

# Oriented Strandboard-GEOGYP™ Underlayment - A Novel Composite Flooring System

B. Noruziaan, A. Shvarzman, R. Leahy

**Abstract**—An innovative flooring underlayment was produced and tested. The composite system is made of common OSB boards and a layer of eco-friendly non-cement gypsum based material (GeoGyp™). It was found that the shear bond between the two materials is sufficient to secure the composite interaction between the two. The very high compressive strength and relatively high tensile strength of the non-cement based component together with its high modulus of elasticity provides enough strength and stiffness for the composite product to cover wider spacing between the joists. The initial findings of this study indicate that with joist spacing as wide as 800 mm, the flooring system provides enough strength without compromising the serviceability requirements of the building codes.

**Keywords**—Composite, floor deck, gypsum based, lumber joist, non-cement, oriented strandboard, shear bond.

## I. INTRODUCTION

THERE is a strong drive in construction industry for using more efficient and environment friendly materials and systems. The drive is in parallel to the trend of the day, which is sustainable development in all areas of human life.

In the light of this trend, Antex Western LTD and Red River College of Applied Arts, Science and Technology (RRC) conducted a collaborative study on the feasibility of incorporating a non-cement gypsum based material (GeoGyp™), called overlay hereafter; as one component of a composite flooring system. The other component of the system could be the commonly used sheets of oriented strandboard (OSB) or plywood.

The main requirement for the components of a composite system to work together is a strong shear bond between them. In case of concrete-wood composite systems, either mechanical shear connectors transfer load between the two layers, i.e. concrete overlay and wood [1], or notches cut into the wood surface act as shear transfer elements [2].

A testing apparatus was designed and used for the measurement of the shear bond between the overlay and OSB. It was found that the shear bond is sufficient for the required composite interaction, eliminating the need for installation of shear transfer elements between the two layers.

B. Noruziaan is with the Red River College of Applied Arts Science and Technology, Winnipeg, MB R3H 0J9 Canada (phone: 204-632-2313; fax: 204-633-6075; e-mail: bnoruziaan@rrc.ca).

A. Shvarzman is with Antex Ltd, 1375 Church Ave, Winnipeg, MB R2X 2T7 Canada (e-mail: asia@antexwestern.com).

R. Leahy was the senior student at Red River College of Applied Arts, Science and Technology, Winnipeg, MB, R3H 0J9 Canada. He is now with Capitol Steel Corp, 1355 Saskatchewan Ave, Winnipeg, MB R3E 3K4, Canada.

Cubical and cylindrical samples, as well as small beam samples of the overlay were cast and tested for characterization of the tensile/flexural and compressive behavior of the material.

Strips of the intended flooring system were fabricated and tested under flexural loading. The bending capacity and vertical deflection of those specimens were measured, recorded and analyzed.

Tests although limited in number proved the concept that the system could carry the specified level of the loads by the codes without violating the deflection requirements even with joist spacing as wide as 800 mm.

## II. MATERIAL CHARACTERIZATION

### A. Composition

The proposed flooring underlayment is fabricated using a layer of oriented strandboard (OSB) and a thin layer of the overlay. OSB is the commonly used construction sheathing product in Canada. The overlay is a high performance gypsum based underlayment material.

A number of experiments were conducted in laboratories to characterize the properties of the composite and its components. The experiments were conducted to measure the shear bond between OSB and the overlay, compressive strength, indirect tensile strength, modulus of elasticity and modulus of rupture of the overlay.

Following paragraphs explain the experiments and the findings of such experiments.

### B. Shear Bond

A strong shear bond between layers of a composite system is essential in holding the system together and maintaining the composite effect.

In order to measure the shear bond between the overlay and the OSB, a test apparatus was designed, fabricated and used in CARS Lab at RRC (Fig. 1). C clamps were put in place to hold the test apparatus from overturning (Fig. 2). The test specimens were fastened to the test apparatus using a number of conventional screws.

Load was applied to the top edge of the overlay layer, pushing it down and exerting a shear load between that layer and the OSB (Fig. 2). Samples were aged for 30 days.

The overlay layer separated from the OSB after the shear bond between two was overcome (Fig. 4)

### C. Tension Tests

Standard cube samples were cast and tested for split tensile test (Fig. 3).

