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Features of designing evacuation exits in the reconstruction of civil protection shelters for public buildings

In the context of the war in Ukraine, the issue of public safety has become acute. Civil protection measures include designing shelters or reconstructing existing basements. A component of the basement reconstruction is the redevelopment of evacuation exits from the shelters. The relevant current regulatory framework is analyzed. The object of the study is the building of an educational institution in the city of Poltava, built in the 19th century. A project for reconstructing the basement into a dual-purpose room with a separate emergency exit outside the building collapse zone has been developed.

Keywords: basement, civil defense. evacuation, shelter, exit.

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Introduction

Public buildings require measures to improve the level of civil protection. A way to improve security is to reconstruct basements into dual-purpose rooms (shelters). Dual-purpose premises can be used for their primary functional purposes and public protection.

Review of the research sources and publications

The world experience and expertise in planning emergency shelters are analysed in [1]. Increasing the level of passive safety of citizens in wartime is described in [2]. The development of planning solutions is studied in [3-4]. According to [5], the movement of human flow in the event of an emergency is analysed. The developed principles of universal design of shelters in the example of the United States are studied in [6]. Foreign design solutions for emergency shelters are analysed in [7]. Global design principles for evacuation centres were analysed [8].

Definition of unsolved aspects of the problem

Following current legislation and building regulations, all buildings must have shelters. In recent pre-war times, there was no need for civil protection measures. In the context of dense existing buildings, the construction of new civil protection facilities is not possible (Fig. 1). Therefore, a resource for increasing the number of relevant facilities is the conversion and reconstruction of basements of existing buildings.

The regulatory literature does not specify a design scheme for the collapse of a building when designing evacuation exits.

Figure 1 – Situation diagram

Problem statement

The work aims to clarify the design solutions for civil protection shelter elements, using the example of a historical building of an educational institution.

Basic material and results

A survey of the historic building of the educational institution was carried out. The basement of the academic institution measures 21.22×66.57 m in plan along the axes. The height of the premises is 2.1 m. The walls are brick, without a waterproofing layer along the outer contour. The blind area is deteriorated in some places. There is high humidity in the basement. The walls are affected by fungus and mould. The protective layer of concrete (exposed reinforcement) in the reinforced concrete floor beams was destroyed (Fig. 2).

During the reconstruction of the facility, it became necessary to convert the basement into a dual-purpose room with the possibility of making a radiation shelter in the future. To this end, a geological survey was conducted to determine the ground conditions and groundwater level. It was decided to lower the floor by 300 mm to comply with the requirements [9] regarding the minimum height of the storage facilities and the need to place ventilation equipment on the ceiling. The project envisages antiseptic treatment of the inner surface of the walls, replacement of the finishes, and restoration of the waterproofing layer and insulation of structures bordering the ground.

A dual-purpose emergency exit shaft was designed. The emergency exit shaft should be designed to withstand the impact of load combinations under steady-state (basic) and emergency design situations. In the calculation for emergency load combinations, the quasi-static load from the airborne shock wave is taken into account in accordance with the class of the protective structure, according to [9].

The storage capacity is 300 people. There is an emergency exit through a vertical shaft with a protective cap. The plan dimensions are 12.26×2.26 m. The internal dimensions of the tunnel and shaft in the lumen are 1.6×1.5 m. The head of the emergency shaft exit, 1.2 m above the ground surface, is equipped with four louvred grilles. The louvres are 0.9×0.9 m in size and open into the shaft. The exit from the shelter to the tunnel is equipped with protective and airtight shutters (hatches) installed on the outer and inner sides of the wall, respectively (Fig. 3).

A calculation was made for the effect of a quasi-static load from the impact of an air shock wave $q_{ex,eqv}$, on the emergency exit structures. The value was 288 kPa.

The calculation methodology is taken from the current regulatory literature [9].

Dual-purpose storage class **– (A-IV)**. Excessive air shock wave pressure $\Delta P_{ex} = 100\ kPa$**.**

When calculating the head of an emergency exit that falls within the zone of possible rubble and is elevated above the ground, the load from the ruins of the destroyed building or structure is considered.

