

Problems in Carrying Out Construction Projects in Large Urban Agglomerations on the Example of the Construction of the Axis and High5ive Office Buildings in Krakow

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Abstract. The paper discusses problems in the carrying out of construction projects in large urban agglomerations on the example of two structures located in Krakow. The location and the specifics of the work that had to be performed generated numerous technological and organisational problems. The manner of solving them, in addition to propositions of guidelines for similar projects are discussed in the paper.

Keywords: technology, organisation, construction project, urban agglomeration

1. Introduction

The term construction project is used to describe an action that is undertaken in order to meet the needs of a property developer, as well of the future users of a structure. A construction project includes work focused on the preparation, organisation and carrying out of construction work, settling the accounts for construction and providing a finished structure that is ready for operation [1,2]. The carrying out of a construction project is a complicated process associated with unique external factors and the individual qualities of a given project.

Urban agglomerations are areas with the highest density of construction projects. In such a case, a property developer is often a public entity and adhering to public procurement laws is required [3]. An urban agglomeration is an area with a very dense built environment and a high density of population - both permanent and that which temporarily stays in its area. This area is typified by a rapid spatial development, well-developed infrastructure and widely understood socio-economic and cultural conditions [4]. The rapid development of urban agglomerations is associated with numerous construction problems. Table 1 contains examples of the causes of problems and a selection of problems that occur in construction projects carried out in large urban agglomerations.

The goal of the paper is to discuss problems related to construction projects that are carried out in large urban agglomerations in Polish conditions on the example of two office building projects located in Krakow.

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Table 1 Examples problems in the carrying out of construction projects on the territory of large urban agglomerations, as well as their causes. Original work based on [5,6,7,8,9,10,11,12,13]

DEPENDENT CONSTRUCTION PROBLEMS	CONSTRUCTION PROBLEMS THAT ARE INDEPENDENT OF EITHER PARTY	<ul style="list-style-type: none"> • A dense built environment (the need to perform deep excavation, height limits for buildings) • Limitations in available space for performing work and setting up storage areas • Difficulties in logistics (traffic jams) • Dynamic (e.g. vibrations) and mechanical loads influencing the structure and the ground • Negative influence on humans due to noise, traffic difficulties, dirt • Difficult soil and water, as well as atmospheric conditions (wind, snow, rain, temperature) • Natural disasters (flooding, hurricane, landslides) • Equipment failure • Intermissions in power and water supply • Sudden price increases, inflation • The requirement of conservation supervision in the case of historical buildings or work that is being carried out in the vicinity of areas of historical importance (specific construction and material requirements, additional work that is difficult to foresee)
	ON THE PROPERTY DEVELOPER	<ul style="list-style-type: none"> • Financial difficulties • Requirements of constructing more representative structures first (for instance from the side of the street with increased traffic in the case of a multiple-building project) • Delays in the decision-making process • Problems with coordination and communication between project participants
	ON THE DESIGNER	<ul style="list-style-type: none"> • Changes in structural and material solutions in the design of a structure already under construction • Administrative and legal problems • Mistakes in the technical documentation • An insufficient level of detail in the design • Delays in the decision-making process • Problems with coordination and communication between project participants
	ON THE CONTRACTOR	<ul style="list-style-type: none"> • Changes in the timetable resulting in delays in performing work and material deliveries • Picking insufficient scheduling tools • Inappropriate construction technology choices • Lack of appropriate equipment for given construction work • Lack of specialist management and construction staff • Mistakes in material and service commissions • Delays in material and service commissions • Lack of financial resources for the procurement of materials and equipment rental • Not adhering to health and safety regulations, resulting in work accidents, intermissions in work and financial penalties • Improperly organised logistics (transport on the construction site and the work of tower cranes) • Delays in the decision-making process • Problems with coordination and communication between project participants
	ON THE SUPPLIERS	<ul style="list-style-type: none"> • Problems with timely order delivery • Materials out of stock • Difficulties in the delivery of non-typical materials and construction products • Providing products and services of inferior quality • Insufficient transport pool • Production plant failure (e.g. concrete mixing facility)

2. Characteristics of the analysed structures

Characteristic of the first structure - Axis Krakow

The Axis building (fig.1) is an office building with services on the ground floor. The construction of a part of the structure of the Axis office building began in 2014 and took 22 months to complete. The office surface area of the building amounts to 19 298 m², while retail and service areas amount to 1183 m². The building has 9 storeys above ground and three underground levels with parking lots. The building is a class A office building [14]. The load-bearing structure is composed of monolithic and prefabricated reinforced concrete elements. The subterranean levels were constructed as entirely monolithic, while those above ground used prefabricated reinforced concrete pillars, beams, staircases and FILIGRAN-type floor slabs, in addition to monolithic shafts and landings [15].



Fig. 1 View of the finished Axis building. Original photograph.

