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THE DEFORMATION DEGREE OF HIGH-STRENGTH CONCRETE AFTER THE BULLET IMPACT

Abstract: *The deformation degree of concrete (strength up to 140 MPa) upon impact of the steel bullet flying at an initial speed of 720 m/s was investigated in the article. Temperature, plastic and elastic deformations of concrete in the direction of load were considered.*

Key words: *high-strength concrete, impact, deformation, the area.*
Language: *English*
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Introduction

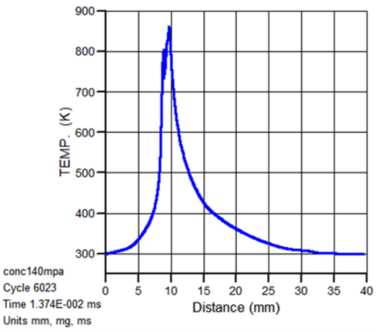
High-strength concretes can withstand long-term high static loads without damage [1-3]. Short-term local dynamic load (for example, the bullet penetration) causes partial damage of concrete at the point of contact. Concrete has a heterogeneous porous structure. This suggests that deformation under loads occurs unevenly in the material volume. The formation of cracks during compressive deformation is possible. Cyclic loads contribute to the further development of cracks until the complete damage of concrete. Evaluation of the deformation degree of concrete products under loads by conducting experimental tests and visual modeling will make it possible to draw a conclusion about the strength characteristics of material in the real operating conditions. In this paper, the analysis of the stress and strain state of a concrete slab after penetration of the Kalashnikov assault rifle bullet into it at an angle of zero degrees was carried out.

Materials and methods

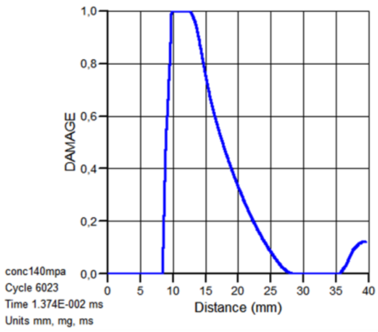
The calculations were carried out in the Ansys Autodyn. For this, models of the slab (thickness of 40 mm) and the Kalashnikov assault rifle bullet (7.62 mm caliber) were built on the plane. The slab and bullet models were given the properties of concrete (strength up to 140 MPa) [4-5] and carbon steel, respectively. Concrete had the equation of state (*P* alpha), the strength model type (*RHT* concrete), the failure model type (*RHT* concrete) and the erosion model type (geometric strain). The concrete slab model was fixed vertically on one of the sides, and an initial velocity of the bullet was taken as 720 m/s according to the experimental conditions. The bullet moved along the *X*-axis of the rectangular coordinate system plotted on the plane. The bullet penetration was performed in the center of the slab. The bullet deformation was not taken into account in the study. Case studies of the properties and the stress and strain state of various grades of concretes under various loads were carried out in the works [6-10].

Results and discussion

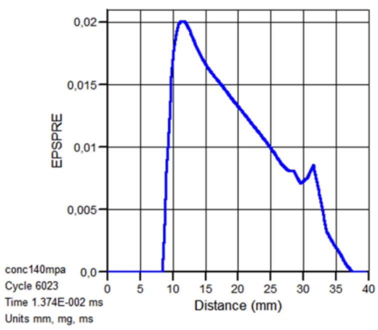
Measurements of the stress and strain state of concrete were carried out in the load direction. Dependences of the deformed state of high-strength concrete after removal of dynamic load on the slab thickness are presented in the Fig. 1.



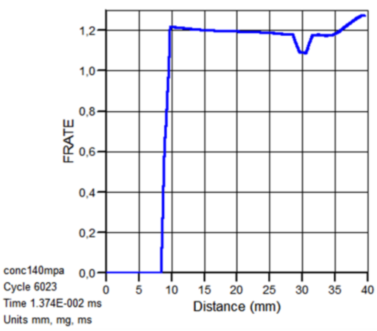
Temperature vs. Distance plot



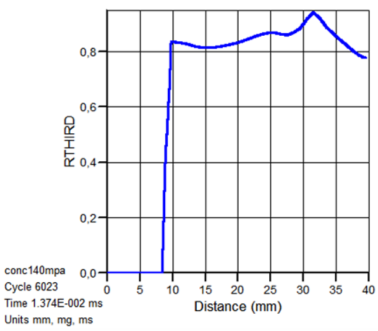
Damage vs. Distance plot



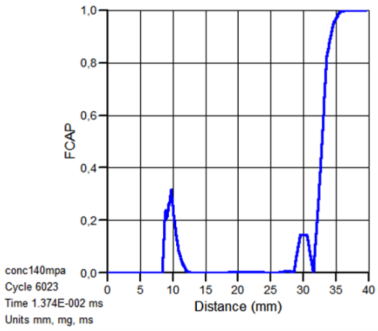
RHT pre-softening plastic strain vs. Distance plot



RHT strain rate enhancement vs. Distance plot



RHT Lode angle vs. Distance plot



RHT elastic cap factor vs. Distance plot

Figure 1 – Dependences of the deformed state of high-strength concrete after removal of dynamic load on the slab thickness.

Heating of the slab by 570 K occurs in the area of maximum deformation of material. The temperature field occurs within a radius of 25 mm from the area of concrete damage. In this case, main damage to concrete (cracks, etc.) occurs within a radius of 18 mm. Dynamic impact causes both plastic and elastic deformations in the slab. Dependence of the occurrence of plastic deformation of preliminary softening, taking into account the magnitude of concrete deformation rate, can be traced in the presented plots. Plastic deformation of material in the impact area is no more than 2%. Deformation rate reaches its maximum at the moment of the bullet impact and practically does not change within a radius of 30 mm. The type of deformation of high-strength concrete under the conditions of penetration of the steel bullet changes from deviatoric pure shear in the impact area to axisymmetric compression in the layers of material, the most distant from the damage area. Impact leads to the occurrence of high pressure, concrete pores are crushed behind the damage area (elastic deformation decreases to almost zero in the middle part of the slab).

Conclusion

Based on the analysis of the results of computer simulation of the bullet penetration into the slab, the following conclusions were made about the degree of concrete deformation:

1. The bullet impact on the concrete slab causes complete damage of material at the point of contact.
2. After impact, plastic and elastic deformations are observed in material, while the former have the maximum magnitude at the point of impact.
3. The areas of elastic deformations and high pressure, located closer to the opposite (to impact) wall of the slab and its middle, respectively, are revealed.

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