Figure 2 – Detachment of the protective layer of concrete in the reinforced concrete floor beams of the basement.

The emergency exit head, elevated above the ground, is designed for horizontal quasi-static loading $q_{ex,eqv}$, $125\ kPa$.

Water supply, heating and sewerage networks of a building that run in an adjacent room are laid in special collectors (concrete or reinforced concrete channels), accessible for inspection and repair work during the operation of these networks in peacetime. The collectors have a slope of 2-3% towards the drain.

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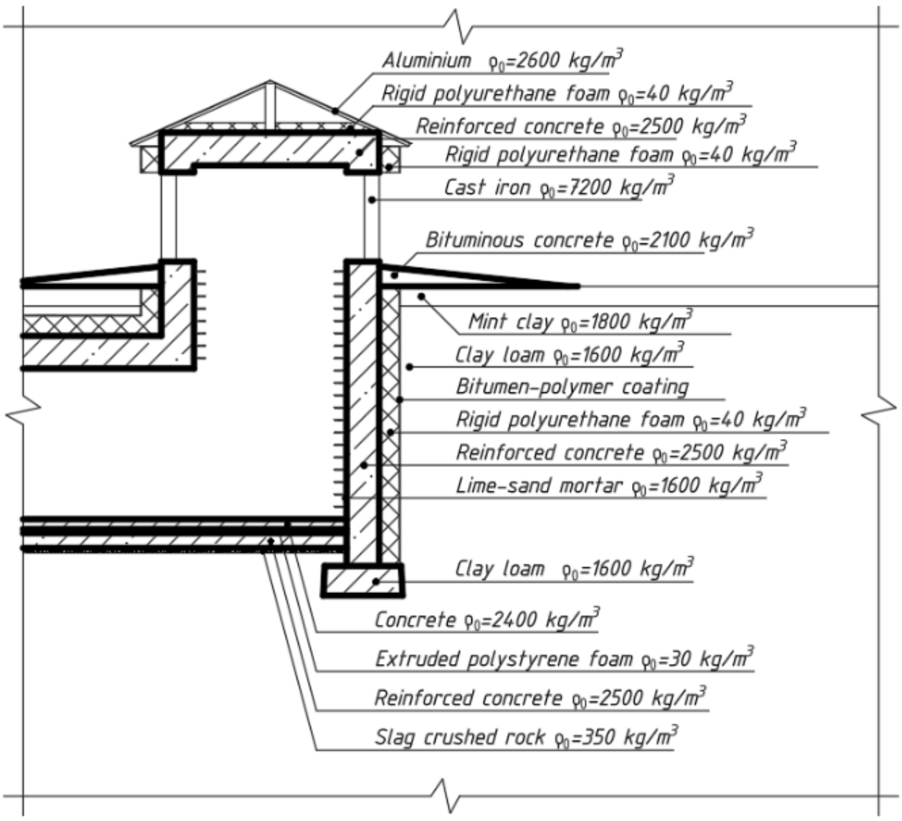


Figure 3 – Section of the head of the emergency shaft (design solution)

The embedded parts for cable entries, air ducts, water and heat supply pipes and sewage outlets are arranged in metal pipes with flanges welded in their middle part. The embedded parts will be installed in the enclosing structures before concrete concreting.

The regulatory framework does not specify which part of the building is included in the collapse volume. Taking into account the scenario of collapse of a part of the building, two types of collapse are provided for the emergency exit cover combined with the ventilation shaft

- collapse of the external load-bearing brick wall with half of the inter-floor floor and the covering above the 1st floor (inclusive);
- the collapse of the outer and inner load-bearing brick wall with half of the inter-floor ceiling of the common corridor, and the collapse of classrooms above the 1st floor (inclusive) and the building's roof.

The vertical static load on the bearing structures of the roof of an emergency mine is the dead weight of these structures and the weight of the roof structures. The weight of the supporting structures and the elements of the roof and lining is a constant value. The load per 1 m2 of the emergency shaft cover structures was calculated to be 33.11 kPa.

