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RENOVATION OF SHAFT MINING BUILDING NO. 2 IN KŁODAWA SALT MINE

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Abstract

The paper presents the renovation process of the shaft mining building No. 2 situated in the Kłodawa Salt Mine. A technical state of the facility required immediate reinforcement of structural elements, which was confirmed by expertise carried out by the authors. A lack of repairs could be the cause of building damage. The progress of corrosion in some steel profiles of columns or floors was very advanced. The state of the building was rapidly worsening due to the very high salinity of the indoor environment, moisture (building not insulated) and vibrating engines of machinery operating on different floors felt throughout the facility. After carrying out the technical expertise, working plans and specifications, and relevant numerical analysis, the modernization process was realized by the reinforcement or rebuilding of structural elements.

Keywords: strengthening of steel structures, renovation, modernization, durability of steel structures, corrosion

1. INTRODUCTION

Building No. 2 of the Barbara Mining Shaft is one of the many above-ground technological structures in the area occupied by the Klodawa Salt Mine. In addition to it, there are also different kinds of salt transport systems, service systems, mill facilities, bagging plant buildings and warehouses.

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The majority of these structures were designed and built employing steel construction. Such a solution, despite an unfavorable work environment, is justified by the ease of forming the constructions, the speed of assembly and its low costs. However, it also requires diligent and frequent conservation works to be carried out by the owner of such a structure. Frequent technical inspections of the construction on the basis of which renovation work can be carried out are also necessary. This significantly lowers the costs of repairs and does not pose a threat of breakdown or collapse. In the case of building No. 2 of the mining shaft and many of the other objects listed above, the owner of the mine did not adhere to the proposed recommendations and allowed for the significant deterioration of the load-bearing structure and its external walls. The construction elements of the building, despite repairs carried out earlier in 2002 [1], required immediate reinforcement which was also confirmed by the expertise carried out by the authors [2]. Putting off repair work any further could lead to a risk of collapse. The progression of corrosion in certain profiles of steel columns or floor elements was very advanced (as much as 70% of the cross-section was affected by corrosion). The state of the object was degrading quickly due to the high salinity of the environment, dampness (building not insulated), as well as machines operating at different levels, producing strong vibrations which could be felt throughout the entire building. Before commencing renovation work, a technical expertise [2] and detailed design [3] were carried out. Fitting numerical analysis of the building was performed, accounting for elements affected by corrosion in the calculation model, decreasing their strength parameters. Based on the above, adequate reinforcements were proposed. Reinforcement technologies were applied, involving the replacement of steel profiles, welding in additional profiles or sheet metal, as well as creating joined profiles by surrounding the damaged element with a box of sheet metal and then filling the empty area in with concrete, thus stopping the development of corrosion by cutting off the oxygen supply. A key element of the reinforcement was also adequate hardening of the portal frame structure connections in order to maintain the shape stiffness of the entire building. Following repair work and fulfilling the maintenance recommendations, the construction elements of the building do not reveal any problems. Through proper technical solutions, the durability of the building was greatly increased. The majority of the remaining process facilities in the area of the mine were also repaired according to solutions presented in the work or are currently being repaired based on professional evaluation and working plans and specifications prepared by the authors.

2. DESCRIPTION OF SHAFT TOP BUILDING NO. 2

Shaft top building No. 2 is the northernmost facility of the P-2 Kłodawa Salt Mine Processing Plant, and is integrally connected with the Barbara shaft (see Fig. 1).

Fig. 1. View of Barbara mining shaft and shaft top building No. 2

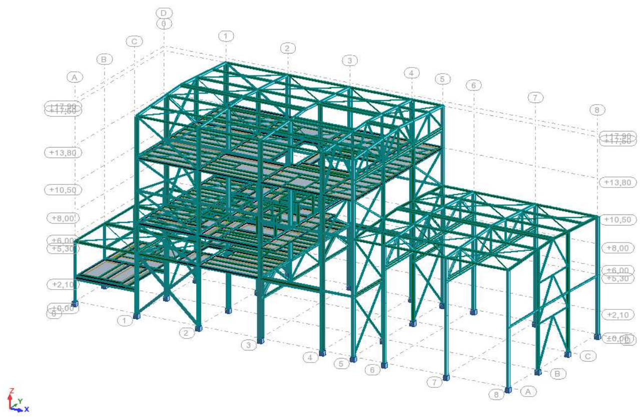

Fig. 2. Calculation model of the structural model of shaft top building No. 2

The building (Fig. 2) is composed of the following elements:

