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MONITORING AND STRENGTHENING OF EXISTING FACILITIES IN THE NEIGHBOURHOOD OF IN-FILL BUILDING

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Abstract

This paper focuses on the following issues:
- technical issues regarding the construction of infill buildings and their influence on the old neighbouring buildings,
- analysis of the dangers, damages and catastrophes of old traditional buildings,
- rules regarding monitoring of the technical conditions of existing old buildings,
- settlements of the ground and their influence on the neighbouring buildings,
- examples of the ground settlements observed during construction of infill buildings in Warsaw,
- examples of strengthenings realized near brick buildings and listed buildings.

Keywords: buildings, deep excavations, infill buildings, monitoring, strengthenings.

1. INTRODUCTION

Observed, in the former period, urban development, in the downtown area, requires the use of even small plots of land, located in the high-density housing. The high cost of such parcels make planning high-rise buildings, usually with several underground levels. It is connected with the need to perform deep excavations in the immediate or close proximity to existing buildings, usually erected on a small depth below ground level. To build the underground part of the new building requires the necessary excavation, usually with a depth of several meters. Such excavations must have adequate housing, fully spread and

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anchored properly, usually in the form of a cavity wall, properly supported at the height. Movements of excavation housing, and hence the subsoil, also cause displacement of housing nearby the excavation. Impact of deep excavation on neighbouring buildings should already be examined at the stage of designing a new building [10]. An important issue is also contraindications with respect to lowering groundwater levels, resulting from the need to protect e. g. wooden foundation elements of historic buildings [6]. It can be concluded that the deep foundation of buildings and their impact on neighbouring buildings is one of the most important problems to solve when planning a new investment [9].

The impact of newly erected objects on existing buildings is essentially made through the subsoil - changes to geotechnical parameters. It leaves out instances where any element of design of the new building object directly affects the structural elements of an existing object (e. g. supporting the new foundation on the existing one), or there is a mechanical effect on an existing object, e. g. hitting the construction crane against the building wall.

In carrying out construction works there may be changes in the subsoil as a result of [7]:

- the lessening of land after excavation,
- additional loading of land with a new structure,
- reductions in groundwater levels due to the excavation or water pumping,
- moisture of ground with rainwater with open excavations,
- moisture and scouring of the ground due to faulty water systems or sewage,
- dynamic (e. g. vibrations) and mechanical loads occurring during construction works,
- interference in the subsoil, for example, by injection.

As a result of these changes, in the subsoil may occur:

- displacement and subsidence,
- displacement and cracking of existing foundations,
- a reduction in load capacity and rigidity of the existing foundations,
- structural damage of existing buildings (developing of scratches and cracks in structural components),
- states of emergency or disaster of neighbouring buildings,
- faulty wiring (e. g. gas, water supply) and equipment of neighbouring buildings,
- accumulation of stresses in structural elements, which may cause their damage in the future.

Thus, the preparation and design phase of investment in a downtown high-density housing should include:

- comprehensive diagnosis of soil-water conditions, both-in the planned facility construction as well as in the region of its impact on neighbouring buildings,
- specifying the requirements concerning functional and spatial solutions of the underground section (number of floors underground, the location of entrances to the underground part),
- choice of housing and methods of implementation of the underground part of the designed object,
- determining the zones of influence of the proposed facility on the neighbouring building,
- monitoring of existing facilities.

The paper described the threats which are subject to existing buildings in the vicinity of ongoing infill buildings in a dense city centres, monitoring the status of these buildings, as well as ways to strengthen them. The explanations are illustrated with examples of engineering practice.

