New Models for Old Buildings

Péter LENKEI
Professor Emeritus
Pécs University
Pécs, Hungary

András MESKÓ
Associate Professor
Pécs University
Pécs, Hungary

Summary

The possible factors influencing the changes of the mechanical models for structures in use are analyzed. Special attention is given to reuse of old buildings. Several practical case studies are presented. The necessary interventions and the consequences are discussed. It is concluded, that each case has some specific features, the interventions are further changing the structural model, and almost in all cases exist several different solutions.

Keywords: Mechanical models, material degradation, reuse of old buildings, life time extension, building rehabilitation and reconstruction, monument preservation, interventions in the structural behaviour.

1. Introduction

During the last years/decades the life time extension of buildings used up to their design life time or the reuse of old buildings with the connected necessary alterations (the so-called "brown field" investments) are an increased part of the structural engineering tasks [3].

In addition to this a bigger attention is given to the monument preservation, which is an important part of the national heritage in each country. The upgrading, the rehabilitation and the reconstruction of historic buildings and/or the historic built infrastructure are preferred not only for patriotic sentiments, but sometimes motivated by economic reasons too, e.g. tourism. These tasks are usually connected - sometimes very complicated - structural engineering problems.

From the wide range of necessary interventions should be mentioned the originally bad quality of construction, the aging of the structural materials and components, the deterioration caused by the non-intended use, the change of the function of the old building, the value added reconstruction, the monument preservation, the changes of the codes for urban planning, for environmental protection and for structural design, and last but not least the life time extension of buildings.

At the same time due to the increased aggressiveness of the surrounding atmosphere the degradation process of the structural materials (concrete, steel, mortar, brick, stone, etc.) of old buildings, and consequently the aging of these materials are accelerating and the remaining life time is decreasing.

On the other hand the maintenance problems (e.g. leakage in the Paris Pantheon) in old buildings and in comparatively younger ones, leading to serious structural problems should not be neglected too.

To assess the influence of the above factors are connected with considerable uncertainties, because the systematic monitoring data is very scarce.

The climatic changes of our globe leads to the even bigger uncertainties, because from the statistical evaluation of the past events would not be possible to determine with the required accuracy the future values of the earthquake magnitude, the levels of high floods, the levels of high groundwater and the maximal wind effects. It is probable, that the wind effects will increase in the future and this would (should?) lead to some consequences in the relevant codes.

Another effect of the material degradation should be taken into account too. This is the change of the mechanical models of the structures. Just to mention the deterioration of bond between the compound structural materials/elements, the choke up of hinges, the change of fully clamped connections into partial ones, the earlier formation of plastic hinges.

2. Short Case Studies

2.1. Reuse of Old Buildings (so-called brown field investments)

2.1.1. The Bank-Engine Shop for a Mining Shaft

Fig. 1a The view of the old shop interior

Fig. 1b The view of the interior after alteration

Due to the termination of coal mining in the region of the City of Pécs, as it happened in plenty of places in Europe too, a bank-engine shop had to be converted into an warehouse of 11 m high clearance. The original lay-out of the shop (Fig.1a) was ~18*40 m in plan, the outside brick walls were ~650-800 mm thick.

On the ground floor were the machine foundations for the equipment, placed on 3 m elevation. The intermediate floor was supported by columns and machine foundation for the equipment over this floor. In addition this floor has openings, anchor places and masses for the equipment. The roof structure and the bridge crane are supported by a two hinged metal frame with bolted connection built in the walls and with steel ties built in the intermediate concrete floor.

The building in its original form was not suitable for a 11 m high warehouse. The intermediate floor had to be removed, the ties were replaced over the bridge crane beams and the bridge crane was dismantled too (Fig. 1b). The horizontal connecting function of the intermediate floor was replaced by side supports.

2.1.2. The Camber Vaulted Floor

A beer pub in the ground floor of a 100 year old building was converted to a bank branch office. The design load on the floor over the cellar was before conversion 12.5 kN/m^2. The camber vault floor, consisted of vaults supported along the longer spans by steel I profiles, and along the shorter spans by the cellar walls (Fig. 2). The steel beams were highly corroded, but the load bearing capacity in spite of the high load was sufficient. The reason was the following: in the diagonal direction the section of the ~1.80*4.80 m vault cells formed elliptical arches with camber about 180 mm. The approximate analysis showed that the compression stress in the arch was 147 MPa, which seems realistic for a good quality brickwork. Consequently the ring laid vault working as an arch could significantly decrease the overload on the corroded steel beams.

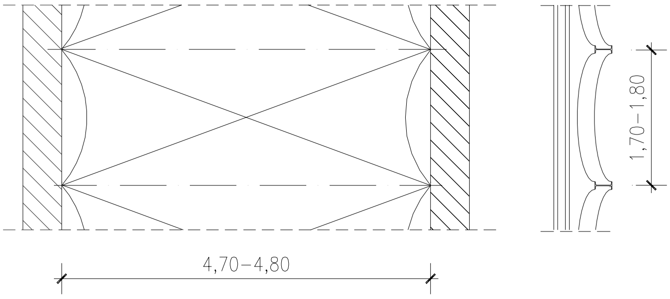

Fig. 2 The camber vault

To suit the new function, the building was altered. The dead and live loads from the vault were removed and in the resulting free places over it, but not supported by the vault a new concrete floor on corrugated steel plates was built, supported by new steel beams.

