STRENGTH OF STIFFENED COMPOSITE PLATES WITH CUTOUT UNDER A COMBINATION OF AXIAL AND OUT-OF-PLANE LOAD

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Introduction

Stiffened plates are used in aircraft structures, ship structures and offshore oil platforms due to their high strength-to-weight ratio, high stiffness-to-weight ratio, excellent corrosion resistance, good fatigue strength, etc. Openings are provided in stiffened composite plates for access and service. These openings substantially influence the strength and stability of these panels. Stiffened composite plates are generally fabricated by bonding stiffeners to the flange plate and they fail by flange plate-stiffener debonding mode of failure [1,2] before reaching its full strength. Limited information is available on the behaviour of stiffened composite plates with opening [3]. The objective of this study is to fabricate stiffened composite plates with stiffeners as an integral part of the flange plate and to test under a combination of axial and out-of-plane load.

Test Details

Four stiffened composite plates, SCP1 without cutout and SCPO2, SCPO3 and SCPO4 with square cutout at the centre (Fig. 1) were fabricated by hand lay-up process. Four longitudinal stiffeners were cast on the flange plate.

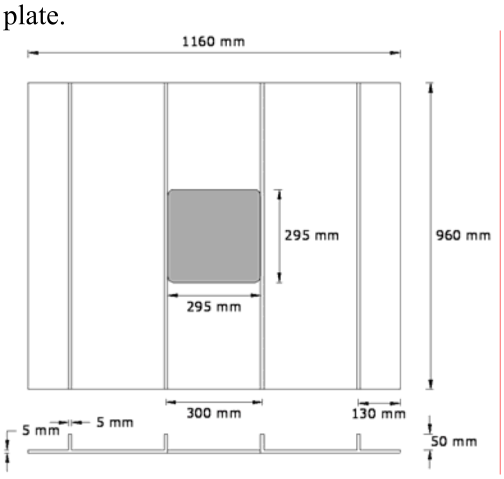

Fig. 1. Stiffened Composite Plate

Glass fiber fabric woven roving mat (WRM) of area density 610gsm and epoxy resin LY556 with hardener HY951 were used for the fabrication. A special lay-up structure was adopted such that the stiffeners become an integral part of the flange plate. Initial geometric imperfections are formed during fabrication of these panels and are measured (Fig. 2). The plate imperfection Δ_x, torsional imperfection of stiffeners Δ_{sy} and overall imperfection of the panel Δ_{sx} were calculated from the measured data. The initial geometric imperfections were within the tolerance limit [4]. Characterization of materials was done. The test rig is shown in Fig. 3. Panels SCP1 and SCPO2 were tested under axial compression. Panels SCPO3 and SCPO4 were tested under a constant 1/3rd and 2/3rd out-of-plane load with incremental axial load. Axial deformation, out-of-plane deflection and strains at critical locations were measured and the failure load was obtained from the load/axial deformation graphs.

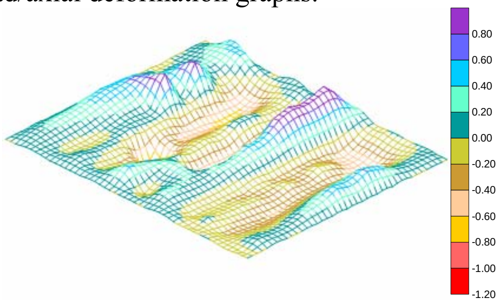

Fig. 2 Initial Imperfection Profile

Fig. 3 Test Rig

Finite Element Analysis

A finite element model using SHELL181 elements was developed for the analysis using FE software ANSYS 10. The same loading and simply supported boundary conditions as per the test setup were simulated in the analysis. Orthotropic material properties obtained from the characterization of materials were given as input. The actual values of measured imperfections were also generated in the geometry of the model. A non-linear static analysis was carried out employing Newton-Raphson and arc-length method to trace the load-displacement curve and to find the failure load.

