DYNAMIC FRACTURE BEHAVIOR OF LAYERED COMPOSITE AGAINST MULTIPLE PROJECTILE IMPACT LOADING

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Abstract
A layered composite comprising of reinforced concrete, steel plates, and boulder-mixed soil are used as a bunker which can safely protect military personnel against multiple projectile impacts. This paper uses computational methods (Ansys AUTODYN) for the fracture to check the structural integrity of the layered target against projectile impact.

1. Introduction
In a war-like situation, it is not at all necessary that only one projectile will hit the bunker. Therefore, protecting military bunkers against multiple projectile impacts is of serious concern. These bunkers are generally constructed using locally available materials, reinforced concrete only, or a combination of both. Several researches showed that these bunkers might not suffice the purpose, even in case of a single projectile impact, as it will perforate the bunker. Researchers are developing cost-effective and efficient bunkers made of fiber-reinforced concrete or layered composite, which can provide improved protection against single projectile impact. Layered composite structures have been observed to provide enhanced protection against single projectile impact loading compared to reinforced concrete and fiber-reinforced concrete. Therefore, this paper investigates the dynamic fracture behavior of layered composite structures as a bunker and their performance under multiple projectile impact loading. The layered composite target consists of reinforced concrete, steel plates, and boulder-mixed soil. The composite target has been subjected to the projectile impact of a 5.9 *kg* ogive-nose hard steel cylindrical projectile having a 77.5 *mm* diameter. Additionally, a reinforced concrete mono-layer target of equivalent thickness has been considered for the performance evaluation and comparison with the layered composite target. The mechanical performance in terms of the velocity profile of the projectile, residual velocity, penetration depth, crater diameter, plastic deformation, shear band, and damage of the target have been quantified through numerical simulations. Compared with the mono-layer counterpart, a layered composite target has been observed to provide enhanced protection against multiple projectile impacts.

2. Results
As a preliminary analysis, the experimental results of Hanchak et al. [1] have been used to validate the numerical model. Hanchak et al. [1], in their study, have considered the ogival-nose steel projectile of caliber 30 *mm* and ogive radius of 76.2 *mm*, impacted at a velocity of between 330 *m/s* to 1100 *m/s* on the targets. The total mass of the projectile is 0.50 *kg*. The targets are reinforced concrete targets of 48 *MPa* and 140 *MPa* of unconfined compressive strength. The size of the reinforced target is taken as 610 *mm* × 610 *mm* × 178 *mm*. The concrete consists of reinforcements of 5.69 *mm* diameter. The mesh convergence plot for Hanchak et al. [1] validation of the 48*MPa* reinforced concrete target of 749 *m/s* impact velocity for which experimental residual velocity is 615 *m/s* is presented in Fig.1.

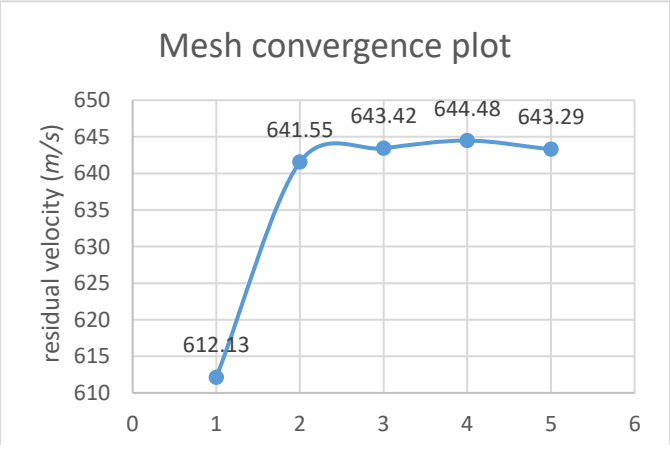

Fig.1- Mesh convergence plot for impact velocity of 749 *m/s*.

