Assessment of Damage to Cubic Buildings in Flooded Areas

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Abstract

Natural disasters can be defined as sudden and destructive phenomena occurring in nature that have an extremely negative impact on the environment, human life and property in the broadest sense. The article discusses a selected type of natural disaster, namely flooding, its characteristics and negative impact on buildings. This phenomenon is discussed using the example of the flood that hit southern Poland in September 2024. The first part of the article presents and characterises the types of damage to buildings caused by the destructive force of flood waters. Numerous building damages required expert assessment in order to approve the building for reuse or to exclude it from use. The next part of the article describes the procedures and applicable legal acts related to the process of assessing buildings for use or decommissioning. It is extremely important to follow the correct sequence of diagnostic activities to ensure the safety and effectiveness of construction works in damaged buildings. The procedure in such cases is discussed using the example of buildings damaged by flooding in September 2024 in southern Poland. At the end, a summary was made, along with conclusions in the context of potential future actions that should be taken in order to effectively assess the technical condition of the building and formulate recommendations for the further operation of the building structures.

Keywords: *natural disasters, flood damage to buildings, construction sites, building closure, technical condition assessment.*

1. Introduction

For centuries, humanity has sought shelter from the negative effects of natural phenomena such as rain or wind. Such shelters are certainly provided by various types of buildings. Unfortunately, in some situations, the forces of nature are too powerful, and shelters in the form of buildings are destroyed. Such cases involve natural disasters. One of the most dangerous natural phenomena of this type is flooding. Polish law defines this phenomenon as 'temporary coverage by water of an area that is not normally covered by water, in particular caused by flooding in natural watercourses, water reservoirs, canals and from the sea, excluding coverage by water caused by flooding in sewage systems' [1].

A phenomenon such as flooding can cause serious damage to infrastructure, including residential buildings, public utilities and industrial facilities. Excessive rainfall and the resulting rise in water levels. Structural elements of buildings in flood-prone areas are exposed to flooding, foundation erosion and ground subsidence. Damage to buildings caused by flooding has far-reaching consequences, mainly for owners who are direct users. Nevertheless, knowledge of how to proceed with the process of restoring a building to use also concerns other persons involved in the operation of the building, e.g. property managers, as well as persons with the technical knowledge necessary to assess the technical condition of damaged structural elements.

The person making the decision on further use and the conditions under which it could be continued, or on demolition, must have an appropriate level of technical knowledge, in particular knowledge of issues related to the assessment of the technical condition of the building, typical damage caused by the impact of water on building structures, as well as methods of temporary and permanent protection and reinforcement of structures.

In the context of reconstruction procedures, i.e. the restoration of a building in whole or in part, renovation and demolition, a very important legal aspect of an engineer's work is knowledge of the legal provisions that specify both the necessary legal steps to be taken in the event of reconstruction or demolition, i.e. which structures require a building or demolition permit, which notifications are required, and in which cases it is permissible not to inform the architectural and construction administration authority [2].

The subject of this thesis are selected technical and legal aspects of the classification of building structures in terms of their potential restoration to use or the necessity to exclude them from use.

The aim of this study is to analyse the impact of flooding on the technical condition of buildings in floodplains and to discuss measures aimed at determining the possibility of reuse, methods of restoration to use or permanent decommissioning of damaged buildings.

The scope of work includes a discussion of the events that took place during the floods in Poland in 2024, a description of the damage caused by the forces of nature to buildings, the effects on the safety and stability of structures, as well as a description of the procedures for restoring buildings to use or taking them out of use.

2. The flood in southern Poland in September 2024 as an example of a natural disaster

In September 2024, Poland, as one of the European Union countries, experienced a severe flood that claimed many lives and caused material damage. The main events related to this natural disaster began in September 2024, when a series of intense rainfall and storms affected southern Poland, mainly Lower Silesia and the Opole region (Fig. 1) [3, 4].

