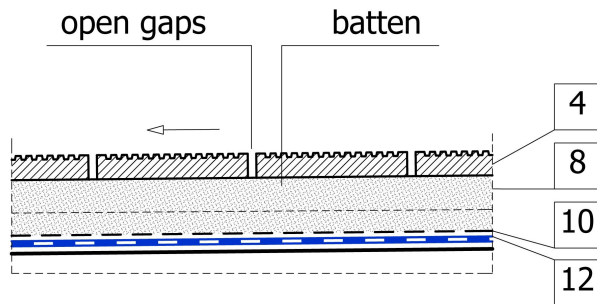
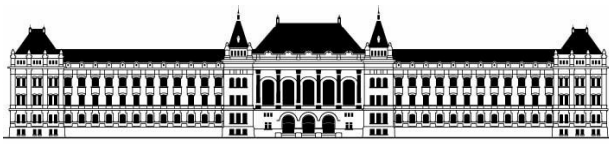


figure 39. Wood cover in a water transmitting base

- | | |
|--|---|
| 1 low water absorber tiling | 7 filtering concrete or mortar |
| 2 natural stone covering | 8 fine concrete gravel as a base |
| 3 fabricated stone covering | 9 drain sheet with plastic filter layer |
| 4 saturated or heat treated wood surface | 10 protection for the waterproofing |
| 5 full surface (no bubble) gluing | 11 waterproofing, min. 2 mm against percipitation |
| 6 lestrich or concrete that provides incline | 12 waterproofing against percipitation |

6.3 Variations of the water drainage solution

Balconies and hanging corridors traditionally have external, line drainage solutions. This more often than not, means the mere dropping of the water off the external edge. Sometimes, when the façade is exposed to winds or when the underlying surfaces are prone to water damage, a gutter is inserted at the edge of the slab. The location of the vertical rainwater collection lines (downspouts) is, however, often a problem. In the case of a small balcony, it is easier to find a good spot for the downspout, as opposed to a long hanging corridor. (see picture)

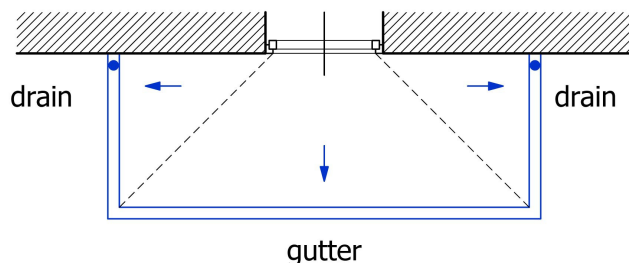


figure 40. railing with a hanging gutter



Spot-like external water outlets may easily be realized as simple water spouts. This nevertheless is a solution with many drawbacks and frequent faults. The spouts will quickly freeze up in winter and the removal of the snow is of a greater problem when compared to the open gutter. Only the artificial heating (anti-frost base heating) of the spout and the walking surface will assure the avoiding of leaks in the long run. Multi-level buildings, especially on the wind exposed side, may experience faults even with base heating as the concentrated water downpour hits the façade. The designer is to weigh the risks.

Balcony water outlet options:

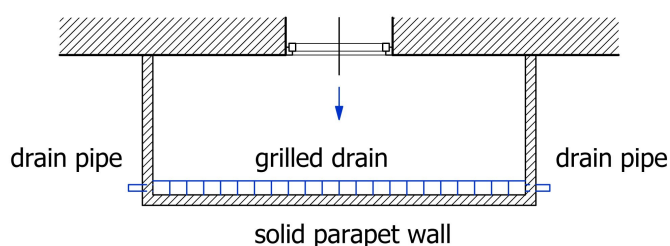


figure 41. Solid parapet with linear drainage and spout

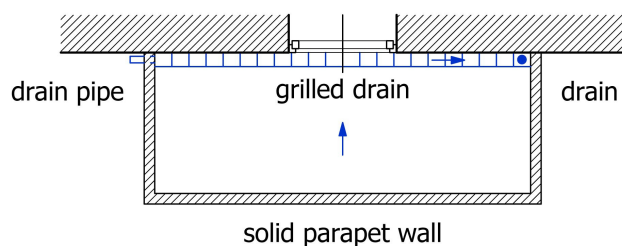


figure 42. Solid parapet with linear drainage and downspout 1

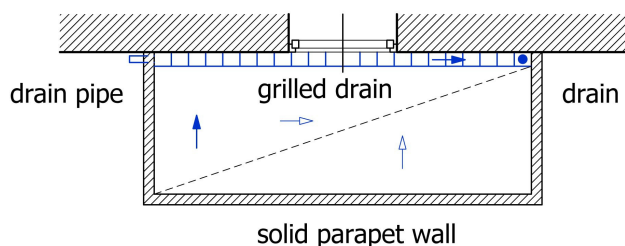


figure 43. Solid parapet with linear drainage and downspout 2

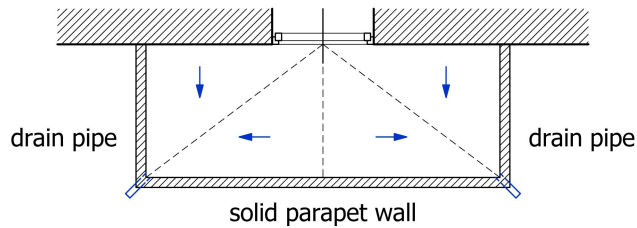
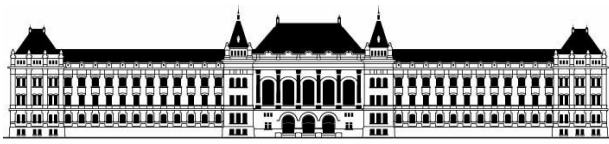


figure 44. Solid parapet with spouts

Internal water outlets may be suggested in cases of railings with a low parapet wall or where solid parapet walls function as railings. In these cases both linear and spot directed inclines are acceptable. In both cases however, the freezing of the internal gutter and the filling of the cavity-like balcony or corridor with snow is to be hindered. When a solid parapet wall is built, secondary water spouts are to be used.

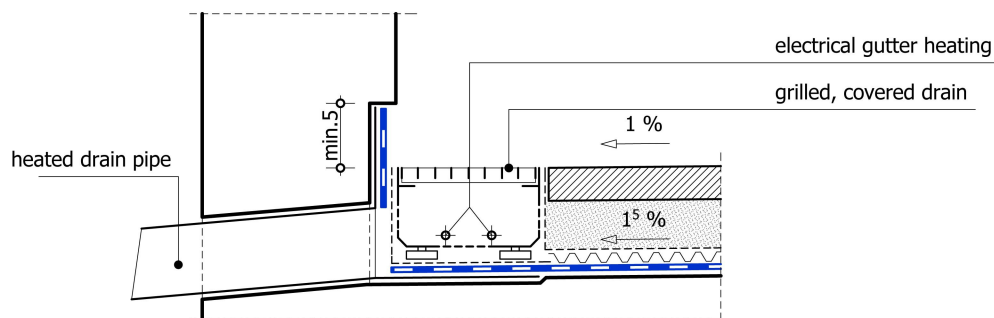


Figure 45. Solid base balcony drain method 1.

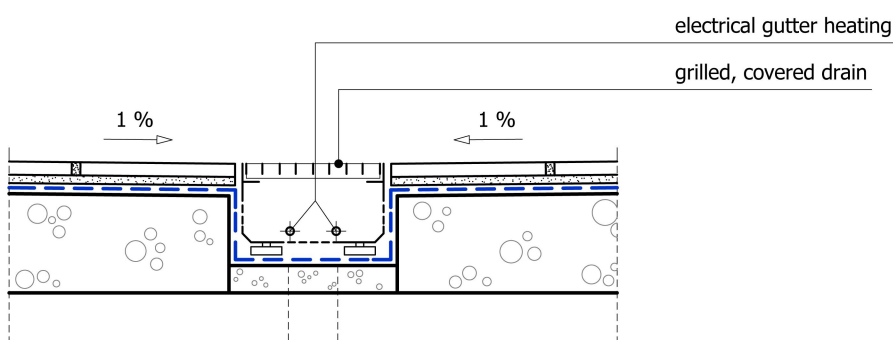
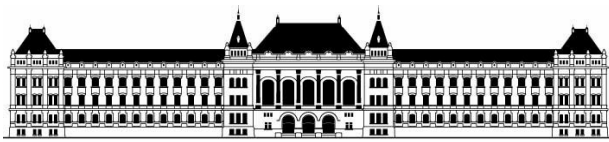


Figure 46. Solid base balcony drain method 2.