2. HAZARD AND FAILURE ANALYSIS OF THE OLD BUILDING

Analyzing the risks of subjected buildings existing in the vicinity of the planned infill building, one must be aware of the causes of accidents and disasters that have occurred in our country over the last 50 years. Data on this topic are collected and analyzed at ITB since 1962 [5]. The percentage input of the resulting risks, failures and disasters, according to division of construction types, was shown in Figure 1, and according to the distribution of materials division, from which the objects were made - in Figure 2. From the presented drawings results that failures are most at risk with public buildings and residential buildings of wall, framework or columnar and plate construction. Such buildings are often heavily exploited, because they were not regularly repaired and maintained and continue to be subject to systematic degradation.
Taking the designing of the object, requiring the deep execution, one needs to point the zone range of excavation influence and say what buildings are located in this zone. These buildings should be subjected to tests with a view to assess the technical state of constructions and their components. Test results should allow the possibility of transferring, by the construction of these buildings, additional burdens due to foreseen uneven ground movement in the zone of their foundations. If the building constructions are not able to transfer these additional burdens, it will be necessary to design appropriate reinforcement of the building structure and the ground [11].

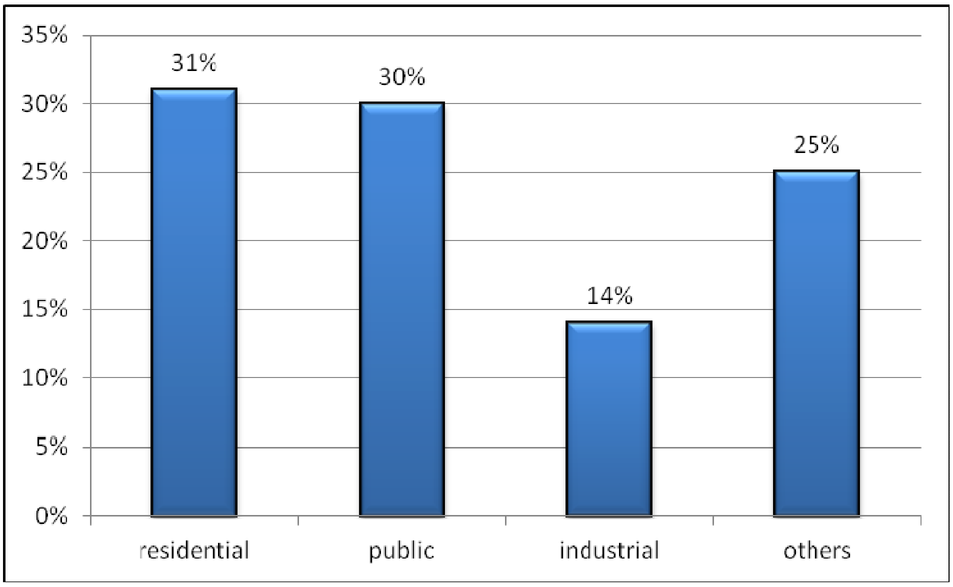

Fig. 1. Percentage failures and disasters in the years 1962-2013 according to the division by construction types

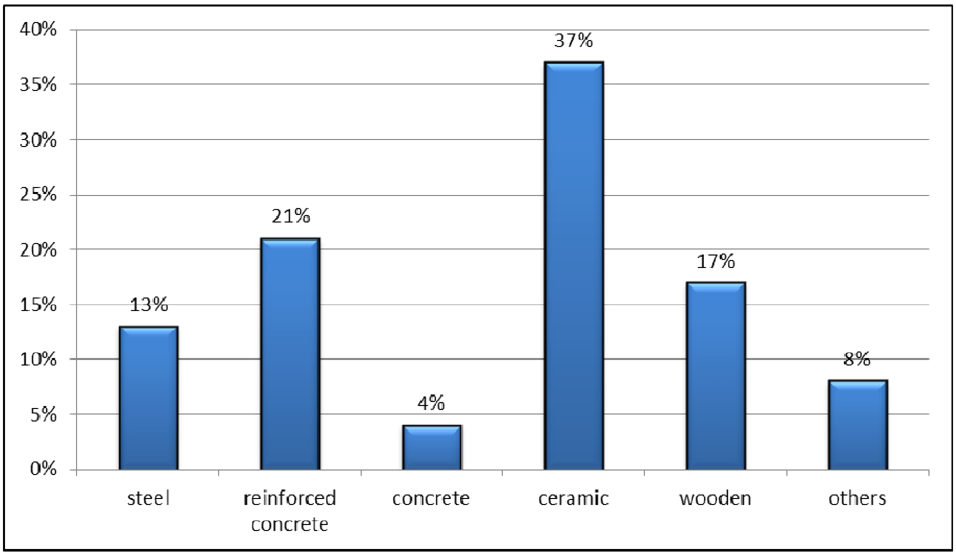

Fig. 2. The percentage of failures and disasters in the years 1962-2013 according to the division by materials

