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Structural Behavior of Timber Aluminum Composite Beams under Static Loads

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***Abstract*—An experimental analysis has been carried out to investigate the structural behavior of simply supported timber aluminum composite beams under static loads. The composite beam specimens are made by connecting plywood slabs with aluminum beams (box sections) using adhesive epoxy material and self tapping self drilling screw mechanical fasteners. A series of tests was conducted to investigate the effects of several parameters on the structural behavior and strength of timber aluminum composite beams. The tested composite beams were subjected to three point loading. Tests revealed that the proposed beams (timber – aluminum composite beams) have a good load carrying capacity relative to their weight. The composite system of plywood slab and aluminum beam was efficient in eliminating local buckling of aluminum beams. It was observed that the adopted method of connection between the components of the tested composite beams could be considered as a method by which a full interaction can be developed.**

***Keywords*—timber; plywood; aluminum; composite beams.**

I. INTRODUCTION

One of the major developments in the civil engineering has a significant trend to compositely design structural units with different materials. This composite construction has been proven popular because it combines structural efficiency with speed of construction to offer an economic solution for a wide range of construction types include commercial, industrial, and residential constructions. This approach of using different materials which are arranged in an optimum geometric configuration, taking into account that only the desirable property of each material will be utilized by virtue of its designated position, leads to many benefits in the structural design and construction especially the increase in the stiffness and load capacity and reduction in the overall depths of these composite members in comparison with their non-composite counterparts and as a result saving in the weight of the overall structure.

The fundamental point for the structural behavior and design of composite beams is the level of connection and interaction between the supporting beam and the slab. The term “full shear connection” relates to the case in which the connection between the components is able to fully resist the forces applied to it. This is possibly the most common situation; however, the use of beams in building construction has led to many instances where the interconnection cannot resist all the applied forces (partial shear connection). In this case, the connection may fail in shear before either of the other components reaches its own failure state. The condition when the connection between the components is considered as infinitely stiff is said to comprise “full interaction”. Whilst this is often assumed in design, it is theoretically impossible and cases where the connection has more limited stiffness (partial interaction) often need to be considered. In this case, the connection itself may deform, resulting in relative movement along the composite beam components interface, and less stiffness and strength. Therefore, partial interaction occurs to some extent in all beams whether fully connected or not [1]. The connection may be either at discrete points along the beams like the mechanical connecters, or continuously which is a solution to eliminate concentrated stresses and the risk of fatigue damage in the connectors by using adhesive materials [2].

In the present work, the structural behavior of composite beams consisting of plywood panels, which is one of the Engineering Wood Products (EWPs), as slabs and aluminum box sections as beams is investigated under the effect of static loads. The proper properties of timber, especially the EWPs, and aluminum in additional to composite action benefits give a chance that the two materials respective advantages can be utilized to the fullest extent.

II. EXPERIMENTAL PROGRAM

A. Materials

The mechanical properties of the materials used in this investigation including structural aluminum alloy box section, plywood sheet panels, and thixotropic epoxy resin adhesive (Sikadur-31), were determined experimentally according to the American Society for Testing and Materials Standards (ASTM standards) [3,4,5,6,7]. The final results of these tests are summarized in Tables (1), (2), and (3).

TABLE 1 MECHANICAL PROPERTIES OF ALUMINUM ALLOY

Yield Stress (MPa)	**Ultimate Stress (MPa)**	**E (GPa)**	**Fracture Elongation (%)**
191.84	236.32	67.67	7.33

TABLE 2 MECHANICAL PROPERTIES OF PLYWOOD

Item	Plywood Face Grain Direction	Value (MPa)
Ultimate Compressive Strength	Parallel to Applied Load	18.03
	Perpendicular to Applied Load	13.69
Ultimate Tensile Strength	Parallel to Applied Load	13.27
	Perpendicular to to Applied Load	9.39
Ultimate Flexural Strength	Parallel to Span	34.77
	Perpendicular to Span	25.19
Modulus of Elasticity	Parallel to Span	7357.62
	Perpendicular to Span	4871.82
Shear Modulus	---------------------	662.91

TABLE 3 MECHANICAL PROPERTIES OF SIKADUR-31 EPOXY RESIN

Compressive Strength (MPa)	Tensile Strength (MPa)	Flexural Strength (MPa)	Modulus of Elasticity (MPa)
35.0	25.0	40.0	4600

B. Fabrication

The fabrication of the beam specimens was done in two stages. In the first stage, the plywood slabs of the specimens were prepared by cutting them out of the available standard plywood panels. The dimensions of these slabs were (1200×300×18mm) and (2400×300× 18mm) taking into account that the direction of face grains of some of these slabs was parallel to, and the others perpendicular to, the direction of the span length. In order to provide plywood slabs with thickness of (37mm), two plywood pieces having (18mm) thickness, which is the nominal thickness of the used plywood panel, were connected together by epoxy adhesive layer (Sikadur 31) of (1mm) thickness, and pressed by steel clamps from both sides and left for about three days for the epoxy hardening.

