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Foam/composite panels for protective aims – crashworthiness studies

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The motivation to undertake the work was development of passive protection for critical structural elements of some facilities exposed to possible terrorist attacks [5,7]. This issue is very important due to increased terrorist activities in recent years. The authors found that majority of terrorist attacks are bombing attacks. Integral part of those are explosives producing violent exothermic reactions induced by external effects. These reactions result in mechanical work through the evolution of highly compressed hot gases. The surrounding gas medium generates a sudden pressure jump, reaching values of tens of GPa [4]. To minimize the damage caused by the blast wave the most critical construction elements are covered with energy–absorbing elements. Presented research is focused on a development of multimaterial and multilayer protective panel able to absorb as much energy produced from the detonation process as possible. Therefore to study the problem some chosen composite panels with different combinations of layers were selected and tested both experimentally and numerically.

The investigated multilayer protective panels consisted of external aluminium sheet, glass fibre reinforced, carbon/epoxy fibre reinforced composites and metallic foam [4,6]. It was assumed, that two different phenomena will be responsible for minimization of shock wave effects: flow around the cylindrical panel and energy absorption by panel structure. The choice of such a layout was partially driven by experimental results showing very good crashworthiness of foam and composites assembled together [2,5,6,8]. Multilayer setup of the panel takes advantage of many different energy dissipation mechanisms such as compacting of metallic foam, composite failure due to delamination, fibre damage and matrix crushing.

The performed tests and analyses clearly revealed that a relatively small amount of high explosives placed [4], for example, in a briefcase can cause serious damage of supporting construction elements and prevents further usage of the entire building. Presented numerical and experimental results show that it is possible to develop passive protective panel, which provides the safe service of analysed structural elements, as well as whole buildings in the case of terrorist attack with high explosives.

The crashworthiness studies showed that the blast energy is mainly dissipated by mechanisms of metallic foam compacting, composite failure due to delamination, fibre damage and matrix crushing. Thanks to the high crashworthiness of the protective cover the pressure acting on the steel pillar was significantly reduced. Moreover the area of interaction between blast wave and protected structure was much smaller. In consequence the amount of energy absorbed by the supporting pillar was significantly lower when compared to the energy absorbed by the both studied multimaterial solutions: glass fibre reinforced and fibre reinforced carbon/epoxy composites and metallic foam.

Finally, it can be concluded that tested multimaterial and multicomponent structures can significantly reduce the destructive effect of the blast wave loading. Additionally, thanks to the advanced computational studies utilizing fluid–structure interactions [1,3,7] and optimization algorithms showed that further panel minimizations base on such variables like layers thickness, layers sequence and material type is possible.

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