During the evaluation of the technical condition of existing buildings it is necessary to define:

- the age of the structure,

- the type of foundation - indirect, direct,
- structural system - wall, skeletal, frame,
- types of floors - prefabricated, monolithic,
- the roof structure - flat roof, steep roof
- the way to ensure stereo rigidity
- material solutions of structural elements,
- ways of using the building - provided in the project and current,
- occurring damaging of structural elements and equipment.

In addition, certain factors should be determined, occurring during the exploitation of buildings that could affect the technical condition of the structural elements, for example, underground utilities network failures nearby buildings, fires.

One should also take into account the vibrations transmitted through the substrate that will be generated during sheet pile ramming, demolition of structures, etc. [1].

The measure of construction displacements of objects in the vicinity of the construction of deep excavations are inclinations, bending and breakage of structural elements. Building inclination from the vertical is an important factor in the assessment of its technical properties and utility. The permissible deflection value of the building is 3 per mille; higher values of inclination require appropriate technical intervention.

3. IMPLEMENTATION OF IN-FILL CONSTRUCTION

The value of vertical displacement of the surface and the shape of the subsidence basin depend mainly on the type of housing excavation and scheme of its static work and the type of land surface.

Range of influence of excavation depends on the deformability of land, the depth of excavation, trench projection size, scope and duration of any reduction in the groundwater table, as well as the length and capacity of ground anchors - if stability of excavation walls was secured with ground anchors [4]. The largest vertical displacements of land surface appear in an area with a width of 0.50 to 0.75 *h* (where *h*-excavation depth) and those movements disappear within 2 *h*, and the application of lowering of the ground water (by depression wells located outside the contour of the excavation) 3 to 4 *h* from the edge of the excavation [4].

According to [3] in assessing the impact of the excavation on neighbouring buildings, it is advisable to distinguish two zones of influence of excavation:

- zone S_I - direct impact zone of the excavation, i. e. the area in the immediate vicinity of the excavation, wherein in special cases (e. g. by insufficient bearing capacity of the housing, excessive deflection of the housing) can occur displacement of the substrate, threatening bearing capacity of building construction,

- zone S_{II} - zone fragment of the excavation impact, wherein the common movement of the substrate may cause damage to the building, however, it does not threaten the structure carrying capacity.

Scope of the S_I zone should be taken as equal to the maximum distance from the housing to the most likely slip lines in the soil (maximum width of the soil wedge).
The zone range of excavation impact for the most common land was given in [2], in table 1.

Table 1. The zone range of excavation impact

Type of ground	S_I	S_{II}
Excavation in the sands	0,5 H_w	2,0 H_w
Excavation in clay	0,75 H_w	2,5 H_w
Excavation in silts	1,0 H_w	3÷4 H_w
H_w - excavation depth		

If the performance of the excavation is not expected to lower the groundwater table, given in the table 1S_{II} values can be reduced by 20%.
In the case of historic buildings acceptable ranges of excavation impact is recommended to be increased by 50%.
The values given in table 1 should be, where possible, verified and adjusted on the basis of measurement results in buildings movements carried out while performing deep excavations in the area [3]. The actual movement of the substrate is determined by benchmarks placed on the walls, foundations and other elements existing in the vicinity of buildings.
Acceptable movement of the substrate is determined for each building depending on its location, technology of performance and technical condition.

4. CONDITION MONITORING OF EXISTING BUILDINGS

Existing damage to the building should be inventoried both as documentation of photographs and drawings defining the location of damage and its size (length and opening of scratches and cracks).
The scope of existing building observation depends on the position and distance from the edge of the erected building. In the closest zone to the erected object, visual and geodetic observation should be covered places, such as:

- vertical and horizontal elements of load-bearing structure (columns, walls); in the case of buildings consisting of several dilated segments - of each dilated part,
- horizontal crown of excavation casing at a depth of indirect supports, - vertical bottom slab of erected building.

