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Experimental and numerical study of concrete targets under high rate of loading

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Abstract

In order to examine the ballistic resistance of plain concrete and reinforced concrete targets the perforation tests conducted in the laboratory, on square concrete targets size (450 mm x 450 mm x 80 mm) of plain concrete and reinforced concrete and to validate the experimentally obtained results Numerical simulations were carried out in Abaqus/Explicit finite element code. The unconfined target compressive strength of concrete was 48 MPa. A grid of steel bars having 8mm diameter has been incorporated in reinforced concrete plates. The plates were subjected to normal impact of 0.5 kg ogive nosed hard steel cylindrical projectile having diameter of shaft 19mm. The projectiles were accelerated by the laboratory pneumatic gun to velocities range between 53m/s to 220m/s. impact and residual velocities were measured with the help of Phantom-V411 high speed digital camera system. Ballistic limit of plain concrete and reinforced concrete targets had been obtained in the experiments as well as in the Numerical simulations in Finite element code Abaqus\explicit. Also calculated spalling and scabbing volume of plain and reinforced concrete targets after perforation experiments, the reinforcement in the concrete has been found to be effective in minimizing the scabbing and spalling of material. The ballistic limit of reinforced concrete target was experimentally found 16.9% higher than plain concrete target, However Numerical simulations predicted the ballistic limit of plain concrete target within 8% and that of reinforced concrete target within 3% deviation in comparison to experimentally obtained ballistic limits.

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Keywords: Ballistic Impact; Spalling; Scabbing; Calibre Radius Head (CRH); Rigid Projectile

1. INTRODUCTION

Concrete structures have been widely used in construction of civilian structures and important structures such as bunkers, nuclear power plants, buildings, brides, dams, tunnels etc. for those structures important criteria is to with

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stand against impact load produced by projectiles. So many researchers did perforation experiments on high strength concrete slabs, beams, grouts etc. Projectile impact on different grade of concrete and varying diameters of concrete plates and grouts they found striking velocities corresponding to maximum depth of penetration, effect of concrete target diameter on depth of penetration [1-4]. Shirai et. al [5] presented a method to improve the impact resistance of reinforced concrete plates against projectile impact they reported to reduce local damage due to impact load provide steel plate lining at impacted and rear surface, double layered RC plates can be expected to have higher impact resistance than the standard one. Beppu et. al [6] carried out the damage evaluation of concrete plates at higher impact velocities and also the launch acceleration in the gun bore and the deceleration during the perforation event was recorded with an acceleration transducer. Several perforation tests using concrete targets of different thicknesses were conducted with a nominal striking velocity of 400 m/s. and the residual velocity against kinetic energy consumed versus the target thickness was analyzed, the perforation limit was also obtained [7]. Li et. al [8] studied the effect of hard missile impact on concrete plates and proposed analytical formulae to measure the ballistic resistance of the target. In this study perforation experiments and numerical simulations have been done on plain and reinforced concrete of low compressive strength of 48 MPa with hard steel projectile of 0.5 kg and 19mm diameter. The projectiles were accelerated by the laboratory pneumatic gun to velocities range between 124 m/s to 180 m/s. impact and residual velocities were measured by the high speed digital camera system. Ballistic resistance of plain concrete and reinforced concrete at different thicknesses had been find out in the experiments. Damage pattern of concrete also discussed.

2. CONCRETE TARGETS

In the earlier studies several researchers have studied with high strength concrete and also normal strength concrete but they have found that there is very minor effect in performance of the concrete targets with respect to their compressive strengths. The target materials used were M40 concrete grade see Table-1, Different thicknesses of 80mm and 100mm of M40 grade concrete had been casted, and 6 cube of dimension (150*150*150) mm also casted. The samples for the compressive strength tests were allowed to cure for at least 28 days. After curing of concrete cubes had been tested on compression testing machine which gives unconfined average compressive strength of 48 MPa.

Table 1. Constituents of concrete

Cement (kg/m^3)	Water (kg/m^3)	Aggregate (10mm) (kg/m^3)	Sand (kg/m^3)	admixture
437.9	166.4	1040.92	720	0.25%

The square concrete plates of span 450 mm x 450 mm were taken and concrete plates thickness were considered 80mm. geometry of concrete plate shown in fig-1a. The experiments were conducted on a pneumatic gun. 1 kg projectile as shown in Fig-1b, was launched up to an incidence velocity 200 m/s. The length of the barrel was considered 18 m to enable adequate acceleration of the projectile for obtaining the required velocity see Fig-2. The angle of incidence was considered normal to the target.