6.4 The exposed edge

Most of the investigated structures are manufactured with an exposed edge, where the rainwater will drop off freely. For the solving of this detail, on the basis of the layer structure and according to architectural preference, there are several solutions. The dropping off of the water may be helped by an inserted profile, or by a special element of the surface finish



(ceramics, artificial stone, stone etc.). Sometimes this drip line has aesthetic accentuation: it may hide the edge of the inclined concrete or estrich base, as the edge is often rugged in appearance. The drip line must not only lead off water accumulating on the surface, but also water that enters through the gaps in the tiling and which eventually will seep out from in-between the layers. This is the point where the spread-type waterproofings (liquid waterproofings) and the sheet-type waterproofings under the load distribution screed layer will begin to deviate from each other.

The gutter which is connected to the edge of the slab will, in the case of prefabricated systems, be directly connected to the edge of the drip lines. When the envelop thermal insulation method is selected, additional steel profile (galvanized or stainless) insertion may be required as the thermal insulation affixed to the edge of the slab will not hold the drip line profile in place.

Áttört mellvédű erkély vízelvezetésének változatai 1.

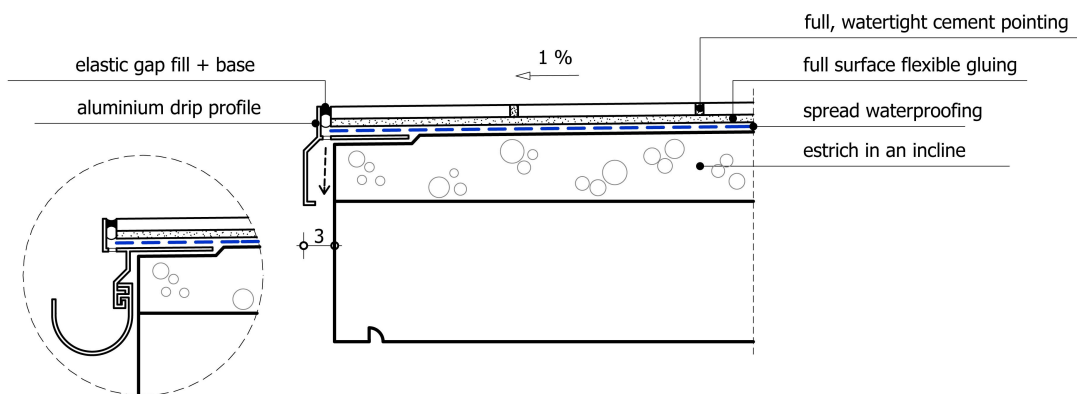


figure 47. Railing type balcony, external water outlet, type 1.

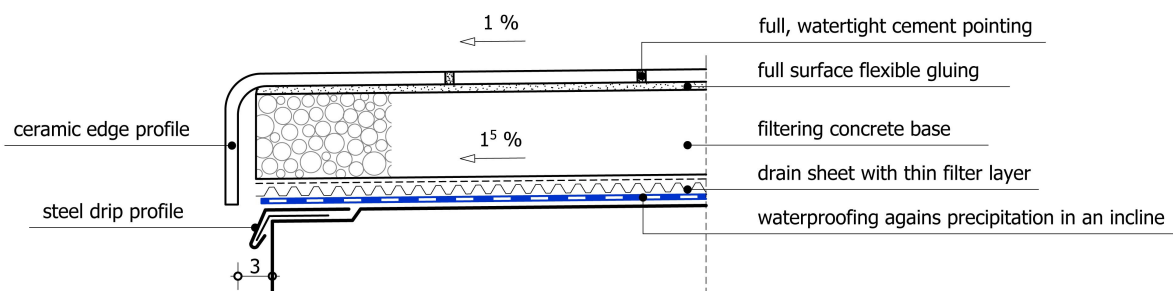


figure 48. Railing type balcony, external water outlet, type 2.

