SECTION 2. ARCHITECTURE, CONSTRUCTION

DOI: 10.46299/ISG.2024.MONO.TECH.1.2.1

2.1 Calculation of the building's stability against progressive destruction on the example of a real project

The problem of progressive collapse has been known to design engineers for a long time and is associated with very sad events in history, the most shocking of which was the collapse of the World Trade Center towers in New York as a result of the terrorist attack on September 11, 2001 (Figure 1). However, issues related to the phenomenon of progressive collapse have only recently begun to be reflected in design codes around the world.

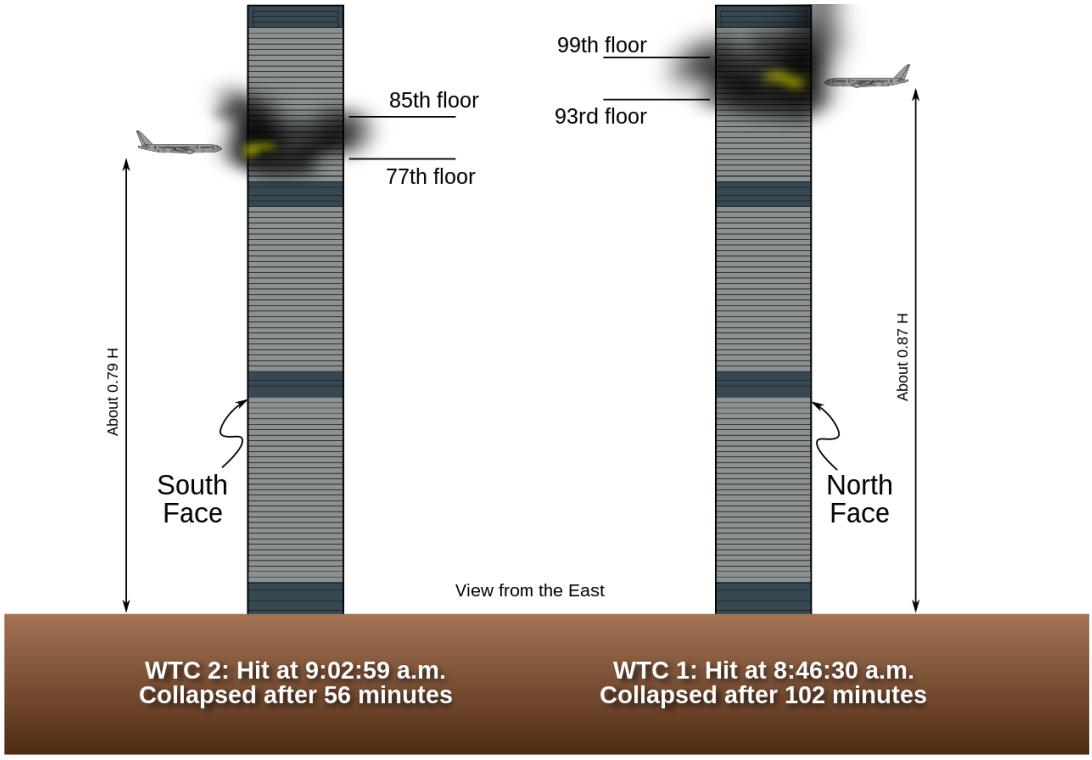

Figure 1. Aircraft impact points on the south and north towers of the World Trade Center (photo from Wikipedia)

The NIST investigation showed that when the planes hit the towers in different ways, the process of ruining the Pivnichnaya and Pivdennaya towers was disrupted, although the fire was similar. After the impact of the flyers, the internal joints of power were seriously damaged, although the external joints were noticeably weaker. This led to a significant overgrowth of the emphasis between them. The upper structure of the

towers played a great role in this reorganization, the weight of which now fell primarily on the peripheral stages, and not on the internal ones.

The NIST investigation revealed that, through the fact that the fliers were destroyed at the tower in a variety of ways, the process of rebuilding the Pivnichnaya and Pivdennaya towers also changed a little, although the similarity was clearly visible. After the attack of the pilots, the internal parts of the force were seriously damaged, although the external ones were much easier. This screamed seriously overrozed the desire between them. The upper power structure of the towers played a significant role in this reorganization, which now fell most importantly on the peripheral stages, and not on the internal ones.