Characteristics of the second structure - the High5ive complex (buildings D and E)

The High5ive office building complex (fig.2) is being built in Krakow near Pawia street. The surface area of two of the buildings from among the five-building complex amounts to around 23 500 m². Both of the buildings have six storeys and have subterranean levels with parking lots (building D – one underground level, building E – two underground levels). They are class A buildings. The load-bearing structure of both buildings is a spatial post and slab structural system with monolithic shafts that provide rigidity.



Fig.2 Visualisation of the High5ive buildings [16]

3. Problems in constructing the analysed buildings in Krakow

Problems associated with a dense built environment

The Axis office and service building is located in the central part of the city of Krakow in the area of Rondo Mogilskie. The building's surroundings include a hotel, a green square and some of Krakow's largest and most important streets. The area designated for the construction of the second building - the High5ive office and service building complex is located in the strict city centre of Krakow. The immediate vicinity includes a shopping gallery and hotels. The construction site is adjacent to the main train station and a street with a tram line that is partially on the surface and partially in a tunnel. A part of the site is located over an existing road tunnel. Such a site (fig. 3) generates serious difficulties and limitations in construction work and influences their duration. In the case of a construction project carried out in a dense built environment, the preparatory and design phases are particularly crucial, including: a comprehensive identification of soil and water conditions both underneath the designed structure, as well as in its zone of influence on surrounding buildings, determining the functional and spatial solutions of the underground section, a selection of the support and construction method of the underground part of the designed building and the monitoring of the condition of adjacent structures [8,18].

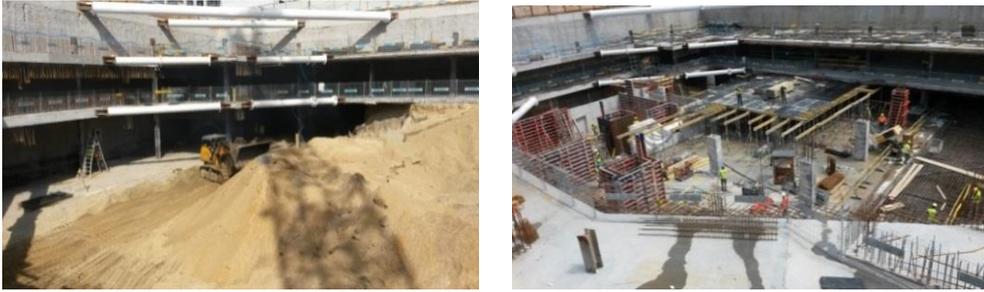


Fig. 4 The construction of the underground levels of the AXIS office building using the top and down method. Original photograph.

Problems associated with logistics and limited storage area

A large project scope with a limited construction site area, short completion time and a specific location add up to a complex logistical problem. The partnering relations between the participants of the project and effective logistics are the groundwork for success and are responsible for the delivery of the required resources, such as: materials, equipment, people, money and information [20, 21].

In urban agglomerations, internal on-site circulation is often a problem. In both of the analysed cases, expensive parcels in the city centre have been completely developed with the constructed buildings in mind, at the same time limiting storage area to a minimum (fig. 5). The newly built levels, the work of tower cranes and the quick pace of work, in addition to the simultaneous presence of several hundred people at the construction site required the establishment of a separate logistics department. Delivery deadlines and locations in the case of such a location and the difficulties that had been encountered had to be met in accordance with a strict schedule that were given by construction supervisors to the logistics department. A common practice in the event of having limited space at a site is transport and assembly without storage. This method has been used in the projects that are discussed. This was a very important matter in the case of the construction of the Axis building. The delivered elements needed to be assembled and incorporated into the structure in an established sequence, which is why transport delays, alterations in the sequence of the arrival of trucks with material or the wrong orientation of an element on a truck would cause delays. The small storage area resulted in limited capabilities of ordering elements that were supposed to be installed ahead of time (for instance steel rebar was delivered slightly ahead of the assembly time). Due to the lack of space on the site, the site's backrooms had to be located in a place some distance away from it.

Traffic jams are a serious problem in city centres. Both construction projects are located near large, busy streets, which is a plus for future users as it provides good transport accessibility to the rest of the city, but has proven to be difficult during construction. The greatest logistical difficulties in this regard occur during the excavation stage and the transport of large masses of earth, as well as during the erection of the concrete structure. Concrete transport trucks would often stand in traffic jams long enough that the mix would not be fit for construction due to changing its consistency. After performing concrete slump tests by an accredited laboratory, the mix had to be sent back to the production plant for processing, which generated costs for the contractor and supplier and negatively impacted the environment due to air pollution from the concrete transport trucks' exhaust.

Another additional cost affecting a project's budget in a large city in the case of limited construction site area is the need to temporarily or permanently take over walkways or streets that belong to a city or a private owner (e.g. that of Galeria Krakowska in the case of High5ive). Sometimes heavy transports can damage the pavements or streets that are used, which requires unscheduled repairs. Such areas also need to be kept appropriately clean, which requires additional work.