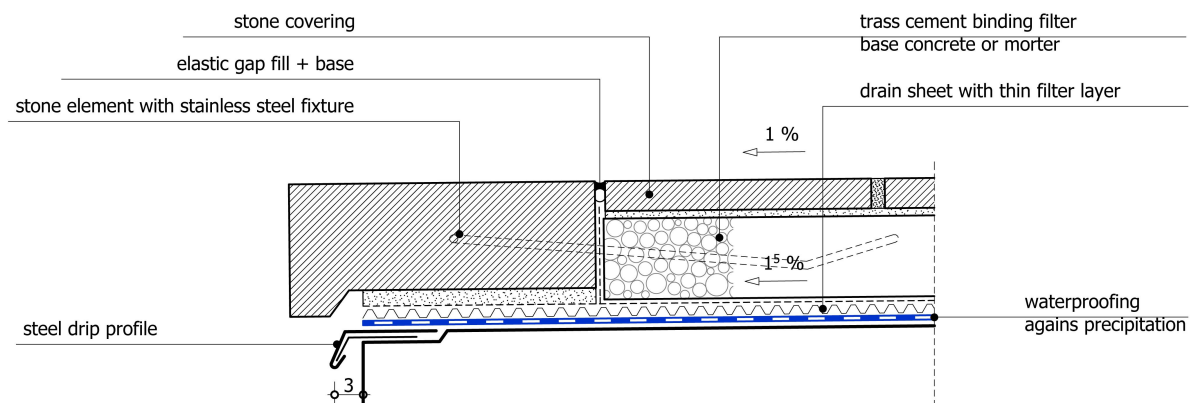
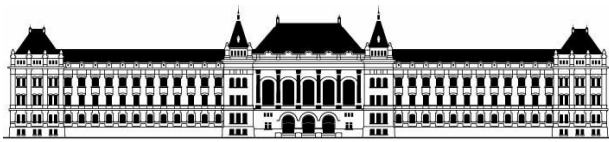


figure 49. Railing type balcony, external water outlet, type 3.

6.5 The solid parapet

The solid parapet may be made of glued security glass or of reinforced concrete. In any case the connection of the balcony or corridor waterproofing and the footing must be solved. In order to appreciate the risks involved with the solid parapet, an actual real-life example is given: The small, solid parapet balcony with only 3 m² area was built in Budapest, in the Normafa area. The balcony was provided with a soft PVC waterproofing and spot-type internal water collection. The owner left for a winter ski holiday. In the meantime, snow also fell in the Buda Mountains and soon about 50cm snow covered the balcony area. After a few days, the snow melted, however, the frozen water downspout could collect the water as intended. The water rather entered the building through the balcony door thereby destroying the parquet floor on the level and the gypsum stuccoes on the level below. Who was responsible for that? The architect or the constructor? The constructor was saved by the fact that the waterproofing was made in a basin manner, appropriately folded up at the edges to the specified height and that its waterproof nature was proven by saturation tests.

When we consider the above scenario, it may become apparent why we emphasize the illustrated solutions (gutter heating, anti-frost block heating etc.) which may seem overly complicated at first.

