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RESEARCH ARTICLE

Floor Slabs Which are Frightening From Underneath, But Following Minor Repair Repeatedly Durable

Tamás K. Simon

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Abstract

The paper is intended to deal with a certain failure of a floor slab type, which was favored in the beginning of the 20th century in Hungary. The main features are: between skeleton ceramic filling elements in situ reinforced concrete beams are prepared during the construction of the relatively narrowly spaced RC beamed slabs. In the studied cases mainly due to the pure workmanship of concrete construction, and/or due to some other influencing factors the bottom surface of the ceilings of such construction systems delaminated. The first underneath sight of such failures are usually frightening, and if an inexperienced person views the result, the statement of the slab to be life dangerous, and it should be reconstructed may be made. At the same time the slab may be saved, and the repair is much more cost effective than demolishing and reconstructing the structure.

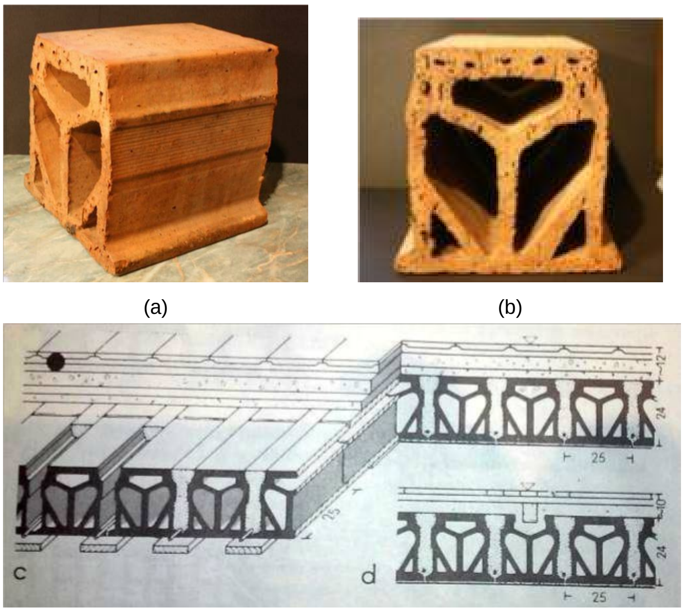
Keywords

Bohn type reinforced concrete slab · densely ribbed in situ RC slabs · RC slabs with filling elements · durability of RC slabs with skeleton ceramic elements · hollow block floor.

Tamás K. Simon
Department of Construction Materials and Technologies, Faculty of Civil Engineering, Budapest University of Techology and Economics, Műegyetem rkp. 3, H-1111 Budapest, Hungary
e-mail: t.simon@eik.bme.hu

1 Introduction

During the development in construction technologies, around the beginning of the 20th century were introduced several types of in situ RC slabs, with embedded hollow ceramic blocks between the beams (called RC ribs). Actually the beams, following placement of the necessary reinforcement were constructed out of in situ concrete between the hollow elements (Fig. 1). Several shapes of hollow blocks were developed in those years, but after the firstly introduced such system in Hungary such structures were generally named as Bohn type slabs.



(a) (b) (c)

Fig. 1. a) & b) Bohn type ceramic hollow filling element block, c) Perspectivic and cross sectional drawing of Bohn hollow block slab [1]

It can clearly be seen on Fig. 1c), the reinforcement of the concrete beams between the filling elements are in the bottom, the shape and the numbers of the steel bars were freely chosen by the designer. Depending on the necessary load bearing capacity of the slab the amount of the reinforcement could be increased, and if it was necessary, then even an overlay of concrete on the top of the slab could also be applied. If the necessary load bearing capacity was low, then it was also possible to reinforce only every second or third rib of the slab. The ribs between the elements act as simply supported beams.

A question may be raised regarding the function in load bearing of such kind of filling elements. This will also be analyzed in the following topics.

2 The first emerged case in the authors profession

In the year of 2002 the owner of a building, which originally accommodated biochemical industry and offices (Fig. 2) contacted the author to investigate an occurrence.

Fig. 2. The building in which the discussed failure occurred

At that time the industrial activity was ceased from the building, only the offices were functioning. One morning, when the cleaning lady has finished her task and closed the door behind her of one of the offices, heard a big noise from inside. As she reopened the door the picture of the ceiling on Fig. 3. appeared for her.

Fig. 3. Appearance of the ceiling

After this the question was that, what caused the failure, is the slab endangering life, is there any possibility of repair or the structural element as a whole is sentenced to demolition and rebuilding. A further task was to determine the condition of all floor slabs in the building to avoid such occurrences in the future. To answer these questions, the failure initiating factors had to be studied. The other floors were investigated as well later.

