VOLUME CHANGES IN SLAG IN THE SUBSOIL OF CONSTRUCTIONS AND THEIR INFLUENCE ON LOAD-BEARING STRUCTURES

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Introduction

The load-bearing structure of the entrance building of the Faculty Hospital in Ostrava-Poruba consists of a monolithic reinforced concrete skeleton structure with hidden beams and ceiling slabs with dimensions of approx. 64 x 31 m. One floor of the building is projected above ground, and the other two floors are sunk beneath it. Transitions between different elevation levels were, during the construction completed with a slag sub-base, which in some parts reaches up to 4 m of thickness. The floor structures of 100 to 200 mm thickness made of class C 16/20 concrete sit on a concrete base of 150 mm thickness with a welded grid [1].
When examining the building in 10/2006, inclined shear cracks in external walls and connecting non-load bearing walls were recorded in the entrance area, public areas, supermarket, storage rooms, and connecting corridors. The door openings and doorframes are distorted and skewed; the floor surface is bulged upward and penetrated by cracks. See Figure 1 for the bulges and the peeled tiles at the entrance area outside the public area facilities (men's and women's restroom, cleaning room). In some places deformations already reach values such that it resulted in the destruction of the brickwork and crumbled parts of perforated bricks, see Figure 2 [1].

Figure 1: Deformation of the floor and tiles

Recorded increases of vertical displacement

Measurements of vertical displacements were initiated on September 18, 2001. The recorded continuous unevenness of the floors reached up to 110 mm, however the height was not related to fixed points.

Figure 2: View of damaged brickwork of the non-load bearing wall

Further measurements as of January 23, 2002 have been related to the firm fixed (stabilized) elevation points mounted on the floor and load-bearing columns.
The measurement results clearly show that there is no subsidence of pile foundations present, but the upward bulging of floor structures is present. The upward deformation of some columns is even measured (negative subsidence).
The maximum bulge of the floor reached the value of 39.6 mm within the period of January 23, 2002 to January 24, 2007, and then the value of even 46.1 mm within next 15 months to April 24, 2008 (maximum increase of 6.5 mm in 15 months). However, the initial deformations of approximately 110 mm need to be added to this value, so the last height unevenness of the floor reached over 150 mm as of the date of the last measurement, and the deformations are still continuing. The ongoing deformations are probably related to another reaction with water or water vapor, which could be fed into the subsoil primarily in the form of rainwater infiltration, but also secondarily through a damaged horizontal water and sewer system due to the ongoing subsoil deformations [1].

Analysis of secondary mineral fillers

The analysis of secondary mineral fillers from the backfill under the floor was conducted to make a final decision on the real options of subsoil rehabilitation and reconstruction of the building [2]. For additional laboratory tests, an 8kg sample was taken at the side of the probe, approximately 10-20 cm above the bottom of the probe. The sample was taken by P. Martinec and R.

Čajka in the presence of the representative of the owner of the building [1], [2].

Pieces of steel slag

Optical microscopy using the transmitted polarized light shows thin seams of a hydrated slag-forming glass in the cut on the surface of the slag glassy grains. The power can be estimated (depending on the proportion of gehlenite crystals and glass in a particular space) with an accuracy of the first tenths to millimeters. Using infrared spectroscopy, the light, silty creamy white fillings of up to approximately 5-6 mm were found on the surface of the pieces of slag in their pores.

The reaction of the infusion is alkaline (pH 8-9). The spectroscopic analysis can be used to identify the product of the MgO periclase hydration to the brucite Mg(OH)2, and its carbonized product - magnesite MgCO3 in the separated material. These are minerals whose volume is greatly increasing during the hydration and carbonation.

The separated sample taken from the surface of the glassy slag pieces includes some hydrated Ca(Mg?) silicates (CSH) together with brucite Mg(OH)2 and opal (?) material again during the hydration and increasing the volume of secondary, hydrated mineral.

