Methods of Removing Buildings Deflection Used in Poland

Krzysztof Gromysz 1
1 Silesian University of Technology, 5 Akademicka 2A, 44-100 Gliwice, Poland
krzysztof.gromysz@polsl.pl

Abstract. The deflection of the building in relation to the vertical is caused by its uneven lowering. The deflection hinders the use of the building and causes occurrence of the additional inner forces which the construction of the building is not designed to take. Therefore, the deflections of the buildings should be removed. Three methods of removing building deflection have been used in Poland. The first method is removing the soil from under the part of the building which is positioned too high. The second method is elevating parts of the building that are too low. The third method is simultaneous removing the soil and elevating the building. In this work all three methods are presented and analysed showing their advantages and disadvantages. Removing the soil from under the part of the building which is positioned too high can be achieved by drilling holes under the building or cutting parts of the soil under the building. After removing the soil, the building returns to the vertical. The advantage of this method is no interference in the construction of the building. The disadvantages are the lack of precise control over the process and the necessity of occupancy for the construction site the considerable area around the building. The second method to remove the deflection of building is elevating using the hydraulic jacks. These jacks are usually built-up in the openings made in the walls of the lowest level. Removing deflection through elevating is performed through inflicting shifting to the jacks. It consists of three phases: tearing the building, steady elevating and not steady elevating. In practice two types of jacks are used: hydraulic piston jacks and hydraulic diaphragm jacks. These jacks can be manually or computer controlled. The advantage of this method is full control of the levelling process. The disadvantage is the interference in the construction of the building (tearing the building). The last method is simultaneous elevating parts of the building located too low and lowering parts of the building positioned too high. Removing building deflection through non uniform elevating with the help of hydraulic piston jacks is the method being used the most often.

1. Introduction
The deflection of the buildings in relation to the vertical is a phenomenon occurring in many parts of Poland. It is caused by insufficient bearing capacity of the ground, mistake in designing or uneven lowering of the ground caused by mining exploitation. The use of the deflected building is difficult and sometimes impossible [1]. Therefore, the building deflection must be removed. Practical methods were described in further parts of this work. In all cases the advantages and disadvantages were shown.

There group of methods of removing building deflection (levelling) have been used in Poland in last years. The first group of method is removing the soil from under the parts of the building that are positioned too high (figure 1a), the second one is elevating parts of the building that are too low with the use of hydraulic jacks (figure 1b). The third method is simultaneous removing the soil from under the parts that are too high and elevating the parts of the building that are too low.
However, no matter which method of levelling we choose, it is necessary to define the size and the direction of deflection of the object. Usually the components of the deflection are defined in two directions \( T_1 \) and \( T_2 \) (figure 2). These directions usually define the directions of two perpendicular walls. Then the resultant of vector \( T_{\text{max}} \) is determined. Vector \( T_{\text{max}} \) indicates the value and direction of levelling the building.

Figure 1. Methods of removing the deflection of buildings: a) removing the soil from under the parts of the building that is too high, b) elevating parts of the buildings that are too low

Removing the object deflection is just a rotation of the building in a vertical plane round the perpendicular axis to the direction of vector \( T_{\text{max}} \) (figure 2). In case of methods where the soil is removed it is axis \( I \), and in case of methods where parts of the building are elevated it is axis \( 2 \). In case of the third method the building is rotated in relation to the axis that is located between axis \( I \) and \( 2 \).

In the first group of methods of removing deflection there are two ways. The first way is drilling openings under the building. Some soil is removed and the rest that is under the building is considerably weakened. Therefore the bearing capacity of the ground is reduced and the building returns to the vertical. In the second way the vertical position of the building is achieved by cutting out layers of the soil.

In the second group of methods of removal buildings deflection three ways were used in practice. The first way is removing deflections with the use of hydraulic piston jacks controlled by shifting, the second way is removing deflections with the use of piston jacks controlled by the value of force and the third way is levelling with the use of hydraulic diaphragm jacks.

The third group of methods, is called indirect methods. Its usage causes lowering the part of the building that is too high and elevating the part of the building that is too low. It can be achieved for example by
cramming to the ground the medium with bulging features. It causes shifting parts of the building that are situated lower.

2. Methods removing the soil from under the parts of the building

The aim of methods that involve removing the soil is lowering parts of the building that are too high. In practice two ways of removing the soil were used: drilling holes under the building or cutting out layers of the soil from under the building.