2.2. Necessary Intervention on Account of Bad Workmanship [1]

Fig. 3 The supporting spring

The multistory building of a big consulting engineering office has reinforced concrete frames with 13 m span beams on the upper floors, forming large office rooms. Due to early removing of the formwork and bad quality of the concrete the beams gave large deflections. The contractor tried to correct this blunder by making an even bigger blunder, putting thick layers of concrete over the beam top at mid span and thick layers of plaster under the beam bottom near the columns, to level the deflections. As a consequence the load bearing capacity of the beams were exhausted, and due to moment redistribution in the beam-column joints intensive cracking was detected.

The intervention was a really radical upgrading, changing completely the mechanical model. The 13 m span was divided into two lines of smaller rooms with a corridor in between. On both sides of the middle corridor at each lateral frame two pair of steel columns supported by new foundations were placed.

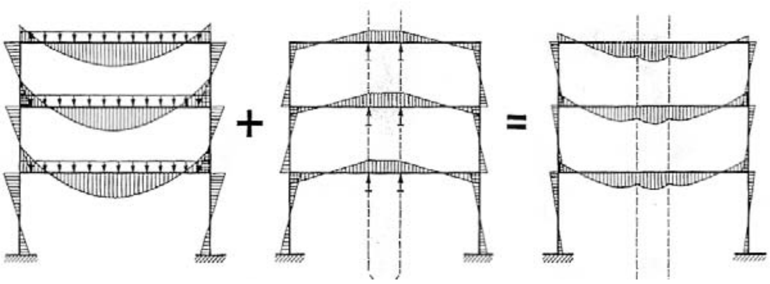

Fig. 4 The resulting moment diagram

A heavy spring (Fig. 3) acting on the bottom of the reinforced concrete beam was installed on each small cross beam between the twin steel columns. The spring prestressing by a bolt was controlled not to have tension on the top surface of the concrete beam. This was illustrated by summing up the original bending moment diagram and the bending moment diagram from the springs' action, reducing the bending moment at the mid span considerably, but not changing its sign (Fig. 4).

The solution is in use more than 30 years without any problem.

2.3. Non-Foreseen Changes in Natural Actions [2]

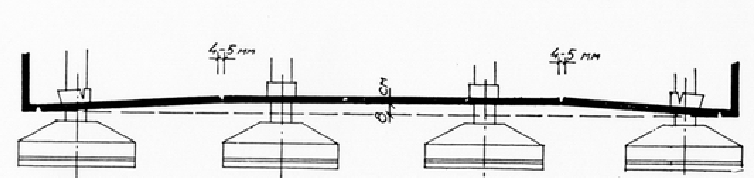

Fig. 5 Displacements and cracks due to ice lens formation

A multistory warehouse built very near to the Danube river embankment was left open without doors, windows and heating during whole winter. By the end of the severe frost period at first sight it seemed that the independent column foundations in the middle column lines showed up ~80 mm differential settlements, because the collars around the middle columns showed such differential movements (Fig. 5). After detailed investigation was cleared, that not the column foundations had been settled, but the bottom reinforced concrete slab with the collars had lifted up accompanied with crack formation. The cause was formation of an ice lens in the soil due to the high ground water level, and consecutive migration of the ground water to this lens.

The reinforced concrete slab had been subjected to bending moments of opposite sign against the design bending moments. After spring melt, the cracks in the slab closed and the slab vent nearly back to the design geometry.

3. Discussion

From the above (and many others) case studies the following theoretical considerations could be drawn:

- The originally assumed linear elastic behavior for old structures due to unfavorable effects during long use is not applicable. Often some parts exhibit plastic behavior, hinges and/or yield lines are formed, the mechanical model essentially changed.
- Each rehabilitation, reconstruction or upgrading is either a small or a significant intervention in the structure. The interventions usually change the mechanical model.
- What could be the extent of the structural intervention, e.g. for the sake of compound behavior of the old and new the new structure? The answer is , that the extent should not induce overstressing in the old structural elements.
- Is existing and to which extent the original compound behavior between the parts of the old structure? If the answer is not, then how to achieve it?

Conclusions

First of all it should be stated, there are not existing two analogical cases. Even in case of originally analogical buildings or structures due to differences in construction, in use and in the environmental effects, i.e. due to differences in time histories, their state at late investigations could be different.

Secondly, during interventions into an old structure it is very important to know how much has changed the mechanical model during previous use, and how much the proposed intervention would add further changes to the previous ones.

Thirdly, during an evolution or in case of intervention into an old structure there is not existing only one unique "happy" solution. There are several solutions, which may be simpler or more comprehensive.

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