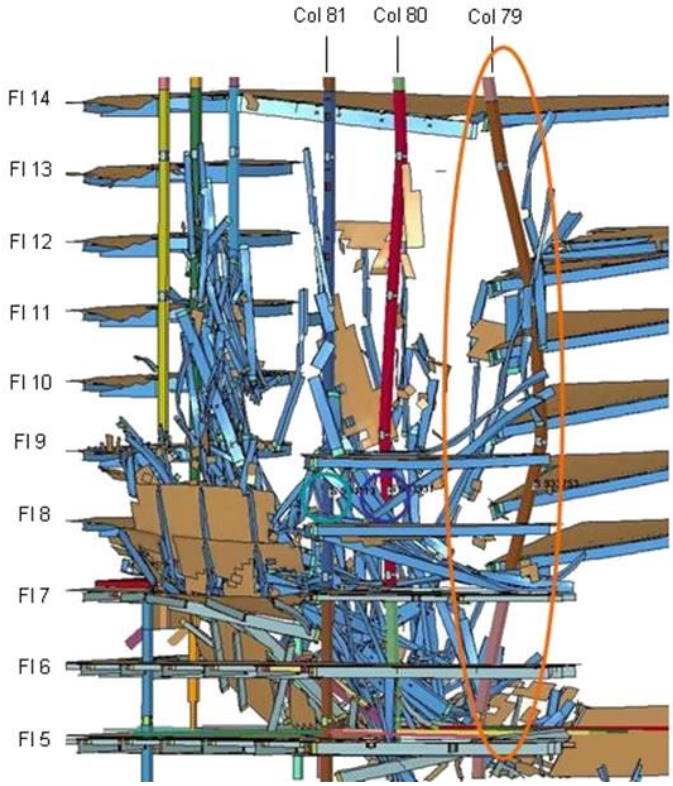

Figure 2. NIST diagram showing the bending of Column 79 (outlined in orange) that began the progressive collapse of the WTC7 building (photo from Wikipedia).

The planes that were lost in the fire destroyed significant parts of the steel structures, which led to their direct spilling into the fire. Extending 102 miles, before the fall of the Pivnichnaya Tower, the temperature, although significantly below the melting point of metal, reached a sufficient level to change the internal pillars, which began to deform and bend out. upper surfaces.

A similar situation occurred at the Pivdenny Tower (the internal structures were seriously damaged). The peripheral pillars and substructures of both towers were weakened by the fire, which led to the substructures settling on the damaged levels and the creation of significant pressure on the peripheral pillars, which made the center straight.

The reason that the Pivnichna Tower stood longer than Pivdenna was due to the combination of three factors: the area of impact of the flyer at the Pivnichna Tower was larger (and the area of the upper part was also smaller), the There is a fly that, having sunk from the tower, was the least, besides, the fly having struck near the river, kidnapped by a firefighter, who had often been thoroughly drilled before.

The requirements of Ukrainian construction standards and regulations.

In clause 4.2 DBN V.1.1-7:2016 Fire safety of construction objects. The general requirements are stated: "Buildings with a class of consequences (responsibility) CC3 (significant consequences) in accordance with DSTU-NB B.1.2-16, should be calculated for progressive collapse due to fire in accordance with DBN B.1.2-14, DBN B .2.2-24 and other regulatory documents.

Calculation of the building's stability against progressive destruction on the example of a real project in Ukraine.

The forces in the structural elements and their connections were obtained on the basis of the calculation in the case of local destruction and a comparison was made with their bearing capacity.

Protection of the structure from progressive collapse is ensured, for any elements and their connections the condition is fulfilled:

$$F \leq S,$$

Where F is the effort in the structural elements or in their connections, found from the performed calculation, S is the bearing capacity of the structural elements and their connections.

When calculating structures for resistance against progressive collapse, the calculated strength characteristics and deformation characteristics of materials were

assumed to be equal to their normative values, which are determined in accordance with current regulatory documents.

When calculating structures for resistance against progressive collapse, the load reliability coefficients were taken.

Calculation of structures for resistance against progressive collapse was performed on a combination of loads, consisting of constant and long-term loads, taking into account the change in the calculation scheme caused by local destruction.

$$C_S^{PO} = P_d + P_l$$

The reliability factor for responsibility when calculating structures for resistance against progressive collapse is accepted $\gamma_n = 1{,}0$. In the design task, the customer can set a reliability factor for responsibility $\gamma_n > 1{,}0$.