Fig. 1. Area of the country covered by a state of natural disaster - as of September 18, 2024 [author: K. Sobczyk].

On 13 September 2024, heavy rainfall hit the provinces of Opole and Lower Silesia. A day later (14 September 2024), a newly built bridge over the Biała Głuchołaska River in Głuchołazy was destroyed due to excessive flood pressure. Immediately after these events, the mandatory evacuation of residents from the affected areas was carried out. Subsequently, between 14 and 16 September 2024, a number of alarm levels were exceeded at 82 measuring stations. This mainly affected the Odra river basin. The failure of flood embankments in Kłodzko and Nysa caused the centre of Kłodzko to be flooded to a height of 150 cm, resulting in the evacuation of residents and the closure of schools in Nysa, Kłodzko and Jelenia Góra. Railway lines were also flooded. This caused the interruption of train traffic due to damage to the track structure and fallen trees. On 16 September, the Polish Prime Minister declared a state of natural disaster. On that day, approximately 2,600 people were also evacuated. Uncontrolled overflow from reservoirs in Międzygórze and Stronie Śląskie caused damage to residential buildings. In addition, on the night of 15-16 September, uncontrolled overflow of water through the Pilchowice dam caused flooding in, among others, the towns of Lwówek Śląski, Gryfów Śląski and Wleń. Other towns affected by the flood include Bystrzyca Kłodzka, Lądek-Zdrój and Lewin Brzeski. [3].

The scale of the damage was significant. According to official data, nine people died as a result of the floods in Poland. Thousands of people were forced to evacuate. Between 50,000 and 70,000 consumers were affected by power outages due to damage to the power infrastructure. The value of material losses is estimated at nearly PLN 5.5 billion [5].

The effects of the floods in September 2024 demonstrate the need to invest in flood protection infrastructure and optimise crisis management systems and procedures in order to minimise the risk and impact of future natural disasters.

Following the tragic events in southern Poland in September 2024, there was an urgent need to help the population living in the flood-affected areas. The scope of technical assistance required mainly involved flood damage repair – cleaning up the area, assessing the technical condition of buildings, and restoring transport infrastructure in the flooded areas. In view of these needs, the Armed Forces of the Republic of Poland launched Operation Phoenix, which aimed to support the local population in combating the effects of the flood. The Polish engineering troops and representatives of military universities played an extremely important role in these activities. Engineering subunits built temporary bridges from prefabricated bridge structures and removed debris using specialised military equipment, such as the PTS-M amphibious vehicle. Military specialists from the Military University of Technology assessed the technical condition of buildings damaged by the natural disaster by evaluating the possibility of restoring individual structures to operation (Fig. 2).

Fig. 2. Activities of Polish soldiers during flood relief efforts: a) removal of the destroyed structure of a temporary bridge; b) assessment of the technical condition of a building damaged by flooding [author: R. Chmielewski].

Civilian groups of Polish civil engineers affiliated with the Polish Chamber of Civil Engineers also took part in combating the effects of the flood. In total, several hundred civil engineers were involved in providing assistance on site. It is worth mentioning that the assistance was provided on a voluntary basis. During their activities, the civil engineers assessed almost 4,500 flats, houses and farm buildings [6].

3. Damage to buildings in southern Poland after the 2024 flood

The direct effects of the flood manifested themselves in widespread destruction, including completely collapsed buildings, widespread mud flooding, and critical disruptions to basic services such as electricity and drinking water supplies. In addition to visible structural damage, the flood created serious safety hazards, including the risk of electric shock from damaged electrical installations, potential explosions from damaged gas installations, and the danger of buildings collapsing due to compromised structural integrity..

