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# Preliminary Study on Multilayer Bulletproof Concrete Panel: Impact Energy Absorption and Failure Pattern of Fibre Reinforced Concrete, Para-Rubber and Styrofoam Sheets

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**Abstract**

This manuscript presents the preliminary test results from the multilayer bulletproof concrete panel project. The purposed multilayer panel consisted of steel fibre reinforced concrete, Para-rubber and Styrofoam sheet. In this study, the failure patterns and energy absorption of each material with different thickness subjected to direct fire arm with 9 and 11 mm. bullets were investigated. The obtained information will later be used in designing the multilayer bulletproof concrete panel based on combination of energy absorption. The results showed that the energy absorption of each material increased with the increasing thickness. In case of FRC, the energy absorption also depended on fibre type and volume fractions. Comparing at the same thickness, FRC was the most effective energy absorption followed by Para-rubber and Styrofoam sheet.



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*Keywords:* Bulletproof concrete panel; Impact energy absorption; fibre reinforced concrete; Styrofoam sheet; Para-rubber sheet;

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## 1. Introduction and background

The damage of material subjected to high velocity impact can be divided into four types: flexural, perforation, penetration and spalling (Fig.1). In general, 'no perforation or complete penetration' is the main requirement for a bulletproof panel to pass most of the standardized tests [1]. However, in actual practice, beside from the perforation, flying debris such as spalling or scabbing, and bullet ricocheting can also cause unexpected damages. In order to make the buildings safer and prevent the secondary damage to occur, the bulletproof panels must not only prevent complete penetrating, it must also maintain its integrity to keep the hazardous debris to minimum. Therefore, the objective of this research is to develop the bulletproof concrete panel that is capable of preventing perforation, bullet ricocheting and concrete spalling by optimizing combinations of different material with different thickness the satisfy the above requirements.

Concrete is a brittle material, when subjected to impacted loading, severely broken and spalling at the front and back surfaces are often observed [2-3]. To improve the brittleness, short fibres were mixed into concrete (fibre reinforced concrete, FRC) [4-5]. With the ability of fibers to bridge across the cracks, the impact resistance of FRC is much more superior to that of plain concrete.

Although FRC offers excellent impact resisting property to the bullet proof panel, there are some properties that can be improved, for example, reducing weight and decreasing bullet ricocheting. In our previous study [6], the double layer concrete panels made of fibre reinforced concrete (FRC) and rubberized concrete (RC) were investigated and proofed to be able to prevent bullet perforation. However, because of the surface hardness of FRC layer, the ricocheting of bullets was still observed. Therefore, in this project, a multilayer system of three or more layers with combinations of soft and hard materials is proposed. The new system consists of FRC layers with different thickness at the outer front and back of the panel. The intermediate layers are inserted with soft materials like Styrofoam and Para-rubber sheets. The strong but thin front layer of FRC will allow a bullet to penetrate through with significant loss of energy. The middle layers will perform as a cushion to absorb the leftover kinetic energy prior to reaching the back layer (thicker FRC).

This paper described the experimental results from the early part of the project which consisted of basic information such as the kinetic energy absorption of each individual material with different thickness, and failure characteristics such as spalling diameter, penetration depth and diameter. In addition, effect of bullet size and fibre type were also included. After this study, the obtained results from this study will later be used in designing and optimizing the multilayer bulletproof concrete panel based on level of energy its can absorb.

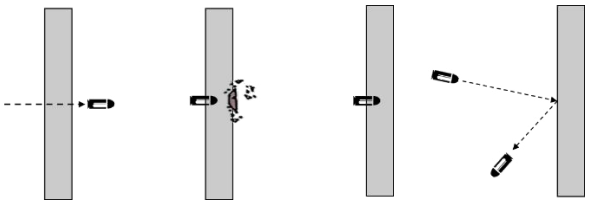


Fig. 1. (a) perforation; (b) spalling; (c) penetration; (d) ricocheting

## 2. Research methodology

### *2.1. Materials*

Materials used in the experiment consist of

- Portland cement type I, clean water, river sand (sieve size #16 - #50.)
- Two type of steel fibres (hooked-end and double hooked-end, Table 1).
- Para-rubber sheet (Table 2).
- Styrofoam sheet (Table 3).