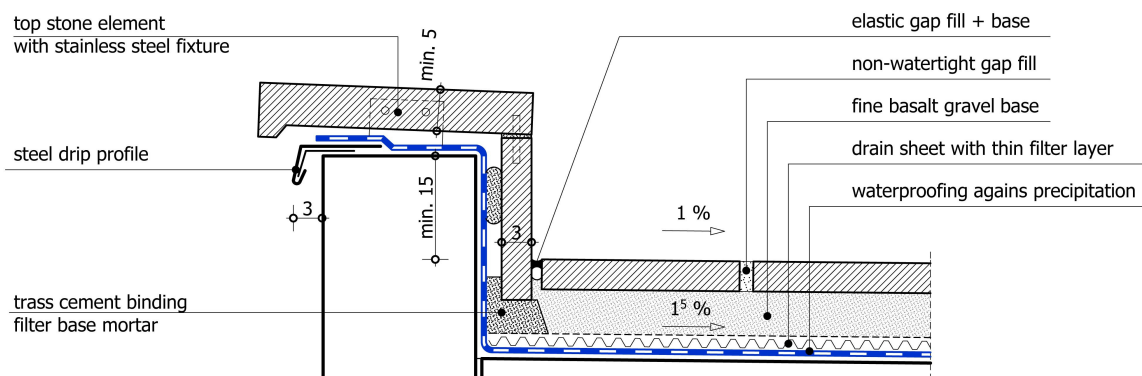




Figure 50. Low parapet balcony edge detail.

6.6 Rail installation

Structures with linear external water collection (without parapets) need barriers at the outer edge to prevent accidental falling (handlebars). The barrier posts are practically affixed to the outer surface of the slab structure, thus they will not reduce the useful area of the corridor or the balcony. Furthermore, the posts themselves will not penetrate the waterproofing and the surface covering. The posts need to be fabricated with enough outcrops, so that the drip line profiles, or the gutter itself, may also be appropriately located. If this is not considered, the drip line will need to be moved to the bottom edge of the slab. When internal water collection is made, a minimal parapet is suggested onto which the water insulation and the surface tiling may be led and affixed (see solid parapet). The railing post is then connected to the top of the mini-parapet or to the outer surface of the slab.

6.7 Footings

Waterproofing is to be folded up onto upwards structures (walls, pillars) to the height of the external surface finish, or at least to a 15 cm height (as there is no national standard, we use DIN values). The waterproofing is to be protected from external mechanical damages and from direct UV exposure. The practical solution is a footing, with a surface finish appropriate for the expected mechanical loads. If the connecting structure is layered, the waterproofing is to be folded onto the solid surface (wall) and not onto the thermal insulation. When a thermally non-insulated wall is to be connected to, we may only use waterproofings onto which the footing may be directly fixed to (spread type cement or epoxy based waterproofings). (see picture)

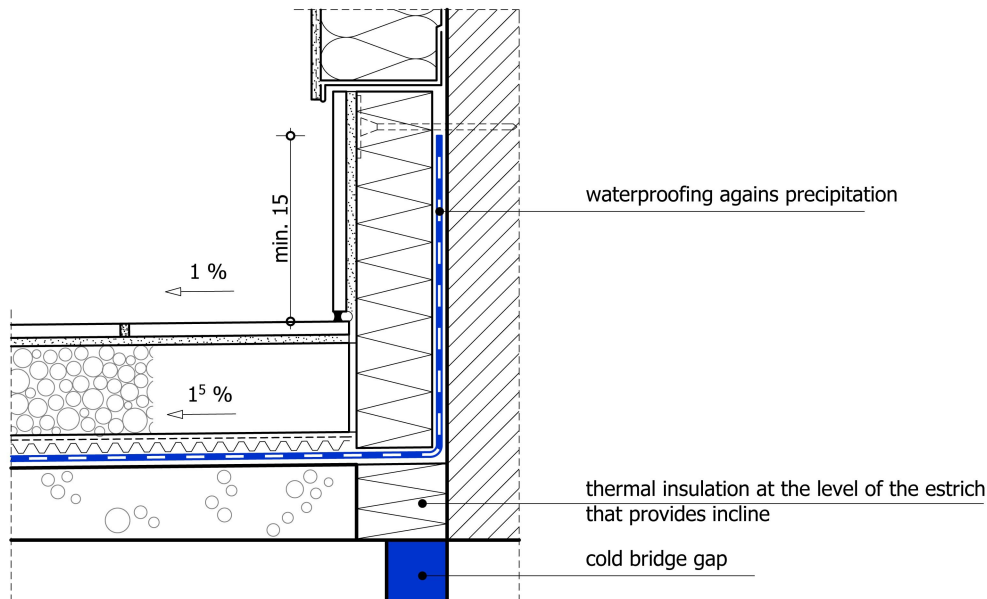
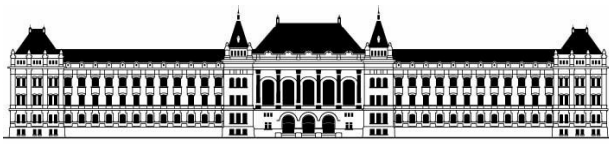


Figure 51. Detail at the footing connection of the waterproofing.