2.1 Factors initiating the failure

1. During the years when these structures were constructed, not much care was taken for precise reinforcement placing and compacting of the concrete when poured. Space keepers between rebars and shuttering to enable the concrete to flow around the steel and produce the necessary concrete cover on them for corrosion protection were not applied. 2. The lack or insufficient compaction produced porous concrete. In certain cases the workers deliberately threw rubbish into the shuttering possibly because of politically reasoned sabotage (Fig. 4)

Fig. 4. Unexplainable located fired ceramic pieces above reinforcement preventing concrete to envelop rebars in an RC slab

Anyone of these two circumstances is enough to allow the rebars to corrode. Even if concrete is covering the steel, since the volume of the product of the corrosion (rust) is of around eight times as much as of steel [2], the concrete cover would be strained off due to the internal tensile stresses which are born during the swollening of the embedded rebars. On Fig. 5. which is a closer picture about a small part of the failed ceiling both of these insufficiencies may be well detected.

Fig. 5. Close view of the ceiling failure

In case of a reinforced concrete slab however just the above mentioned deficiencies would not be enough to induce such an extensive occurrence on the bottom plane. This is because of the alkaline rendering mortar would offer adequate protection for the steel bars, which are sticking out from the bottom of the concrete structure. In our case however the mortar does not get into direct contact with the rebars for in between the hollow ceramic filling element separates them.

Corrosion of the steel just in air moisture conditions would not have been so extensive, so some other factor must have played role. Indeed there was something more. Above the subjected office, during the bio industrial ages a deepfreezing room was operating. For this reason the slab could cool in such an extent that vapour precipitation occurred especially on the surface of the rebars. This circumstance has increased the rate of corrosion, which initiated the extensive failure. The bottom portion of the relatively brittle hollow ceramic elements sort of exploded downwards as a consequence.

2.2 The verdict

The bottom of the slab could be repaired. Following the cleaning of the rebars the missing concrete was recouped by an appropriate concrete repair system and a false ceiling was installed. Naturally, the adequate working together capability of the accepting and new layer must have been ensured [3] during the refurbishment. The structure is well serving since. Demolition and reconstruction was unnecessary.

To understand, why even if a significant portion of the hollow filling elements were missing it was possible to maintain load bearing capacity of the structure needs a bit of explanation. In load bearing only the top portion of the hollow ceramic elements take role. The bottom part is only ensuring a plane surface which may accept the rendering mortar layer. If only this ceramic part suffers fault or failure, and in case the real load bearing ribs acting as RC beams may be repaired, the only thing remains to be corrected is aesthetical. From the durability point of view repaired, but visually frightening scene could be hidden by the false ceiling.

A very similar case occurred regarding a same type of slab downtown in Budapest, Hungary. The difference was that, it was the living room of a flat on the top level of the house, above which a low pitched roof was constructed. The roof was leaking, and the structure was left moist for years. Exactly the same type of failure occurred as in the above explained case, only on a smaller scale.

3 The latest emerged case in the authors profession

In the beginning of 2014 during the roof terrace refurbishment of a cottage house in Budapest (Hungary), most probably due to the dynamic effect of the concrete layer demolishing machinery on the slab the false ceiling at about two m^2 surface area has fallen from the ceiling. The until then, by the false ceiling hidden view of the bottom surface of the load bearing slab has frightened the workers. They have removed the false ceiling totally in the room and Fig. 6. shows the picture what was unfolded before the viewer. The type of ceiling was not the one described in section 2., but the system is identical, the difference is only in the shape of the hollow ceramic filling elements. Within the hollow block floor denomination, the name of the slab is "Ujlaki" hollow block slab.

Fig. 6. Failure of bottom plane of RC slab above the false ceiling

It is also important to note, the cottage house was constructed originally by a famous architect, Professor Möller in 1933 for his family's residence. He was also the author of a then famous handbook in construction. These may indicate that the workmanship may not have been poor. In his handbook can be found the cross sectional drawing of the type of slab, but I am introducing the drawing from a different source [1] on Fig. 7.

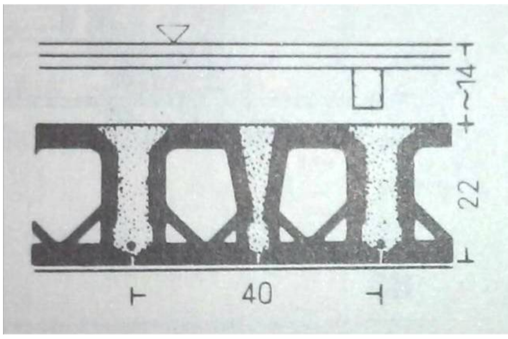


Fig. 7. Cross sectional drawing of "Ujlaki" hollow block floor

On Fig. 7. two important factors may be detected. The first is that, only every second concrete rib is reinforced. As such the distance between the RC beams is 40 cm. This fact may also be detected on Fig. 6, where in the middle of the picture a plain concrete rib is visible. An other important factor is the obviously very small concrete cover on the rebars in the RC ribs. This shows the historically unknown importance of concrete cover at that time.

