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Gyakori zsalubalesetek monolit vasbetonszerkezetek építése közben, azok okai és megelőzése

Frequent formwork accidents during the construction of monolithic reinforced concrete structures, including causes and prevention

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Bevezetés

Az utóbbi évtizedben nagy mértékben megnőtt a magyarországi ipari és nagyberuházások száma, amik részben új beruházásokból, részben a régi ipartelepek felújításából, bővítéséből származik. Szerkezetépítés szempontjából ezek azépületek jellemzően acélszerkezetből, előregyártott vasbeton szerkezetből, illetve monolit vasbetonból épülnek. Hogy mikor melyik rendszer kerül előtérbe az építésnél az függ a beruházás méretétől, a funkciójától, valamint a környezet adottságaitól. Nagyléptékű, komplex beruházások esetében általában a vegyes szerkezet a jellemző, tekintve, hogy többféle épületek és csarnokrendszerek kerülnek megépítésre. Jelen cikk kifejezetten a monolit vasbetonszerkezetek építésére korlátozódik, mert itt található az a segéd szerkezet, nevezetten a zsaluzat, amit a végtermék megjelenítésében már nem látunk, de mégis meghatározó szerepe van mind költség és építési idő tekintetébe, illetve munka és balesetvédelem szempontjából. A felgyorsuló világunkban, ahol az idő, és a költségek válnak a legfontosabb gazdasági mutatókká egy beruházás sikerességét tekintve nem szabad megfeledkezni az ezzel járó kockázatvállalással sem. Az építőipari beruházások tekintetében az egyik legfontosabb az biztonság és a megfelelő munka és balesetvédelem fenntartása. A kérdés, hogy a zsaluzási munkáknál a kifeszített norma és a maximális költség hatékonyság hogyan hat a biztonságra.

Introduction

In the last decade, the number of industrial and large-scale investments in Hungary has increased significantly, partly from new investments, partly from the renovation and expansion of old industrial sites. From a structural point of view, these buildings are typically constructed of steel structures, prefabricated reinforced concrete structures or monolithic reinforced concrete. Which system comes to the fore during construction depends on the size of the investment, its function

and the characteristics of the environment. In the case of large-scale, complex investments, a mixed structure is usually typical, given that several types of buildings and hall systems are constructed. This article is specifically limited to the construction of monolithic reinforced concrete structures, because here you can find the auxiliary structure, namely formwork, which we can no longer see in the display of the final product, but nevertheless plays a decisive role both in terms of cost and construction time, as well as in terms of work and accident protection.
In our accelerating world, where time and costs become the most important economic indicators for the success of an investment, we must not forget about the risk-taking that this entails. One of the most important things for construction investments is to maintain safety and proper work and accident protection. The question is how the stretched norm and maximum cost efficiency affect safety in formwork work.

Kulcsszavak: baleset, építőipar, födémzsalu, falzsalu, megelőzés, munkavédelem

Keywords: accident, construction, floor formwork, wall formwork, prevention, occupational safety

About formwork in general

Formwork can be grouped in many ways. If we want to group them according to the technological sequence, then we distinguish between horizontal and vertical formwork structures. Horizontal formwork usually refers to slab and cantilever formwork, beam formwork and staircase formwork. Among slab formwork, the most common formwork system in Hungary is the timber durable slab system. Its structure is based on a simple, main and drawer support system, where the final load transfer is carried out through steel supports to the lower slab. As a rule, the main and drawer holders are glued wooden supports of the same cross section with an "I" profile design. For main supports, it is usually the shear force that causes the support to fail, while for drawer holders it is the bending force overload that causes the support to fail. [1] The concrete surface of the formwork is made up of wooden formwork boards with a three-layer glued pine design, but phenol-coated plywood is also commonly used. Since the joining and connection of the wooden supports is not fixed-bonded, only laid or interlaced, the formwork of structures with different geometry can be followed very well. Of course, the aluminium-framed slab formwork system and its drop-head version are also used, but due to its framework, its geometric possibilities are more limited.