To consider the dynamic impact of vertical loads during the building collapse process, we introduce a dynamism coefficient equal to 1.1 by [10].

$$q_{overall.} = q \times 1{,}1 = 33{,}11 \times 1{,}1 = 36{,}42\ kPa.$$

The emergency exit design includes reinforced concrete structures with a thickness of 330 mm (concrete class C25/30). To prevent concrete particles from exfoliating from the inside of the wall, the project provides for installation of additional anti-chipping reinforcement on the inside of the protective layer of concrete at a depth of no more than 25 mm from the inner surface of the reinforced concrete structure with steel mesh with a rod diameter of at least Ø 2 mm, with a mesh spacing of no more than 40 mm, attached to the primary reinforcement of the structure (fastening should be performed with at least three turns of knitting wire at each point, with a spacing of at least 500 mm in both directions).

The roof was designed using metal profiles and embedded parts. The embedded parts are 100×100 and 100×200 mm in size. Metal profiles with a square cross-section are welded to the embedded parts with dimensions of 100×100 mm rafters and 30×30 mm.

The effectiveness of the facility's insulation was verified by finite element modelling according to the design scheme (Fig. 3). The reconstruction project provides for external insulation of the buried part of the basement to the floor level with extruded polystyrene foam 150 mm thick with a PVC membrane.

The study was conducted using Poltava's initial data. Initial conditions: outdoor air temperature -22°C; indoor air temperature +5°C according to the calculation scheme in Fig. 4.

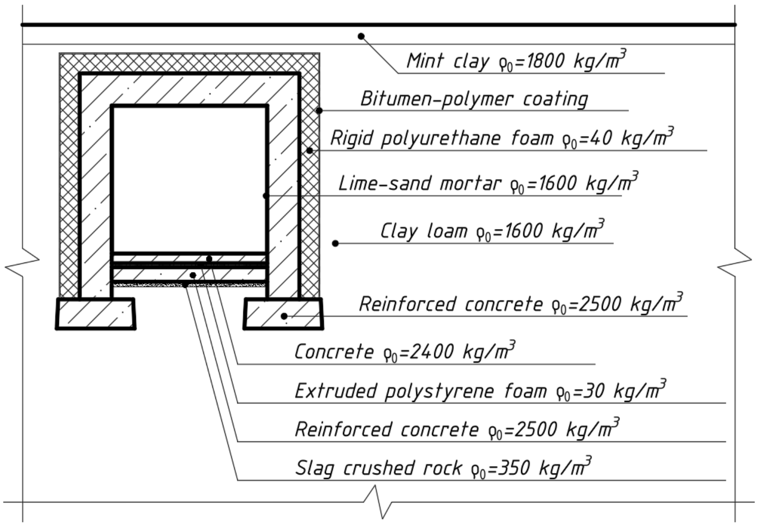
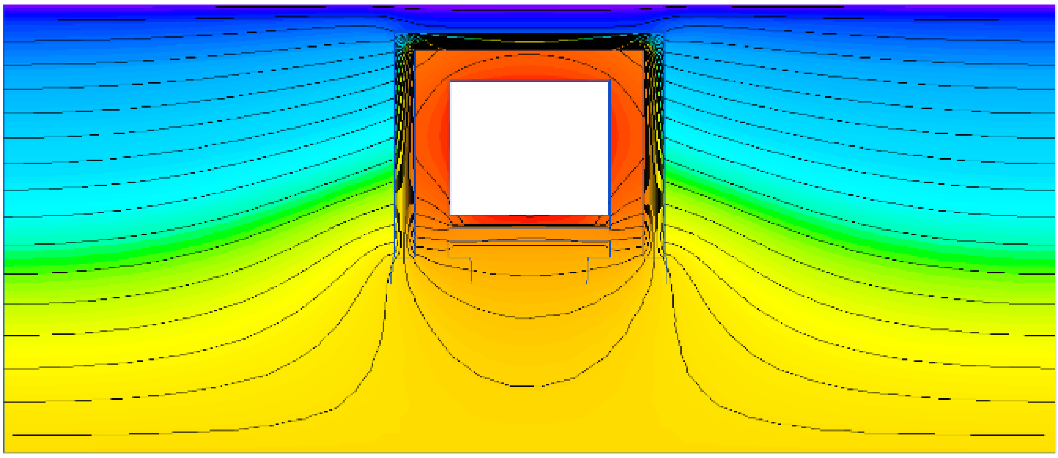
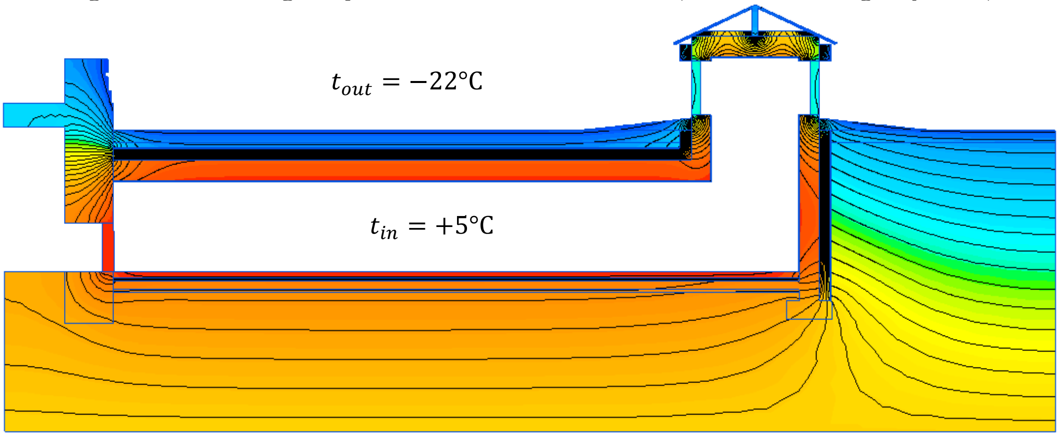