3.1 The possible cause of the failure

Again, as in the case described in section 2., several factors are to be taken into consideration if we want to find the most possible cause of the failure. This structure was constructed between the first and second World Wars. The owner (Professor Möller) and his family became victims of the Second World War. Then the house became unoccupied for years. There are rumours about a fire in the house, but it is not documented. Troubled years followed, and new inhabitants moved into the cottage house. Most probably before the moving in of the new occupants, repair works were carried out on the building. During this refurbishment could have been repaired the bottom plane of the hollow block slab in subject. Fig. 8 shows a bigger view of the slab from underneath. The reader should notice several facts on Fig. 7 and 8, to which I would now like to draw attention.

At first sight can be seen that not all, but only a relatively small part of the ceiling is harmed by the bottom plane failure. The missing pieces from the hollow blocks are randomly located, which indicates that their failure is not due to a concentrated effect like leaking roof etc. The white strips of mortar indicate that before hiding the scene with a false ceiling, the substitution of the concrete cover on the bottom rebars of the RC ribs was carried out.

Fig. 8. Underneath view of a bigger portion of the subjected "Ujlaki" hollow block floor

On Fig. 7 is clearly visible that, the inside of the broken ceramic blocks is black, stained by soot.

By putting two and two together from all these information, one may arrive to the following conclusions:

1 When the structure was constructed, originally the ceiling was mortar rendered.

2 The soot stained ceramic blocks offer a proof for the rumored fire.

3 During the fire, due to the thermal expansion of the bottom part of the ceramic blocks broke at some places and fell, this is why not the total surface is soot stained. On most of the surface rendering remained in place during the fire and it protected the surface from getting stained.

4 During refurbishment, when the concrete cover was recouped by mortar it was impossible to obtain a plane surface any more to accept rendering, and this induced the necessity to install a false ceiling below the slab.

5 At the time of the reconstruction works modern false ceiling systems were not available. Due to this reason the only possibility was to hang from the bottom of the slab by thin steel wires a layer of reed planks in the thickness of 5 cm, to offer a surface which is able to accept rendering.

6 The only failure which has occurred was the corrosion of the hanging wires during the passed decades and so could the portion of the false ceiling fall due to the dynamic effect of the reconstruction works above.

7 The load bearing slab remained sound and was still serving its role.

3.2 Verdict in the second case

Based on an experts report this slab was sentenced for demolition. The experts argument was that, since the bottom part of the hollow ceramic elements were missing in significant amount, the whole structure is unable to serve its load bearing role.

This was an absolutely unreasonable verdict. As explained earlier, the bottom of the ceramic filling elements only serve to offer a plane surface for rendering purposes. The failure of this part does not influence load bearing capacity. There was no function change above the room, which would trigger the necessity of higher load bearing capacity than earlier was needed. The slab did not show or suffer from any deflection which would indicate harmful movements. After chiselling off the supplemented concrete cover from the bottom of the RC ribs, a new, up to date concrete repair system could have been applied, and the scene could have been hidden by a modern false ceiling system. This statement regarding the verdict is supported by Fig. 9, where the originally embedded steel bars are visible in the demolished RC ribs of the slab.

Fig. 9. Rebars which were unwrapped from the concrete of the RC ribs do not show the sign of extensive corrosion

The more or less corrosion free rebars indicate that the concrete, which was poured between the ceramic filling elements was compacted properly, it could protect the steel from corrosion through many decades. These RC ribs could have served for further decades, and from load bearing point of view there was nothing wrong with the filling elements.

4 Conclusions

Many times in case of old structures frightening sights may open for spectators, but with the necessary experience and considering all circumstances which are available, one should be able to make correct verdict regarding the existing load bearing capacity and further durability of a load bearing structure.

Through two examples were shown how good and bad verdicts can be made when considering the reparability of a structure.

Extreme responsibility is laying on an expert when examining and reporting on a load bearing structure, one may draw such conclusions, with may draw extensive unnecessary financial effects.

If a construction expert is not experienced in some failure cases, it is not a shame, since the time of polyhistors is long over. In such cases such a person should be found and hired, who much more is at home (experienced) in the generated problem.

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