– a low outhouse between axes 0 and 1; in this outhouse, salt is moved to the conveyors transporting salt to salt mill No. 2 and mill P-1,

- a high outhouse between axes 1 and 5 in which the grinding facility is located (axes 1-3) as well as the actual shaft top (axes 3-5), the grinding facility is a 4-storey building, the shaft top - a 2-storey building,
- the extension of the shaft top building from axis 5 to axis 8, a single-storey building currently serving as a warehouse and transshipment facility.

All columns are fixed in reinforced concrete pad foundations. The stud walls of the building are filled with silicate brick 12 cm in thickness. In fields 1- 2, at the level of +13.8 m, a reinforced concrete floor was constructed on rolled steel beams. The remaining floors are covered with wooden planks measuring 56 mm in thickness placed on top of rolled steel beams.

3. DESCRIPTION OF TECHNICAL STATE

An assessment of the technical state of the building was made along with necessary photographic documentation. The level of damage caused by the corrosion of the steel construction was measured, with particular attention paid to the main load-bearing construction of the floors and columns in areas of increased loads. The state of the construction has been shown in Fig. 3.

Fig. 3. View of the technical state of load-carrying beams and main beams of the frame

A percentage scale indicating the degree in which the thickness of the walls of profiles are reduced in relation to their initial thickness was used to assess the degree of corrosion. This facilitated the introduction of the actual characteristics of the cross-section into a computer program at a later stage of the analysis. Measurements of the depth of corrosion in the cross-sections of columns, secondary beams, primary beams, girders and joists were taken. It was established that the depth of corrosion varies in the different steel profiles. Some of the steel construction is in good shape (elements repaired in 2002), whereas some at immediate risk of failure and requiring replacement. On the basis of the above inspection as well as statistical calculations indicating the stress level of the individual beams of the building accounting for the actual cross-section parameters (Robot software model shown in Fig. 2), the floors on the level of +13.80 m between axes 1 and 2 at the location of dust extractors, inside columns of the high part between axes 1 and 5, the load-bearing lattice beneath the level of +5.30 m in axis 3, floor and load-bearing beams in the area of sieves at the level of +8.00 m in axes 1 and 3, load bearing beams of the silo at the level of +8.00 m and +13.80 m, between axes 2 and 4, main beams running through the floors and joints, inside column in the wall of axis B - 5, lattice in axis 4, roofing slabs in the outhouse - axis 0 to 1, inside and outside walls made of Silka 12 cm in thickness.

4. NUMERICAL ANALYSIS

In order to demonstrate the durability analysis procedure and accepting necessary reinforcement on its basis, sample calculations of the load-bearing lattice in axis 3 below the level of +5.30 m have been presented in this chapter. This is a very important element of the construction, as it carries the loads of many higher floors. The calculations were carried out in the Autodesk Robot Structural Analysis program. The spatial model has been presented in Fig. 2. Figure 4 presents the level at which the lattice bars are used, accounting for 30% weakening due to corrosion (state determined on the basis of studies). A coefficient of 1 indicates 100% use. As indicated, the stress-strain state of most profiles in the central zone of the girder significantly exceeds the permissible limits. It should be recognized that a beam with a use of 2.95 was improperly selected at the initial design stage of the construction or that the technological load increased over the time the building was in service. Fig. 5 shows the stress-strain state of the elements of the lattice accounting for strengthening. Examples of how the profiles can be strengthened have been presented in pt. 5.