Figure 4 – Computational scheme for modelling temperature fields



Average internal surface temperature: + 4.185 °C; Heat flux: 43.209 W.

Figure 5 –Modelling temperature fields in section 1-1 (across the emergency shaft)



Average internal surface temperature: + 2.861 °C; Heat flux: 585.96 W.

Figure 6 –Modelling temperature fields in section 2-2 (along the emergency shaft)

Conclusions.

A design of an emergency exit from a dual-purpose room of an educational building in Poltava was developed. The influence of quasi-static load on the exit structure was analysed. Thermal insulation materials were selected. Calculation schemes for determining the dynamic loads on the emergency exit are proposed. When calculating the loads, the loads from the complete collapse of the following were considered: brick wall, roof structures and rafter system; attic and inter-floor floors to the ground level. The 1st-floor ceiling structures in the form of a brick vault were not considered, as the collapse of such structures has a vertical motion vector.

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Дослідження тепловологісного режиму холодних горищ інструмента

В умовах збройного конфлікту на території України питання забезпечення безпеки цивільного населення набуло особливої актуальності. Відповідно до сучасних вимог нормативно-правової бази у сфері цивільного захисту, всі громадські будівлі мають бути обладнані відповідними захисними спорудами, зокрема сховищами та укриттями. В умовах щільної забудови та обмежених ресурсів на нове будівництво одним з ефективних рішень є реконструкція підвальних приміщень існуючих будівель у приміщення подвійного призначення. У таких приміщеннях поєднуються функції звичайної експлуатації в мирний час із можливістю використання як захисних споруд у надзвичайних ситуаціях. Основною метою реконструкції є забезпечення відповідності технічного стану приміщення чинним вимогам до укриттів класу А-IV, включаючи вимоги до мінімальної висоти приміщень, вентиляції, гідроізоляції, протигрибкової обробки та конструктивної надійності в умовах впливу надлишкового тиску повітряної ударної хвилі. Проєктом передбачено перепланування з улаштуванням аварійного евакуаційного виходу через вертикальний шахтний канал, винесений за межі зони можливого обвалу основної будівлі. У межах роботи виконано обстеження існуючих конструкцій. метою забезпечення належного теплозахисту захисної споруди виконано моделювання теплофізичних процесів із застосуванням скінченно-елементного аналізу, що дозволило обґрунтувати вибір теплоізоляційних матеріалів та конструктивних рішень.

Ключові слова: евакуація, сховище, вихід, підвал, цивільний захист.

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