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Credence Of A Novel Analytical Method Forthe Determination Of Stiffness Of Simply Supported Sandwich Plates With Corrugated Core By Experimentation

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Abstract: *The paper presents a laboratory confirmation of an analytical model for the analysis of sandwich plates with corrugated cores of different forms. The Flexural strength of the plate is determined as the ratio of maximum bending moment to the maximum deflection. The experimental result was compared to the results of an analytical method described in this work. In the analytical model a unit cell of the sandwich plate is used to obtain the required geometrical properties of the composite member. Though it could be applied for other support and loading system, a four point loading system with a simply support on two opposite sides is considered in the work. Steel plate was used as the face and core material. The cores considered are Triangular, Trapezoidal, sinusoidal and rectangular for the five sandwich plates tested in the laboratory. The results were comparable within 10% and the model which is a table method is recommended for use in sandwich plate problems.*

Keywords: *sandwich plates, corrugated core, flexural strength, moment, deflection.*

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I. INTRODUCTION

Sandwich structures have been in usage as far back as the 19th century. Most researchers have used s equivalent plate model to find effective stiffness.(Libove and Huka 1951) are pioneers in this area of study. (Lok and Cheng 2000) determined the Maximum plates deflection of truss-core sandwich panel made of aluminum alloy using the homogenous equivalent thick plate approach. (Luo et al 1992) evaluated the bending stiffness of corrugated board. (Carlsson et al 2001) used the first shear deformation laminated plate theory to analyze the elastic stiffness of corrugated board sandwich panels. The importance of core shape on transverse shear moduli was further demonstrated by (Nordstrand et al 1994), using lateral compression, three point bending and simple shear tests. (Lu and Zhu 2001) determined the elastic constants of corrugated board panels. (Valdevit et al 2006) carried out an analytical and experimental study on the flexural response of steel sandwich panels with corrugated core under both longitudinal and transverse loadings. (Tian and Lu 2005) considered optimum designs of corrugated core sandwich panels and hat-stiffened panels under longitudinal compression for minimum weight. (Buannic et al 2003) and (Biancolini 2005)] combined homogenization and finite element methods to determine the deflection of corrugated core sandwich panels. (Marinez et al 2007) were the first authors to develop an equivalent plate model for composite corrugated-core sandwich panels using micromechanics approach. They idealized the composite corrugated sandwich plate as an equivalent orthotropic thick plate continuum. (Mckee et al 1962) determined the bending stiffness for 3 point and 4 point loading tests. (Gilchrist et al 1999) used finite element method to determine the bending and twisting of a corrugated board. (Seong et al 2010) determined the bending stiffness result of sandwich plates bidirectional corrugation core while (Magnucki et al 2011) worked on Strength of sandwich beams with corrugated core under pure bending These works together with the recommendation of (Orumu 2003) open broader perspectives in this area of knowledge and call for deeper research into the development of a simple table method for analysis of sandwich plates. This paper therefore develops an analytical method of determining the flexural strength of a sandwich plate with a corrugated core and presents results from experimental test to confirm the accuracy of the model. The striking results between the experimental and theoretical works give credence to the analytical model so developed. .

II. METHODOLOGY

The sandwich plates with corrugated core are analyzed for deflection bending moment and shear force for distribution. The sandwich plate is first transformed into an equivalent isotropic plate using the analytical model from parallel axis theorem for second moment of area. The bending response is then calculated using the simple beam theory, from where the deflection is also computed, having known the stiffness. The geometric parameters and the laminated construction in the sandwich plate are symmetrically varied to determine their effect on bending responses.

2.1 Analytical Formulations

The sandwich plate with corrugated core consists of a steel corrugated core and too thin skin or plates bonded together. The analysis is carried out by considering the section shown in fig. 2.1. It consists of two thin faces labeled 1 and 2 and two inclined webs labeled 3 and 4. Both the faces and the web are made of steel.

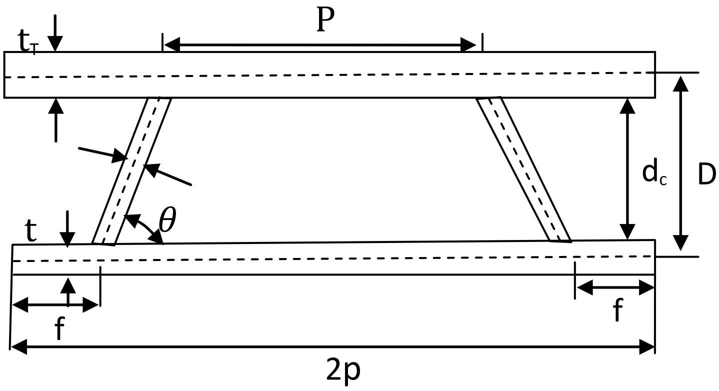

fig 2.1 Showing a generalized a unit cell

The analysis is performed using a unit cell of the type shown in fig 2.1. The unit cell is made of two thin faces (indicated as members 1 and 2 in fig 2.1) and two inclined webs (indicated as members 3,4,5 and 6 in fig 2.2) as the core.

The material in faces and the webs are steel laminates. The unit cell is aligned with the x-direction. It is symmetric with respect to the xz plane and normal to the corrugation direction is the y-direction.