2.1. The way involving drilling holes under the building

To lower parts of the building positioned too high an appropriate solid ground is removed from under the foundation with the use of horizontal openings (figure 3a) [2]. Therefore changes of ground features are forced, especially the change of its compressibility. This phenomenon is used to carry out the controlled not uniform lowering the building and therefore causes its deflection removal. Depending on the needs the opening is drilled under the foundations horizontally, vertically or diagonally, one-meter-deep under the base of the foundation. Additional flooding the openings with water, especially in case of loess soils, fastens the process of changes in the ground and the desired movement of the building. The openings are made with drilling rig (figure 3b) moving on especially prepared guide rails laid at the bottom of a ditch mined next to the building. To drill the openings, the drilling rig is used. The diameter of the openings depends on the soil.

The openings clench under the load of the building and it causes the controlled uneven lowering the building. At the same time the building rotates. In this way two buildings in Raciborz were levelled.

![Figure 3. Involving drilling holes under the building: a) the idea of the method [2], b) example of the implementation](image)

2.2. The way involving cutting parts of the soil

Cutting layers of the soil means removing the excess soil with the use of a cutting device. The cutting device consisted of (figure 4a): scraper conveyor, cutting chain on star wheels, engine and guide rails [3]. Operating principle of the device is based on removing soil from the part of the building that is positioned higher by moving chain on star wheels.

![Figure 4. Cutting soil: a) the idea of the method, b) example of the implementation](image)
The described way was used to remove the deflection of three detached houses in Rybnik Coal Area in the 1980s. This process lasted from one year up to two years and although the building was strengthened (figure 4c), they were not only difficult to use but also many damages in the buildings were caused.

Figure 4. The method of cutting layers of the soil: a) the principle of works, b) mining device, c) strengthened building during the levelling
The advantage of the methods involving removing the soil from under the building is no interference in the construction of the building during works. The disadvantages are:

- subsidence of the building in the ground, what may cause flooding the basements and the necessity to rebuilding the infrastructure around the building,
- damages of the buildings during cutting the soil,
- a lot of preparatory works,
- necessity of occupancy for the construction site the considerable area around the building.

In the opinion of the author of this article the methods involving removing the soil from under the building are good in the case of loess soils. In case of heterogeneous and concise soils controlling the process of lowering is harder. This results in rapid increase in ground deformation under the levelled building and in lack of full control over the levelling process.

3. Methods that involve elevating the buildings.

Removing buildings deflection in relation to the vertical through uneven elevating is technology that has been used in Silesia Region since 1994. The method involves uneven elevating the building using the hydraulic jacks built-up in the openings made in the walls of the lowest level.

The process of removing deflection of the building consists of three phases (figure 5). The first phase is tearing the building. The horizontal gap emerges between the jacks. In case of buildings with reinforced concrete walls the gap depends on the construction (linking of the prefabricated elements or the cross-section in which the reinforcement was cut in case of monolithic structures). In case of brick structures the gap goes under the built in strengthening of walls. The emerging of this gap is simulated with sequential extortion of shifting in the jacks.

![Figure 5. Rectification phases – not steady elevating](image)

The second phase is parallel elevating. All jacks do the same number of steps and the building is elevated to the height of 20-30 mm. It is necessary because in the next phase of levelling the edges of the shifted part of the building and left in the ground cannot touch each other.

The third phase is not steady elevating of the building. Each building destined for levelling needs a lot of preparatory works:

- drilling the openings for the jacks,
- performing necessary strengthening of walls,
- building-up the jacks in the walls of lowest level,
- temporary cutting off the central heating, gas and water supply and sewage systems.

Nowadays three ways of levelling the buildings by not uniform elevating has developed. The difference between them is the type of jacks they are using and the way of controlling them (controlling by shifting the piston of the jack and controlling the force in the jack).
3.1. Removing the deflections with shift controlled jacks

Levelling with this kind of jacks involves building-up the jacks usually in the walls in basements. The computer controlled jacks with capacity from 450 kN to 800 kN are placed in especially prepared openings or in the windows of the basement. The placement of the jacks (figure 6) depends on the stress distribution in the tearing plane. Additionally, the chimneys, basement stairs and all kinds of outbuildings are secured. For the time of levelling the building is strengthened. The most frequently two steel channels bars placed on both sides of the tearing wall are used.

In case of levelling the building with shift controlled jacks the single step of elevating is kept and equals from 0.2 to 0.5 mm. The elevating of the building is continued in following courses. Such courses can be even a few hundred depending on the deflection, average step and the position of the jack. For example, in a building where one corner is lowered in relation to the other for about one meter, the number of steps (0.5 mm) in some of the jacks will be 2000.

If the value of elevating equals more than 190 mm, the limited extension of the piston in a jack forces its periodic underlying with wooden or steel blocks (figure 7). In this way a few hundred detached houses, several dozen 11-storey buildings [4] and three churches were levelled.