In the second stage, the two components (plywood slab and the aluminum beam) of the composite beams were connected together by using epoxy adhesive layer (Sikadur 31) of about 3mm thickness and pressed by steel clamps from both sides, and left for about three days for the epoxy hardening. Finally, 6mm diameter of aluminum self-drilling self tapping screws, which were used as mechanical fasteners, were driven along the overall length of the beam specimens with 150mm spacing, in order to provide a complete interaction between the plywood flange and the aluminum beam.

The intended use of adhesive epoxy material with the mechanical fasteners is firstly to provide full interaction between the components of the composite beams and secondly to increase the spacing between the mechanical fasteners, which may reach (30 mm) for these composite beams to satisfy full interaction without epoxy material. Using the adhesive epoxy material and mechanical fasteners prevent the concentration of stresses and local damage that may develop the aluminum beams or the plywood slabs.

C. Specimens Dimensions

The timber – aluminum composite beams were of (1.2m) and (2.4m) overall length and consisted of timber (plywood) slab of (0.018m) and (0.036m) thickness and (0.3m) breadth. A box section aluminum beam with (0.1m) depth, (0.05m) width, (0.004m) wall thickness, and a weight equal to (3.0 kg/m) was used.

The main variables considered in this investigation were the thickness of the timber slab, the orientation with respect to the span direction of the face grain of the plywood slab, the span length, as well as the type of bending moment (sagging and hogging bending moments).

D. Test of Specimens

Eight specimens of the composite beams, two specimens of aluminum beams, and four specimens of plywood flanges were tested in this program under three point loading. The full details of tested composite beams, tested aluminum beams, and tested plywood slabs are summarized in Tables (4), (5), and (6), respectively. Typical composite sections are shown in Fig. (1).

TABLE 4 DETAILS OF TIMBER - ALUMINUM COMPOSITE BEAMS

No	Designation	Plywood Flange Dimensions (mm)		Orientation of Plywood Face Grain to Span Direction	Beam Overall Length (m)	Beam Overall Depth (mm)	Region of Bending Moment
		Width	Depth				
1	S1Pr1S	300	18	Parallel	1.2	121	Sagging
2	S1Pn1S		18	Perpendi-cular	1.2	121	
3	S1Pr2S		37	Parallel	1.2	140	
4	S1Pn2S		37	Perpendi-cular	1.2	140	
5	S2Pr1S		18	Parallel	2.4	121	
6	S2Pr2S		37	Parallel	2.4	140	
7	S2Pr1H		18	Parallel	2.4	121	Hogging
8	S2Pr2H		37	Parallel	2.4	140	

TABLE 5 DETAILS OF TESTED ALUMINUM BEAMS

No.	Designation	Weight (kg/m)	Full depth (mm)	Flange width, mm	Flange thickness (mm)	Web thickness (mm)	Cross Sectional Area (mm^2)	Calculated Moment of Inertia (mm^4)	Overall length (m)
1	SA1	3.05	100	50	4	4	1136	1441259	1.2
2	SA2								2.4

TABLE 6 DETAILS OF TESTED PLYWOOD FLANGES

No	Designation	Dimensions (mm)		Orientation of Plywood Face Grain to Span Direction	Overall Length (m)
		Width	Depth		
1	ST1Pr	300	18	Parallel	1.2
2	ST1Pn		18	Perpendicular	
3	ST2Pr		37	Parallel	
4	ST2Pn		37	Perpendicular	