2.2 Geometric Parameters

The following are the geometric parameters of the section

2p: pitch of the unit cell
d: distance between the center of the top and that of the bottom
t_{TF}: thickness of top face
t_{BF}: thickness of bottom face
t_C: thickness of web
θ: inclination of web
d_C: depth of core = $d - \frac{1}{2} t_{TF} - \frac{1}{2} t_{BF}$
s: length of web = $d_C/\sin\theta$
f: Location of web on either side of the bottom face = $\frac{1}{2}(p - {}^{d}/_{\tan\theta})$

For the section considered, the maximum web inclination angle is 90^0, which corresponds to $f = 0.5p$ and produces a rectangular core. The minimum web inclination angle is given by $\theta_{mm} = \tan^{-1}\left(\frac{d}{P}\right)$, which corresponds to $f = 0$ and produces a triangular core.

The cross-sectional area A_θ of the section with web inclination angle θ is given by the summation of the flange area and web area

Area of web = $2d_c\, t_c/\sin\theta$ ………………………………………………2.1
Area of flange = $(t_T+t_B)\, 2p$…..…………………………………………..2.2
Area of section = $A_\theta = 2p(t_{TF} + t_{BF})+2d_c(t_c/\sin\theta)$………… ……………. 2.3

2.3 Moment of Inertia for Corrugated Laminated plate

If laminated top & Bottom

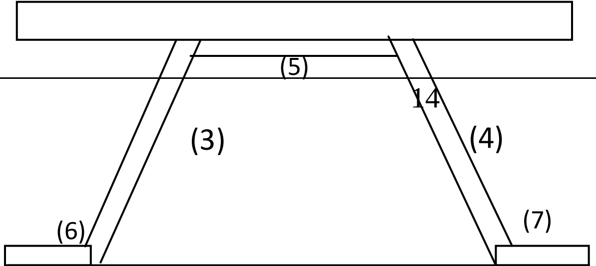

Fig. 2.2: Shows a unit cell of the corrugated core

2.4 Moment of inertia using the parallel axis theorem

For profiles of various web inclination

$$I_{zz}^{xx} = k[I_1+A_1h_1^2] + [I_2+A_2h_2^2] + [I_3+A_3h_3^2] + [I_4+A_4h_4^2] + [I_5+A_5h_5^2] + [I_6+A_6h_6^2] + [I_7+A_7h_7^2] \qquad 2.4$$

and Here 1 = 2; 5 = 6 + 7; 3 = $A_3h_3^2 = A_4h_4^2 = 0$

$$\therefore I_{zz}^{xx} = 2\,[I_1+A_1h_1^2] + 2I_3 + 2\,(I_5 + A_5h_5^2)] \qquad 2.5$$

$$I_{zz}^{xx}/2\text{p} = \frac{1}{p}[I_1+A_1h_1^2] + (I_3) + (I_5+A_5h_5^2)] \qquad 2.6$$

$$(A_1h_1I_1) = \frac{2pt^3}{12} + \frac{2pt\,(\frac{d+t}{2} - \frac{t}{2})^2}{1}$$

$$= [\frac{pt^3}{6} + \frac{ptd^2}{2}]$$

$$I_3 = \frac{t(d-t)^3}{2}$$

$$(I_5+A_5h_5^2) = \frac{2ft^3}{12} + \frac{2ft\,(\frac{d+t}{2} - \frac{3t}{2})^2}{1} = \frac{ft^3 +^3}{6}\frac{ft\,(d-2t)^2}{4}$$

$$\therefore I_{zz}^{xx}/\text{unit width} = \frac{t^3}{6} + \frac{td^2}{2} + \frac{t(d-t)^3}{12\text{p}} + \frac{ft^3}{6\text{p}} + \frac{ft(d-2t)^2}{4\text{p}}$$

$$\therefore I_{zz}^{xx}/\text{unit width} = \frac{t^3}{6} + \frac{td^2}{2} + \frac{t(d-t)^3}{12\text{p}} + \frac{ft^3}{6\text{p}} + \frac{ft(d-2t)^2}{4\text{p}} \qquad 2.7$$

I_{zz}^{yy} should be taken as I_{yy}.

$$I_{zz}^{yy} = [I_1+A_1y_1^2]\ \text{x}\frac{2P}{2p} + [I_2+A_2y_2^2]\ \text{x}\ \frac{2P}{2p} + [I_3+A_3y_3^2]\frac{t}{2p} + [I_4+A_4y_4^2]\ \frac{t}{2p} + [I_5+A_5y_5^2]\frac{2f}{2p} + [I_6+A_6y_6^2]\ \frac{f}{2p} + [I_7+A_7y_7^2]\ \frac{f}{2p}$$

following the same characteristics above

1 = 2, 3 = 4 + 5 = 6 +7

$$I_{zz}^{yy} = 2\,[I_1+A_1y_1^2]\,[2I_3]\,\frac{t}{2p} + 2\,[I_5+A_5y_5^2]\ \text{x}\ \frac{2f}{2p}$$

$$\frac{I_{zz}^{yy}}{2p} = I_{zz}^{yy}/\text{unit Lenght} = \frac{1}{p}\,[(I_1+A_1y_1^2)+I_3\frac{t}{2p} + [I_5+A_5y_5^2]\ \text{x}\ \frac{f}{p}$$

$$= \frac{I}{p}\,[\frac{2pt^3}{12} + {}^{2\text{pt}}(\frac{d+t}{2} - \frac{t}{2})^2 + \frac{t\,(d-t)^3}{12}\ \text{x}\ \frac{t}{2p} + [\frac{2ft^3}{12} + \frac{2ft(\frac{d+t}{2} - (\frac{3}{2}t)^2}{12}\,]\,\frac{f}{p}$$

$$= \frac{t^3}{6} + \frac{td^2}{2} + \frac{t\,(d-t)^3}{24p2} + \frac{f^2t^3}{6p} + \frac{f^2t(d-2t)^2}{2p}$$

$$I_{zz}^{yy} = \frac{t^3}{6} + \frac{td^2}{2} + \frac{t^2\,(d-t)^3}{24p^2} + \frac{f^2t^3}{6p} + \frac{f^2t(d-2t)^2}{2p} \qquad 2.8$$