The classic drop head used in traditional timber formwork is a special fork head that accelerates the formwork process with the help of a wedge. In wood-durable systems, the formwork process begins with the relief of the slab supports. Then the thread spindle slab supports must be lowered to such an extent that the drawer supports can be toppled down. To tilt down wooden supports 8 cm wide and 20 cm high, the supports must be lowered by at least 3-4 centimetres. Without a drop head, this means that the trapezoidal threads must be manually unwound together with the formwork load on them. This is a serious physical strain for workers and a time-consuming process, which means that it takes 3-5 minutes per support to unwind the spindle. For a 500 m2 slab, this means nearly 300 supports, which only takes about 1200 minutes, or 20 working hours, for the above work process. This time can be reduced to one-tenth with the drop head, which uses the built-in wedge system with a hammer blow to drop the main brackets by 4 cm and thus the drawer holders can be downloaded. After knocking down the drawer holders, formwork boards can be removed.

The drop head used for early formwork in the case of timber formwork is a special head, the middle core of which supports the formwork shell immediately above it, and the wooden supports are seated in the forked part on both sides of the head. When form working, knocking out the wedge system of the drop head, the main feeders fall by 3-4 cm, but the formwork shell in the

shaft remains squeezed under the fresh concrete. In aluminium frame formwork systems, the solution is to install a beam line with a drop head in the formwork, usually around torque maximums. In case of early formwork, these beams continue to support the fresh concrete surface, while formwork boards hung on the beam can be lifted off using the drop fellow. The main motivation for creating early formwork is to shorten construction time, which can achieve significant cost savings. This means that less labour will be required, organizational costs will be reduced, and crane time will be shortened.

The group of vertical formwork includes wall and pillar formwork. [2] Thinking about the modern formwork system, wall formwork can be divided into two main groups based on their structure: large-panel formwork with timber durable systemi and framed formwork systems:

- Wood-durable large-panel formwork: in terms of its structural principle, it rather evokes the past, in a modern guise. This means that instead of the classic wall supports, modern glued I section wooden supports take up the load and transfer it to modern double U profile crossbars. Its shell is glued plywood board, coated with phenol, but with free edges.
- Framed formwork systems: typically enclosed in a steel support frame with plywood form lining. From a wide variety of board widths (usually in raster jumps of 10-15 cm), level high (270-300-330 cm) to half-element height (120-150 cm), systems can be fitted with quick-clamping clips. Movable structures with cranes or manual power (in the case of level-high boards, these are aluminium frames).

Similarly to pillar formwork, pillar formwork can be divided into two large groups based on their structure: timber-durable system and framed structure. In the frame system, the boards have a special jumper. This means that not only is there a possibility of jumping at the edges, but the boards are perforated one after the other with 5 cm divisions. Thus, with a butterfly knitting, it is possible to make a pillar 30x30 cm or even 60x60 cm with the same board, for example, 75 cm wide.

Accidents at work

Accidents at work affect all sectors of the economy. For both the health of workers and a smooth production process, great emphasis should be placed on preventing accidents. In addition to the loss of life and the suffering caused by workers and their families, accidents also affect business and society. Fewer accidents mean less sick leave, which means lower costs and fewer interruptions in the production process. [3]

The construction sector has the highest accident risk in the European Union, with more than 1300 people dying in construction accidents every year. Construction workers worldwide are three times more likely to die and twice as likely to be injured than workers in other occupations.

