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Dynamic Response of sandwich Plates

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Abstract: This paper presents the vibration analysis of sandwich panels and a comparison of natural frequencies using various theories. A simple software has been developed for calculating the natural frequency of panels. The software was validated by comparing the natural frequency using the software package NISA and ANSYS

Keywords**:** Sandwich plates, Dynamic response, Natural Frequency, Equivalent isotropic plate element.

I.INTRODUCTION

The engineering of modern composite materials has had a significant impact on the technology of design and construction. By combining two or more materials together it is able to make advanced composite materials which are lighter, stiffer and stronger than any other structural materials. Composite construction is favoured for all but the heaviest load intensities because, unlike skin-stringer construction, it is relatively free from buckling deformations at working loads.

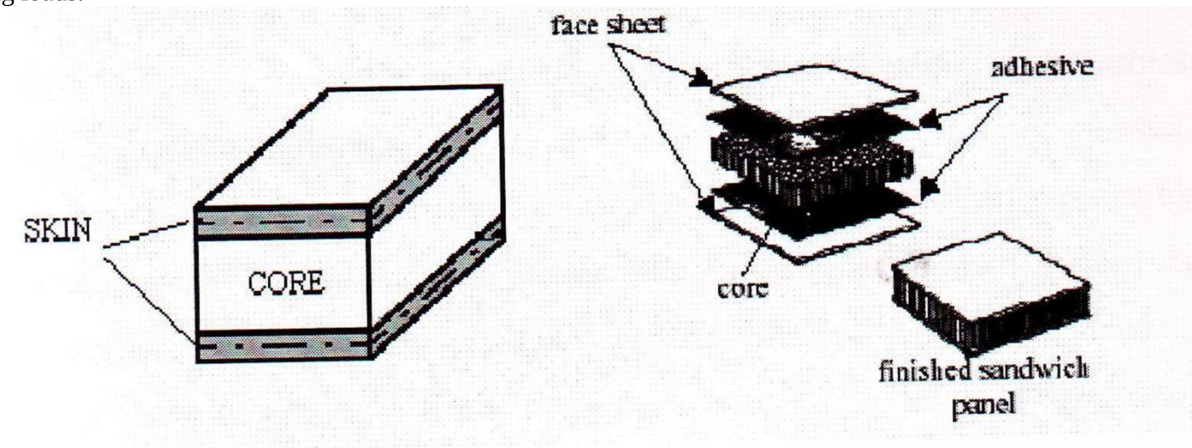

Fig.1.1. Sandwich construction

Sandwich construction is a special class of laminates where the inner layers are often thicker and composed of more flexible materials. Its concept is simply an extension of “I” beams in which bending is resisted by the flange and the shear is resisted by the web. Advantages that attract the designers into the sandwich construction are optimum strength to weight ratio, high buckling strength, optimum stiffness to weight ratio, good resistance, smooth or flat surface, thermal and acoustic versatility.

Light weight low cost materials and simple manufacturing processes will provide cost effective products. One of such design techniques which are commonly employed is the use of aluminium honeycomb sandwich design. Aluminium honeycomb sandwich plates are used in different areas of aerospace structures such as solar panel substructure, equipment mounting decks, heat shields, satellite antennae, airplane wing panels, helicopter blades, launch vehicle and space crafts.

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II. ANALYSIS METHEDOLOGY

The response of the laminated plates are investigated by following two approaches

Equivalent single layer theory.

In this approach the composite laminate was considered as a homogeneous material where the effect of constituent materials is treated as average properties of composites. The classical plate theories like Kirchooff's theory and Mindlin's theory can be used for the analysis of composite laminate for stresses.

Three dimensional elasticity theory (3-D)

Layered analysis in which layer wise displacements are calculated. In the layer wise theory, displacements are expanded within each layer using Lagrangian interpolation. In the analysis of composite laminates with embedded delamination, free edges or regions of 3-D stress fields, theory based on 3-D kinematics is used to develop an efficient computational model.

III. STATIC RESPONSE OF SANDWICH PLATES

Static analysis was carried out to determine the deflection of rectangular plate (0.5mx0.5m & 0.5mx0.4m) with sandwich plate element (shell99). The equivalent isotropic plate element thickness was calculated and isotropic 8 nodded shell element (shell93) was used for the analysis. Both the above elements consider the shear deformation.