Thus the flexural rigidity of the sandwich beam with the corrugated core can be written as

$$D_X = EI_y \qquad D_y = EI_X$$

where E is Young's modulus.

2.5 Theoretical setup

A four point loading system consist of two action loads acting on the structure together with two corresponding reactions. The spacing in this work is equidistant, which implies that the loads are positioned at one-third span from each end of the simply supported plate.

The maximum bending moment and deflection of this set up is given as

$$\text{Mmax} = \frac{\text{PL}}{6} \qquad 2.9$$

$$\Delta\text{max} = \frac{PL^3}{86.4\ \text{EI}} \qquad 2.10$$

$$\frac{\text{Mmax}}{\Delta\text{max}} = \frac{14.4\text{EI}}{L^2} \qquad 2.11$$

Where P is the total load on the structure and L is the span from support to support.

2.6 Experimental Set Up

The last section introduced a model approach to investigate the influence of several parameters on an equivalent sandwich plate. This section deals with experimental results which are compared to the model. On the whole six sandwich plates with corruption of various core parameters were produced. Steel plates where details for the material properties can be found were used.

All experiment where conducted with a reactant frame set up in the concrete laboratory of Niger Delta University. In all experiments, displacements transverse to the corruptions were applied. The derivation for the unit cell shows that the rotation about the x-axis in the middle plane of the sandwich plate with corrugated core is hinged at both sides.

For all corrugation and boundary condition displacements with defined steps were prescribed. For all experiment the force displacement curves were recorded. Furthermore, the load circle was interrupted at each step for 5 seconds which allowed that a photo can be taken.

2.61 Production of the sandwich plates

Pate 1: A view of Preparation of corrugates to be glued to Laminates using Steel to Steel Epoxy Resin

Plate 2: Sandwich plates with sinusoidal corrugated core

Plate 3: Sandwich plates with triangular corrugated core

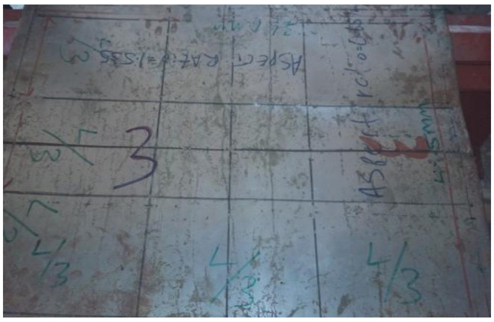

Plate 4: Plan view of sandwich plates with 90^0 corrugated core

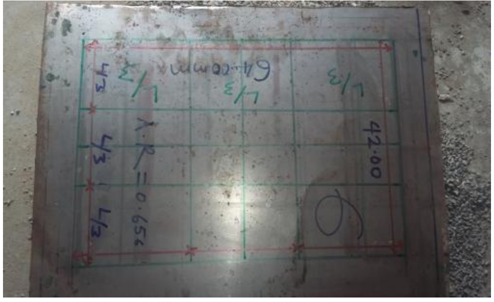

Plate 5: Plan view of sandwich plates corrugated core type 6

III. COMPARISON TO MODELS

The next step is a detailed numerical comparison of the experimental results with the equivalent model. This section present result models considering the complete structure which was tested instead of simulating only a unit cell. Thereby, the values from experiments are given in the table of this section.

A simple code is written here to easily handle the problems. One needs to only input the required variables to match a trapezoidal, triangular or rectangular core to obtain the right results.

Table 3.1 Simple code for analysis of sandwich plates with corrugated cores with transverse loads at 1/3 span from each support.

Line	Action
B1	Input tt
B2	0.6 or any thickness
B3	Input tb
B4	0.6 or any thickness
B5	Input tc
B6	0.6 or any thickness
B7	Calculate d
B8	=B10-B2/2-B4/2
B9	Input df
B10	25 or any total depth of plate
B11	Input f
B12	=75/4 or any f
B13	Input b
B14	0 or any b
B15	Input 2p
B16	75 or any length of unit cell
B17	Calculate I/Length
B18	=1/12*(B2^3+B6^3+B4^3+3*B2*(B10-B2)^2+3*B4*(B10-B4)^2)
B19	Calculate I1
B20	=B16*B2^3/6+B16*B2/2*(B10-B2)^2
B21	Calculate I2
B22	=B16*B4^3/6+B16*B4/2*(B10-B4)^2
B23	Calculate I3
B24	=B12*B6^3/6+B12*B6/2*(B10-2*B2-B6)^2
B25	Calculate I4,5
B26	=B12*B6^3/12+B12*B6/4*(B10-2*B4-B6)^2
B27	Calculate I6,7
B28	=B6/12*(B10-B2-B4)^3+(B14*B6^3/12+B14*B6/4*(B10-2*B4-B6)^2)*0
B29	Calculate Itotal
B30	=B20+B22+B24+2*B26+2*B28
B31	Calculate I/2P virtual
B32	=B10^3/12
B33	Calculate I/2P
B34	=B30/B16
B35	Input Young modulus E N/mm2
B36	=200000
B37	Input P
B38	0
B39	Input L
B40	510
B41	Input W
B42	770
B43	Calculate M
B44	=(B38*1000/B42/2)*B40/3
B45	Calculate def E=18000
B46	=4*(B38/2/B42*1000)*B40^3*0.03549/$B$36/$B$34
B47	Calculate M/W
B48	=B44/B46