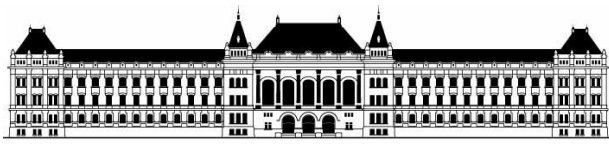
6.8 Joining the thresholds

The most delicate detail of the balcony and corridor waterproofing is the connection at the thresholds. Here, several professional preferences are to be coordinated and the most appropriate compromise is to be reached.

The main idea is that the waterproofing is always to be led onto the vertical surface to a height of minimum 15 cm (according to DIN). If we adhere to this rule, then we would need to make 15 cm high thresholds which would be overly burdensome, not to mention wheelchair access as a requirement. Such solution may only be acceptable for small balconies. If the water collection area is near the door, the 15 cm minimum height may be reduced to 5 cm (according to DIN).

The height of the threshold, however, still remains uncomfortable. Water collection “near” the door may be achieved by a grid covered collection gutter at the doorstep. The water collected by the gutter need to be led on: either in the layer structure (seeping layer) or into the water collection point. If we adhere to the 5 cm high waterproofing rule, this, in effect means that the waterproofing is folded onto the threshold. The waterproofing thus needs to be affixed and sealed so that water must not enter into or behind the line of the material. The joint is protected by metal sheeting against mechanical impacts.

There are some door types (e.g. lift-slide operation) that only allow waterproofing connection below the surface finish line. The risk of leaking in these cases is great, even if there is a grid covered gutter inserted directly at the footing of the door. We may reduce the chances of



leakage with appropriately selected layers (transmitting gaps in the surface), gutter heating against freezing, close-by located water collection and with canopies that protect against rain.

According to the regulations that require free wheelchair access in certain areas (OTÉK) a maximum of 20 mm, round edge threshold barrier is allowed at doors. This is a strict rule that may only be satisfied if the gutter covering grid is built-in at an incline, in a way overlapping the difference in the levels.

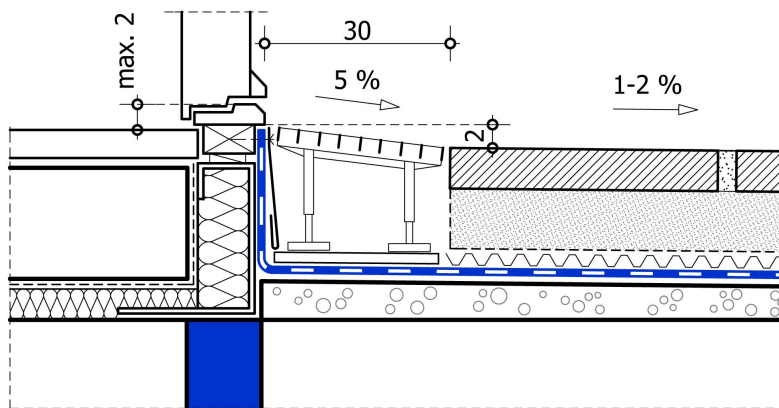


figure 52. Wheelchair access door in between internal and external areas.