To calculate the stability of buildings against progressive collapse, a spatial calculation model was used, which takes into account the interaction with the soil foundation. The calculation models take into account the possible inclusion in the work of elements that under normal operating conditions of the building are non-load-bearing (for example, hinged external wall panels, parapets, reinforced concrete fences of balconies, partitions, etc.), and in case of local destruction actively participate in the redistribution of forces in the elements of the constructive system.

When calculating structures for resistance against progressive collapse, the possibility of staged calculation is provided. At the initial stage, the stress-strain state of structures under normal operation conditions is determined. At the next stages, the stress-strain state of the structures that occurs during local destruction was determined, provided that the deformations of the structures that occurred as a result of normal operation were taken into account.

The calculation of structural schemes was carried out, in case of possible destruction of one of the structural elements, and the load-bearing capacity of the elements was checked when the structural scheme was changed.

Selected separate calculation schemes are attached.

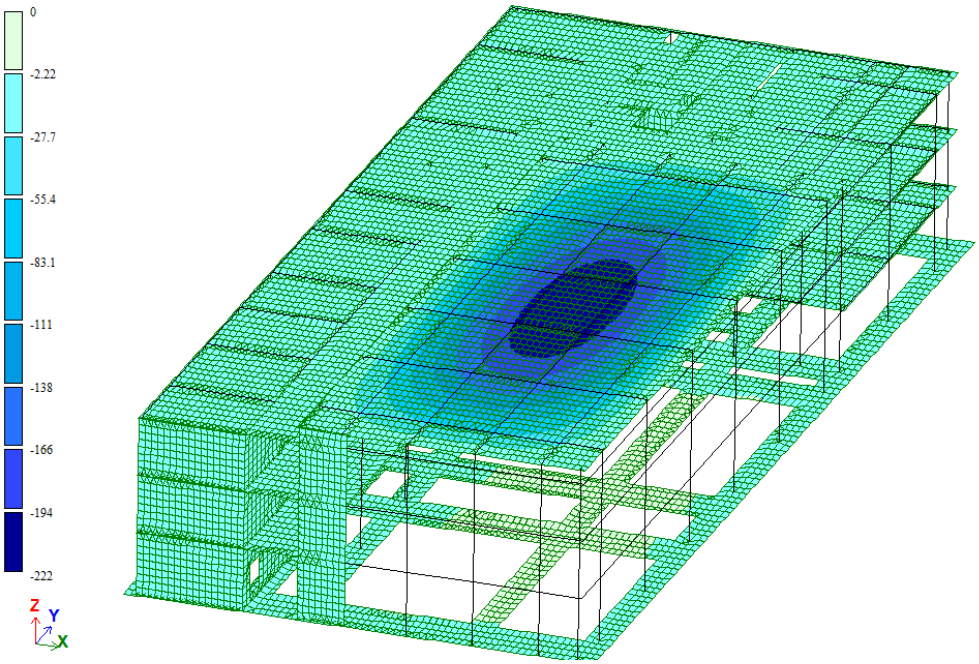

Figure 3. Deformed diagram of section A while preserving all structural elements

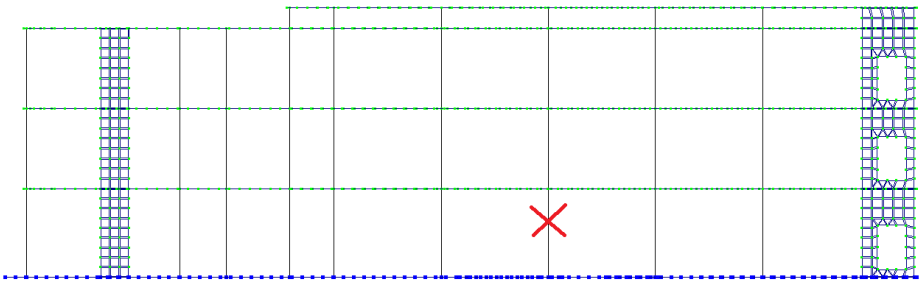

Figure 4. Section in the calculation scheme, when one of the columns of section A is excluded from operation