In Hungary, the construction and manufacturing industries have the highest number of accidents. According to the data, since 2013 the number of work accidents involving injuries that heal beyond three days has been steadily increasing. Most of the time, inattention and lack of adequate information are the cause of the problem. An accident at work is a reported accident involving incapacity for work lasting more than 3 days that occurs to an employee during or in connection with organised work, regardless of the place and time thereof and the extent of the employee's (injured) involvement. A fatal accident at work is an accident at work where, according to medical opinion, the injured person died within one year of the occurrence of the accident. [4] Analysing the statistics of the past 5 years, it can be concluded that there are fewer accidents at work in the construction industry compared to previous years, but it still has the highest proportion of serious and fatal accidents. However, a positive picture does not necessarily mean that jobs have become safer. In the last five years, we have experienced the covid pandemic, which forced some people to

stay at home, and employers paused their operations. There were simply fewer accidents in those two years than before.

Unfortunately, however, the death toll has been higher than in previous years. This can be seen from Figure 1.

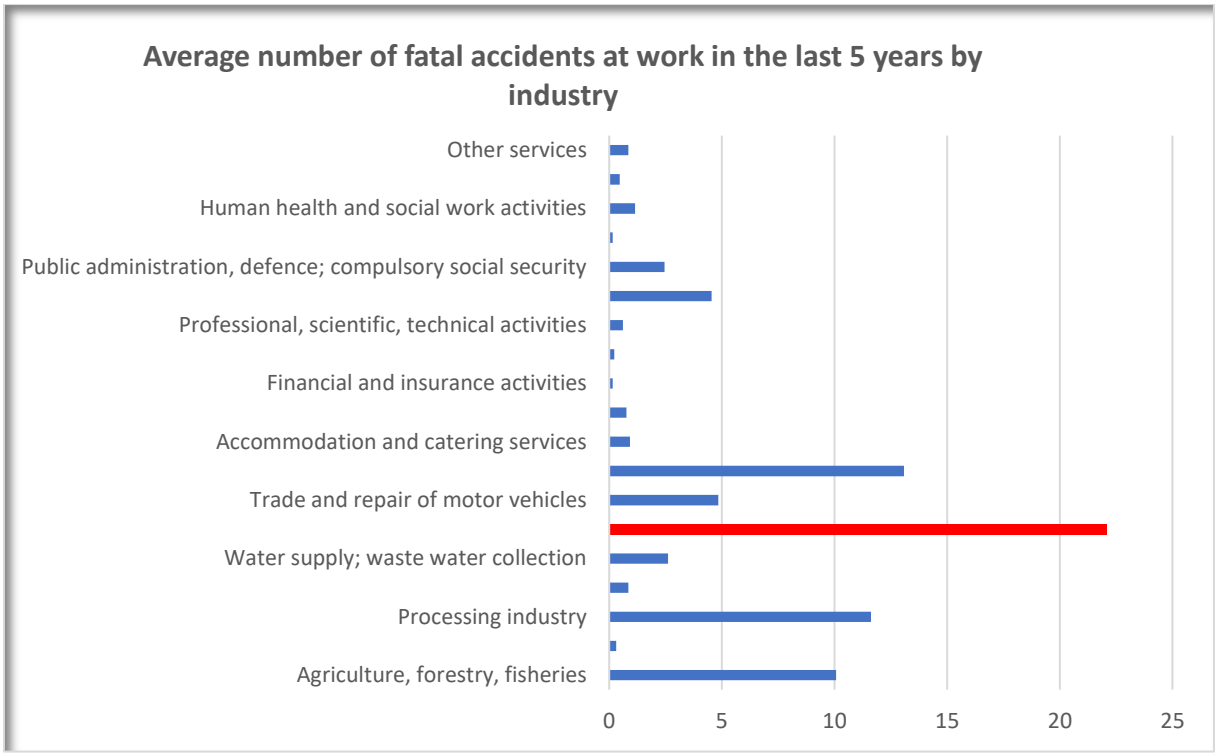

Figure 1 — Fatal industrial accidents [5]

Not only the number of fatalities, but also the number of serious accidents increased by more than 30 percent. This is painful because the rate of serious and fatal accidents has increased more strongly than that of all accidents. In other words, there were more serious accidents than last year. While the total number of accidents increased by 3.5 percent, the number of fatal and serious accidents increased by 30 percent.