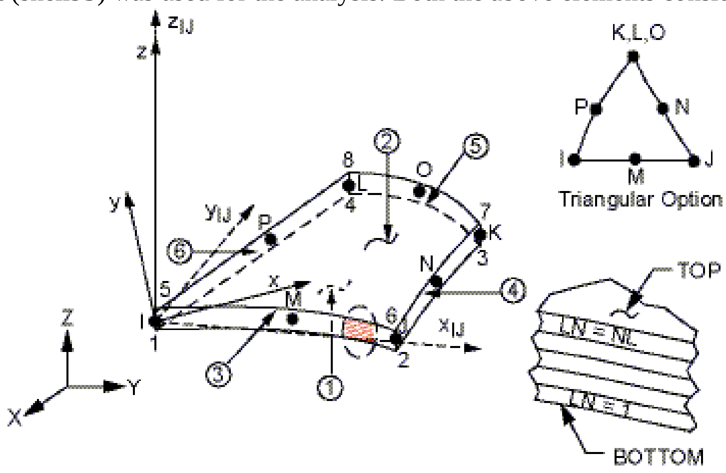

Fig.2. shell99

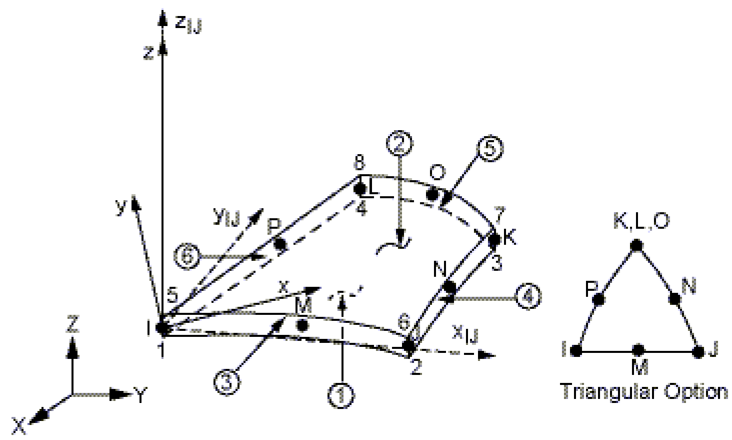

Fig.3 shell93

The analysis was carried out for different skin thickness by keeping the core thickness (30mm) same and for different core thicknesses by keeping the skin thickness (1.2mm) same shows that the deflection obtained from the isotropic plate element with equivalent single-layer was less than the deflection obtained from sandwich element. The reason being, equivalent thickness evaluation, the transverse shear strengths of the core is not considered. The shear deformation due to this material layer is neglected. The shear deformation occurring in sandwich panel is (Ks x P x L) / (h x G_C) Where, K_s = Factor for the support conditions

h = Total depth of the beam

G_C = Shear Rigidity

P = Load acting on unit width beam

L = Span of beam

The deflections obtained from the finite element analysis is compared with the deflection obtained from the developed software which uses the analysis steps in Aurther and Leissa [12] and the results were very near to :he finite element analysis using isotropic element. This software can e used for preliminary deflection checking to select the cross section.

Table 1: Deflection of a plate 0.5m xO.5m, core 30mm with central point load 2500N and all edges pinned

SKIN (mm)	Equivalent thickness (mm)	Equivalent mass (kg/m3)	Defln using sandwich element (mm)	Defln using equivalent element (mm)	Percentage difference
0.18	9.945	309.125	1.386	1.194	13.85
0.3	11.82	316.875	0.839	0.714	14.89
0.5	14.08	345.64	0.505	0.426	15.64
0.8	16.57	394.93	0.314	0.267	14.97
1.0	17.9	427.48	0.249	0.210	15.66

Table 2:Deflection of a plate 0.5m xO.5m, core 30mm with central point load 2500N and all edges fixed

SKIN (mm)	**Equivalent thickness (mm)**	**Equivalent mass (kg/m3)**	**Defln using sandwich element (mm)**	**Defln using equivalent element (mm)**	**Percentage difference**
0.18	9.945	309.125	0.723	0.574	21
0.3	11.82	316.875	0.442	0.344	22
0.5	14.08	345.64	0.269	0.205	23
0.8	16.57	394.93	0.169	0.127	25
1.0	17.9	427.48	0.134	0.102	24
1.2	19.14	459.05	0.112	0.084	25

Static Deflections of Sandwich Beams

The developed software uses the theory given in J.N Reddy [10] and the deflections obtained for a hinged beam with central point load was compared with the deflections obtained from ANSYS by using the sandwich element shell99. The results were further checked with NISA by using composite element (NKTP 33). Keeping the core thickness as 30mm, the skin thickness was varied and the results obtained were tabulated in table 3 and deflection comparisons are given in fig.4.