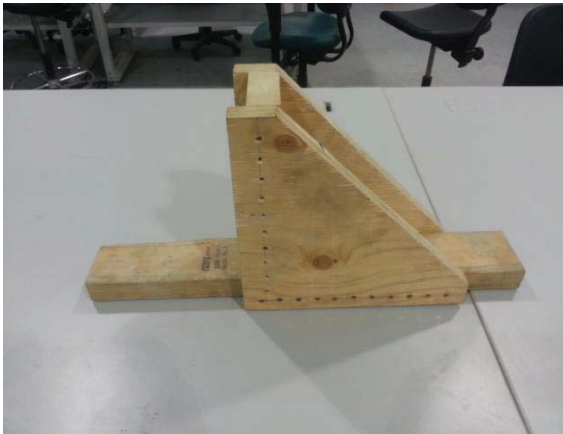


Fig. 1 The Shear Bond Test Apparatus



Fig. 2 The overlay layer was pushed down in order to measure the shear bond strength between OSB and the overlay



Fig. 3 Standard Cube and Shear Bond Specimen Molds



Fig. 4 The overlay separated from OSB due to slip failure

#### *D. Compressive Strength*

Depending on the direction of the bending moment, the overlay may experience compressive stress (conventional positive bending moment) or tensile bending stress (negative bending moment).

In order to measure the compressive strength of the overlay material, standard 100mmX200mm cylindrical specimens were poured and tested after 28 days (Fig. 5).



Fig. 5 Compressive Testing of the Overlay Material



Fig. 6 The Structural Test Specimen



Fig. 7 The Side Span Loaded by the Distributed Load System



Fig. 8 Center Span Loaded by the Distributed Load

#### E. Modulus of Rupture

In order to measure tensile capacity of the overlay material in bending, standard modulus of rupture tests were performed at Antex Western LTD. facility. Tests were performed according to ASTM C1609 [3] after 28 days.

### III. STRUCTURAL SYSTEM

Composite test specimens were fabricated by Antex Western LTD. The specimens were 2400 mm long and 300 mm wide. The length was divided into three equal spans of 800 mm each to represent three spans of a flooring system. Four 38x89 mm SPF pieces of lumber were used as supports. An 18mm thick OSB sheet was covered by 7.5 mm of the overlay material to create the underlayment (Fig. 6).

The 800 mm span exceeds the maximum joist spacing of 610mm allowed by the Canadian Code for system case 1 and 2 [4].

For the sake of comparison, a few specimens with the same geometry but using OSB only as the underlayment were fabricated for testing.

Specimens were tested under two different load arrangements. In the first arrangement a distributed load was applied on the side span for the measurement of deflection in the same span as well as deflection in the center span (Fig. 7).

In the second arrangement, a similar distributed load was applied on the center span to measure deflection in the center span and one of the side spans as well as the load capacity of the system as a whole (Fig. 8).

A 6mm thick steel bar was used to distribute the point load from the loading ram to a series of closely spaced 38mmX89mm pieces of SPF lumber that in turn transferred the load to the surface of the test specimens to mimic an approximation of a uniformly distribute load (Fig. 9).



Fig. 9 The uniformly distributed load is mimicked by a series of wood blocks under the steel bar

A load cell measured the applied load and two LDS's measured the vertical deflection of the test specimens.

For the case where center span was loaded, the two ends of the specimen tend to separate from the support frame. In order to keep the ends in place; C clamps were used (Fig. 10).

### IV. TEST RESULTS

In what follows the results of experiments are presented and discussed.





Fig. 10 C clamps were put in place to hold the end supports from lifting

*A. Compressive Tests*

The test results on three compression specimens are presented in

Table I. Like Portland cement based concrete, the gypsum based material gains more strength by the passage of time. The 28 day strength of 42.02 MPa is comparable to the stronger Portland cement concretes used in construction. Readers should notice the rather high strength of 23.2 MPa only after 3 hours of casting.

The significant rate of strength increase for this material in comparison to cement based concrete allows quicker access to the floor and continuation of construction.

*B. Flexural Tests (Modulus of Rupture)*

Standard modulus of rupture experiments were conducted on three specimens fabricated by the gypsum based material. The average of the tensile capacity (in bending) is shown in Table II. The 6.65 MPa capacity is well above the tensile strength observed for Portland cement based concrete beams, where the modulus of rupture for a strong concrete of say 40MPa is about 3.8 MPa [5].

TABLE I  
AVERAGE COMPRESSIVE STRENGTH OF THE MATERIAL (3 SPECIMENS)

Age	Compressive Strength, (MPa)
3 hours	23.2
1 day	23.53
3 days	28.66
7 days	33.14
14 days	39.34
28 days	42.02

TABLE II  
MODULUS OF RUPTURE (3 SPECIMENS)

Age	Peak Strength, (MPa)
7 days	4.7
28 days	6.65

*C. Indirect Tensile (Split Tests)*

Standard tensile tests were performed on three standard cubes. The average of the split tensile capacity increased as the material aged and approached a high value of 11.15 MPa. Results of the experiments are presented in Table III.

One must notice the rather high tensile capacity of 9.3 MPa even after 7 days of casting. This high value is well beyond the 8% to 12% of the compressive strength [6] for conventional 30 MPa-35MPa concrete.