IV. RESULTS AND DISCUSSIONS

When parameters of the produced sandwich platers given in each table was imputed in the code above, the analytical (theoretical) results were found and reported. The experimental measurements are also reported in the tables given below.

Table 4.1: Experimental result of plate 1 subjected to transverse leading

Plate 1 with Rectangular core								
Load KN	Length mm	**Width mm**	**Moment Analytical**	**Max Moment**	**Deflection Analytical**	**Deflection Exp**	**Moment/Def Analytical**	**Moment /Def Exp**

0.00	510.00	770.00	0.00	0.00	0.00	0.00	#DIV/0!	#DIV/0!
0.73	510.00	770.00	82.34	80.88	0.10	0.09	823.35	898.87
1.47	510.00	770.00	164.67	161.77	0.20	0.20	823.35	808.85
2.20	510.00	770.00	238.77	242.65	0.29	0.30	823.35	808.85
2.93	510.00	770.00	321.11	323.54	0.39	0.42	823.35	808.83
3.66	510.00	770.00	403.44	404.42	0.49	0.50	823.35	808.84
5.13	510.00	770.00	568.11	566.19	0.69	0.75	823.35	754.92
6.59	510.00	770.00	724.55	727.96	0.88	0.90	823.35	808.84
8.06	510.00	770.00	889.22	889.73	1.08	1.04	823.35	855.51
9.53	510.00	770.00	1053.59	1051.50	1.28	1.35	823.35	778.88
10.99	510.00	770.00	1210.76	1213.27	1.47	1.57	823.35	772.78
12.46	510.00	770.00	1374.11	1375.04	1.67	1.77	823.35	776.88
13.92	510.00	770.00	1539.57	1536.81	1.87	1.87	823.35	821.82
14.29	510.00	770.00	1580.60	1577.25	1.92	3.00	823.35	525.75
14.65	510.00	770.00	1613.76	1617.69	1.96	4.85	823.35	333.55

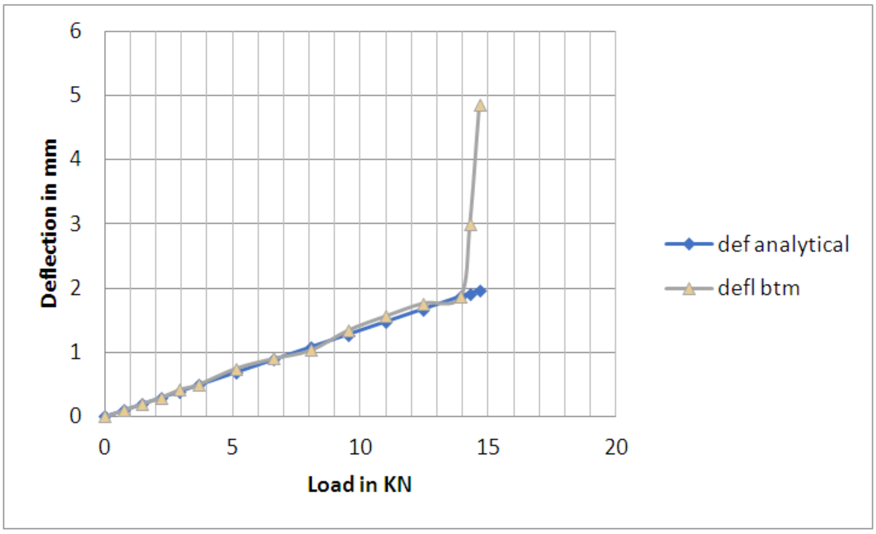

Fig 4.1: Analytical and Experimental Deflections (mm) vs Load (KN)