The causes of the most serious accidents in the construction industry are:

- Falls from heights: responsible for 49 percent of fatal accidents and 18 percent of non-fatal injuries.
- Slipping, tripping or falling at the same level causes 25 percent of nonfatal injuries.
- Trapping caused by a collapsing or overturning object: responsible for 14% of fatal accidents.
- Accidents caused by moving, falling or flying objects: responsible for 10 percent of fatal injuries and 12 percent of non-fatal injuries.
- Injury while loading, lifting or carrying accounts for 20 percent of nonfatal injuries.

Analysing the above data, it can be concluded that in the process of formwork work all the listed causes of accidents can be found.

Formwork accidents and their prevention

Formwork accidents can be divided into three large groups. The first is accidents during the assembly and dismantling of formwork, second is lifting, i.e. accidents during crane riding, and the third is the collapse of already finished formwork structures during the concreting process.

Accidents during the assembly and disassembly of formwork typically occur with floor formwork. When building timber slab formwork, the most typical is the misuse of a temporary auxiliary structure, a three-legged bollard. The task of this auxiliary structure is to absorb horizontal forces during construction. In the absence of these, or if fewer pieces are used than required, the formwork still under construction may collapse, burying those working underneath. When formwork, a typical source of accidents is the dismantling of the structure in the wrong order. As a result, demolished formwork boards and beams fall on those working underneath, causing injuries.

Accidents during crane riding typically occur when lifting massive formwork. In the case of modern, steel-framed formwork, small-element structures that can be moved by hand can be transformed into large, continuous structures with the help of special clips. These interconnected formwork with a large surface area weigh several tons. They should only be lifted by a factory rope equipped with a special crane hook. In the absence of these, it is common for the inappropriate crane hook to hook and fall into the depths of the formwork. [6]

Most slab accidents occur during the concreting of the structure. One of the reasons is the inadequate absorption of horizontal loads, which have already been mentioned several times. In this case, in the absence of wedges or St. Andrew's crosses, the formwork moves out horizontally sideways and collapses. Another reason may be sudden overloading, which can occur with concrete of dense consistency, if for some reason the concrete pump is not in continuous motion and can squeeze out in one place, even half a meter or a cubic meter of concrete, which can cause an overload of the slab by 3-4 times. In such cases, most often the bearing capacity of wooden supports is exhausted and simply breaks, dragging the formwork boards along with the reinforcing steel and concrete. A similar accident can happen if the formwork is not installed on site, the supports are distributed according to the static plans, overload is created, and the slab breaks off.

The collapse of wall formwork during concreting is due to incorrect absorption of forces due to concrete pressure. The elements connecting modern framed wall formwork, the so-called quick clips, are designed to connect the boards and ensure that the formwork is kept flat. These are robust strong terminals, but it is a misconception that they are also suitable for absorbing the pressure of concrete, since the load capacity of these terminals is no more than 8.00 kN. The concrete pressure transmitted through the steel frame must be absorbed by the jumper screw stems, i.e. threaded reinforcing steels, which can reach 90kN/m2. If these screw stems are not threaded at all board joints, the concrete pressure would have to be absorbed by the terminals, for which they are not dimensioned. In such cases, above a certain concrete height, the staples break, break and the formwork open. In addition to the fact that the reinforced concrete structure under construction will be destroyed, the concrete spilling out under high pressure will carry away the occupants. If it is on a hanging rack several stories high, the concrete will push everything down into the depths. [7]

