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RELOCATION OF A HISTORIC BUILDING AT THE OLD NORBLIN FACTORY IN WARSAW

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The present article relates to the subject of the relocation of buildings. It presents a historical background of operations of this type carried out in the past around the world, as well as in Poland. It goes on to discuss in more detail some pioneering structural and technological solutions used during the relocation of the Rogatka Grochowska (Grochowska tollgate) building, carried out in 1961 in Warsaw. The article's main theme is the process of relocation of a historic building No. 15 within the old Norblin Factory in Warsaw, which took place during the final months of 2018. The article briefly presents the factory's history. It also describes the assumptions of the related project, which covers the development of the old Norblin Factory. It discusses in detail the concept and the scope of the relocation of building No. 15, with the description of the structural and technical design related to this process. The progress of the relocation which took place in 2018 has been reported in detail.

Keywords: *historic buildings; relocation of buildings; special construction works; special engineering.*

1. INTRODUCTION

The development of historic buildings almost always entails a range of problems [1, 4–6]. Major of them include obligatory compliance with restrictive conservation requirements, successful integration of the building with urban landscape and its adaptation to current technical requirements.

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It would often be easier to demolish an historic building and reconstruct it from scratch, but such a process would involve the permanent loss of the original, complete listed substance. Therefore, in some cases and where necessary, the investors, in agreement with the appropriate conservation authorities, decide to relocate (reposition) the building in its entirety, without demolishing it. In technical terms, this operation is extremely complex, expensive, laborious, but feasible, as demonstrated by the existing examples.

Building relocation operations are rarely performed in Poland, so every project of this kind represents a major event. This article describes the case of the relocation of a historic building No. 15 situated within the old Norblin Factory in Warsaw, which took place between November and December 2018, and subsequently in April of the following year. The author of this article participated in this project as an expert within the technical team, who was responsible for the development of the structural and technological design and for the physical relocation of the related building.

2. RELOCATION OF BUILDINGS

The problem of relocation of buildings has been around for a fairly long time, since the expansion of metropolitan areas, and especially their centres. Technical progress, not only in the building sector, has enabled the development of the technology of relocation of existing buildings without the need for their demolition [14]. Operations of this type were carried out with increasing frequency already at the end of the 19th century, especially in countries such as the United States, Russia or France. In Russia, for example, the first attempt of relocating a building was made and completed successfully at the end of the 19th century, when one building which interfered with the widening of the Mikołajowska Railway was relocated. A major factor was the development of Moscow in the years 1936-1941. A number of buildings of significant size were relocated in this period. It is notable that many of these projects were quite amazing, not only by their contemporary standards. For example, the three-floor building of Sawińskie Podworie, currently under the address of 6 Twerska Street, was saved from demolition. The relocation began on 4th March 1939 before dawn. The house was situated on rails and gradually moved by 50 metres in the course of three days, which was a world record for this type of operation. First of all, this was the first time in the world when a building was moved along rails together with its residents, who didn't even feel they were being moved. And secondly, Sawińskie Podworie weighed over 20 000 tonnes, i.e. it was almost twice as heavy as an American telephone station. Another record was established on Gorki Street in 1940, during the relocation of the Moscow Council building – currently the mayor's office, situated under the address of 13 Twerska

Street. In a time of only 41 minutes, using two winches and 25 jacks, the building was relocated by 14 metres, together with its basement. One of the biggest achievements in this field in the USA was for example the relocation of the 11 000 tonne, 8-floor telephone station building in Indianapolis.