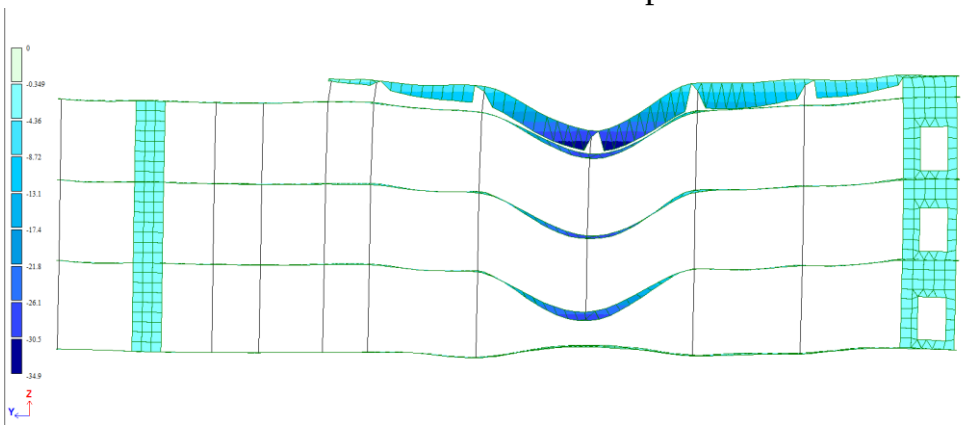

Figure 5. Deformed scheme in the frame, when one of the columns of section A is disabled