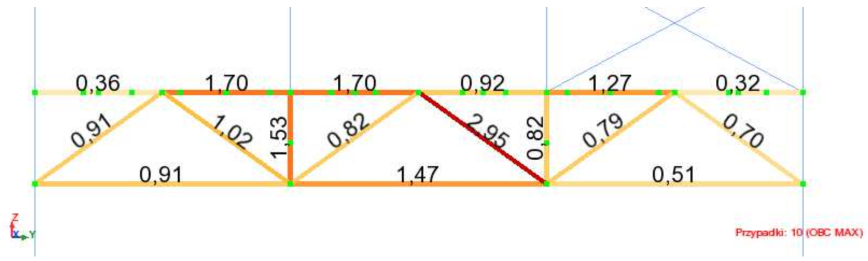

Fig. 4. Stress-strain state of lattice in axis 3 with profiles weakened by corrosion

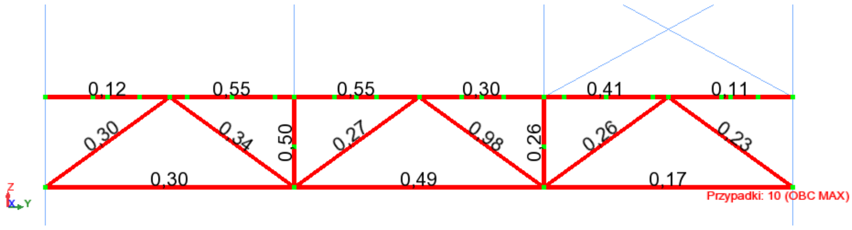

Fig. 5. Stress-strain state of lattice in axis "3" following strengthening

5. PROPOSED METHODS OF REPAIR

Reinforced concrete floors at the level of +13.80 m, between axes 1 and 2 at the location of dynamically operating dust extractors were renewed by shotcreting and filling in the uneven areas with concrete. Next, after cleaning the exposed steel structure and subjecting it to anticorrosion treatment, a steel grillage supporting the existing structure was designed.

Strengthening the outside columns of the high part between axes 1 and 5 involved enclosure in a box using 15 mm sheet metal. The sheet metal was welded to the existing ledges of profiles which created enclosed areas which are precisely filled with cement mortar of the 15 brand and tightly sealed in order to cut off oxygen supply and prevent their further inner corrosion.

The lattice under the level of +5.30 m in axis 3, due to the high stress-strain state of the bars and progression of corrosion, was strengthened by fitting cross braces and additional angle sections adding a minimum of 50% to the cross-section of strengthened bars. The connection of the lattice beam to the existing studs was additionally strengthened by constructing a table under the lower strip. Attention was given to maintaining the continuity of the added angle brackets in the upper and lower strips of the lattice girder. The angle brackets were connected outside the joints on full butt welds.

Ceiling and load-carrying beams in the area of the sieves at the level of +8.00 m, between axes 1 and 3 were severely damaged by corrosion and practically impossible to repair. Moreover, they were covered by a thick layer of salt. Immediate replacement of these beams was recommended, as they posed an actual threat to damaging the operating machinery.

The load carrying beams of the silo at the level of +8.00 m and 13.80 m, between axes 2 and 4, which support the salt chute weighing approximately 20 tons (when full), required reinforcement by enclosure in a box using 15 mm (upper and lower strip) and 10 mm (both sides of the web) sheet metal. In areas where it was not possible to apply the designed method of reinforcement, it was recommended that additional profiles be welded beneath the existing ones.

The main beams at the various floor levels as well as their connections with columns were strengthened by enclosure in a box using 15 mm (upper and lower strips) and 10 mm (both sides of the web) sheet metal. For this purpose, the wood construction of the ceiling was successively taken apart and upon reinforcing the construction areas, renovation work carried out. In areas where it was not possible to apply the designed methods of reinforcement, additional profiles were welded beneath the existing ones. The connections of columns with beams were strengthened using 15 mm sheet metal and, what is very important, the continuity of strength being carried over from the beams to columns ensured.
Successive renovation of walls made of 12 cm Silka brick and bars was recommended, based on periodical observation of the progressing damage.