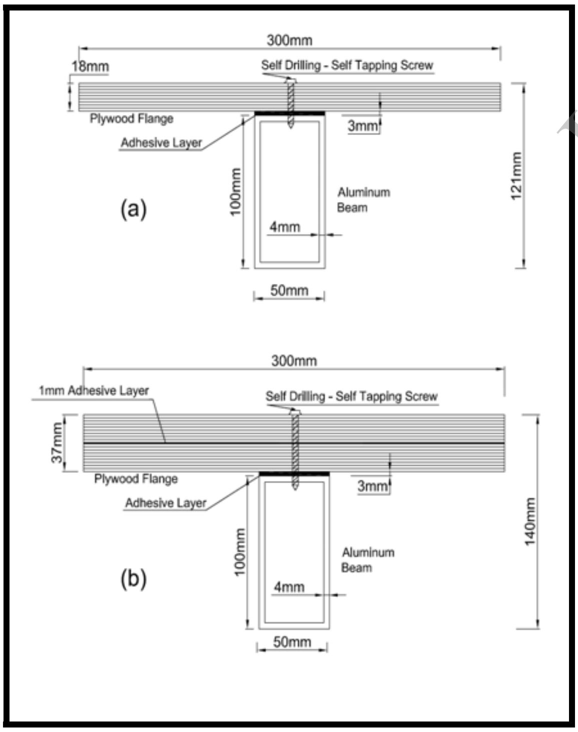

FIGURE 1 TYPICAL CROSS SECTION OF TIMBER - ALUMINUM COMPOSITE BEAMS (A) ONE LAYER PLYWOOD FLANGE, (B) TWO LAYERS PLYWOOD FLANGE

The tests of composite beams were carried out by the Universal Testing Machine (TORSEE) 20 tons capacity with 1.1m and 2.3m simply supported span length and the load was applied at the mid-point of beam span as shown in Plate (1).

PLATE 1 COMPOSITE BEAM SPECIMENS TEST SETUP

Mechanical dial gauges were used to measure the midspan deflection and end slip for each specimen. The load was applied to the beams by using a loading block made of wood, placed on a steel load plate under which a thin rubber sheet was used to achieve a uniform distribution of load on the beam. The load was applied on the top surface of plywood slab, for the case of sagging bending moment, and on the box aluminum beam for the case of hogging bending moment. In all tests the load was applied in small increments up to failure. Tests were terminated when the pointer of the machine load gauge started to drop off.

III. RESULTS AND DISCUSSION

A. Plywood Slab Flexural Tests

The plywood slab specimens are of 1.1 m span length and subjected to three point loading. The maximum load recorded during the tests is considered as the ultimate load of these specimens. The results of these tests are summarized in Table (7).

TABLE 7 EXPERIMENTAL RESULTS OF TESTED PLYWOOD SLABS

No.	**Designation**	**Ultimate Load (kN)**	**Ultimate Moment * (kN.m)**	**Extrapolated Midspan Deflection at Ultimate Load (mm)**	**Service** Load (kN)**	**Midspan Deflection at Service Load (mm)**
1	ST1Pr	1.478	0.425	60.88	0.985	37.85
2	ST1Pn	1.073	0.308	64.92	0.715	35.00
3	ST2Pr	4.728	1.359	31.03	3.152	17.05
4	ST2Pn	4.309	1.239	35.00	2.873	19.97
* Effective Span = 1.1 m ** Service Load = 2/3 (Ultimate Load)						

Two modes of failure are observed during the tests of the four plywood specimens. The first mode of failure is characterized by the development of fine transverse cracks at the bottom face of the tension zone under the applied load, followed by delamination failure of the near surface plies in the compression zone which are finally crashed. This type of failure occurs in the specimens having only one layer (18 mm thickness). The orientation of the face grain with respect to the span direction has no effect on the type of failure. The second type of failure occurs in the specimens having two layers (37mm thickness). This failure is also started with the development of fine transverse cracks at the tension zone under applied load, and then sudden breakage of the test specimens happens in the mid zone under the applied load. The same failure is noticed for both specimens in which the face grain orientation is parallel and perpendicular to span direction.

The load-midspan deflection relationships of these specimens are shown in Fig. (2). The figure shows, and as expected, that the plywood specimens with face grain orientation parallel to span direction are more stiff than those with face grain orientation perpendicular to span direction. Also, the relationships are approximately linear for all specimens and followed by small nonlinear regions just before reaching the ultimate loads. This indicates that plywood specimens behave linearly for a wide range of loading until the fine transverse cracks occur after which the behavior changes to nonlinear near the ultimate load. When the thickness of plywood panels is doubled by connecting two panels using glue, the strength of the specimens increases three to four times, however, the deflection becomes less indicating more brittle behavior.