In Poland the first building relocation operations took place later, after the Second World War. This problem was previously non-existent, because firstly there was no need for the relocation of buildings, and secondly World War Two resulted in the destruction of buildings on a massive scale, which unfortunately created natural conditions for the reorganisation of the urban landscape. Several of the first relocations of buildings took place in Warsaw. The first operation of this type involved the relocation of the northern building of the Rogatka Grochowska (Grochowska tollgate) in 1961 [8, 10]. It was necessitated by the reconstruction of Grochowska Street. The listed tollgate building was erected in 1823 and survived the destructive effects of war almost intact as an isolated case across the whole of Warsaw. It was therefore decided to relocate the building. It is also worth mentioning that the second, southern building of the tollgate was relocated after 40 years, in 2001 [12]. Due to the fact that the relocation of the northern building of the Grochowska Tollgate was the first operation of this kind in Poland, its procedure requires a detailed analysis, which was carried out on the basis of an article by Jan Lenard [10]. Although the northern building of the tollgate was relatively small, as its dimensions in plan view were 8.5 m × 16 m, its height was 7.6 m and weight approx. 600 tonnes, the building's relocation represented a major technical issue. First of all, as already mentioned, it was the first operation of its kind, therefore the technical authorities didn't have any experience with this type of procedure. They needed to develop and test the technology related to the building's relocation, with the consideration of all specific characteristics of the related works. Secondly, the building represented a masonry structure made of bricks and lime mortar, and its walls demonstrated major cracks running across its entire height. It was therefore decided to replace the foundation walls, and then to install steel tie rods protecting the structure against further cracking during the execution of preparatory works, as well as during the movement of the building. Reinforced concrete tie beams were constructed underneath all of the walls, in the form of double beams with a 30×40 cm cross-section, which were embedded into one half of the walls' width, and bound together using reinforced concrete connectors. These tie beams constituted a rigid frame on which the building was based and moved. 9 tracks were provided underneath the tie beams, made of double I 200 beams, for the purpose of moving the building. The tracks were supported upon wooden sleepers, based on a newly made concrete base. The cross-section of the supporting structure which served as the base for the relocation of the northern tollgate building, is shown in Figure 1.

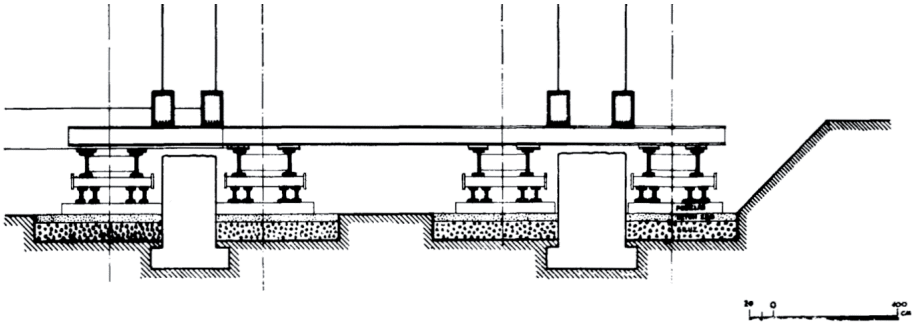


Fig. 1. View of supporting structure which served as the base for the relocation of the northern building of the Grochowska Tollgate ([10] on the basis of original design by W. Makowiecki)

The process of moving the building was carried out by way of rolling it on top of steel rollers of the diameter of 100 mm and spaced apart at distances of 60 cm, and using I 200 steel profile support beams, joined together via steel diaphragms. The building was lifted onto the supporting structure by cutting it off and elevating it using steel wedges (see Fig. 2).

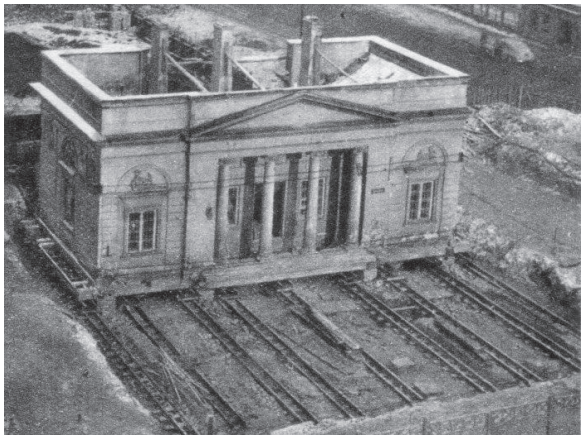


Fig. 2. View of northern building of the Grochowska Tollgate in Warsaw during relocation [15]

The process of rolling was carried out using a system of 4 winches of the combined power of 20 tonnes. The speed of movement of the building was 10 cm/min, which allowed the building to be moved by 10.56 m in a time of 106 minutes, i.e. less than 2 hours. The total time of the execution of preparatory works and the relocation was 82 days. Finishing works were completed within 14 days. It is interesting to note that the building team consisted of one carpenter and 9 unskilled workers.