Table 4.2: Experimental result of plate 2 subjected to transverse loading

Plate 2 with Rectangular core								
Load KN	Length mm	**Width mm**	**Moment Analytical**	Max Moment	deflection analytical	deflection Experimental	Moment/def analytical	Moment /def Exp
0.00	610.00	820.00	0.00	0.00	0.00	0.00	#DIV/0!	#DIV/0!
0.37	610.50	820.00	54.94	45.46	0.08	0.06	574.28	757.67
0.73	610.50	820.00	91.88	90.92	0.16	0.11	574.28	826.54
1.10	610.50	820.00	137.83	136.38	0.24	0.21	574.28	649.43
1.47	610.50	820.00	183.77	181.84	0.32	0.31	574.28	586.58
1.98	610.50	820.00	246.94	245.48	0.43	0.42	574.28	584.48
2.34	610.50	820.00	292.88	290.94	0.51	0.55	574.28	528.98
2.71	610.50	820.00	338.84	336.40	0.59	0.58	574.28	576.55
3.33	610.50	820.00	413.48	413.69	0.72	0.68	574.28	608.37
3.66	610.50	820.00	453.68	454.60	0.79	0.72	574.28	631.39
4.03	610.50	820.00	499.62	500.06	0.87	0.77	574.28	649.43
4.76	610.50	820.00	591.51	590.98	1.03	0.76	574.28	777.61
5.13	610.50	820.00	637.45	636.44	1.11	0.92	574.28	691.78
5.86	610.50	820.00	729.34	727.36	1.27	1.09	574.28	667.30
6.59	610.50	820.00	815.48	818.28	1.42	1.27	574.28	644.31
8.06	610.50	820.00	999.25	1000.12	1.74	1.50	574.28	668.08
9.16	610.50	820.00	1137.07	1136.50	1.98	1.69	574.28	672.48
10.26	610.50	820.00	574.28	1272.88	2.22	1.90	574.28	669.94
12.09	610.50	820.00	1498.87	1500.18	2.61	2.17	574.28	691.33
12.82	610.50	820.00	1590.76	1591.10	2.77	2.36	574.28	674.20
13.56	610.50	820.00	1682.64	1682.02	2.93	2.65	574.28	634.72
13.92	610.50	820.00	1728.58	1727.48	3.01	3.32	574.28	520.32

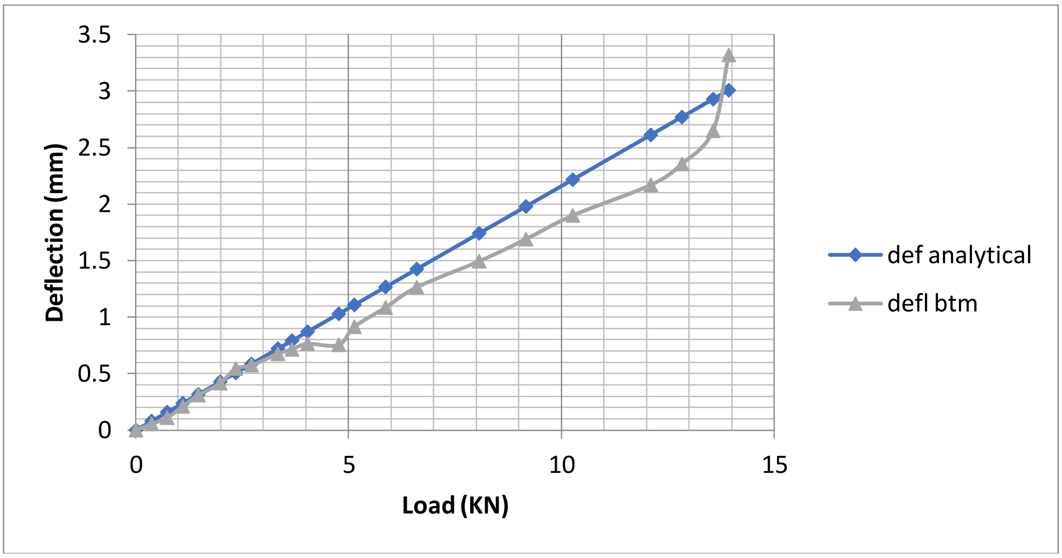

Fig. 4.2: Analytical and Experimental Deflections (mm) vs Load (KN) for plate 2

Table 4.3: Experimental result of plate 3 subject to transverse loading

Plate 3 with Trapezoidal core								
Load KN	Length mm	**Width mm**	**Moment Analytical**	Max Moment	deflection analytical	deflection Experimental	Moment/def analytical	Moment /def Exp
0.00	590.00	760.00	0.00	0.00	0.00	0	#DIV/0!	#DIV/0!
0.37	590.00	760.00	46.87	47.40	0.08	0.025	585.93	1896.07
0.73	590.00	760.00	93.75	94.80	0.16	0.05	585.93	1896.07
1.10	590.00	760.00	140.62	142.21	0.24	0.12	585.93	1185.05
1.47	590.00	760.00	187.50	189.61	0.32	0.175	585.93	1083.47
1.83	590.00	760.00	234.37	237.01	0.40	0.235	585.93	1008.55
2.20	590.00	760.00	287.11	284.41	0.49	0.295	585.93	964.11
2.56	590.00	760.00	333.98	331.81	0.57	0.39	585.93	850.80
3.30	590.00	760.00	427.73	426.62	0.73	0.59	585.93	723.08
4.03	590.00	760.00	521.48	521.42	0.89	0.825	585.93	632.02
4.76	590.00	760.00	615.23	616.22	1.05	1.065	585.93	578.61
5.50	590.00	760.00	708.98	711.03	1.21	1.31	585.93	542.77
5.86	590.00	760.00	755.85	758.43	1.29	1.445	585.93	524.86
6.23	590.00	760.00	808.58	805.83	1.38	1.58	585.93	510.02
6.59	590.00	760.00	855.46	853.23	1.46	1.715	585.93	497.51
6.96	590.00	760.00	902.33	900.64	1.54	1.8	585.93	500.35
7.69	590.00	760.00	996.08	995.44	1.70	1.895	585.93	525.30
8.06	590.00	760.00	1042.96	1042.84	1.78	1.99	585.93	524.04
8.43	590.00	760.00	1089.83	1090.24	1.86	2.09	585.93	521.65
8.79	590.00	760.00	1136.70	1137.64	1.94	2.17	585.93	524.26
9.16	590.00	760.00	1183.58	1185.05	2.02	2.4	585.93	493.77