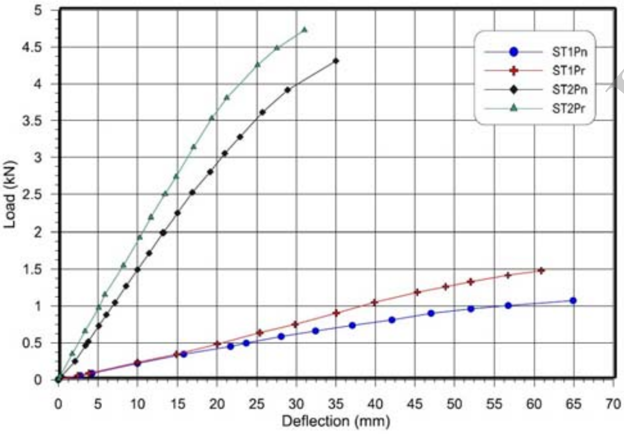

FIGURE 2 VARIATION OF MIDSPAN DEFLECTION WITH LOAD FOR PLYWOOD PANELS

B. Aluminum Beams Flexural Tests

Two specimens of box section aluminum beams are tested with span length of 1.1 m and 2.3 m. The two beams were loaded with a three point loading. The maximum load recorded by the testing machine is considered as the ultimate load.

In general, both beam specimens exhibited local buckling during failure, which is the property of slender metal sections. Actually the local buckling was noticed after the tension zone of the beams reached the yield tensile stress. Then the stresses in the compression zone increased and finally produced the local buckling.

The load deflection relationships for the two aluminum beam specimens are shown in Fig. (3). The relations exhibit a behavior of two stages, linear and nonlinear. These linear and nonlinear stages clearly appeared in the behavior of the aluminum beam specimen (SA1), which has an effective span length of 1.1 m, as compared with the aluminum beam specimen (SA2), which has an effective span length of 2.3m, since the two relationships are drawn on the same figure with the same scale although there is large difference in ordinates of points of both curves. The results of tested aluminum beam specimens are summarized in Table (8).

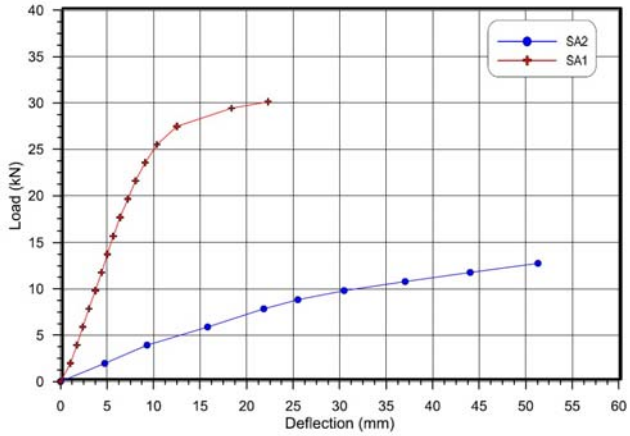

FIGURE 3 VARIATION OF MIDSPAN DEFLECTION WITH LOAD FOR ALUMINUM BEAMS

TABLE 8 EXPERIMENTAL RESULTS OF TESTED ALUMINUM BEAM SPECIMENS

No.	Designation	Ultimate Load (kN)	Ultimate* Moment (kN.m)	Extrapolated Midspan Deflection at Ultimate Load (mm)	Service** Load (kN)	Midspan Deflection at Service Load (mm)
1	SA1	30.12	8.66	22.31	20.08	7.41
2	SA2	12.75	7.49	51.32	8.50	24.29
* Effective Span = 1.1m and 2.3m ** Service Load = 2/3 (Ultimate Load)						

C. Timber Aluminum Composite Beams

1) Modes of Failure: Various modes of failure were observed during the static tests of the composite beams. These modes related to two main factors, the plywood slab thickness (18 or 37 mm) and the type of applied bending moment (sagging or hogging). The composite beam specimens subjected to sagging bending moment failed firstly by the yield of the aluminum beams at midspan tension zone, and then a delamination failure occurred in plies of plywood panel in the compression zone at the beams midspan. No local buckling in the aluminum beams was noticed at failure of these composite beams. The orientations of the face grain of the plywood slab with respect to span direction have no effect on the modes of failure. On the other hand, the composite beam subjected to hogging bending moment and having plywood slab thickness of 18 mm, (S2Pr1H) specimen, failed by yield of the aluminum beam at midspan compression zone and then a breakage in the plywood panel occurred at the midspan region of the composite beam. However the failure mode of the specimen (S2Pr2H), which have plywood slab thickness of 37 mm and also subjected to hogging bending moment, started by local buckling of the aluminum beam at midspan compression zone and then a breakage in the plywood panel occurred.