3.2. Removing the deflections with force controlled jacks

Removing the deflections with force controlled jacks involves forcing in each of them the appropriate value of force. The force is activated by adding the oil at the appropriate pressure. Because of the extension of the piston, which is 200 mm, in case of removing deflections that are bigger, there is necessity of periodic underlying under the jacks the wooden or steel blocks. The bearing capacity of one jack presented in figure 8, equals 600 kN. This method is adjusted to levelling the buildings not higher than five stories.

The scope of work connected with the levelling process is similar to the scope of work when removing the deflections with the use of shift controlled jacks. In case of removing deflection of buildings where the basement walls are made of monolithic reinforced concrete all the reinforcement bars must be cut. When levelling process is completed the reinforcement is reconstructed as well as the openings from the jacks on the basement level are filled. The walls are plastered, the floor screed is laid...
up to the desired level and if needed the stairs are rebuilt. The precision of levelling with force controlled jacks mainly depends on the experience of the person who operates with the jacks.

Figure 7. a) Removing the deflections with shift controlled jacks, b) exemplary placement of jacks in walls of building consisting of segments, c) the effect of removing deflection in case of 11 story segment of building

Figure 8. The example of jacks built-up in the wall of the building
3.3. Removing the deflections with hydraulic diaphragm jacks

The jacks in this method are membranes filled up with oil. The initial height of jack is 60 mm and the diameter is 520 mm (figure 9a). Specially selected shape of the jack causes that after filling up with oil it increases by 60 mm (figure 9b). Round gaskets transmitting the force from the jack to the building have a diameter of 440 mm and the pressure in the hydraulic system is 13 MPa. Together the force transmitted from one jack equals 2000 kN. In practice during the levelling this force does not exceed 1200 kN. In this method the jacks are powered centrally from one oil pump and are controlled by forcing oil pressure individually in each jack. Large abutment surface of the jack causes that despite considerable downforce transmitting to the foundation and the elevated part of the building the stresses under the jack do not exceed 10 MPa and can be transmitted through middle class concrete. The construction of the jack and the control system ensure full control of the vertical shifting and that guarantees keeping surface stability of the elevated part of the building.

Walls strengthening is designed according to load bearing capacity of the walls and the reinforcement used. In most cases two steel sections are placed on both sides of the wall (figure 9c).

4. Indirect methods

Indirect methods of removing buildings deflection can be defined as a combination of levelling by removing the soil from under the building and not steady elevating the building.

Figure 9. Diaphragm jacks: a) jacks prepared for building up in the construction b) system of two diaphragm jacks built-up in the basement: 1 - Diaphragm jack, 2 – Underlay, 3 – Steel ring filled with sand, 4 – Opening 600/200 mm in the wall, 5 – [200, 6 – Ø25 each 300 mm, 7 – Iron plate 10 mm, L 75x75x8, 9 – Widening of foundation rib, 10 – Foundation rib, 11 - Wall
4.1. One-sided lever

One-sided lever involves elevating the excessively lowered part of the building and simultaneous undermining the opposite part. This method was used in practice to level a 13-storey building in Rzeszow deflected about 400 mm [5].

The building was set on the ground in plastic condition and soft plastic condition and under one of the edges there was about 2 m thick sand lens. Bearing soils appeared on the depth of 12 m. These foundation conditions caused the deflection. Lowering one of the edges equalled about 350 mm, and the opposite edge equalled about 140 mm. The difference equalled 210 mm.

To level of the building of Wolfsholz piles were stuck into the ground and the additional cantilever was fastened to the (figure 10). With the help of hydraulic jacks supported on these piles and affecting the additional cantilever the lower part of the foundation was elevated. Six 2000 kN jacks were installed. Thanks of the work of jacks and removing the soil from under the part of the building, the maximum lowering diminished for 30 mm. The lowering of the opposite edge diminished for 130 mm. Therefore the difference of lowering after the levelling equalled only 50 mm. The described method can only be applied when the direction of building deflection equals its structural form and the load bearing layer of soil is not too deep.

4.2. Injection

Injection involves applying under high pressure the medium that can penetrate and bind part of the building that is too low. This method was used in Katowice and the results were positive [6]. The grout was applied under pressure of 0.8 MPa. The deflection was stopped and two neighbouring buildings (7 and 9 storeys high) were partially levelled.

5. Summary and conclusions

The deflection of the building is often treated as a permanent defect, which cannot be removed. Most frequently the deflection is accepted and the users of the building agree to the inconvenience connected with that. Meanwhile in the last few years a few methods appeared that can remove the deflections. Removal deflection of buildings is a very interesting problem from the technical point of view. It is also a serious social problem. Until now the buildings which were deflected over 5% were demolished.
Nowadays a lot of buildings are levelled. The majority of deflections of the buildings is removed with shift controlled hydraulic piston jacks.

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