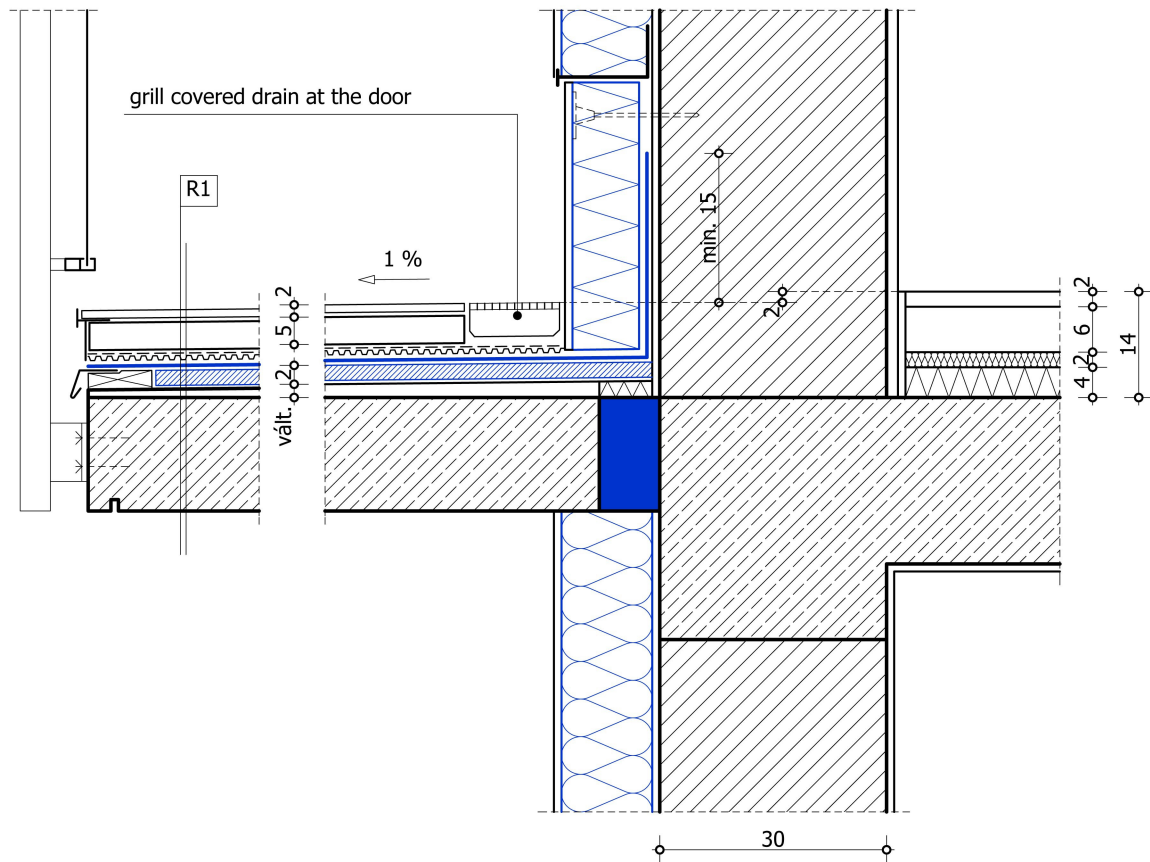
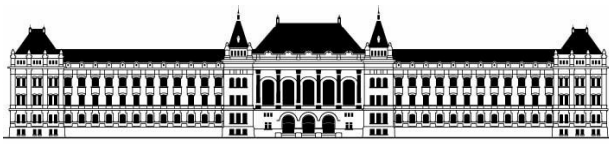


figure 53. Cold bridge gap steel fixture element in a reinforced concrete slab with noise insulation layer.