The situation is similar with one-sided wall formwork. The typical design of one-sided wall formwork is when there is already an existing structure on one side of the reinforced concrete wall structure, such as a gap wall or pile wall. In this case, only one side of the wall to be built is form worked. In the case of bilateral formwork, the concrete pressure is absorbed by threaded ribbed reinforcing steel between the facing formboards, but this method cannot be used in the case of unilateral formwork. In such cases, the formwork must be supported by heavy-duty support bollards, which can absorb concrete pressure through anchors cemented into the base plate. A

common source of accidents is when anchors with thread ribs are connected to the reinforcement of the base plate to the wrong height before it is concreted. If it is concreted to the upper mesh, the 80-100 kN forces will cause the upper belt of the base plate to burst and the formwork will break apart together with the robust bollards. Another typical source of error is when anchors not to be placed in the base plate are used, but only try to absorb concrete pressure with conventional inclined supports. In such cases, due to the vertical component of the rod force formed from the pressure of the concrete, the formwork rises and concrete spills out at the bottom with high pressure. The most common injury in this case is a broken leg of workers. [8]

Based on the above, it can be said that most formwork accidents are due to human error, which could be prevented. The biggest problems when assembling formwork are the lack of foremanship, non-compliance with the prescribed technological discipline and professional control of the result. Earlier, in the 60s and 70s, accidents also occurred, but at that time they were mostly caused by weak lifting mechanisms and lack of occupational safety. Despite today's modern building technology, the lack of expertise causes most accidents. While earlier formwork was carried out by carpentry brigades with skilled foremen, today Lego-like modular systems [9] are carried out by trained workers, often with incomplete technical knowledge. They cannot assess the risk of an accident because they are not aware of the pressure and weight of concrete, they do not know the load bearing capacity and static load capacity of formwork structures. With greater technical discipline, accidents could be avoided.

A particularly important area of protection of industrial buildings is the activities dealing with dangerous substances occurring in industry [10], such as plants producing, processing and storing dangerous substances. During the establishment and operation of dangerous activities, major industrial accidents can occur, the prevention of which is the responsibility of the operator and the task of the state authorities [11]. We pay particular attention to activities dealing with dangerous substances, such as chemical warehouses, where, in addition to fire protection and industrial safety issues, the issue of environmental safety also appears [12-13]. The environmental effects of chemical warehouse fires can manifest themselves through the pollution of surface and subsurface waters, the regulation of which is becoming more and more stringent internationally [14]. As a result of technological development, together with fire protection alarm systems, also public safety technical systems installed for the purpose of property and occupational safety tasks have also come to the fore [15]

Summary

Based on the above, it can be said that most formwork accidents are due to human error, which could be prevented. The biggest problems when assembling formwork are the lack of foremanship, non-compliance with the prescribed technological discipline and professional control of the result. Earlier, in the 60s and 70s, accidents also occurred, but at that time they were mostly caused by weak lifting mechanisms and lack of occupational safety. Despite today's modern building technology, the lack of expertise causes most accidents. [16] While earlier formwork was carried out by carpentry brigades with skilled foremen, today Lego-like modular systems are carried out by trained workers, often with incomplete technical knowledge. They cannot assess the risk of an accident because they are not aware of the pressure and weight of the concrete,

Options for preventing formwork accidents and construction accidents in general:

- One of the most important methods of prevention is compliance with strict labour protection rules and their regular monitoring. Making it mandatory to use appropriate protective equipment and follow safety procedures can reduce the number of accidents.

- Regular training and education are essential for workers to work safely. Workers must be familiar with safety regulations, the correct use of machinery and be aware of potential hazards.
- Regular maintenance and inspection of machinery and equipment is essential for safe operation. Adherence to maintenance schedules and regular inspections of machinery can significantly reduce the risk of accidents.
- Regular monitoring of the work environment and identifying and eliminating potential hazards are essential. Placing appropriate signage on construction sites, securing unstable structures and creating safe work areas can reduce the risk of accidents.
- Regulating working hours and ensuring regular rest periods can help reduce the risk of accidents caused by fatigue and stress. Ensuring the physical and mental well-being of employees increases safety at work.

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