Idaho Incubation Fund Program

Bi-Annual Progress Report Form

Proposal No.	IF13-003
Name:	An Chen and Richard Nielsen
Name of Institution:	University of Idaho
Project Title:	Development of an Energy Efficient Integrated FRP-confined Precast Concrete Sandwich Roof Panel for Green Buildings

Information to be reported in your progress report is as follows:

1. Provide a summary of project goals/milestones for the period just completed, accomplishments for the period just completed, and plans and goals for the coming quarter:

1) Project goal/milestone for the period ending in December 31, 2012:

- Develop Finite Element (FE) models to simulate insulated precast concrete sandwich panels.
- Conduct bending tests of scaled specimens.

2) Accomplishments:

Development of FE models:
Finite Element (FE) models (Figure 1) have been developed to simulate insulated precast concrete sandwich panels and are calibrated against existing test results. The FE models incorporate FRP plates, FRP shear connectors, top and bottom concrete wythes, and foam core.

Bending tests of scaled specimens:
Bending tests on twelve scaled specimens have been conducted, including two solid panels, six sandwich panels, and four sandwich panels with FRP plates. The specimens were 10 inch deep, 2 ft wide, and 9 ft long. The panels with FRP plates consisted of four layers from top to bottom: an FRP top plate, top concrete wythe, foam core, and bottom concrete wythe, as shown in Figure 2. Two types of shear connectors were adopted, including a continuous shear connector and a segmental shear connector. Table 1 lists details for each specimen.