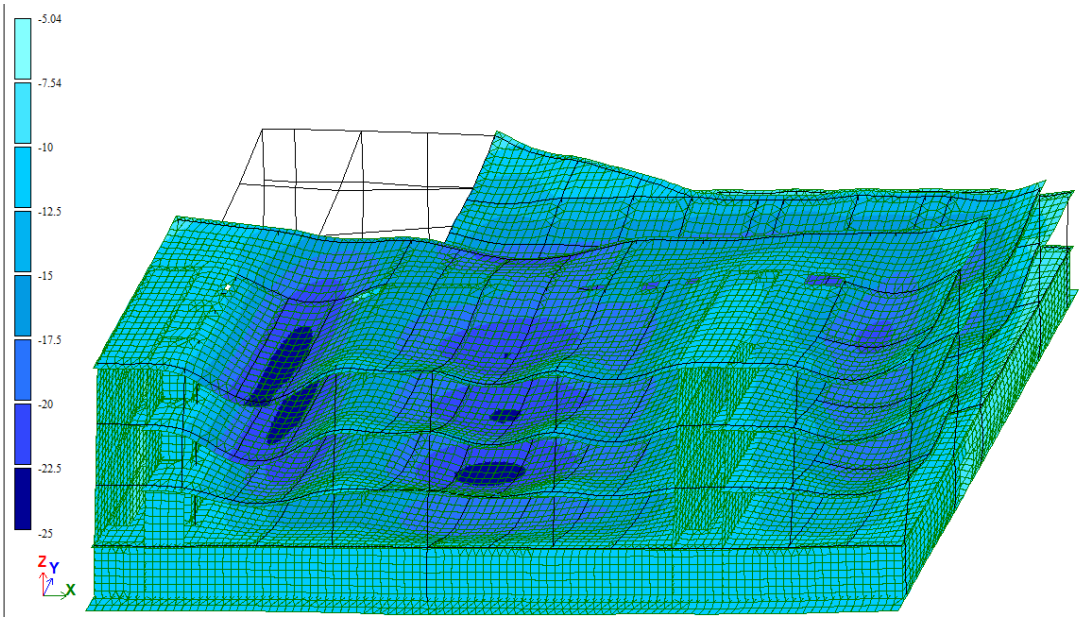

Figure 6. Deformed diagram of section B while preserving all structural elements

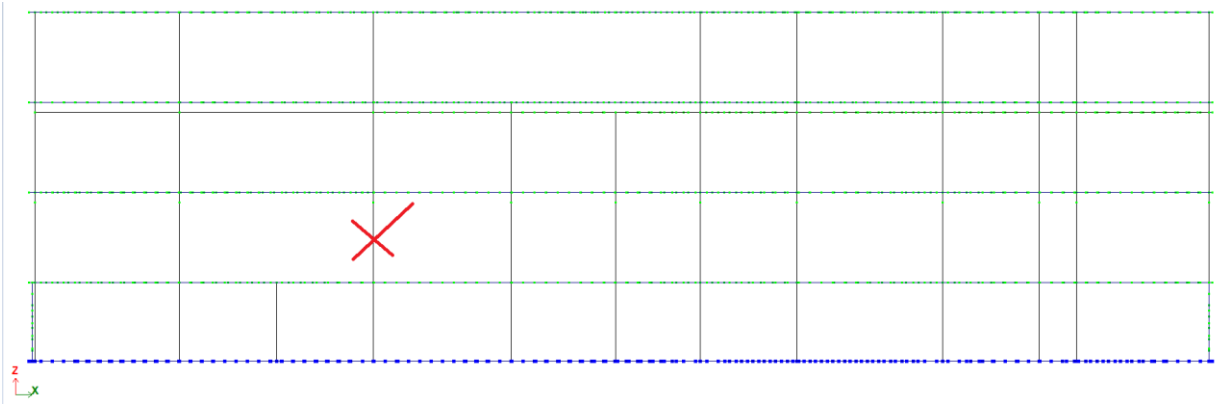

Figure 7. Section in the calculation scheme, when one of the columns of section B is excluded from operation

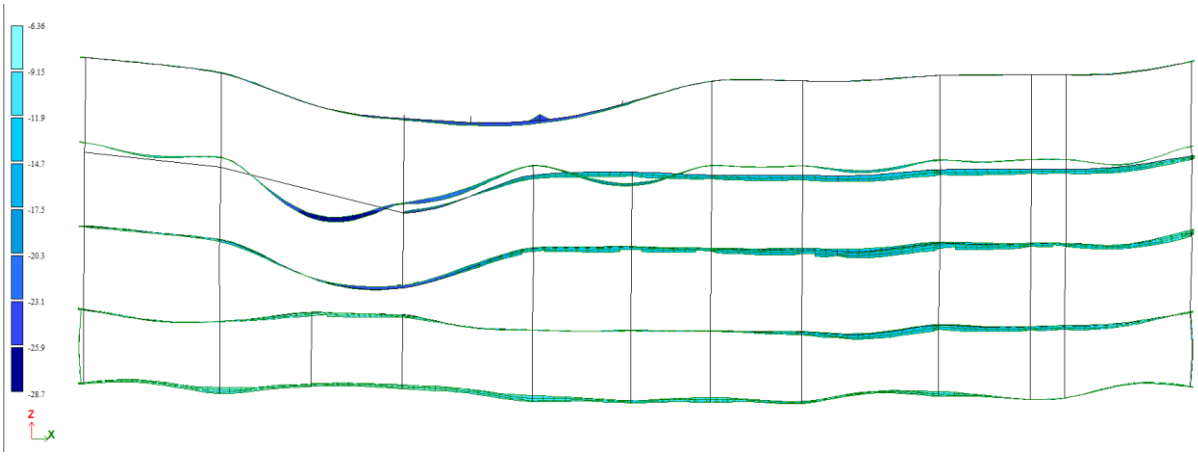

Figure 8. Deformed scheme in the frame, when one of the columns of section B is disabled