TABLE III  
INDIRECT TENSILE TEST (SPLIT TEST) RESULTS

Age	Average capacity (MPa)
7 days	9.3
14 days	10.5
28 days	11.15

*D. Direct Shear Bond*

Six shear bond specimens were fabricated and tested in the lab. The specimens were aged for 30 days before testing. The average value for the shear bond strength was 0.402 MPa which is a reasonably large value to safeguard a composite interaction between OSB and the overlay material. Test results are presented in Table IV.

TABLE IV  
DIRECT SHEAR (BOND) STRENGTH BETWEEN OSB AND THE OVERLAY

Day 30 results (MPa)	
Sample 1	0.345
Sample 2	0.367
Sample 3	0.395
Sample 4	0.399
Sample 5	0.494
Sample 6	0.41
Average	0.402

TABLE V  
THE RUPTURE LOAD (PRESSURE) FOR DIFFERENT GRADES OF OSB AND JOIST SPACING

	Rupture pressure (kPa)		
	1F24 (18mm OSB) 800 mm joist spacing	1R24 (11mm OSB) 600mm joist spacing	1F20 (15mm OSB) 600mm joist spacing
Control	25.2	33.3	48.8
Composite	Sample 1	26.5	36.5
	Sample 2	35.2	35.3
	Sample 3	30.79	40.8
	Average	30.8	37.5

TABLE VI  
DEFLECTION AT CENTER OF THE END SPAN AND THE MIDDLE SPAN UNDER VARIOUS LEVELS OF LOADING

Material	Loading		Deflections (mm)						
			1F24 (18mm OSB) 800 mm joist spacing		1R24 (11mm OSB) 600mm joist spacing		1F20 (15mm OSB) 600mm joist spacing		
			End Span $\Delta$	Center Span $\Delta$	End Span $\Delta$	Center Span $\Delta$	End Span $\Delta$	Center Span $\Delta$	
Control	2 kN Center	Sample 1	1.70	6.20	2.51	8.22	1.04	4.04	
		Sample 1	N/A	N/A	6.30	2.01	5.21	1.62	
	2 kN End	Rupture	Sample 1	4.10	25.20	8.94	27.52	7.13	24.22
		Sample 1	0.38	2.10	0.28	2.26	0.34	1.05	
	2 kN Center	Sample 2	1.82	2.00	0.47	2.21	0.23	1.16	
		Sample 3	0.55	1.60	0.46	3.30	0.44	1.64	
		Average	0.92	1.90	0.40	2.59	0.34	1.28	
	Composite	2 kN End	Sample 1	2.38	0.64	1.58	0.58	1.33	0.35
			Sample 2	1.93	0.58	1.76	0.39	N/A	0.29
			Sample 3	1.89	0.11	1.62	0.42	1.47	0.45
Average		2.07	0.44	1.65	0.46	1.40	0.36		
4 kN Center		Sample 1	0.80	4.89	0.57	5.15	0.61	2.69	
		Sample 2	0.51	3.80	0.70	3.81	0.35	2.32	
	Sample 3	0.75	4.12	0.66	5.27	0.38	3.21		
Average	0.69	4.27	0.64	4.74	0.45	2.74			
Rupture	Sample 1	1.19	8.55	4.64	29.00	7.23	22.84		
	Sample 2	1.49	10.39	3.23	29.15	9.09	21.67		
	Sample 3	1.37	8.44	3.39	25.48	6.19	21.04		
	Average	1.35	9.13	3.75	27.88	7.50	21.85		

#### E. Large Scale Floor Sections Testing (Structural Samples)

Table V presents the rupture pressure for different combination of OSB grades and joist spacing. Load was applied on the middle span for failure (rupture) studies. The Control specimens were the panels of OSB only. The composite specimens were OSB panels covered by the overlay. Notations such as 1F24 are the performance grades for OSB panels ([7]).

Pressure is calculated by dividing the ram load over the surface area of one panel of the structural system. The numbers in this table reveal that adding the gypsum based material on top of the OSB may significantly increase the load bearing capacity of the structural system (up to 22% for 800 mm joist spacing).

Table VI presents the measured deflection of the floor panel under various levels of loading on the end and middle spans.

By looking at the average values obtained from the corresponding experiments one can draw the following conclusions.

In case of the center span loaded to 2 kN (8.33 kPa), the deflection of both the center and end span decrease with the composite effect. The central span deflection is reduced significantly from 8.22 mm to 2.59 mm in case of the 1R24 (11 mm) OSB and from 6.20 mm to 1.90 mm for 1F24 (18 mm) OSB.

When the load of 2kN was applied to the end span, the deflections were also decreased for the composite system in comparison with the OSB alone deck (for example, compare 6.30 mm to 1.65 mm for 1R24 with 600 joist spacing).