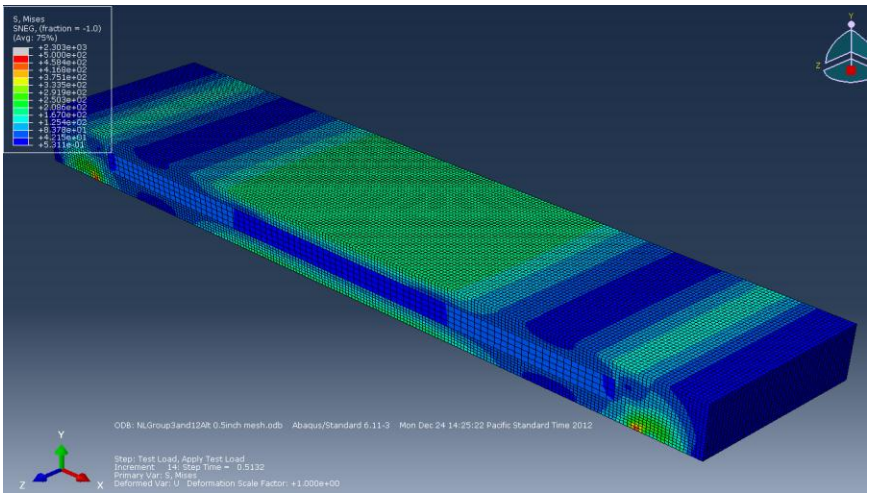

Figure 1. Finite Element Model

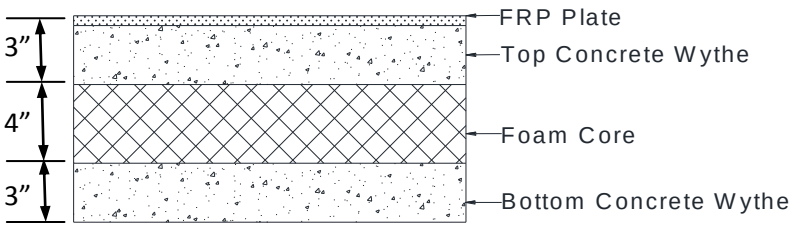

Figure 2. FPCS Panel Specimen

Table 1. Specimen Details

Group #	Compression Steel (#4 bars)	Tension Steel (#5 bars)	Top Temp. Steel (#4 bars)	Bottom Temp. Steel (#4 bars)	Load Condition	Shear Connectors	FRP Plate
1	(2) @ 18" O.C.	(2) @ 12" O.C.	(6) @ 18" O.C.	(6) @ 18" O.C.	3-pt Bending	N/A	N/A
2	(2) @ 18" O.C.	(2) @ 12" O.C.	(6) @ 18" O.C.	(6) @ 18" O.C.	3-pt Bending	N/A	N/A
3	(2) @ 18" O.C.	(2) @ 12" O.C.	(6) @ 18" O.C.	(6) @ 18" O.C.	4-pt Bending	Discrete 6"	N/A
4	(2) @ 18" O.C.	(2) @ 12" O.C.	(6) @ 18" O.C.	(6) @ 18" O.C.	3-pt Bending	Segmented	N/A
5	(2) @ 18" O.C.	(2) @ 12" O.C.	(6) @ 18" O.C.	(6) @ 18" O.C.	3-pt Bending	Segmented	N/A
6	(2) @ 18" O.C.	(2) @ 12" O.C.	(6) @ 18" O.C.	(6) @ 18" O.C.	3-pt Bending	Continuous	N/A
7	(2) @ 18" O.C.	(2) @ 12" O.C.	(6) @ 18" O.C.	(6) @ 18" O.C.	3-pt Bending	Continuous	N/A
8	N/A	(2) @ 12" O.C.	N/A	(6) @ 18" O.C.	3-pt Bending	Segmented	Yes
9	N/A	(2) @ 12" O.C.	N/A	(6) @ 18" O.C.	3-pt Bending	Segmented	Yes
10	N/A	(2) @ 12" O.C.	N/A	(6) @ 18" O.C.	3-pt Bending	Continuous	Yes
11	N/A	(2) @ 12" O.C.	N/A	(6) @ 18" O.C.	3-pt Bending	Continuous	Yes
12	(2) @ 18" O.C.	(2) @ 12" O.C.	(6) @ 18" O.C.	(6) @ 18" O.C.	4-pt Bending	Discrete 6"	N/A

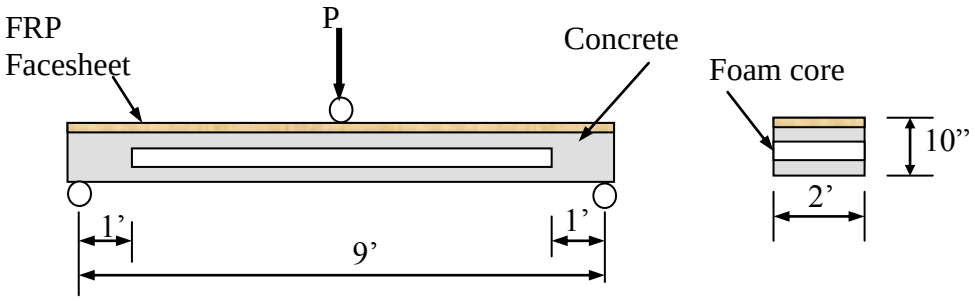

Figure 3: Schematic Test Setup

Figure 4: Photo of Test Setup

Three-point bending tests were conducted, with a schematic plan and photo of the test setup shown in Figures 3 and 4, respectively. Strain gages were bonded along the depth of the specimen to study composite behavior. Load-displacement relation was recorded to study stiffness. All specimens were tested until failure to study strength and failure modes. The specimens either failed due to bending failure or shear failure initiated from the support, as shown in Figure 5. Typical load-displacement curves are shown in Figure 6.

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a: Bending Failure – Concrete Crushing **b: Shear Failure – Diagonal Crack**

Figure 5: Failure Modes

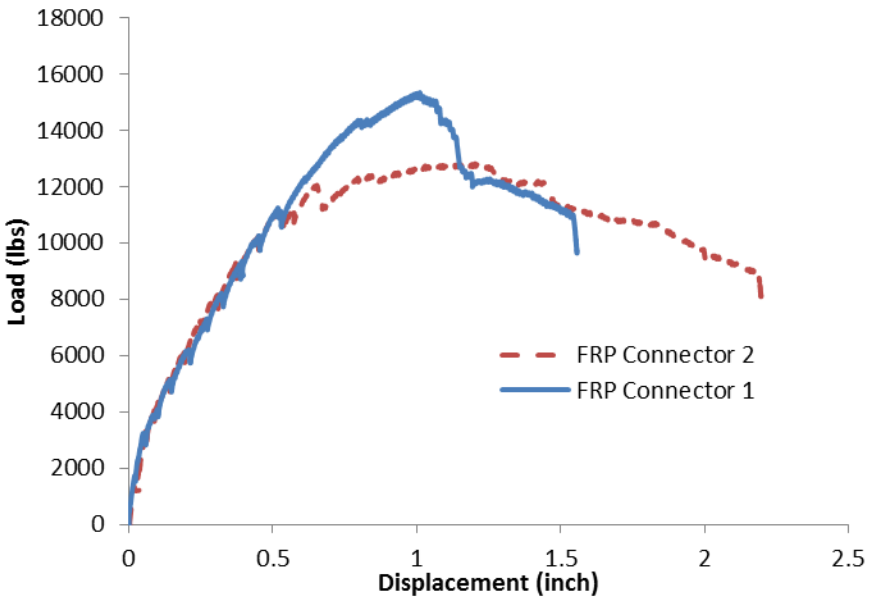


Figure 6: Load-displacement Curves

3) Plan and Goals for the coming six-month:

The plan and goals for the coming six-month include:

- Creep tests: Creep tests will be conducted to study long-term deflection of the panels under sustained loads. The same specimens as described above will be subjected to a four-month creep in bending at 40% of the static capacity, as determined above. Two specimens will be tested, with one specimen for each group.