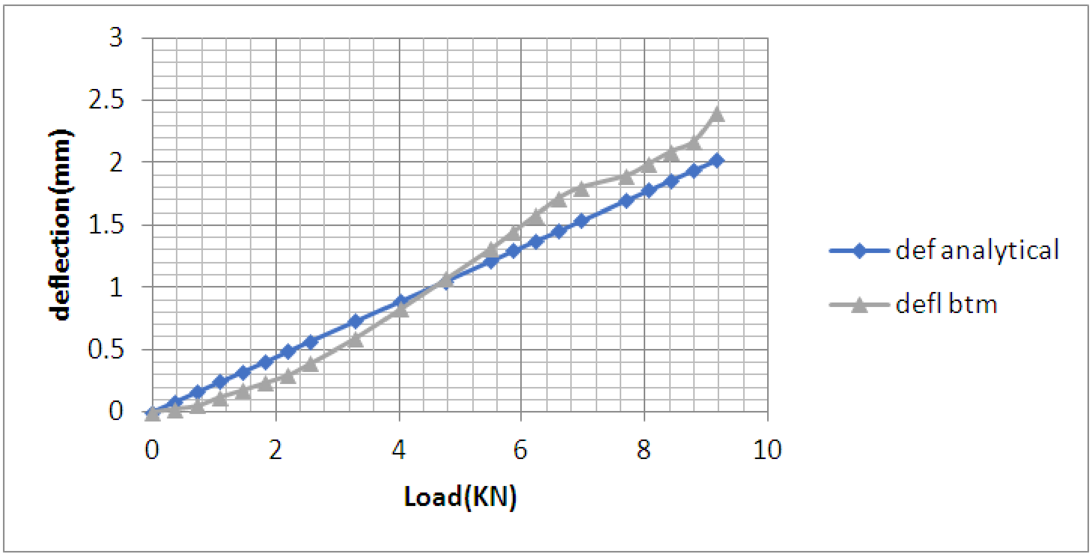

Fig 4.3: Bottom deflection (mm) vs Load(KN) for plate 3

Table 4.4: Experimental result of plate 5 subjected to transverse loading

Plate 5 with Triangular core								
Load KN	Length mm	**Width mm**	**Moment Analytical**	Max Moment	deflection analytical	deflection Experimental	Moment/def analytical	Moment /def Exp
0.00	680.00	700.00	0.00	0.00	0.00	0.00	#DIV/0!	#DIV/0!
0.37	680.00	700.00	56.62	59.32	0.14	0.20	418.69	296.58
1.10	680.00	700.00	18.04	177.95	0.43	0.40	418.69	444.87
1.83	680.00	700.00	297.27	296.58	0.71	0.70	418.69	423.68
2.56	680.00	700.00	414.50	415.21	0.99	0.96	418.69	432.51
3.30	680.00	700.00	535.92	533.84	1.28	1.15	418.69	464.21
4.03	680.00	700.00	653.16	652.47	1.56	1.35	418.69	483.31
4.40	680.00	700.00	711.77	711.79	1.70	1.50	418.69	474.52
4.76	680.00	700.00	770.39	771.10	1.84	1.63	418.69	473.07
5.13	680.00	700.00	829.01	830.42	1.98	1.80	418.69	461.34
5.50	680.00	700.00	891.81	889.73	2.13	1.94	418.69	458.62
5.86	680.00	700.00	950.43	949.05	2.27	2.06	418.69	460.70
6.23	680.00	700.00	1009.04	1008.36	2.41	2.20	418.69	458.35
6.78	680.00	700.00	1096.97	1097.34	2.62	2.40	418.69	457.22
7.69	680.00	700.00	1247.70	1245.62	2.98	2.60	418.69	479.09
8.06	680.00	700.00	1300.31	1304.94	3.12	2.75	418.69	474.52
8.43	680.00	700.00	1364.93	1364.25	3.26	2.95	418.69	462.46
9.16	680.00	700.00	1482.16	1482.89	3.54	3.15	418.69	470.76
9.89	680.00	700.00	1603.58	1601.52	3.83	3.50	418.69	457.58
10.62	680.00	700.00	1720.82	1720.15	4.11	3.80	418.69	452.67
10.99	680.00	700.00	1779.43	1779.46	4.25	4.13	418.69	430.86
11.36	680.00	700.00	1838.05	1838.78	4.39	4.60	418.69	399.73
12.09	680.00	700.00	1959.47	1957.41	4.68	5.03	418.69	389.15
12.46	680.00	700.00	2018.09	2016.72	4.82	5.45	418.69	370.04
12.82	680.00	700.00	2076.70	2076.04	4.96	5.80	418.69	357.94
13.19	680.00	700.00	2135.32	2135.36	5.10	6.40	418.69	333.65