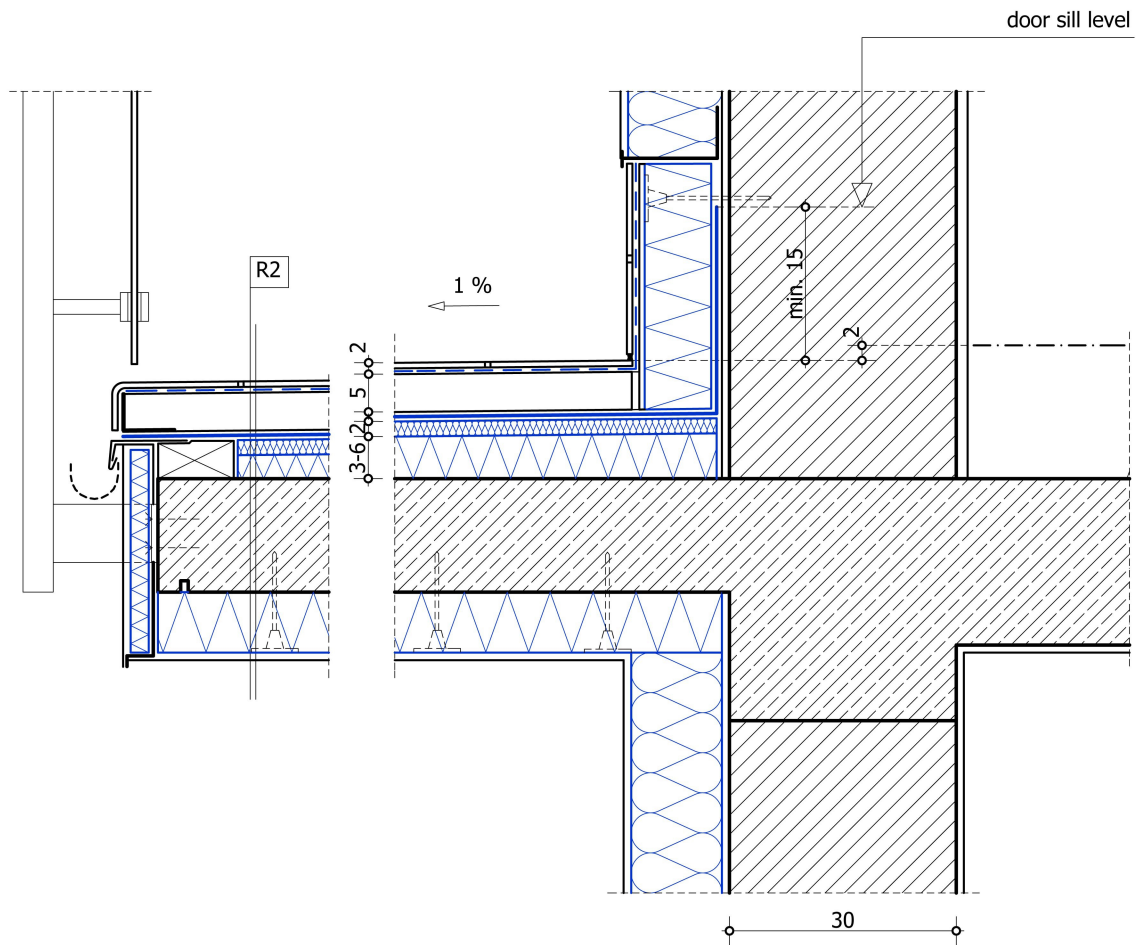
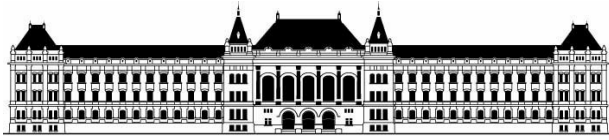


figure 54. Reinforced slab console with envelope thermal insulation and transmitted noise insulation.

6.9 Expansion gaps

Appropriately inserted expansion gaps will prevent most surface cover damages. From a layer development aspect, the most risky is the slab structure with a binding solution. Here the layers (incline layer, spread waterproofing, shallow flexible external glue mortar, tiling) are in direct contact with the structure. Due to the time differences in the thermal expansion of the various elements in the layer structure, considerable tensions will arise. The tensions will naturally damage the surface covering, not the underlying structure. Geometrical deformations due to self-weight (e.g. sagging) will also primarily damage the surface covering materials. Based on these theoretical principles and on the analysis of several cases where damages occurred, we may conclude, that only a small scale or small expected movements may justify this solution.

Where floating and sliding layers are applied, usually a cement estrich (floor foundation) forms the base of the surface finish. In these cases, edge gap and expansion gap rules are to be kept in mind. The surface covering and the estrich base must have the same expansion gap. Where the estrich is heated the appropriate standard for expansion calculations is to be used.



We do not create expansion gaps for finishes that are laid into gravel without glue or mortar and in cases where the thick covering elements are supported by pegs or other free standing support elements.



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