The authors tested the composite deck under a much larger center span load of 4 kN (16.66 KPa) and figured out that the maximum deflection was only 4.89 mm in the worst case scenario for the 800 mm span, which is equivalent to 1/164 of the span. For the 600 mm span, the maximum deflection of 5.27 mm is 1/114 of the span. One needs to note that the

applied pressure of 16.66 kPa is far more than the maximum load of 4.8 kPa as prescribed by the National Building Code of Canada [8].

The center load was increased up to rupture. Buy rupture the authors refer to the failure of the system to take any further load. This happened after the appearance of tensile cracks on the middle supports of the deck and due to overcoming the tensile capacity of the overlay layer followed up by disintegration of the system including the OSB (Fig. 11).

The most commonly observed mode of failure was the delamination of the OSB layer due to excessive shear inside the material (Fig. 12).

Another mode of failure was the delamination at the bond surface between the overlay and the OSB (Fig. 13).



Fig. 11 Tensile crack in the overlay on top of the intermediate supports (negative bending moment)

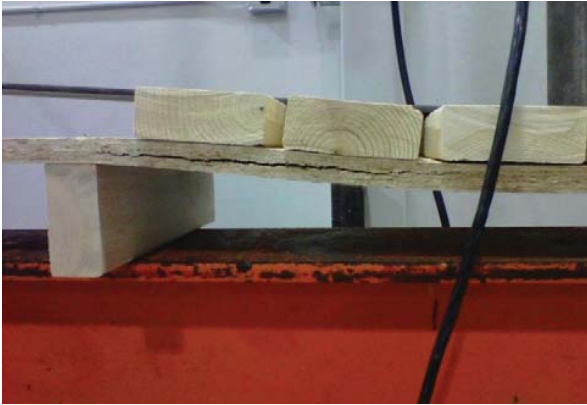


Fig. 12 Delamination within the OSB due to excessive shear stress

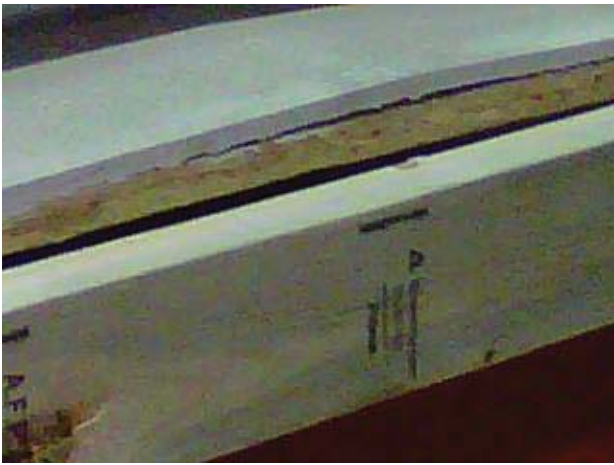


Fig. 13 Delamination between the overlay and the OSB

#### V. CONCLUSION

The experiments in this study revealed that the composite underlayment may have a higher rupture capacity (in the range of 2.5% to 40%) in comparison to OSB. Moreover, it deforms significantly less than an OSB alone underlayment under similar loads.

Covering the wooden underlayment, i.e. the OSB panels with a thin layer of GeoGyp™ not only provides a smooth and finished layer of flooring with a rather short period of setting/gaining strength, but also increases the rigidity of the underlayment, allowing for wider spacing between the floor joists.

This possibility results in reduction of the number of floor joists, saving in labor and construction materials, while reducing the construction time.

#### ACKNOWLEDGMENT

The staff of the Office of Applied Research and Commercialization and the Department of Civil Engineering Technology at RRC; as well as the National Science and Engineering Research Council of Canada (NSERC) and NRC-IRAP Program are acknowledged for providing the technical

and financial support of this project.

#### REFERENCES

- [1] Lukaszewska, E. et al, 2010, "Laboratory Tests and Numerical Analyses of Prefabricated Timber-Concrete Composite Floors", *Journal of Structural Engineering*, Vol 136, No.1, 2010
- [2] Boccadoro, L., and Frangi, A., 2014, "Experimental Analysis of the Structural Behavior of Timber-Concrete Slabs Made of Beach-Laminated Veneer Lumber", *Journal of Performance of Constructed Facilities*, Vol. 28, Issue 6, 2014
- [3] ASTM C1609, "Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam With Third-Point Loading)"
- [4] CSA, 2010, "O86-09, Engineering Design in Wood"
- [5] Cement Association of Canada, 2008, "Concrete Design Handbook", 3<sup>rd</sup> Edition
- [6] Cement Association of Canada, 2011, "Design and Control of Concrete Mixtures"
- [7] Canadian Wood Council, 2010, "Wood Design Manual"
- [8] NRC-CNRC, 2005, "National Building Code of Canada"