The relocation of the northern building of the Grochowska Tollgate, which was a resounding success, represented a learning curve for the engineers, who later drew from its experiences during subsequent works of this type. As a matter of fact, the implemented technical solutions and the experience gained during this operation were utilised during further projects in this field.

Several similar projects of this kind were carried out in Warsaw in the following years. As such we can for example mention the relocation of the Church of the Nativity of the Blessed Virgin Mary in Leszno in 1962 [2, 3, 7, 9, 10], or the relocation of the Lubomirski Palace in 1970 [2, 11]. The latter project was especially interesting, because it effectively represented the rotation of the building by 74° from its original position. As already mentioned, the second building of the tollgate at Grochowska Street was relocated in 2001. There were also several relocations of buildings beyond Warsaw. In 1967 the listed guardhouse No. 1 at Westerplatte was moved by 78 metres [13], while 2014 saw the relocation of the Grüneberg villa in Szczecin-Zdroje.

3. HISTORY OF THE OLD NORBLIN FACTORY AND DESCRIPTION OF THE ARTNORBLIN PROJECT

The industrialisation of Poland, which was at that time partitioned between occupying nations since the end of the 18th century, throughout the 19th century and at the beginning of the 20th century, gave rise, among other things, to the creation of industrial plants of various types and resulted in the development and expansion of industrial regions and cities. A classic example of intensive development and industrialisation is the city of Łódź, which transformed in a short period of time into a large industrial city, dominated by the textile industry. Many of the major factories were naturally located within the biggest cities, contributing to their dynamic development. Some of the manufacturing plants built in the 19th century were still operational until recent times, undergoing natural modernisation in the process. However, many of them, due to economic aspects, experienced gradual reconstruction, reduction or demolition. Factories situated on the outskirts of cities often became adjacent, as a result of urban development, to public utility facilities or residential buildings, which were being built within constantly expanding city centre areas. This naturally resulted in interference with the intended use of the specific areas designated in the spacial zoning plans. It naturally became necessary to develop the post-industrial areas. Many of these facilities were successfully developed within major cities such as Łódź, Poznań or Warsaw itself. In the latter case, we are dealing with intensive development and a change of the intended use of many post-industrial areas which are currently located within the core urban structure. An example of the above is the 19th

century Norblin factory, which is the site of the relocation of one of its buildings that the present article relates to.

The history of this building dates back to 1847 [16], when the plot delimited by the Prosta, Żelaza and Łucka Streets was purchased by a German industrialist Edward Luckfield. Together with his business partner, Gustaw Henninger, he began the production of metal products at the site. In the following years the factory changed ownership. 1893 sees the creation of a company under the name of Towarzystwo Akcyjne Fabryk Metalowych Norblin, Bracia Buch i T. Werner, which in a short period of time becomes a major manufacturer of metal, mainly non-ferrous, products within the Kingdom of Poland. During the II Polish Republic the Norblin Factory, as it is known in short, was also one of the biggest manufacturers of metallic products in the country. After the end of World War II it was hastily rebuilt and operated until 1982 under the name of Walcownia Metali "Warszawa" (Warsaw Metal Rolling Mill). It subsequently served as a museum, being gradually reduced, as in the 1990s manufacturing halls between Sienna and Prosta Streets were demolished. The museum was closed in 2008 because of the facility being previously taken over by a private investor. It was decided to develop the old Norblin Factory into office and commercial buildings, simultaneously preserving some of the post-industrial buildings. In accordance with the developed architectural concept design, it was also decided to set out a generally accessible pedestrian passageway and three streets covered with a glass shelter roof. The visual presentation of this project is shown in Figure 3.

Fig. 3. Visual presentation of the development of the old Norblin Factory in Warsaw [17]