The main types of damage to building structures include:

1) structural damage:
   - weakening of foundations (water can wash away foundations, causing them to weaken and the building to settle unevenly);
   - cracks in walls, ceilings and floors (soil weakening and water pressure from the ground can cause cracks in structural elements);
   - deformations of structural elements of the building (weakening of the structural system could have caused buckling and deviation from the vertical of walls or columns);
2) damage caused by moisture:
   - biological corrosion (fungi and moulds can cause biological corrosion, especially in wooden elements, and pose a threat to human health);
   - moisture penetration of building materials (water penetrating building materials weakens them and leads to their partial or complete degradation);
3) other damage:
   - damage to utility systems in the building (flooding can damage electrical, gas and water/sewerage systems, posing a threat to the safe use of the building);
   - damage to equipment and furniture (water can damage furniture, household appliances and other items in the building).

Below are examples of buildings (mainly single-family and multi-family residential buildings) that suffered various structural damage as a result of flooding in southern Poland in 2024 (Fig. 3).

Fig. 3. Examples of structural damage caused by floodwater in southern Poland in 2024:
a) undermining of foundations, deformation and cracks in structural walls; b) deformation and cracks in structural walls;
c) undermining of foundations, landslide of structural wall; d) undermining of foundations [author: R. Chmielewski].

4. Procedures for assessing the technical condition, protective measures and exclusion from use of buildings in flood areas

Public administration authorities in Poland, in particular the General Office of Building Supervision, have developed guidelines for residents for a simplified procedure to assess the possibility of entering a building [7]:

1) outside and at a safe distance from the building, the following should be checked:
   - that water has not eroded or exposed the foundations;
   - that water has not eroded the ground or exposed the foundations;
   - that no new cracks have appeared on the walls (especially vertical ones);
   - that the walls are not bulging or deviating from the vertical;
2) if there are no external signs of damage or deterioration, check from the inside:
   - that the internal walls are not separating from the external walls (there are no cracks between them);
   - that there are no visible cracks in the ceiling (particularly cracks parallel to the walls) and that it is not deflected;
   - whether windows and doors open easily (settlement of the object may have occurred);
   - that the staircase is intact and not displaced;
   - that the roof trusses are in proper condition (not damaged).

The building inspectors used a template for a simplified assessment form specifically designed for the initial qualification of damage. This standardised approach is intended to streamline the assessment process under emergency conditions. The key task is to assess the state of the emergency, whether there is a:

- damage to the building clearly endangering human life and health;
- damage to the building which may endanger the life and health of persons;
- damage to the building not endangering human life and health.

The form assigns specific percentage weights to the various building elements to calculate the overall degree of damage: roof (30%), ceilings (20%), load-bearing walls (30%), foundations (10%) and other elements (10%), which include utilities, window and door frames. The extent of damage for each element is quantified by percentage (ranging from 0-100%) and then integrated into a formula to obtain the total percentage of damage for the entire building. Based on the established facts, the percentage of damage or destruction for the whole building is calculated according to the scheme in Table 1.

Tab. 1. Scheme for determining the percentage of damage or destruction of the entire building [8].

Building element	Participation rate	Extent of damage	Percentage damage to building
Roof	0,3	A = 0 - 100%	P = 0,3 x A + 0,2 x B + 0,3 x C + 0,1 x D + 0,1 x E
Ceilings	0,2	B = 0 - 100%	
Load-bearing walls	0,3	C = 0 - 100%	
Foundations	0,1	D = 0 - 100%	
Other elements	0,1	E = 0 - 100%	

If the calculated percentage damage to the building is greater than 70% (P>70% according to Table 1), it means that an element of the load-bearing structure or the building has been damaged - the condition of the building is a threat to the safety of the structure or its safe use. Comprehensive building repair work or demolition is required. In the event that the building inspector decides to exclude the building from use, he has carried out safety measures: marking the entrance door to the building with coloured warning tape, writing a warning message with spray on the wall of the building and using stickers to warn of the damage to the building (Fig. 4).

Fig. 4. “Damaged building” warning sticker - used by the building inspector once the actual condition of the building has been established and a decision has been made to exclude it from use [author: R. Chmielewski].

