Stiffened steel panels are commonly used to build structures requiring high strength and low inertia. The orientation or lay-out of the stiffeners can be done in many ways. In this paper, two types of stiffened panels are analysed for their response to impact force, with the objective of assessing their relative merits. One of them is the orthogonally stiffened panel (OSP) and the other is the rhombic stiffened panel (RSP). An instrumented impact hammer of variable mass is dropped on these simply-supported panels from different heights. The impact force and responses are recorded in a tape recorder and processed in a computer. These results are correlated with those predicted by the finite element software developed for this research. The correlation is observed to be good. The studies on the relative merits of the two types of panels indicate that the OSP is more efficient than the RSP. Until a more efficient stiffener lay-out is identified, the OSP can be recommended for impact-resistant panels.

**INTRODUCTION**

Plates are stiffened with ribs of different lay-out patterns to achieve high strength-to-weight ratio. Such stiffened panels are, invariably, used to build all types of vehicular structures such as ships, submarines, aircrafts, and spacecrafts, besides a variety of surface transport vehicles. The objective is to minimise the inertia without sacrificing the strength, so as to keep the dynamic response within the desired limits. This consideration is relevant even to stationary structures subjected to high intensity dynamic loads. But cost considerations limit the use of stiffened panels only for a few important fixed structures.

Impact loads are common in many industries, such as, automobile, aerospace, nuclear, defence, and offshore. Such loads can be either intentional or unintentional. Examples of intentional impacts are forge-hammering and punch-pressing in metal forming process, missile attacks during war, etc. Unintentional impacts can be due to accidental collisions, misguided missiles or aircrafts, etc. Structural resistance to such impact loads can be enhanced either by using stiffened panels or with multi-wall structures. Impact is, basically, an instantaneous load, concentrated over a small area and lasting for a few milliseconds. Its effect ranges from elastic transient vibrations to plastic deformations leading to buckling or crushing. The degree of importance of the structure controls the level of safety requirements considered for its design.

The orientation of plate stiffeners is, usually, unidirectional (along the length or breadth) or bi-directional depending on the functional requirements of the stiffened plate. Hofmeister and Felton investigated the behaviour of a variety of stiffener patterns in an attempt to improve their buckling strength. Houlston and Desrochers analysed the shock response of stiffened and unstiffened ship panels subjected to air-blast loading. They correlated the theoretical and experimental results with the objectives of establishing the accuracy of theoretical predictions. Khalil adopted the finite strip formulation for nonlinear analysis of stiffened plate structures subjected to transient pressure loading. The effects of large deflections and strain-rate sensitive yielding material properties were considered. The results obtained with this simple method were reasonably accurate when correlated with experimental results. Houlsten also recognised the finite strip method as a quick and simple method of design accuracy for blast-loaded plates and stiffened panels. Olsen presented a brief review of the developments relating to efficient modelling of blast-loaded panels and cylindrical shells. The topics covered included rigid-plastic and finite element modelling of orthogonally-stiffened plates, and finite strip modelling of longitudinally stiffened cylindrical shell structures. The modelling demanded small input data, and yet yielded realistic results. Dharaneepathy and Sudhesh carried out finite element studies on stiffened plates with different stiffener patterns in order to arrive at an optimal lay-out of stiffeners for minimising the blast effects. Corbett reviewed this research into the penetration and perforation of plates and cylinders by free-flying projectiles. In their ninety-page review, they covered experimental as well as theoretical studies on steel, concrete and composite structures. In this paper, the results of the theoretical and experimental studies on the impact response of two different types of stiffened panels are presented. The relative merits of the two panels, with reference to that of an equivalent mass unstiffened panel, are discussed. The validity of the numerical approach to predict the impact response is checked by correlating the predicted responses with those measured. Some details of the instrumented impact hammer, developed by the authors for free-fall tests, are furnished.

**EXPERIMENTAL STUDIES**

Two square steel panels of 1 m size with different types of stiffener layouts, have been chosen for this study. One of them is the conventional orthogonal layout (Fig 1).

The other one is the so-called rhombic stiffened panel (RSP) (Fig 2), observed to be ideal for blast-resistant panels. In both cases, a 6 mm mild steel (ms) plate, 1 m x 1 m, is stiffened by mild steel ribs of varying sizes such that the total weight is the same at 53.5 kg for both the panels. Each of these panels is simply-supported on a four-legged steel frame. An instrumented impact hammer, developed by the authors, is allowed to fall freely on the panel. The elevation and top view of the hammer, comprising a dynamic load cell and a mass, can be seen in Fig 3.