The complex of buildings currently under construction operates under the name of the Norblin Factory, or alternatively as ArtNorblin or ArtN. It is situated at Żelazna Street 51/53, at the corner of Łucka and Prosta Streets. Its construction began in December 2017 and its completion is planned for the 4th quarter of 2020. The project entails the construction of a building with 8 overground floors and four underground levels. Its floor space is 64 000 m^2, of which office space occupies 40 000 m^2 and commercial space occupies 24 000 m^2. The development of the area will include the renovation of 9 listed buildings and 2 historic ones, as well as 50 machines and devices of the old factory. Apart from office/commercial spaces, the building will also contain a cultural zone, including a modern theatre and a studio cinema. The Old Norblin Factory Museum will be opened as an integral part of the complex and one of its main attractions. Due to the implemented concept, which successfully enabled the continued existence of post-industrial buildings within the modern structure of newly designed buildings performing vastly different functions, it was necessary to carry out the development of the original, listed buildings. This naturally posed certain problems, some of which were quite easy to overcome. However, the development one of the original, listed buildings numbered as 15, posed a major problem. In accordance with the conservation assumptions it was intended for development and this did not pose any problems. Its form, size, layout and wall arrangement, as well as its technical condition, qualified it as a building suitable for development. The problem was its location, which interfered with the execution of underground works, and the conservation requirements, which stated the lack of possibility of its demolition and subsequent reconstruction. The only solution was to move the entire building.

4. RELOCATION OF BUILDING NO. 15 AT THE OLD NORBLIN FACTORY

4.1. DESCRIPTION OF BUILDING

Building No. 15 was built on a rectangular plan view of the dimensions of 31.5 m × 12.0 m. It is a single-floor building with a pitched roof and a traditional, brickwork structure (Figs. 4 and 5).

Fig. 4. South elevation of building No. 15 at the old Norblin Factory

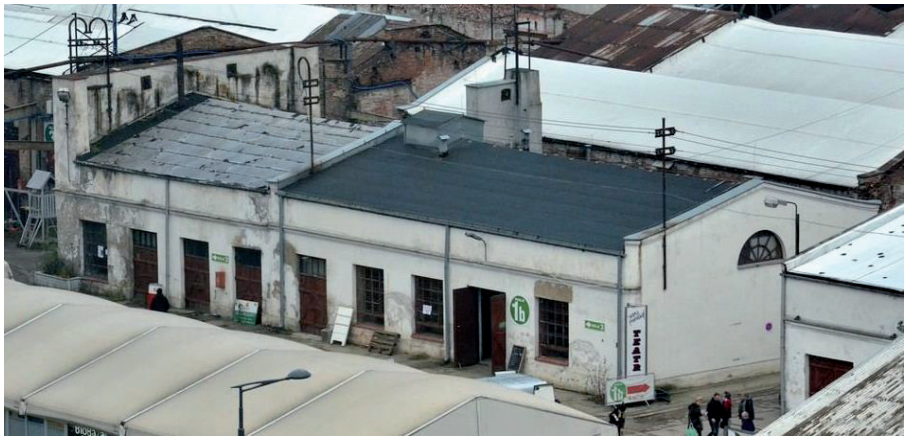


Fig. 5. View of building No. 15 at the old Norblin Factory [18]

Load bearing structure in the form of longitudinal structural walls of the thickness of 60–70cm. External crosswise walls are 45 cm thick on the eastern side and 75 cm thick on the western side. The internal crosswise wall which separates the forging hall from the cleaning hall and is to be preserved, is 65 cm thick. The remaining internal walls were demolished before the relocation of building. Roof in the form of wooden trusses was erected over a section of the old cleaning hall between longitudinal walls; insulated using mineral wool. The trusses were covered with full boarding, which was then covered with bituminous membrane. Roof trusses above the rest of the building were erected as wooden, board, nailed elements, with a clear span of 10.7 m as measured between the walls, spaced approx. 1.0 m apart. In the storage (western) part, wooden roof supported on steel C-profile purlins was erected, which was then covered with wooden rafters with a square cross-section, to which full boarding was then nailed to.

4.2. TECHNICAL CONDITION OF BUILDING

On the basis of site inspections carried out between November 2011 and May 2012 it was observed that the general technical condition of the finishing elements, window framing, flashing elements, etc., is poor, or locally satisfactory. The technical condition of individual structural elements, in terms of their suitability for further operation of the building, was varied. Structural walls (load bearing and stiffening walls) were generally in good technical condition, but needed renovation and local strengthening by stitching or local brickwork reconstruction. Poor condition of masonry of the northern wall was observed in some places, because of the mortar having no binding material at all. There was virtually only sand within the joints. Wooden roof trusses in the cleaning hall were in a good technical condition, did not demonstrate any dampness or any signs of biological corrosion. Roofing in the forging hall was in a poor technical condition. Steel roof purlins were corroded, while roof sheathing made of wooden boards was damp and corroded. An excavation made in the south-eastern section revealed that the foundation was in a good condition, while an excavation in the south-western section, which experienced heavy flooding and dampening of the continuous foundation, the condition was estimated as satisfactory to poor, due to the crumbling and peeling of bricks.