2) Effect of Composite Action: The effect of the composite action on the behavior of the tested timber aluminum composite beams and their components is illustrated in Figs. (4) and (5). In these figures, the behavior of tested composite beams, having effective span of 1.1 m, are compared with their components (plywood slab and aluminum beam) taking into account the main variables considered in this investigation. The composite action effect appears in these figures through the increase of stiffness and strength of composite beams with full connection as compared to their components. These figures clearly indicate that the load capacity of the composite beams significantly exceeds the direct summation of the load capacity of the two individual components. The ultimate loads for the tested composite beams are larger than those for its aluminum beams alone. The increase in strength of composite beams over the aluminum beams varies depending on the properties of the second component of composite beams, plywood slab.

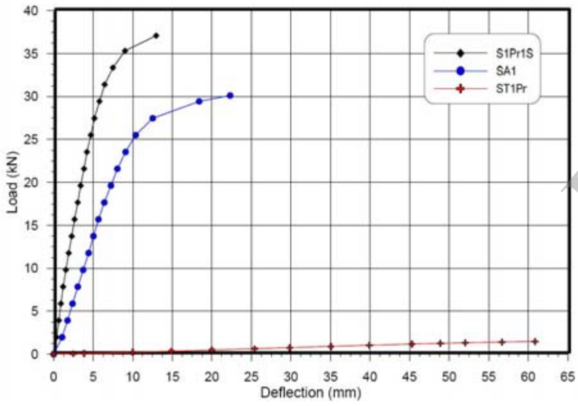

FIGURE 4 LOAD-MIDSPAN DEFLECTION RELATIONSHIPS FOR (S1Pr1S) SPECIMEN AND ITS COMPONENTS

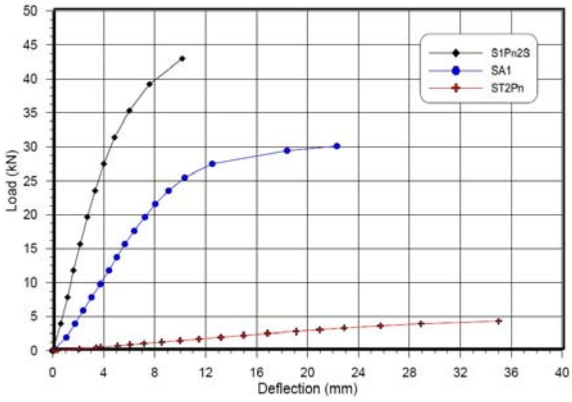

FIGURE 5 LOAD-MIDSPAN DEFLECTION RELATIONSHIPS FOR (S1Pn2S) SPECIMEN AND ITS COMPONENTS

3) Deflection Behavior: The tests of the timber aluminum composite beam specimens show that the global behavior for all tested composite beams have a linear stage followed by a nonlinear behavior as the behavior of their main components, aluminum beam and plywood slab. The results of tested timber aluminum composite beams are summarized in Table (9).

TABLE 9 EXPERIMENTAL RESULTS OF TESTED COMPOSITE BEAMS

No	Designation	Ultimate Load (kN)	Ultimate Moment* (kN.m)	Extrapolated Midspan Deflection at Ultimate Load (mm)	Service Load** (kN)	Midspan Deflection at Service Load (mm)
1	S1Pr1S	37.08	10.66	12.95	24.72	4.50
2	S1Pn1S	35.51	10.21	13.71	23.67	4.56
3	S1Pr2S	47.09	13.54	10.77	31.39	4.53
4	S1Pn2S	42.97	12.35	10.16	28.65	4.27
5	S2Pr1S	17.36	10.20	48.78	11.57	20.53
6	S2Pr2S	23.94	14.06	43.38	15.89	17.25
7	S2Pr1H	16.69	9.81	35.03	11.13	17.20
8	S2Pr2H	21.43	12.59	29.98	14.29	16.82

* Effective Span =1.1 m or 2.3 m
**Service Load = 2/3 (Ultimate Load)

Figures (6) and (7) show load midspan deflection relationships for composite beams with different orientations of the plywood face grain with respect to span direction. These were parallel for (S1Pr1S) and (S1Pr2S), and perpendicular for (S1Pn1S) and (S1Pn2S).