Table 3: Deflection of a beam having width 0.05m and span 0.25m simply supported with central pt load 1000N

CORE (mm)	SKIN (mm)	Deflection ANSYS (mm)	Deflection NISA (mm)	Deflection Using JNR (mm)	Percentage difference
30	0.18	1 .243	1.264	1.142	9.6
30	0.3	0.753	0.789	0.716	9.3
30	0.5	0.453	0.503	0.459	8.7
30	0.8	0.282	0.3395	0.315	*7.2*
30	1.0	0.224	0.284	0.267	6.0
30	1.2	0.185	0.247	0.2344	5.1
30	1.5	0.146	0.208	0.202	2.9

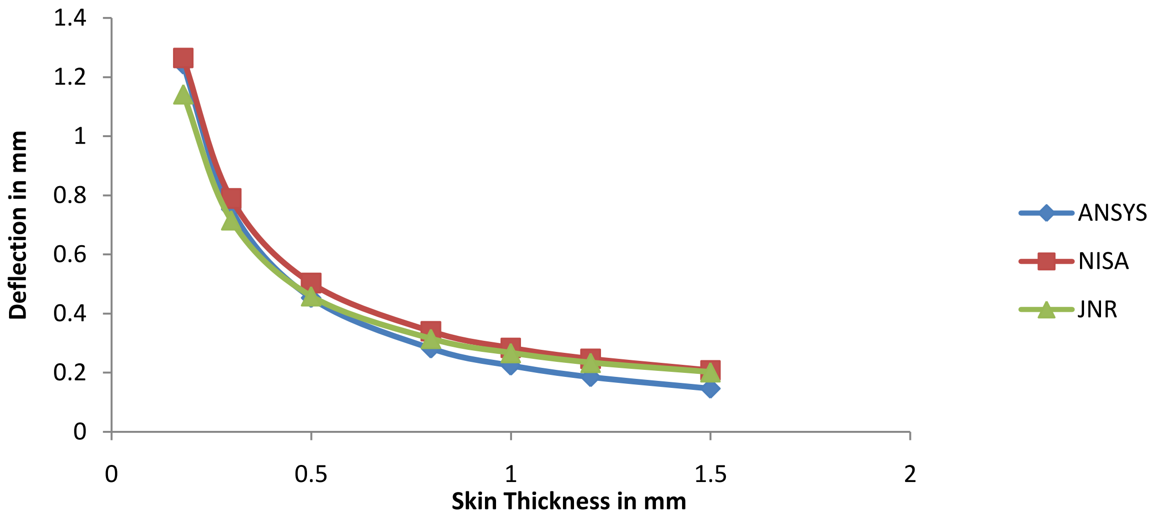

Fig 4. Deflections for sandwich beam using NISA, ANSYS and J.N. Reddy

IV. VIBRATIONAL RESPONSE OF SANDWICH PANELS

INTRODUCTION

The behaviour of composite plate under dynamic conditions is essential because the loading can cause severe damage during vibrations. Free vibration analysis of sandwich panel was conducted using shell99. Block Lanczos mode extraction method was used, which is an advanced form of Lanczos recursive method and its algorithm is found by Grimes et.al [11]. It is combined with Strum sequence checks. Since its convergence is faster than subspace eigen value method and the problem is small, Block Lanczos method is used for analysis. The same analysis was carried out using NISA and got the same results. An equivalent plate analysis was conducted using ANSYS and the results were compared with the developed software which uses the analytical solution methods in Leissa. The results obtained from

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NISA & ANSYS gave the same values and the error was less than 1%. The variation for equivalent plate analysis using developed software was 5% for simply supported condition and 8% for fixed conditions (Tables 4 to 5). As the thickness of the core decreases there is comparable reduction in the error (Table 6 &7), but only a little variation is happening for the skin sheet thickness variation (Table 4&5). The comparisons of the natural frequencies for different parameters are given in fig.5.

Table 4. Natural frequency of plate 0.5m x0.5m, core 30mm with all edges pinned

SKIN (mm)	Eq.thick. (mm)	Eq. mass (kg/m3)	Natural freq. sandwich element (Hz)	Natural frequency using isotropic element (Hz)	Percentage difference
0.18	9.945	309.125	533.6	558.1	4.6
0.3	11.82	316.875	623.8	654.0	4.8
0.5	14.08	345.64	708.3	743.8	5.0
0.8	16.57	394.93	777.4	813.1	4.6
1.0	17.9	427.48	807.2	846.4	4.8
1.2	19.14	459.05	830.2	871.8	5.0

Table 5. Natural frequency of a plate 0.5m x0.5 m, core 30mm with all edges fixed

SKIN (mm)	Equivalent thickness (mm)	Equivalent mass (kg/m3)	Natural frequency using sandwich element (Hz)	Natural frequency using isotropic element (Hz))	Percentage difference
0.18	9.945	309.125	957.5	1023.5	6.8
0.3	11.82	316.875	1115.3	1199.7	7.5
0.5	14.08	345.64	1262.1	1364.5	8.1
0.8	16.57	394.93	1380.8	1497.9	8.5
1.0	17.9	427.48	1431.4	1551.0	8.3
1.2	19.14	459.05	1470.4	1598.2	8.7