4.3. DESIGNED CONDITION OF BUILDING AND SCOPE OF CONSTRUCTION WORKS

The building was designated for preservation, development and adaptation to the new project. Building No. 15 was designated for relocation to a temporary location in the direction of Prosta Street, in order to facilitate the erection of a diaphragm wall between the building itself and the adjacent building No. 9. After the completion of the diaphragm wall and floor, the building was to be moved to its designated final position, conforming with the original position, and to be permanently based on a new level 0 floor of the newly designed building of the ArtNorblin complex.

The process of relocation of building No. 15 itself was to include 3 main stages. The first stage comprised the construction of a diaphragm wall in a location not interfering with the location of the building. This scope of works included the execution of a transfer floor, supported on temporary pillars, in the temporary location of building No. 15, the bricking up of existing openings in walls, the construction of an internal strengthening steel structure for the period of the relocation of building, demolition of passageway between buildings 9 and 15, separation of building from its foundations, construction of fastening beams along the entire perimeter of all external and internal load bearing

walls, carving out of seats for guide beams in load bearing walls, construction of base for the relocation of building inside the building itself, and along the planned route of relocation, and the construction of guide beams. The second stage included the movement of building No. 15 by about 15 m onto the transfer floor, the demolition of old (existing) foundations under building No. 15 and the construction of the remaining part of the underground wall, barette piles and the transfer floor in the location of the original positioning of this building. The last, third stage of the works included the movement of building No. 15 to its original location, the construction of the underground section of building in its location and the disassembly of the internal steel strengthening structure, so as to prepare building No. 15 for development works.

4.4. DESIGN AND TECHNOLOGY OF RELOCATION OF BUILDING NO. 15

The first phase of works comprising the operation of the relocation of building No. 15 consisted of the development of a structural/technological concept design. One of its key elements consisted of the static calculations, which analysed the spatial model of the building's strengthening structure and defined forces generated during the relocation of the building.

In order to ensure the safe relocation of building B15, a frame made of HEA 240 steel profiles was designed, which were stiffened using C 160 posts and cross braces and type X vertical bracing made of two 20 mm diameter rods (Figs. 6 and 7). Near masonry walls, the frames were to be bolted together using M16 bolts spaced apart 170 cm maximum. In order to ensure adequate stability, the spatial structure was braced in the bottom and top plane of the frame using type X bracing made of two 20 mm diameter rods. All bracings were provided with the possibility of tension adjustment. In places of the occurrence of high crosswise forces, I-beams were additionally strengthened using longitudinal ribs. A steel profile C 200 girder was designed in the place of the removed wall in order to support the existing steel beams.