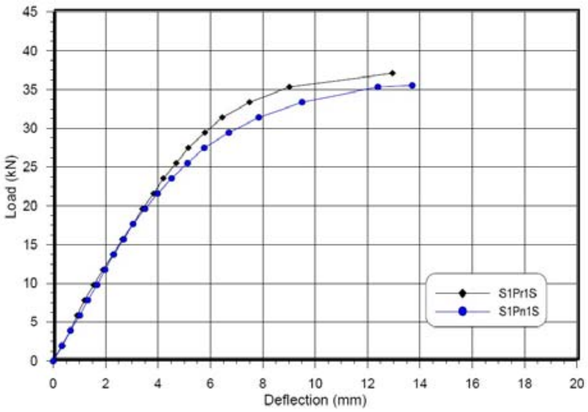

FIGURE 6 BEHAVIOR OF COMPOSITE BEAMS OF 18MM THICKNESS PLYWOOD SLAB WITH DIFFERENT ORIENTATIONS OF PLYWOOD FACE GRAIN W.R.T. SPAN DIRECTION

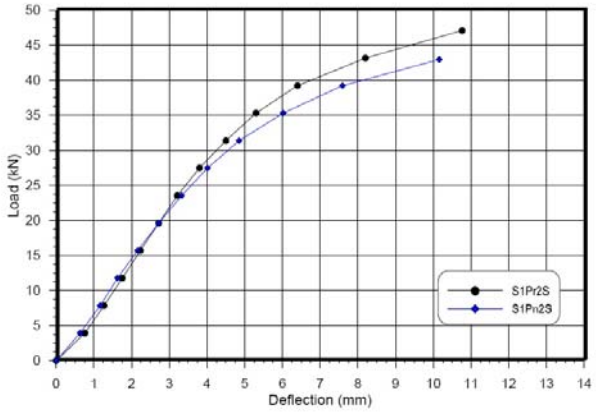

FIGURE 7 BEHAVIOR OF COMPOSITE BEAMS OF 37MM THICKNESS PLYWOOD SLAB WITH DIFFERENT ORIENTATIONS OF PLYWOOD FACE GRAIN W.R.T. SPAN DIRECTION

It can be seen that this variable have a considerable effect on the behavior of these composite beams. These figures show also that the relationships approximately coincide during the first linear stage, which means that they have approximately the same initial stiffness, and the orientation of plywood slab face grain significantly affects the second region of the load-deflection relationship of the composite beam.

Numerically, it can be shown from Table (9) that the change of the orientation of plywood slab face grain increases the stiffness, which are calculated at the service loads, from (5191 kN/m) to (5493 kN/m) with a ratio of (5.8 %) for composite beams having a plywood slab thickness of 18mm, and from (6710 kN/m) to (6929 kN/m) with a ratio of (3.3 %) for the composite beams having a plywood slab thickness of 37mm. The larger value of stiffness is recorded in specimens with the orientation of face grain of plywood slab parallel to span direction of these composite beams. So, it can be concluded that the effect of this variable on the behavior of composite beams reduces with the increase of the plywood slab thickness.

The load midspan deflection relationships for tested composite beams with parallel orientation of face grain with respect to span direction for plywood slab with different thicknesses are shown in Figs. (8) and (9).