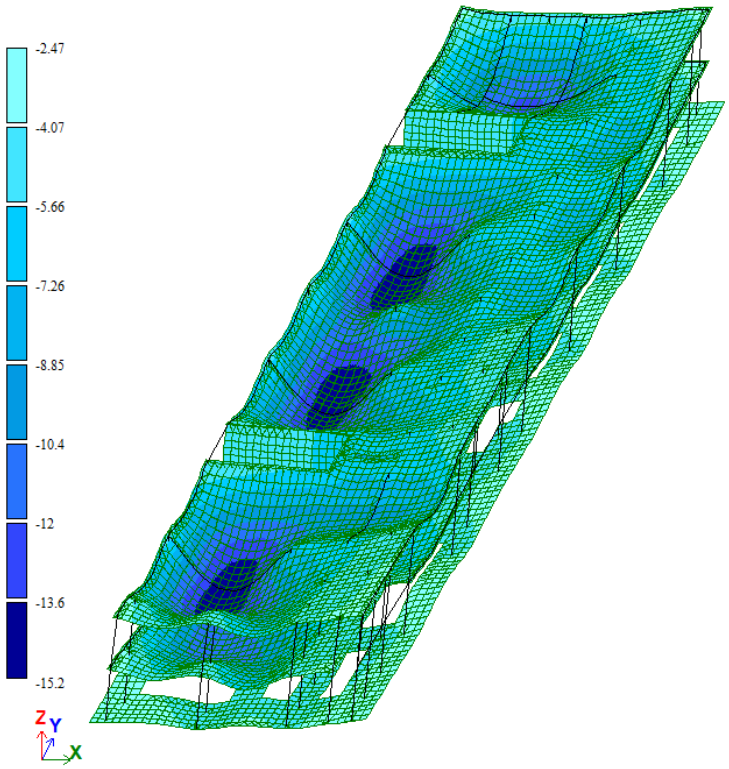

Figure 9. Deformed diagram of section D while preserving all structural elements

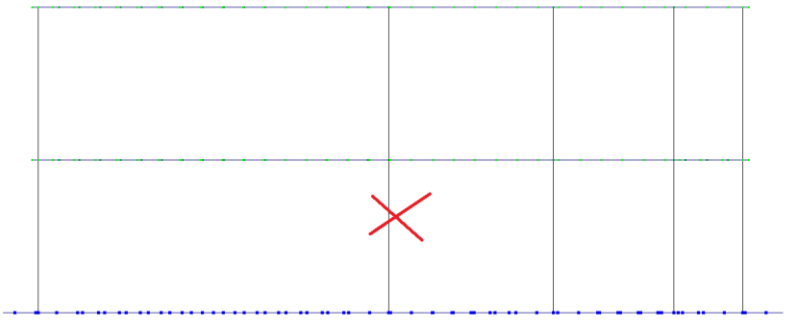

Figure 10. Section in the calculation scheme, when one of the columns of section D is excluded from operation

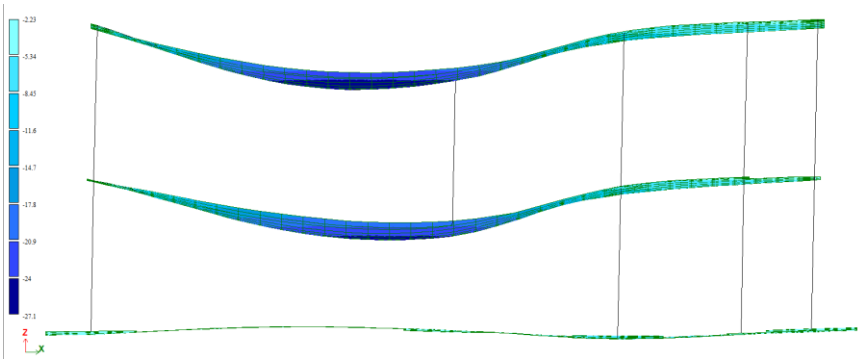

Figure 11. Deformed scheme in the frame, when one of the columns of section D is disabled

On the basis of calculations, it was established that in the case of exclusion of individual elements of the calculation scheme from work, the stability of the frame against progressive collapse is ensured.

The main constructive measures to protect structures from progressive collapse are:

- ensuring the necessary load-bearing capacity of structural elements and connections between them in the event of an emergency impact, which leads to local destruction;

- ensuring the necessary plastic deformations in the joints of structural elements.

- ensuring the sufficiency of the armature anchoring length when it works as a shear connection;

- provision in the intersections of lintels, beams, crossbars, slabs, in the ultimate state of failure in bending, not in shear.

Calculation of the progressive collapse of building structures during a fire makes it possible to identify "weak places" and find out what exactly can be done to delay the possible destruction of these structures. For example, to take certain measures from among those listed above. Why is this "postponement" necessary? At least in order to increase the period of time for safe evacuation from the building in case of fire, that is, to give existing persons more chances to escape.

The norms that determine the reliability of buildings and structures should be significantly expanded, especially regarding the rules regarding their durability and calculations in the event of structural collapse. In connection with the increased risks of emergency situations and terrorist acts, which are relevant in Ukraine today, it is reasonable to establish single survivability requirements for all objects of the SS3 consequence class and develop special norms to ensure it for various types of such buildings. This will correspond to the recognized foreign experience and will increase the national security of Ukraine.