PENETRATION OF CONCRETE TARGETS WITH OGIVE-NOSE STEEL RODS

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Summary—We conducted depth of penetration experiments in concrete targets with 3.0 caliber-radius-head, steel rod projectiles. The concrete targets with 9.5 mm diameter limestone aggregate had a nominal unconstrained compressive strength of 58.4 MPa (8.5 ksi) and density 2320 kg/m$^3$. To explore geometric projectile scales, we conducted two sets of experiments. Projectiles with length-to-diameter ratio of ten were machined from 4340R® steel, round stock and had diameters and masses of 20.3 mm, 0.478 kg and 30.5 mm, 1.62 kg. Powder guns launched the projectiles to striking velocities between 400 and 1200 m/s. For these experiments, penetration depth increased as striking velocity increased. When depth of penetration data was divided by a length scale determined from our model, the data collapsed on a single curve. Thus, a single dimensionless penetration depth versus striking velocity prediction was in good agreement with the data at two geometric projectile scales for striking velocities between 400 and 1200 m/s. In addition, we conducted experiments with AerMet 100R® steel projectiles and compared depth of penetration and post-test nose erosion data with results from the 4340R® steel projectiles.

Keywords: penetration, ogive-nose steel rods, geometric and material scales.

INTRODUCTION

This paper completes our work on laboratory-scale, concrete-penetration experiments for striking velocities between 400 and 1200 m/s. In our first study [1], we present a depth-of-penetration equation for ogive-nose projectiles and concrete targets. This penetration equation contains a single, dimensionless empirical constant $S$ for fixed values of the target, unconstrained compressive strength $f'_{uc}$. The dimensionless constant $S$ is obtained from depth of penetration versus striking velocity data and is independent of the projectile mass and geometry. In our second study [2], we present the special case of our penetration equation for ogive-nose, solid-rod projectiles. For solid-rod projectiles, the penetration equation [2] contains dimensionless groups of variables that display clearly the problem parameters. Our method requires penetration data to obtain the constant $S$, which depends only on target strength and is independent of the projectile parameters. So, from laboratory-scale experiments, we obtain $S$ and can predict or estimate depth of penetration versus striking velocity for much more expensive field tests with larger-scale projectiles. While our laboratory-scale experiments are limited to 30.5 mm diameter, 1.62 kg projectiles, our equation predicts accurately the data published by Canfield and Clator [1, 3] for 76.2 mm diameter, 5.9 kg projectiles.

This study presents additional data and examines further the accuracy of our penetration models [1, 2]. In particular, the concrete targets for this study used a limestone aggregate (Mohs hardness scale [4] of 3.0), whereas the work in Ref. [2] used a harder quartz-based aggregate (Mohs hardness scale [4] of 7.0). In addition, we conducted experiments at two geometric projectile scales with 4340 R®, 45 and AerMet 100 R®, 53 [5] steel rod projectiles. While the aggregate and projectile hardnesses changed the amount of nose erosion, we

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