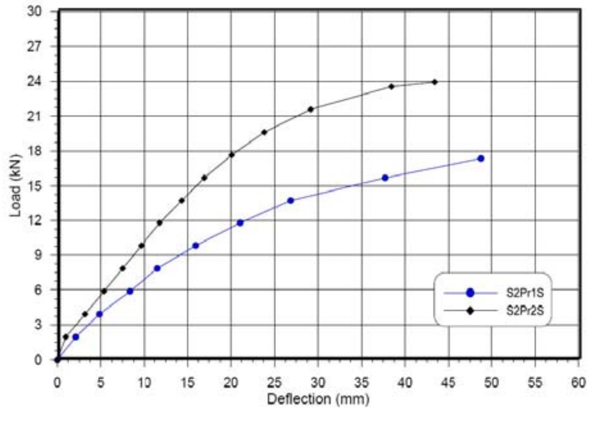

FIGURE 8 BEHAVIOR OF COMPOSITE BEAMS UNDER SAGGING B.M. WITH DIFFERENT PLYWOOD SLAB THICKNESS

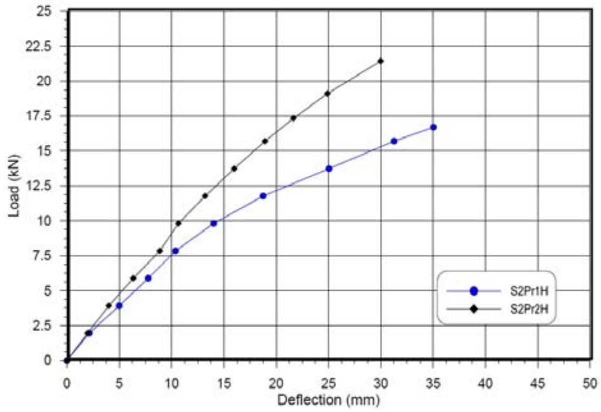

FIGURE 9 BEHAVIOR OF COMPOSITE BEAMS UNDER HOGGING B.M. WITH DIFFERENT PLYWOOD SLAB THICKNESS

The effect of this parameter (plywood slab thickness) can be illustrated clearly from the results in Table (9). When the slab thickness increases from 18mm for (S1Pr1S) to 37mm for (S1Pr2S), the extrapolated maximum deflection value decreases by a ratio of (17%) and the ultimate load value increases with a ratio of (27%), for 1.1 m composite effective span length. While for 2.3 m effective span length, when the slab thickness increases from 18mm for (S2Pr1S) to 37mm for (S2Pr2S), the extrapolated maximum deflection value decreases by a ratio of (11%) and the ultimate load value increases with a ratio of (38%). This occurs when the applied load developed a sagging bending moment. Also, when the slab thickness increases from 18mm for (S1Pr1H) to 37mm for (S1Pr2H), which have 2.3 m effective span length and subjected to hogging bending moment, the extrapolated maximum deflection value decreases by a ratio of (14%) and the ultimate load value increases with a ratio of (28%). This reveals that the plywood slab properties play a signification role in increasing the stiffness of the composite system, whether the plywood was located in the tension zone or compression zone during the loading.

Figures (10) and (11) show the load midspan deflection relationships with different loading types (sagging or hogging bending moment) for composite beams having an effective span length of 2.3 m and orientation of their plywood slabs face grain parallel to span direction. It can be seen that the behavior of the composite beams (S2Pr1H) and (S2Pr2H), which were subjected to hogging bending moment, have short linear stage behavior compared with the behavior of composite beams (S2Pr1S) and (S2Pr2S), respectively, which have the same cross sectional properties but were subjected to sagging bending moment. The ratio of deflection at ultimate load to the deflection corresponding to the end of linear stage is about (5.86) for composite beam (S2Pr1S). This value reduces to about (3.38) for composite beam (S2Pr1H), with a decrease ratio of about (42%). While this ratio reduces from about (3.67) for composite beam (S2Pr2S) to about (2.27) for composite beam (S2Pr2H), with a decrease ratio of about (38%). This difference occurs in spite of that the first part of the global behavior of the composite beams with same cross section is approximately the same when they are subjected to sagging or hogging bending moment. The difference in the length of linear stage behavior observed in the composite beams with same cross sectional properties when the type of the applied bending moment changes from sagging to hogging may be attributed to the behavior of plywood slab. It is known that the plywood have different behavior when it is subjected to different types of loading. When these composite beams are subjected to sagging bending moment, the plywood slab is subjected to compressive stresses and its behavior reveals elastic – plastic trend with large linear stage behavior. On the other hand, when these composite beams are subjected to hogging bending moment, the plywood slab is subjected to tensile stresses, and it is known that the wood behaves as a brittle material in tension giving small linear stage behavior [8].