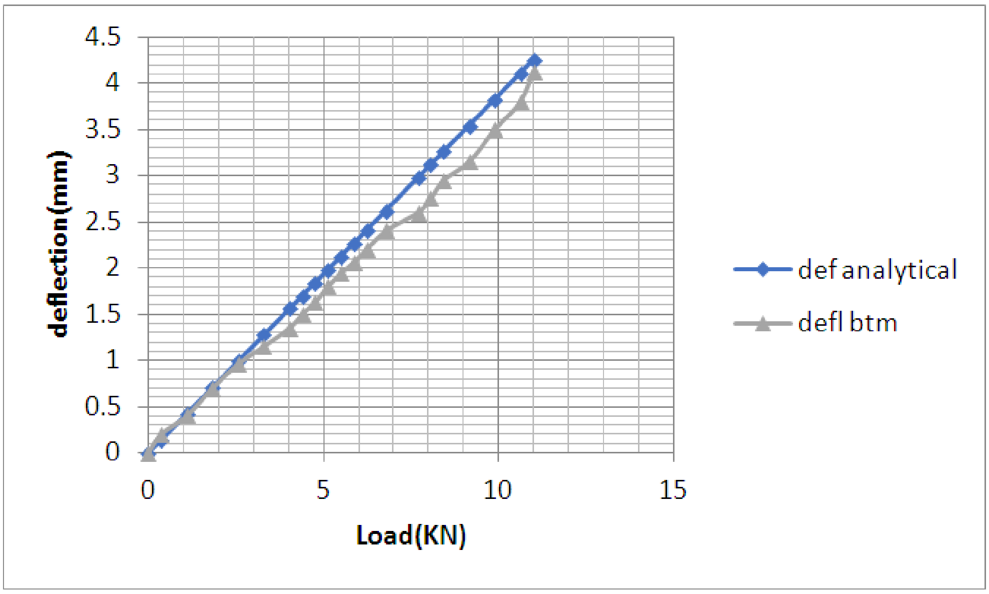

Fig 4.4: Deflection (mm) vs Load (KN) for plate 5

Table 4.5 : Experimental result of plate 6 subjected to transverse loading

Plate 6 with Sinusoidal core								
Load KN	Length mm	**Width mm**	**Moment Analytical**	Max Moment	deflection analytical	deflection Experimental	Moment/def analytical	Moment /def Exp
0.00	600.00	710.00	0.00	0.00	0.00	0.00	#DIV/0!	#DIV/0!
0.37	600.00	710.00	53.58	51.60	0.13	0.20	412.12	258.00
1.10	600.00	710.00	156.61	154.80	0.38	0.40	412.12	387.00
1.83	600.00	710.00	259.64	258.00	0.63	0.70	412.12	368.57
2.56	600.00	710.00	362.67	361.20	0.88	0.96	412.12	376.25
3.30	600.00	710.00	465.70	464.40	1.13	1.15	412.12	403.83
4.03	600.00	710.00	568.73	567.60	1.38	1.35	412.12	420.44
4.40	600.00	710.00	618.18	619.20	1.50	1.50	412.12	412.80
4.76	600.00	710.00	671.76	670.80	1.63	1.63	412.12	411.53
5.13	600.00	710.00	721.21	722.40	1.75	1.80	412.12	401.33
5.50	600.00	710.00	774.79	774.00	1.88	1.94	412.12	398.97
5.86	600.00	710.00	824.24	825.60	2.00	2.06	412.12	400.78
6.23	600.00	710.00	877.82	877.20	2.13	2.20	412.12	398.73
6.78	600.00	710.00	956.12	954.60	2.32	2.40	412.12	397.75
7.69	600.00	710.00	1083.88	1083.60	2.63	2.60	412.12	416.77
8.06	600.00	710.00	1133.33	1135.20	2.75	2.75	412.12	412.80
8.43	600.00	710.00	1186.91	1186.80	2.88	2.95	412.12	402.31
9.16	600.00	710.00	1289.94	1290.00	3.13	3.15	412.12	409.52
9.89	600.00	710.00	1392.97	1393.20	3.38	3.50	412.12	398.06
10.62	600.00	710.00	1496.00	1496.40	3.63	3.80	412.12	393.79
10.99	600.00	710.00	1549.57	1548.00	3.76	4.13	412.12	374.82
11.36	600.00	710.00	1599.03	1599.60	3.88	4.60	412.12	347.74
12.09	600.00	710.00	1702.06	1702.80	4.13	5.03	412.12	338.53
12.46	600.00	710.00	1755.63	1754.40	4.26	5.45	412.12	321.91
12.82	600.00	710.00	1805.09	1806.00	4.38	5.80	412.12	311.38