The frequency of observations should be adapted to the pace of progress of construction works and may be reduced after the completing of underground part of the building. Observations should be carried out until stabilization of the ground deformation which, as a rule, occurs after about a year of construction completion.

The results of geodetic surveys should be immediately analyzed and compared with predicted values, administered in the project documentation. In the event of excessive deformation or displacement all the construction work should be suspended and subjected to static-strength analysis.

Examples of benchmarks arrangements for buildings located in the zone of impact of planned construction in the centre of Warsaw, along with selected graphs of displacements were shown in Fig. 3 to 6. Figure 3 and 4 refer to apartment building, and Figures 5 and 6 - residential building with office and service. Stabilization of deformation in both cases came after more than 1.5 years.

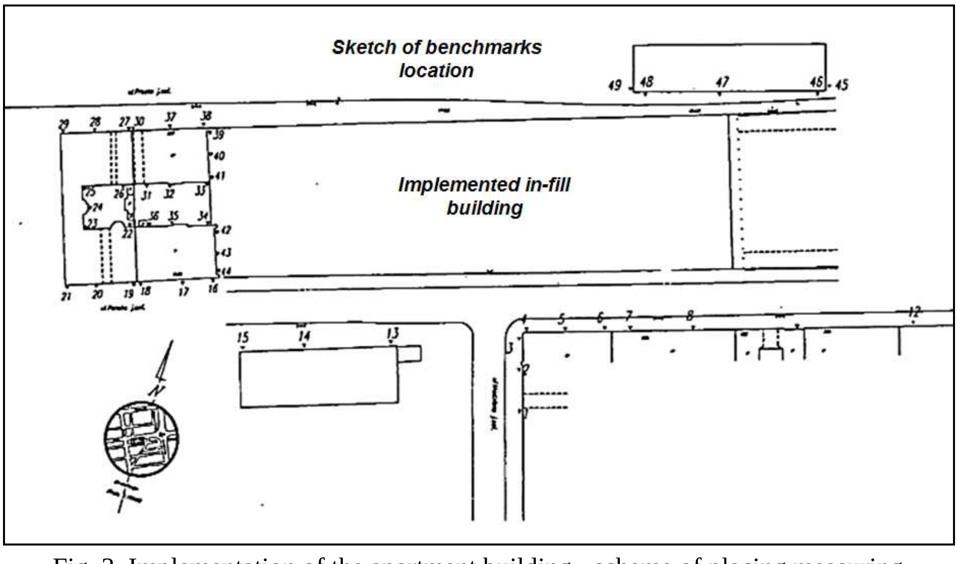

Fig. 3. Implementation of the apartment building - scheme of placing measuring benchmarks

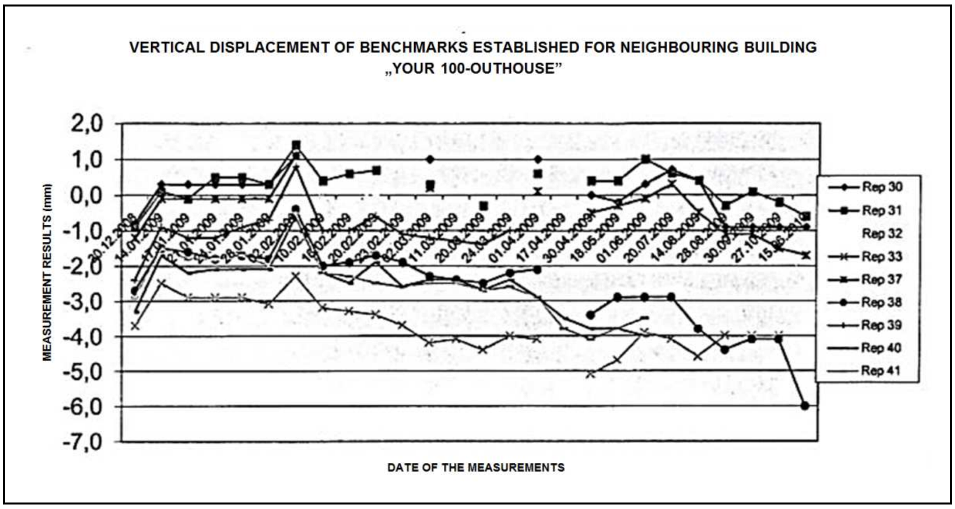

Fig. 4. Implementation of the apartment building - the results of vertical displacements measurements of neighbouring building