Table 6. Natural freq. of a plate 0.5m x0.5m skin 1.2mm with all edges pinned

Core (mm)	Equivalent thickness (mm)	Equivalent mass (Kg/m3)	Natural frequency using sandwich element (Hz)	Natural frequency using isotropic element (Hz))	Percentage difference
06.0	7.22	987.79	226.0	227.2	0.5
08.0	8.49	856.11	284.6	286.7	0.7
10.0	9.67	765.61	341.5	345.2	1.1
15.0	12.37	626.89	477.0	486.2	1 9
20.0	14.79	547.43	603.3	620.4	2.8
25.0	17.03	495.66	720.9	748.7	3.9

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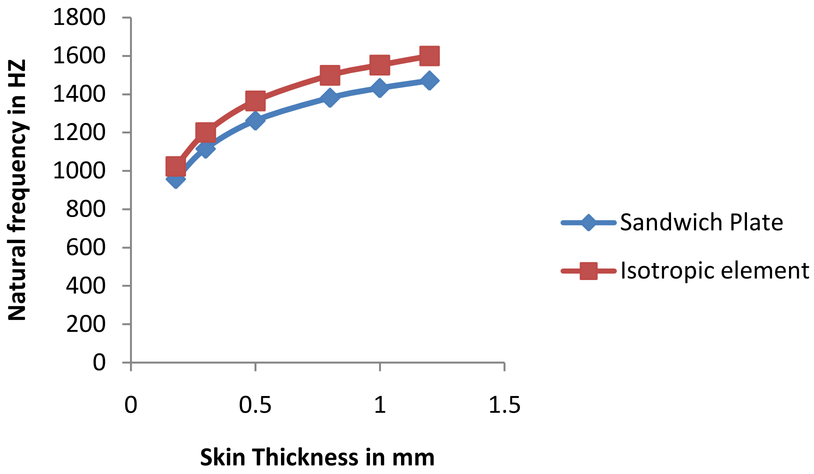
Table7. Natural frequency of a plate 0.5m x0.5m, skin 1.2mm with all edges fixed

Core (mm)	Equivalent thickness (mm)	Equivalent mass (kg/m3)	Natural frequency using sandwich element (Hz)	Natural frequency using isotropic element (Hz))	Percentage difference
06.0	7.22	987.79	414.6	416.5	0.5
08.0	8.49	856.11	522.0	525.6	0.7
10.0	9.67	765.61	625.9	633.1	1.2
15.0	12.37	626.89	870.5	892.0	2.5
20.0	14.79	547.43	1092.6	1138.1	4.2
25.0	17.03	495.66	1292.4	1373.0	6.9



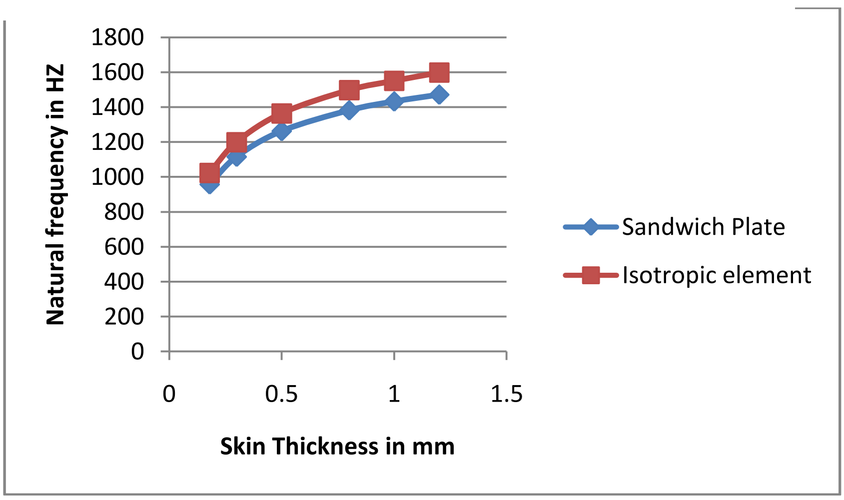


Fig.5. Natural frequencies of Sandwich element: and equivalent isotropic element for fixed ends

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V. CONCLUSIONS

In this report, a brief study of static analysis of sandwich beams and panels were considered with NISA. ANSYS and theoretical calculation from J.N Reddy. The-natural frequencies of sandwich panel were considered with different core and skin materials and thickness. The comparison of results with the developed software using equivalent thickness method and the ANSYS showed very comparable results and this software is found to be very useful for preliminary design. The main advantage of this software is that the calculations are very simple and the input data can be varied very easily to check the natural equivalent thickness and natural frequency

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