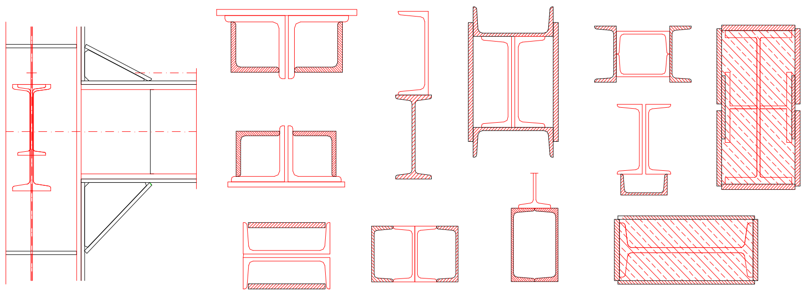

Fig. 6. Examples of ways in which the various load-bearing elements can be repaired

The lattice in axis 4 was strengthened by welding additional rolled profiles and sheet metal, adding a min. of 50% to the cross-section of the reinforced bars.
The roofing sheets in the outhouse - axes 0 to 1 were replaced. Based on categories of corrosion aggressiveness according to ISO 12944: C5-M (very strong), anticorrosion protection was recommended for the steel construction of the entire shaft top building No. 2.
Schematic means of reinforcing the profiles have been presented in Fig. 6.

6. CONCLUSIONS

Shaft top building No. 2 was in a very bad technical state as a result of wear and tear and damage caused by the corrosive environment. Failure to successively subject it to conservation led to a state of structural pre-failure, which resulted in increased costs of repair work. In order to secure the building, a series of works aimed at reducing risk, securing completely worn elements and urgent commencement of renovation works were recommended, which took place immediately. It was also recommended that dynamic impact on the building caused by the operating machinery be reduced by decreasing eccentrics in vibrating parts as well as applying adequate vibration insulation. Situations when steel elements were not subjected to anticorrosion protection were not to be allowed. The construction ought to be cyclically conserved by removing salt and dust, as well as reapplying paint coatings where needed. It was instructed that the building structure be monitored (at least twice a year). Any changes influencing the safety of the building (e.g. bending, cracking of walls) are to be reported immediately to building control.

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RENOWACJA BUDYNKU NADSZYBIA NR 2 NA TERENIE
KOPALNI SOLI "KŁODAWA" S.A.

S t r e s z c z e n i e

Referat przedstawia sposób remontu i naprawy konstrukcji nośnej i obudowy budynku nadszybia nr 2 na terenie Kopalni Soli „Kłodawa". Elementy konstrukcyjne budynku wymagały natychmiastowego wzmocnienia, co potwierdziła ekspertyza wykonana przez autorów. Zaniechanie prac remontowych groziło awarią budowlaną pomimo przeprowadzonej wcześniej w 2002 r. naprawy. Postęp korozji w niektórych profilach stalowych słupów czy stropów był bardzo zaawansowany. Stan obiektu pogarszał się szybko ze względu na bardzo duże zasolenie środowiska, wilgoć (budynek nieocieplony) oraz pracujące na poszczególnych poziomach maszyny wytwarzające duże drgania wyczuwalne w każdym miejscu obiektu. Wykonano ekspertyzę i projekt wykonawczy przed przystąpieniem do prac renowacyjnych. Przeprowadzono stosowną analizę numeryczną budynku uwzględniając w obliczeniach osłabione korozją elementy pomniejszając odpowiednio w modelu ich parametry wytrzymałościowe. Na tej podstawie zaproponowano stosowne wzmocnienia. Zastosowano technologie wzmocnień stosując wymianę profili stalowych, wspawywanie dodatkowych profili lub blach oraz tworzenie profili zespolonych poprzez obudowanie zniszczonego elementu skrzynką z blach, a następnie wypełnianie pustki betonem, hamując w ten sposób postęp korozji poprzez odcięcie tlenu. Kluczowym elementem wzmocnienia było również odpowiednie usztywnienie węzłów ram portalowych w celu zachowania sztywności postaciowej całego budynku. Konstrukcja obiektu, po naprawie i stosowaniu się właściciela do zaleceń eksploatacyjnych, nie wykazuje nieprawidłowości.

Słowa kluczowe: wzmacnianie konstrukcji stalowych, renowacja, modernizacja, trwałość konstrukcji stalowych, korozja

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