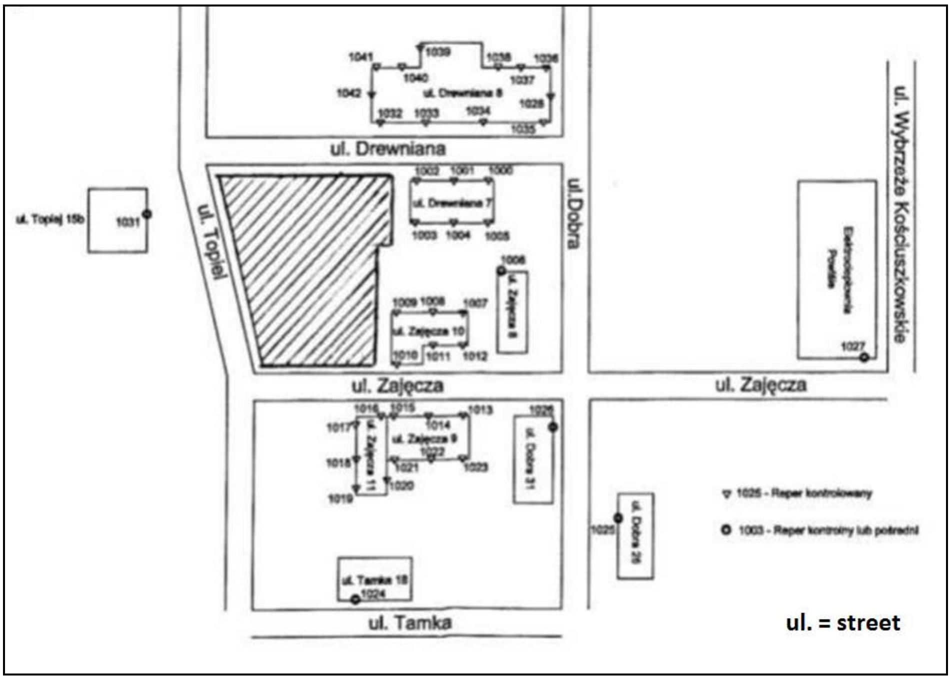

Fig. 5. Implementation of residential building with office and service parts- location scheme of measurement benchmarks