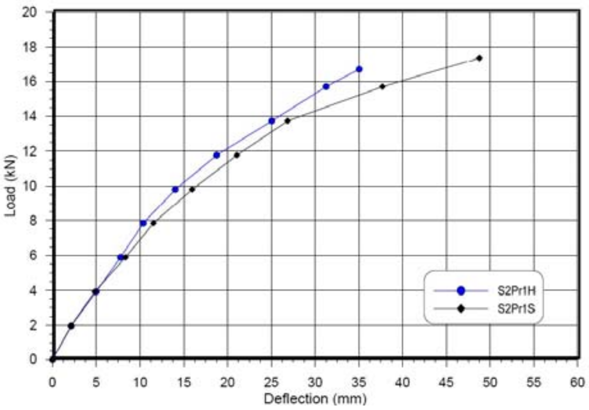

FIGURE 10 BEHAVIOR OF COMPOSITE BEAMS OF 18MM THICKNESS PLYWOOD SLAB FOR DIFFERENT TYPES OF APPLIED BENDING MOMENT

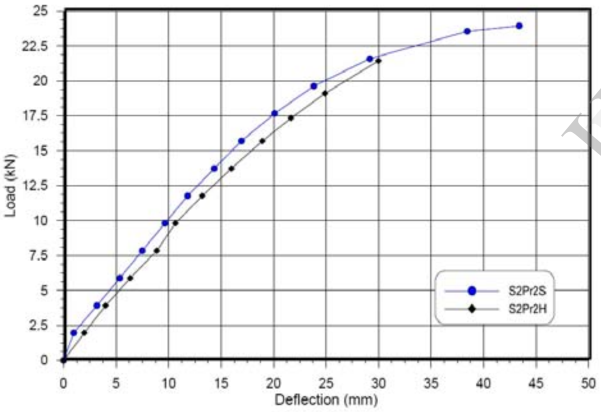

FIGURE 11 BEHAVIOR OF COMPOSITE BEAMS OF 37MM THICKNESS PLYWOOD SLAB FOR DIFFERENT TYPES OF APPLIED BENDING MOMENT

4) End Slip: To investigate the behavior of connection between the components of the tested composite beams, the variations of the experimentally measured values of the end slip between the plywood slab and aluminum beam with load are recorded. These variations are summarized in Table (10). It can be observed that all the tested composite beams have extrapolated slip values not exceeded (0.096 mm). Therefore, this method of connection can be adopted to provide approximately full interaction between the components of timber aluminum composite beams. The change of orientation of plywood face grain from parallel to perpendicular direction with respect to span direction causes the maximum end slip to change. The perpendicular direction of plywood face grain to span direction gives larger end slip. Increasing ration of about (14%) is recorded for composite beam specimens (S1Pr1S) and (S1Pn1S) (plywood thickness 18mm), and (11%) for composite beam specimens (S1Pr2S) and (S1Pn2S) (plywood thickness 37mm). Also, it was observed that the variation of end slip with load for the tested composite beams is also affected by the type of the applied bending moment, sagging or hogging. It can be clearly seen from Table (10) that the end slip occurred in the tested composite beams (S2Pr1S) and (S2Pr2S) under sagging bending moment are larger than that occurred in the tested composite beams (S2Pr1H) and (S2Pr2H) under hogging bending moment, respectively. This occurs despite of that (S2Pr1S) and (S2Pr1H) have the same cross section and same span length and the same thing for (S2Pr2S) and (S2Pr2H). This increase in the end slip of composite beams when the applied bending moment changes from hogging to sagging may be because that the ultimate load capacity of the beam section under sagging bending is slightly larger than that under hogging bending. The larger applied load may be the reason for the larger end slip value under sagging bending.

TABLE 10 EXPERIMENTAL RESULTS OF END SLIP FOR TESTED COMPOSITE BEAMS

No	Designation	Ultimate Load (kN)	Extrapolated End Slip at Ultimate Load (mm)	Service Load* (kN)	End Slip at Service Load (mm)
1	S1Pr1S	37.08	0.036	24.72	0.014
2	S1Pn1S	35.51	0.041	23.67	0.017
3	S1Pr2S	47.09	0.083	31.39	0.038
4	S1Pn2S	42.97	0.092	28.65	0.042
5	S2Pr1S	17.36	0.044	11.57	0.016
6	S2Pr2S	23.94	0.096	15.89	0.042
7	S2Pr1H	16.69	0.021	11.13	0.010
8	S2Pr2H	21.43	0.063	14.29	0.028
* Service Load = 2/3 (Ultimate Load)					

IV. CONCLUSIONS

An experimental study on the proposed Type of timber aluminum composite beams has been conducted in this work program.

One of the main drawn conclusions from this study is that there are two significant modes of failure observed during the tests of the composite beams. The beam specimens subjected to sagging bending moment, failed by the delamination of plywood panel after the aluminum beam yielding, whereas the mode of failure was the breakage of the plywood panel after local buckling in the aluminum beam for those composite beams subjected to hogging bending moment.

The timber aluminum composite beams exhibited a significant increase of section capacity as compared with the aluminum beam. Although the used plywood slab is thin (18-37mm), and it adds only (2.43-4.86 kg/m) for the aluminum beam weight, the overall stiffness and strength of the composite section increase. The stiffness of the composite beams ranges from (1.92) to (2.56) times the stiffness of the aluminum beams, while the strength ranges from (1.18) to (1.56) times the strength of the aluminum beams. Also, the plywood slab provides sufficient constraint for the flange of aluminum beam and eliminates aluminum local buckling to which the aluminum beam may be subjected. In the same time, the increase of the thickness of plywood slab has a significant effect on the strength of the composite beam. With increase in the plywood slab thickness from 18 mm to 37mm the increase ratio in the ultimate loads reaches (38%), whereas reduction ratio in the midspn deflection reaches (17%). Finally, the suggested connection method between the components of the tested composite beams provides adequate interaction between these components to act as one unit, i.e., a complete interaction exists in these composite beams have.

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