In this study, the projectile impact velocity adopted is 700 *m/s*, and the grade of concrete is 60*MPa*. One, two, and three projectile impact loading effects are studied on the following targets:

a. Mono-layer reinforced concrete (600 *mm* × 600 *mm* × 610 *mm*)
b. Layered composite (600 *mm* × 600 *mm* × 610 *mm*) target comprising of:
    1. 1st layer- boulder-mixed soil layer (150 *mm*).
    2. 2nd, 4th, and 6th layer- steel plates (20 *mm*).
    3. 3rd, and 5th layer- reinforced concrete (200 *mm*).

Initial In case (a), the single projectile impact loading perforates the target. So, the target is lethal to one, two, and three projectile impact loading. For single projectile impact loading, the projectile residual velocity is approximately 180 *m/s*, and front/rear average crater diameters are approximately 240 *mm*/150 *mm*.

In case (b), definitely, the three projectile impact loading proves to be the most lethal one. But, the target even sustained the three projectile impact loading, which proved to be better than the case (a).

Hence, the performance of the layered composite is better than the mono-layer reinforced target.

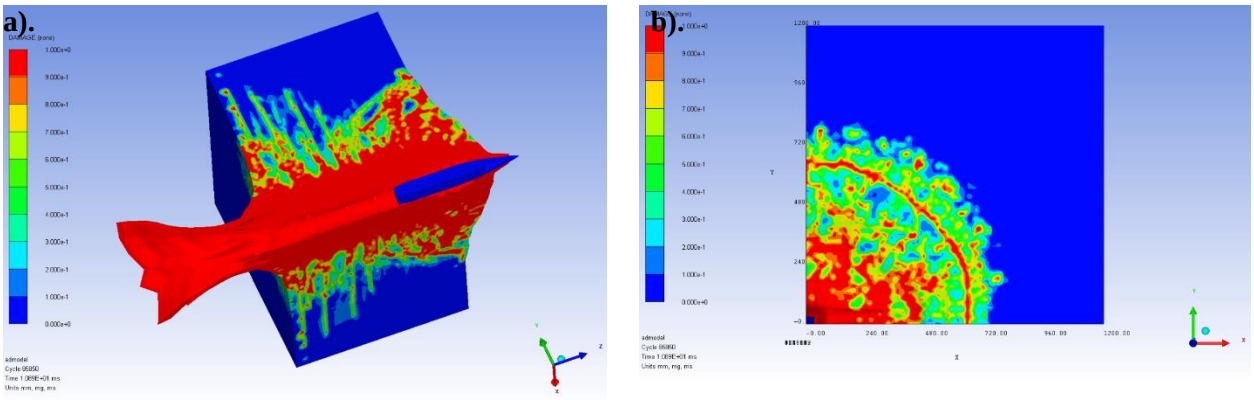

Fig.2- a). Damage view, b). Rear crater diameter.

3. Conclusions

The layered composite target provides enhanced protection against the multiple projectile impact loading as compared to the mono-layer reinforced concrete. The boulder-mixed soil layer in the layered composite target helped sustain the impact loading from multiple projectile impacts as it acts as an anti-penetration layer while the projectile perforated the mono-layer reinforced concrete target. The projectile then hits the steel plates before hitting the reinforced concrete layer, due to which spalling and scabbing also get reduced when compared to the mono-layer reinforced concrete. Boulder-mixed soil is a locally available material that is cost-effective and also increases the penetration resistance of the layered composite target against multiple projectile impact loading. Hence, the mono-layer reinforced concrete target can be replaced with the layered composite target against multiple projectile impact loading.

Acknowledgments

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Reference

[1]. Hanchak, S., Forrestal, M., Young, E., & Ehrgott, J. (1992). Perforation of concrete slabs with 48 MPa (7 ksi) and 140 MPa (20 ksi) unconfined compressive strengths. *International Journal of Impact Engineering*, *12*(1), 1–7. https://doi.org/10.1016/0734-743x(92)90282-x.