Results and Discussions

Panels SCP1 and SCPO2 tested under axial load failed by stiffener buckling. Panels SCPO3 and SCPO4 tested under combined axial and out-of-plane load failed by stiffener tension (Fig. 4). The stiffeners were integral with the flange plate even after failure. Maximum axial deformation (Fig.5) and ultimate load (Table 1) obtained from FE analysis was compared with experimental data. The axial load carrying capacity of SCPO2 reduced by 15 % due to the central square cutout. The axial load carrying capacity of SCPO3 and SCOP4 reduced by 17 % and 43 % compared to SCPO2. FEA results compare well with the experimental data. The mode of failure is also predicted exactly by the developed FE model (Figs. 6 and 7).

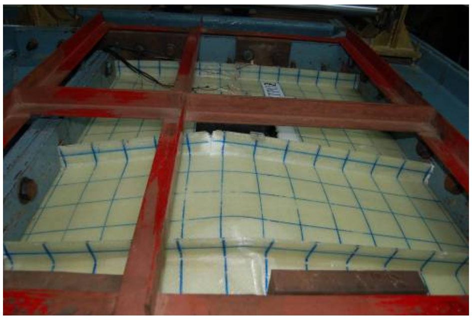

Fig. 4 Panel SCPO3 after Failure

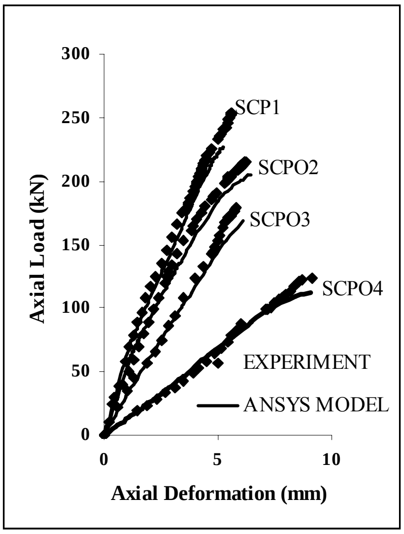

Fig. 5 Load/Axial Deformation Curves

Table 1 Ultimate Strength of Stiffened Composite Plates

Specimen	Ultimate Load (kN)			P_{FEA}/P_{Expt}
	Expt.	Reduction in Load	FEA	
SCP1	249	-	226	0.907
SCPO2	211	15%	204	0.967
SCPO3	176	17 %	169	0.960
SCPO4	121	43 %	112	0.926

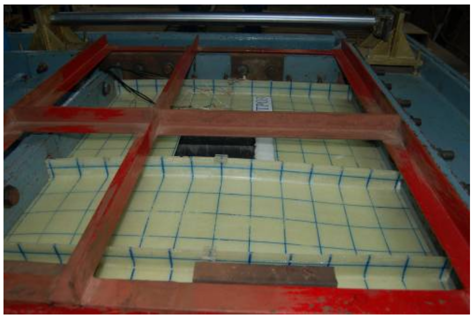

Fig.6 Deflection Pattern of SCPO4

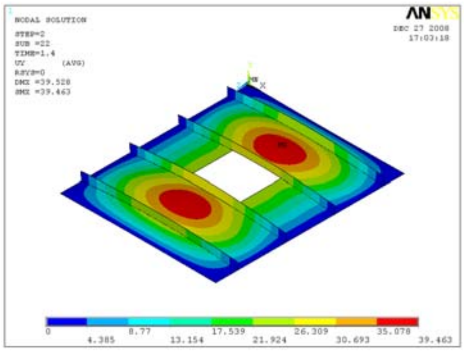

Fig.7 Deflection Contours of SCPO4 at Failure

Conclusions

The following conclusions were drawn based on the experimental and analytical studies

1. The presence of cutout and constant out-of-plane load considerably reduces the axial load carrying capacity of stiffened composite plates.
2. Developed FE model can be used to predict the load/deformation behaviour, ultimate load and mode of failure of stiffened composite plates.

References

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