In order to decide whether or not to restore a building to use again, it is crucial to reinforce its structural elements, depending on the degree of damage identified. Important repair works include: underpinning of the foundations (Fig. 5), construction of reinforced concrete encasements for severely damaged stone foundations, use of steel tie-beams in the vicinity of the ceilings to protect the walls from further delamination, construction of reinforcement seams and fixing of control seals to monitor the work of the structure.

Fig. 5. Example of repair work (underpinning of foundations) to protect a building from a structural disaster [author: R. Chmielewski].

5. Conclusion

The flood that occurred in southern Poland in September 2024 represented a significant challenge, and once again brought to the fore the region's persistent vulnerability to extreme hydrological events. Intense rainfall, concentrated mainly in the Opole and Lower Silesian provinces, resulted in widespread flooding and significant damage to infrastructure, predominantly residential buildings. The scale of the damage, which ranged from structural damage to serious health and safety risks associated with infrastructure, highlights the complexity of crisis management in the face of such events. The response of state public authorities in Poland, coordinated by the General Office of Building Supervision, was characterised by the rapid deployment of building inspectors and the standardisation of initial damage assessments. Whilst a simplified assessment methodology is imperative for a rapid response, it must be complemented by more detailed technical expertise for long-term reconstruction and insurance claims.

A significant element of the contribution of both civilian and military structural engineers was the professional evaluation of building damage, with a particular focus on cubic structures, notably single-family and multi-family residential buildings. A fundamental activity entailed conducting emergency inspections to ascertain the extent of damage to structural elements in buildings in post-flood areas, including the roof, ceilings, load-bearing walls, foundations, and other components. The implementation of the methodology for determining the percentage degree of destruction or damage to the entire building enabled the identification of building structures whose technical condition evidently endangered the life and health of people. Consequently, these structures were taken out of use and people were able to return safely to their inspected houses.

References

1. Ustawa z dnia 20 lipca 2017 r. Prawo wodne. (Dz.U.2024.1087 t.j.).
2. Ustawa z dnia 11 sierpnia 2001 r. o szczególnych zasadach odbudowy, remontów i rozbiórek obiektów budowlanych zniszczonych lub uszkodzonych w wyniku działania żywiołu. (Dz.U.2024.1190 t.j.).
3. Google. Wikipedia, Wydarzenia podczas powodzi w 2025 roku, Accessed: 31.07.2025 r. Available from: https://en.wikipedia.org/wiki/2024_European_floods.
4. Google. Businessinsider.pl, Mapa powiatów objętych stanem klęski żywiołowej, Accessed: 31.07.2025 r. Available from: https://businessinsider.com.pl/wiadomosci/powodz-2024-stan-kleski-zywiolowej-w-polsce-zagrozone-obszary-mapy/y538z2y.
5. Google. Polsatnews.pl, Accessed: 31.07.2025 r. Available from: https://www.polsatnews.pl/wiadomosc/2024-09-23/powodz-w-polsce-nowe-informacje-o-stratach-kwoty-rosna-w-zawrotnym-tempie/.
6. Google. Polska Izba Inżynierów Budownictwa. Accessed: 31.07.2025 r. Available from: https://www.piib.org.pl/aktualnosci/informacje-biezace/5456-podsumowania-glownej-czesci-akcji-inzynierowie-budownictwa-w-walce-ze-skutkami-powodzi.
7. Główny Urząd Nadzoru Budowlanego. Wytyczne, które dotyczą budynków zalanych w wyniku powodzi. Accessed: 31.07.2025 r. Available from: https://www.gunb.gov.pl/strona/powodz-informacje-glownego-inspektora-nadzoru-budowlanego.
8. Główny Urząd Nadzoru Budowlanego. Wytyczne do oceny stanu technicznego zalanych budynków wykonywana przez nadzór budowlany. Accessed: 31.07.2025 r. Available from: https://www.gunb.gov.pl/aktualnosc/ocena-stanu-technicznego-zalanych-budynkow-wykonywana-przez-nadzor-budowlany-szacowanie.