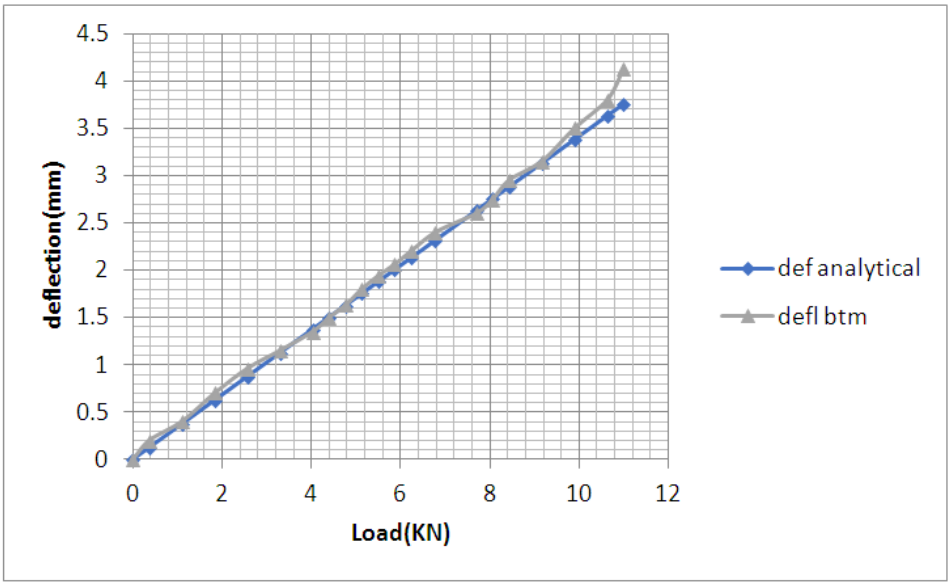

Fig 4.5: Deflection (mm) vs Load (KN) for plate 6

4.1.1 Discussion of results obtained from the analytical model for various core geometry:

In table 4.1 the analytical result in terms of effective stiffness deviate from the experimental result by about 4% for the rectangular core sandwich plate, but as the transverse load increases, the deviation of the analytical model from the laboratory experimentation gets up to 50%, this may be due to some experimental error in the loading pattern. Also in table 4.2 the error analysis between the analytical model and the experimental result for the rectangular core sandwich plate ranges from 10% to 17% as the aspect ratio increases. For the Trapezoidal corrugated sandwich plate subjected to transverse loading, the analytical model deviate from the laboratory experimentation between 7% and 18 % as the load increases. See table 4.3. In table 4.4 the analytical model deviates from the laboratory experiment between 12% and 13% for the triangular corrugated sandwich plate. Also for the sinusoidal corrugated sandwich plate, the result obtained from the analytical model deviate from 1% to 2% when compared to the laboratory experiment.

In order to take care of experimental errors, a linear trendline passing through the origin for displacement vs experimental moment, was used to adjust the experimental displacement. This automatically made the stiffnesses of the plates constants. The table 4.6 below shows the percentage difference and R^2 for the average effective experimental stiffness for the five corrugated sandwich plates described in this work.

Table 4.6 Showing Compaison of Sandwich Plate Stiffnesses from Proposed Analytical method with full scale Laboratory testing.

Plate	Core type	Analitical Stiffness	Adjusted Experimental Stiffness	Stifness Ratio	%diff	R^2
Plate 1	Rectangular	823.35	769.23	1.07	6.57	0.9967
Plate 2	Rectangular	574.28	625	0.92	-8.83	0.972
Plate 3	Trapezoidal	585.93	526.32	1.11	10.17	0.9734
Plate 5	Triangular	418.69	454.55	0.92	-8.56	0.9957
Plate 6	Sinusoidal	412.12	400	1.03	2.94	0.9957

The results compare except that stiffnesses are in increasing order fom plate 6 to plate 1 in the experimental result but for the analytical method it is of the order plate 6, plate 5, plate 2, plate 3 and then plate 1. Whichever way it is considered the rectangular sandwich core is the strongest , while the sinusoidal is the weakest of the plates considered in this work, withing the limits of experimental errors.

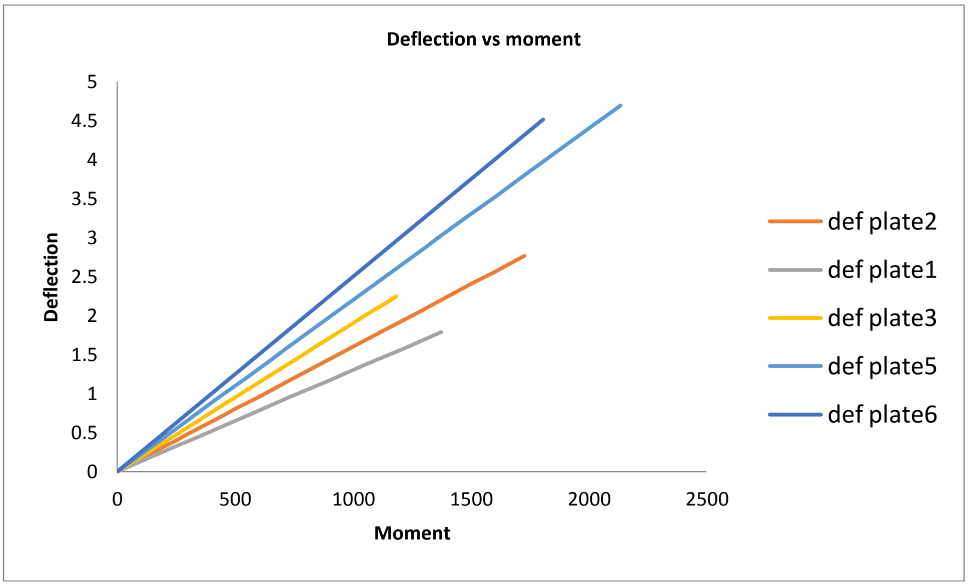

Fig 4.6: Experimental Deflection (mm) vs Moment (KNm) for all plates

V. CONCLUSION AND RECOMMENDATION

Sandwich plates with corrugated core have been analyzed for deflection and bending moment. The sandwich plates were first transformed into an equivalent isotropic plate using the analytical model from parallel axis theorem for second moment of area. The bending response is then calculated using the simple beam theory, from where the deflection is also computed, having known the stiffness. To give credence to this analytical work, six sandwich plates with corrugation of various core parameters were produced as described and tested in the laboratory. But plate 4 is not reported in this work because it was loaded along the edges for buckling.

A simple code is written to easily handle the problems. The cores considered are Triangular, Trapezoidal, sinusoidal and rectangular for the five sandwich plates tested in the laboratory. The results were comparable within 10% and the model which is a table method is good enough for use in sandwich plate problems and is therefore recommended.

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