Fig. 5 A view of the limitations associated with the location of buildings E and D of the High5ive complex (a dense built environment, lack of a storage area, the train station platforms, the parking lot of the shopping gallery). Original photograph.

One of the most important criteria of carrying out work in any location is the safety of the workers on the site. A dense built environment and the site's location near busy streets causes a project's influence on the safety of people that are not associated with the construction to be quite large. This has been a particularly important problem in the case of High Five. It is located near a busy walkway. The problem of protecting people was solved by constructing an additional overhang above the walkway and the fitting of safety nets on each of the levels of the buildings under construction.

Problems with the influence of vibrations on both existing buildings and those under construction

In the case of carrying out a construction project in an urban agglomeration, we can divide the problem of vibrations into two types: the vibrations of the structure under construction under the influence of the project's surroundings and the vibrations of the structures adjacent to the site under the influence of construction work. Performing an analysis of the influence of the space that surrounds the planned project and taking it into account already during the design process is an important problem. Both of the projects that are being discussed are located near busy streets with heavy traffic from cars and trams. Besides, the buildings of the High5ive complex are placed in difficult conditions in terms of vibrations. They are located near the main train station, which services around 240 trains of various types per day. On the other side of the site, it is influenced by the presence of a tunnel for high-speed municipal trams. These surroundings required the adoption of an appropriate excavation technology, the ability to provide the buildings with a safe foundation depth and forced the contractor to constantly monitor the tension of the excavation wall supports, the successively constructed levels, the ground and the walls of the tunnels near the site. The problem of the influence of vibration from traffic has been widely discussed in numerous works, including [22, 23, 24, 25]. Construction work carried out in a dense built environment exerts influence on the surroundings of a site. The work of heavy construction machinery induces vibrations in the ground which affect the buildings that surround a site. This can lead to foundation damage and cause cracking of an entire building's structure. The state of the structures near the site needs to be monitored and taken into account during the technology selection process.

Problems with noise

Noise is a natural problem in an urban environment. Most studies in the case of urban agglomerations are concentrated on noise from traffic. We can also find important studies [26, 27] regarding persons who are directly tied with the process that is being carried out - engineers and workers. Due to the dense built environment of an urban agglomeration, noise from construction sites affecting neighbouring buildings becomes a factor. Although it is a lesser inconvenience in the case of places that are temporarily occupied (in the case of the discussed projects: a court building, an office building, a train station), this becomes

a considerable problem in the case of residential buildings and high class hotels. Studies on the effect of noise from construction in an agglomeration and the means of dealing with it are discussed by the author of [28]. In the case of the analysed projects, the schedule featured work only between the hours of 6-22 in order to limit the negative impact of noise and in order not to significantly affect the business of neighbouring hotels.

Problems associated with archaeologically important sites

The site of the Axis building was located in the vicinity of an archaeological dig (Fort Lubicz), which caused excavation work to fall under the supervision of the Voivodship Conservator of Historical Buildings. No elements of historical value had been discovered during construction, but, as the authors of [12] state, this can cause numerous difficulties and would probably lengthen the unplanned duration of the project. In the case of a project under archaeological oversight, the discovery of an element can lead to problems such as [29]: halting the work for the duration of research, the need to change the planned technology and the design, the possibility of the occurrence of so-called additional work.

4. Conclusions

Table 2 contains the most common causes of problems in the carrying out of a construction project in a large city based on literature and the analysed structures. Guidelines were proposed in order to avoid them or limit their occurrence in similar future projects.

Table 2 Causes of technological and organisational problems in the carrying out of construction projects in urban agglomerations and proposals of limiting or avoiding them. Original work

FACTORS	RECOMMENDATIONS
Dense built environment	A thorough development of a project during the preparatory and design phase by a comprehensive identification of soil and water conditions both beneath the designed structure and in the zone of its influence on neighbouring structures. Determining the zones of influence of the designed building on neighbouring structures and the monitoring of the condition of existing structures.
The need to perform deep excavation	Determining the requirements of the functional and spatial layout of the subterranean section, selecting the most appropriate form of the support and construction of the subterranean section of the designed building, constant monitoring of the tension of the supports and the ground.
Logistical difficulties	Appointing a person to be responsible for effective logistics. Strict adherence to a previously established delivery timetable.
Vibrations	Performing appropriate analyses regarding the propagation of vibrations and the monitoring of the structure under construction, as well as of existing structures.
Noise	Limiting the work to daytime hours, the use of temporary acoustic screens
Archaeological digs	Thoroughly analysing the historical context of the construction site and performing available research as needed.

The carrying out of construction projects in a large urban agglomeration is a difficult undertaking. The space in which construction work is performed, the requirements of the property developer and a long construction time generate organisational and technological problems. Despite difficulties, the analysed projects was completed in accordance with the planned schedule, which means that the implemented actions had been appropriate.

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