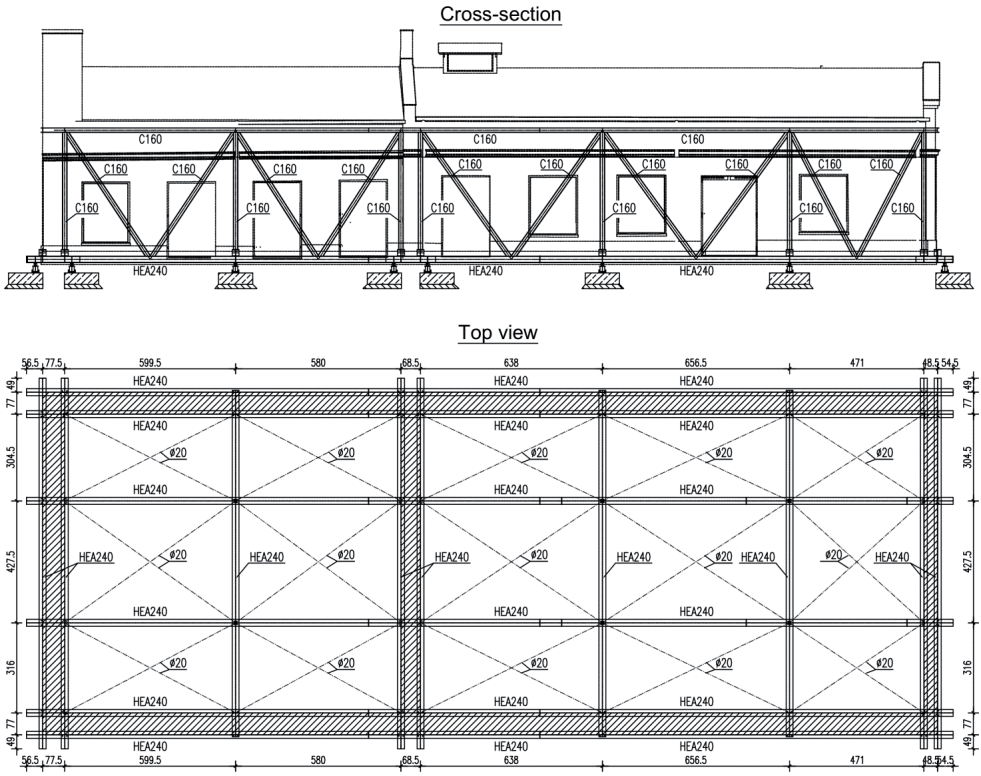
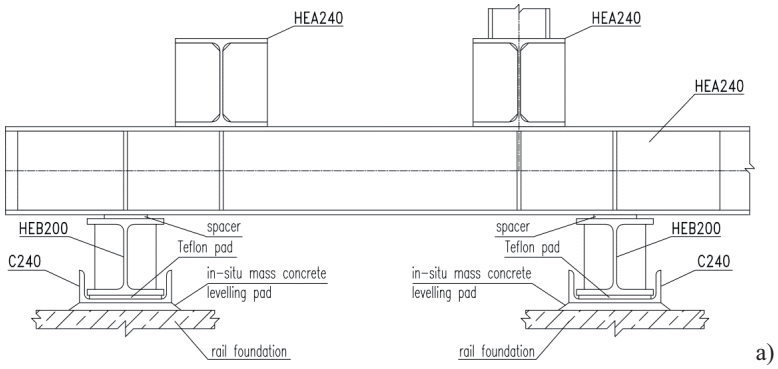


Fig. 6. Strengthening structure of building No. 15

According to the design, the movement of braced frame together with the building was to take place on HEB 200 I-beams, supported on C 240 profiles (Figs. 8 a and b). Teflon was installed between the profiles in order to reduce friction to a minimum. Steel spacers were provided at the interface between HEB 200 and HEA 240 profiles in order to allow any necessary adjustment. C 240 profiles were installed under land survey supervision, with a maximum tolerance of up to 2 mm. In order to reduce the effects of thermal expansion, the possibility of movement by at least 5 mm in the direction perpendicular to the profiles was ensured at the interface between HEB 200 and C 240 profiles.

Fig. 7. View of internal strengthening structure of building No. 15



a)

b)

Fig. 8. Outer node of the bottom frame of the stiffening structure of building No. 15; a) design detail; b) erected structure

Preparatory works necessary for the relocation of building No. 15 included the following stages:
- construction of bands for external walls made of HEA 240 profiles bolted together using M16 bolts placed within the wall; empty space between the wall and profile was filled with injected cement grout,
- support of the supporting structure for the roof of the western section,
- demolition of internal walls not connected with external walls (to improve the rigidity of the remaining external wall structure, internal steel frames were introduced to join together the spacial arrangement of the main steel frame designed for the relocation of the building),
- stiffening of the remaining middle wall in the form of doubled crosswise structural arrangement shown in Fig. 7,
- construction of continuous foundations for the tracks inside and outside of the building,
- construction of the bottom steel grate (Figs. 7 and 8),
- securing of wall openings: upper openings in gable walls were bricked up to the entire wall thickness, whereas openings at the floor level were secured by introducing steel stiffening profiles,
- construction of spatial frame in accordance with the above-mentioned description (Figs. 6 and 7).
- creation of openings for the passage of tracks made of C 240 profiles and track beams,
- installation of tracks made of C 240 profiles on concrete continuous foundations,
- introduction and elevation of HEB 200 track beams; between the beams and C 240 profiles it was decided to install teflon covered stainless steel spacers of the thickness of 0.5 mm, in order to reduce friction,
- installation of actuators generating movement; the design entailed a tensioning system consisting of SAS 1050 steel tensioning rods, which were stabilised in buffer stops and tensioned using pass-through actuators installed inside them; the solution based on pulling the building allowed the reduction of the possibility of flexural bending and/or buckling of the guide rails.
- cutting off of the building at the level of the bottom flange of HEA 240 joining beams, with simultaneous installation of flats to protect the masonry against crumbling.