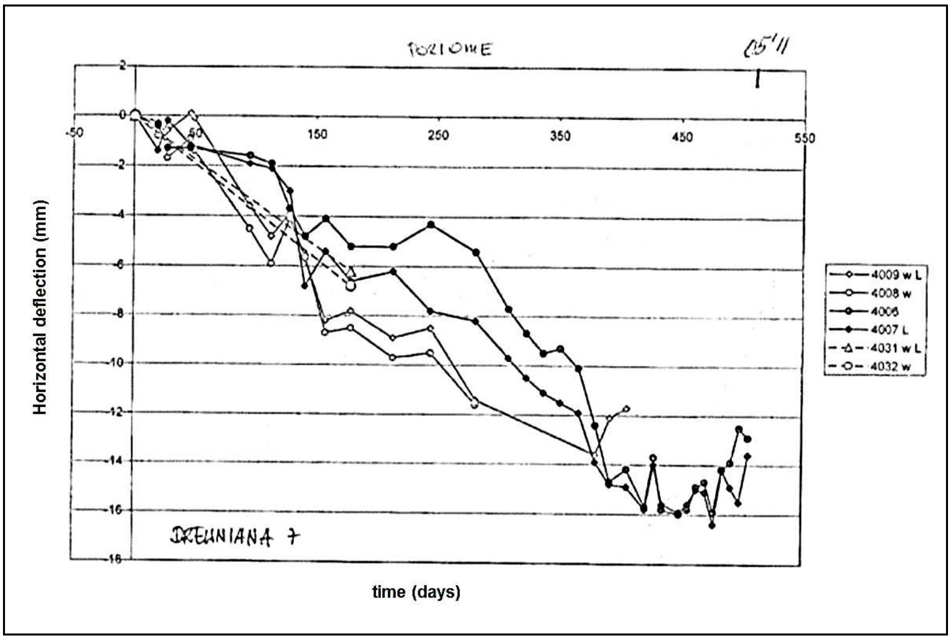

Fig. 6. Implementation of a residential building with office and service parts- the measurements results of horizontal displacements of neighbouring building

Vertical displacements of benchmarks shown in Fig. 3 and 4 were within acceptable limits (<20 mm) for this type of masonry. Also, horizontal displacements of benchmarks shown in Fig. 5 and 6 were within acceptable limits (<10 mm) for this type of masonry. However, in both cases, one recommended prophylactic use of horizontal braces in accordance with the work [8].

5. STRENGTHEN EXISTING STRUCTURES

Depending on the size of the projected displacement of the ground and the technical condition of buildings, it is often necessary to protect or strengthen elements of their design.

Strengthening the foundation zone of buildings can be done by:

- a system of piles or micropiles in order to transfer the burden of building foundations for load-bearing soil layers,
- peripheral reinforced concrete rims situated in a ground zone of the building,
- increasing the soil bearing capacity, e. g. using high-pressure injection.

Strengthening the aboveground part of the existing buildings can be made, for example, a system of steel tie rods, situated along the load-bearing walls, usually in several levels or execution of elements stiffening or concentrating construction.
Rules for implementing reinforcements of buildings construction and their components have already had a rich literature, for example. [8], and therefore will not be presented here.

6. CONCLUSIONS

Realization of the objects with multi-floor underground parts in dense downtown development conditions is a very complex problem, requiring professional preparation of investment and execution of works and ensuring the safety of the use of neighbouring buildings and the use of existing technical infrastructure. Major possibility limitation of occurring adverse effects can be achieved through the implementation of the object, in accordance with the rules of the trade, with current regulations and Polish Norms.
Before the start of each new infill buildings, one needs to assess their impact on neighbouring buildings every time. This enables the use of appropriate safeguards, techniques and technologies that help eliminate damage or failure of the neighbouring buildings.
Knowledge of the neighbouring buildings is generally very limited, which makes that defining the characteristics of the mechanical - strength of structural elements of these buildings requires adequate research, often difficult and time-consuming, costly and burdensome for users. As a result of these tests, decisions are made on the extent of necessary construction reinforcements.
Conducted observations (monitoring) of displacements and deformations that occur during the execution of the object, enable prompt decision making related to the security of both: erected facility and the neighbouring building.
As practice has shown, in the paper, inadequate solutions of presented issues related to the implementation of infill buildings in high-density housing often cause major social and economic damages. Therefore, each case should be dealt with by construction experts (valuers).

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MONITOROWANIE I WZMACNIANIE OBIEKTÓW ISTNIEJĄCYCH W SĄSIEDZTWIE BUDOWY PLOMBOWEJ

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

W artykule (referacie) przedstawione zostały problemy:
- techniczne realizacji budownictwa plombowego i ich wpływu na stare sąsiadujące budynki,
- analizy zagrożeń, awarii i katastrof starych tradycyjnych obiektów budownictwa,
- zasady monitoringu stanu technicznego istniejącej starej zabudowy,
- osiadań podłoża i ich wpływu na sąsiednie budynki,

- przykłady osiadań podłoża przy realizacji budynków plombowych na terenie Warszawy,
- przykłady wzmocnień istniejących w sąsiedztwie budynków murowanych zwykłych i zabytkowych.

Słowa kluczowe: budynki, głębokie wykopy, budownictwo plombowe, monitorowanie, wzmocnienia

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