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Characteristics of glass based energy absorbers exposed to the blast load

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Abstract

Energy absorbing materials can be used as a part of building structure to enhance its blast resistance, with positive impact on the safety of citizens. In the presented study, the new energy absorber based on expanded glass grains was subjected to the high strain rate loading using the Split Hopkinson pressure bar apparatus (SHPB) and to the blast load as a part of the sandwich structure. The influence of the binder amount on the attenuating properties of the material was evaluated. The dynamic response of 6 rectangular sandwich panel constructions (with different core designs) under blast loading was investigated. The objectives were to analyse the panels in terms of deformation and blast resistance and to determine the effect of different core set-ups on blast resistance enhancement of the entire structure. 5 types of core configurations, with almost identical areal density, were prepared and subjected to the blast wave generated by the detonation of 100 g of TNT equivalent explosive from the 100 mm distance. Overall blast resistance of the panel was determined using the certified methodology M-T0-B VTÚO 10/09 based on evaluation of the tension strain curves recorded by strain gages fixed at the back steel plate of the sandwich. The image analysis was used to quantify the damage of the concrete slabs. The best results were achieved in the case of stepwise graded core with decreasing grain size from the blast load epicentre.

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Keywords: Blast resistance; sandwich structure; blast load; blast energy absorbers; high strain rate; Split Hopkinson pressure bar

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1. Introduction

The core materials used in structures play a crucial role in the dynamic behaviour of the whole construction subjected to blast loading. The behaviour of sandwich structures under blast load was studied quite widely in the past two decades. Dharmasena et al. [1], Nurick et al. [2] and Li et al. [3] tested sandwich structures with a metallic honeycomb core material. Their results indicated that the parameters of core materials can effectively reduce the damage of the back face sheet. Tekalur et al. [4] investigated the dynamic response of sandwich structures with polymer foam cores. They concluded the significant reduction of damage when Z-direction pin reinforcements were implemented into the core material. Influence of varying core density on the blast resistance of sandwich panels based on crosslinked PVC cores was investigated by Hassan et al. [5] Experimental blast showed that damage within the sandwich panels becomes more severe as the density of the foam core is increased. Panels based on the lowest density foam (60 $kg{\cdot}m^{-3}$) did not exhibit any fracture or debonding over the range of impulses considered, instead absorbing energy through plastic deformation in the metal skins and compression of the foam core. In contrast, significant damage, cracking and debonding at the skinecore interface, was apparent in the higher density core systems [5]. The dynamic responses and blast resistance of sandwich plates with functionally graded close-celled aluminum foam cores were investigated by Liu [6]. Different graded sandwich plates under air blast loading were analysed in terms of deformation and blast resistance. The results demonstrate that relative to conventional ungraded plates subjected to identical air blast loading, the graded plates possess smaller central transverse deflection and superior blast resistance, with further improvement achievable by optimizing the foam core arrangement.

The present study focuses on the evaluation of shock wave attenuation characteristics of the newly developed blast energy absorber based on porous glass particles and on the blast resistance of sandwich composites with the core realized by mentioned absorber. The obtained results contribute to the knowledge needed for better core design of the structures for protection against blast.

2. Materials and methods

2.1. Specimen manufacture

Expanded glass particles (Trade name Liaver) with grain size of 0,25 to 2 mm were selected as the filler. Two-component solvent-free polyurethane system Leeson was chosen as a binder. Mix proportions of the mixtures prepared for the SHPB dynamic tests are summarized in Tab. 1. Sets of specimens with 3 different amounts of binder were prepared to evaluate the influence of the binder amount on the attenuating properties of the material. Small cylindrical specimens with 15 mm in diameter and 7 mm in height were made for the SHPB tests (see Fig. 1). The pre-prepared two-component binder was added to the filler. The mixture was thoroughly homogenized for 3 minutes and dosed into release-agent-treated silicone moulds. The specimens were let to solidify overnight, then unmoulded and stored. The bulk density was determined for all manufactured samples.

Fig. 1. Specimens to be tested by SHPB.

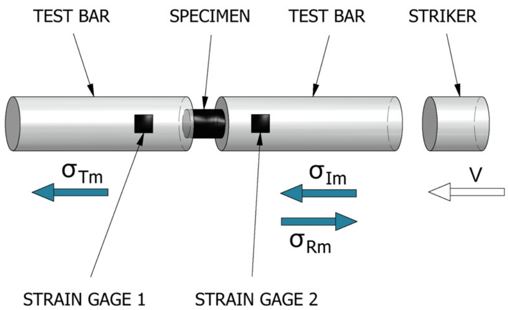

Fig. 2. Split Hopkinson pressure bar device – scheme.