After the completion of the above preparatory works, building No. 15 was ready for relocation to the temporary location.

4.5. OPERATION OF RELOCATION OF BUILDING NO. 15

The operation of relocation of building No. 15 began at about 10:30 on Friday, 30th November 2018, and finished on the following day, on Saturday, 1st December, at about 7:00 in the morning. A view

of the building during relocation and one of the tensioning tracks can be observed in one of the figures below.

Fig. 9. View of building No. 15 during the operation of relocation

The correct progress of this procedure was supervised by over a dozen of persons: engineers, land surveyors, structural supervision engineers and construction workers. The relocation was carried out on site by the DAMPAK company, where the entire process was managed by an engineering team consisting of Damian Pakuła, Mariusz Rogowski, Piotr Pacak, Tomasz Pacak, as well as Paweł Kossakowski, the author of this article. The weather conditions were good, without any precipitation, temperature was quite low, between -12°C at night and -2°C during the day, which was quite uncomfortable for the engineering team who supervised the whole operation for virtually 24 hours. The 900-tonne building moved at a speed of approx. 3 cm per minute, in 25-centimetre cycles, with intervals in between. The building was moved by a total of 15 metres to its temporary location. The subsequent relocation of the building to its original location took place on 25-26 April 2019. The procedure was conducted similarly to the first operation of relocation. Notable is the fact that the building did not suffer any damage during these operations, which was especially important due to its historic character.

5. CONCLUSIONS

Any change of the location of buildings during their operation is always technically problematic. In the case of listed buildings, operations like these are especially difficult. This is mainly related to restrictive conservation requirements, which usually limit to a minimum any interference with the original structure of such buildings, and demand the maintenance of the maximum scope of its original historic substance. Another issue is the significant reduction of the material structure in very old buildings, which means they are prone to damage during the process of their relocation.

During the execution of the above discussed operation, these requirements were successfully met in the case of listed building No. 15 of the ArtNorblin complex in Warsaw. The professional and holistic approach of the team consisting of engineers and experts to the entire operation facilitated the smooth and problem-free progress and completion of the relocation of the building. The above project thus represents yet another example of an unusual engineering operation undertaken in our country, and one that was successfully completed, providing new experience in the field of such operations.

6. SUPPLEMENT

Information, technical documentation and multimedia related to the relocation of the historic building No. 15 at the old Norblin Factory in Warsaw are available under the following web page:

`https://dampak-konstrukcje.pl`

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LIST OF FIGURES AND TABLES:

PRZESUNIĘCIE ZABYTOWEGO BUDYNKU W STAREJ FABRYCE NORBLINA W WARSZAWIE

Słowa kluczowe*: budynki zabytkowe; przesuwanie budynków; budownictwo specjalistyczne; inżynieria specjalistyczna.*

STRESZCZENIE

W artykule podjęto tematykę związaną z przemieszczaniem budynków. Przedstawiono tło historyczne tego typu operacji jakie miały miejsce na świecie, jak również na terenie Polski. Omówiono szerzej pionierskie rozwiązania konstrukcyjnej i technologiczne, które zastosowano podczas przesunięcia budynku Rogatki Grochowskiej, jaka miała miejsce w 1961 roku w Warszawie. Zasadniczym przedmiotem artykułu była operacja przesunięcia zabytkowego budynku nr 15 w starej Fabryce Norblina w Warszawie, która zrealizowano pod koniec 2018. Krótko scharakteryzowano historię fabryki. Przybliżono założenia inwestycji, obejmującą adaptację starej Fabryki Norblina. Szczegółowo omówiono koncepcję i zakres przesunięcia budynku nr 15, przedstawiając projekt konstrukcyjny i technologiczny dotyczący tej operacji. Zdano szczegółową relację z przebiegu przesunięcia obiektu dokonanego w roku 2018.

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