Safety of urban buildings near explosive objects

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Abstract. The article outlines the basic principles for choosing the most rational urban development near explosive urban facilities. The developed principles make it possible to minimize risks both for newly constructed and for constructed urban facilities located near energy-intensive industries.

The following points must first be made. There are several possible options that are pursued in determining the security status of objects, people and territories adjacent to explosive objects. Firstly, it can be preliminary calculations for assessing safety zones, and secondly, the purpose of research can be to determine the degree of safety of a particular object located near the alleged source of an emergency explosion. For example, an oil refinery, which is energy-intensive and occupies a significant territory through which mechanisms and people move and on which industrial and auxiliary buildings are located.

Let us turn to the methodology for calculating the dynamic characteristics at a certain point in the air medium disturbed by the explosion.

The results of the calculation of the effect of compression waves on buildings during a deflagration emergency explosion at a nearby energy-consuming facility – fuel filling station (AZS) are considered.

1. Introduction

The safety of urban buildings is closely intertwined with the layout of explosive objects.

Figure 1 shows the calculation results in the form of instantaneous pressure profiles for different points in time for the layout of residential buildings and fuel filling station in case of emergency explosion of gasoline vapors.

2. Materials and methods

At the borders of the buildings, the condition of not flowing liquid is accepted (equality to zero of the normal component of the air flow rate). It is evidenced that for the first time point $T_1 = \Delta t$ (Figure 1, A), corresponding to 75.8 ms after the explosion, the maximum pressure is about 5 kPa.
3. Results

Compressive wave during this time spread to a distance of 25m from the explosion source. The subsequent time $T_4 = 4\Delta t$ (Figure C1) is characterized by the fact that the explosive burning stopped, a significant vacuum was formed at the “point” of the explosion (about 10 kPa), and the compressive wave reached urban buildings. The left building is located closer to the explosion source, and at time $T_4$, a reflection wave is formed on its facade.

Aerodynamic shadow is observed behind both buildings at time $T_4$ (explosive pressure is zero), i.e. both buildings are shielding explosive loads. The fifth time point $T_5 = 5\Delta t$ (Figure E1) is characterized by the following feature: the interaction of the compressive wave with the facade of the left building has almost ended; the wave began to flow over the building, and a reflection wave is still forming on the facade of the right building. The interference of the wave flowing into the left building and the wave deflected from the facade of the right building leads to increased explosive pressure in the space between the buildings. It should be noted that at $T_5$ between the buildings there are significant wind flows. Then in the space in front of the buildings, the interaction of the compressive and rarefaction waves deflected from the facades and formed after explosive burning, takes place (Figure F1, J1). There is a slight increase in pressure behind both buildings due to the influx of compressive waves into it.
Figure 1. Instant overpressure profiles during a deflagration explosion. The time step is 75.8 ms, the maximum flame propagation velocity is $W = 70 \text{ m/s}$.

The above profiles of dynamic pressures show that their “pattern” is largely determined by the mutual arrangement of buildings between themselves and the explosion source [1]. The structure of urban development (the planned placement and location of buildings near the source of explosive danger, the height of buildings, their size in the plan and others) determines parameter of the field of explosive pressure [2]. The greatest influence on the nature of the pressure field has a mutual location...
of buildings near the explosion source. In this case, the wave flow is significantly affected by obstacles that are comparable or exceed perturbation wavelengths. The maximum values of the pressure field are determined by the parameters of the explosion.

The magnitude of the wavelength of the explosive load that forms during a deflagration explosion [3–6] can be estimated as follows:

$$\lambda = c_0 R_0 / W,$$

where $c_0$ - sound velocity; $R_0$ – size of the explosion area at the end of burning; $W$ - average flame velocity.

The wavelength determines the duration of the compression phase in the pressure wave generated during a deflagration explosion. The compression wave is followed by a rarefaction wave, that length is $\lambda = 2R_0$. The structure of the compression wave and the rarefaction wave determine the consequences of an explosion near an explosive object.

Figure 2 shows a graphical display in space of the maximum and minimum values of explosive pressure, respectively, when a compression wave interacts with buildings. To obtain a diagram at each point in space for the entire time of the blast wave propagation, the maximum and minimum values of pressure were chosen. The time of realization of the selected pressures was different for each point in space.

![Figure 2. Spatial distribution of maximum levels of explosive pressure when a compression wave interacts with buildings](image)

Thus, an integral picture of the development of the blast wave for different points in time is given (Figure 1). Time is excluded from the model, and the criterion are maximum and minimum pressure values considered at a point in space. Taking into account that the time of a blast wave propagation is quite small (not more than a few seconds); the time delay for the pressure realization in space is not taken into account. Therefore, we can assume that the spatial distribution of the maximum (Figure 2) and minimum values of explosive pressure largely describes the whole process of an explosive accident in a space cluttered with buildings located in the way of an air blast wave [7, 8,16].

Figures 3 and 4 show the isolines of equal pressure, respectively, in a compressive wave and a rarefaction wave. They are implemented for a given location of the source of an emergency explosion in an urban area with a specific layout.
Isolines were obtained by horizontal sections at 5; 10; 25; 50 and 75%, respectively, of the maximum pressure value in the compressive wave (Figure 2) and the minimum pressure value in the rarefaction wave. Such structure of the field of explosive pressure is most clear during planning of urban buildings near a source of explosive danger.

![Figure 3](image1.png)  
**Figure 3.** Equal pressure levels in a compressive wave during its interaction with buildings ($W = 70 \text{ m/s}$)

![Figure 4](image2.png)  
**Figure 4.** Equal pressure levels in an expansive wave during its interaction with buildings ($W = 70 \text{ m/s}$)

Thus, the described design scheme allows determining the necessary parameters of explosive load, both in the temporal and in the spatial domain [9-20].

Comparison of the structures of isolines of equal pressure for different visible flame speeds (Figures 3, 4) showed that the nature of the isolines is largely determined by the relative position of the explosive object and urban buildings. With the calculated isolines of equal pressure levels for urban area with an explosive object, it is possible to make the necessary decisions about safety measures for the buildings surrounding this object. For the planned urban area, the calculation can determine the safe distances from the explosive object to civil and residential buildings.

4. Discussions and conclusions

The calculation of pressure fields in case of emergency explosions at energy-intensive objects under conditions of dense urban development showed:

- during an accidental explosion, massive destruction of the glazing may occur, and the pressure field is significantly distorted in the presence of buildings near the source of the explosion;
- when using a building for mass stay of people in it, strengthening of the glazing is necessary. To enhance the glazing, it is possible to glue the inner surface of the glass with a film coating, which will increase the strength characteristics of the glass. The nature of the glazing can be changed: the size of a single cell of glass is reduced by 1.5-2.0 times, which will increase the safety margin of glass in almost two times. When performing these activities protection of people inside and near the building will be guaranteed;
- the building structure determines the parameters of the field of explosive pressures, although the maximum pressure values are determined by the disturbance source, i.e. explosion parameters.

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