Gently reinforced silty-sandy material in the piece steel slag

The space between the pieces of steel slag is filled with a very variably cemented finely fragmental to silty-sandy material. Dark, grey-black grains can be isolated during the separation. When separating the cemented material the following grains can be isolated:

- Pieces and fragments of gray to black steel slag with white secondary minerals
- Sandy and silty grains of black, gray, often glassy slag from steel
- Brownish to light whitish-brown minerals in work fraction

The reaction of the infusion is slightly acidic to neutral (pH 6.1). The mineralogical analysis shows that the filler of this silty-sandy material with fragments of steel slag greater than 2 mm consists of the secondary minerals resulting from hydration and carbonation of steel slag, particularly brucite and carbonate (magnesite and calcite) and then the material, which is similar to opal as well as the CSH from the surface of the grains, especially those of the glassy steel slag. Infrared spectroscopy has shown:

- Sandy to silty black, or gray grains, frequently glassy ones made from the steel slag. The spectroscopic analysis can identify mainly gehlenite, or Ca-silicates with weak hydration to CSH in the separated material, i.e. the volume of newly formed phase on the grains surface is rising again.
- Brownish to light whitish-brown minerals in the silty fraction. These minerals can only be separated gravitationally and manually on a paper and with a different proportion of the steel slag grains.

The separated fraction of the creamy light brownish color is dominated by the product of the MgO periclase hydration into the brucite Mg(OH)2 and its carbonated product – magnesite MgCO3 along with calcite Ca (CO)3. Furthermore, the hydrated silicates such as CSH from the slag are present. These are minerals greatly increasing the volume of the hydration and carbonation.

The gray working fractions are typical by the increasing proportion of steel slag grains with more or less intense hydration to CSH. Association of secondary minerals, however, remains unchanged.

Evaluation of the analysis

The secondary minerals associated with hydration and carbonation of the steel slag in the environment with higher humidity and CO2 presence under favorable temperatures (approximately above 10 ° C) were clearly identified in the slag backfill consisting mainly of unsorted dark steel slag at the bottom of the probe in the supermarket floor located on the first floor of the Faculty Hospital in Ostrava - Poruba. All of these secondary minerals have proven to greatly change their volume and lead to the total volume changes in the backfill. This process is uneven and slow, but steady. According to performed analyses and determination of mineral associations, this process has not finished.

Quantification of the process of increasing the volume of material in the backfill required more detailed analyses of different fractions of the backfill for disproportionately high costs. Discontinuation of the hydration and carbonation processes in the backfill is, according to current experience and possibilities, difficult if not impossible (= complete drying of the backfill - steam is even more effective hydration medium than water - and deprivation of air in the CO2 backfill).

Conclusion

With regard to these findings it can be stated that the floor structures, non-load bearing brick walls, but also the load-bearing structures of the mounted frame are in disrepair, and with regard to security it is necessary to stop use of the mentioned areas. To be able to reliably use the entrance building in the future it is necessary to prevent volume changes in slag sub-base and sewage leaks into the ground. Given the findings, it is unrealistic to stabilize the slag swelling and prevent further increase of deformations. Also, damaged sewer pipes cannot be fixed without their removal. Manifestations of the volume-involatile steel slag in the embankments were also recorded in the construction of roads [3].

References

1. Čajka, R. *Posouzení příčin vzniku trhlin a poruch ve vstupním objektu Fakultní nemocnice v Ostravě Porubě.* Závěrečná zpráva AR-0715, ARMING spol. s r.o., (2009)
2. Martinec, P. *Analýza tmelicích sekundárních minerálů ze zásypu pod podlahou v prodejně v 1. podlaží FN v Ostravě – Porubě*. Dílčí zpráva, Ostrava, (2009)
3. Kresta, F. Použití ocelářské strusky a dalších vedlejších produktů hutní výroby železa v zemním tělese pozemních komunikací. *Silniční obzor*, roč. 72, s. 15 – 20, (2011)