- Evaluation of Full-Scale Specimens: Based on findings from Tasks 1 and 2, full-scale specimens, 16 ft long and 2 ft wide, will be constructed. Bending tests will be conducted. The performance will be evaluated and the failure modes will be characterized.

- Development of a Business Plan: A complete business plan will be developed with the commercialization partner.

2. Provide a summary of budget expenditures for the period just completed:

See below for a summary of budget expenditure ending in November 2012.

Table 2. Budget Summary Ending in November 2012

Grant Summary Report for FC2886 (November 2012)

Back to Budget/Grants

REPORT fwrsumr — RUN DATE: 10-Dec-2012
COAS: 9 — GRANT SUMMARY REPORT — TIME: 11:18 AM
FROM INCEPTION THROUGH NOV-2012 — PAGE: 1

Inception Date: 01-JUL-12
End Date: 30-JUN-13

Budget/Title: FC2886: SBOE Energy Eff Integrated FRP
P/I Manager: An Chen

Percent of Time Remaining: 58%

		ADJUSTED BUDGET	INCEPTION TO DATE ACTIVITY	BUDGET RESERVATIONS	AVAILABLE BALANCE	MONEY REMAINING
01	Salaries	24,600.00	3,840.00	0.00	20,760.00	84%
02	Fringe Benefits	3,000.00	137.70	0.00	2,862.30	95%
03	Irregular Help	12,500.00	1,269.00	0.00	11,231.00	90%
04	Travel	2,800.00	0.00	0.00	2,800.00	100%
05	Other Expense	7,100.00	1,803.88	1,800.00	3,496.12	49%
10	Trustee/Benefits	0.00	3,231.00	0.00	-3,231.00	0%
	GRANT TOTALS	50,000.00	10,281.58	1,800.00	37,918.42	76%
	Personnel Costs	40,100.00	5,246.70	0.00	34,853.30	87%
	Other Direct Costs	9,900.00	5,034.88	1,800.00	3,065.12	76%
	Indirect Costs	0.00	0.00	0.00	0.00	0%

RELEASE: 8.5.1

3. **List patents, copyrights, plant variety protection certificates received or pending:**
   N/A

4. **List invention disclosures, patent, copyright and PVP applications filed, technology licenses/options signed, start-up businesses created, and industry involvement:**
   An international application for filing in the US receiving office has been filed on December 13, 2012, with an application number of PCT/US12/69291 and a title of *Concrete Building Panel*.

5. **Include funding burn rate:**
   The funding burn rate was 24% as of November 2012.

6. **Any other pertinent information:**
   The research has been used as a course project to enhance the curriculum of the PI's course of CE441-Reinforced Concrete Design in Fall 2012 and create an interactive environment for students to explore concepts of reinforced concrete design through design, manufacturing, and physical experiments of the panels. 43 students from the class actively participated in the research. They were divided into 11 groups, with each group responsible for constructing and testing one panel, including rebar cutting, rebar assembling, formwork construction, concrete pouring, concrete vibrating, panel construction, form stripping, test setup, and panel testing (Figure 7). The students were able to create their own knowledge (constructivism) by an inductive experiential active learning approach, from concrete experience of experimental study (grasping experience) to abstract conceptualization of new and key theoretical aspects of reinforced concrete design (transforming experience),

developing innovative and critical thinking and research ability and acquiring life-long learning qualities. The students welcomed this innovation and showed great enthusiasm in participating in this research. Responses from the students are listed below:

"After constructing a reinforced concrete slab and testing it, it gave a better understanding of the designing of reinforced concrete. It was a good opportunity to see how the reinforcements within the concrete affect the strength and durability of a slab or beam when concrete and steel are combined."

"Being able to physically see the behavior of the beam failure helped everyone in the group to better grasp the concepts covered by Dr. Chen in his class. "

"The testing of the specimen was a great way to tie in the concepts lectured throughout the course. It provided a great hands-on opportunity to apply and test our knowledge of reinforced concrete design."

"This project really helped to understand a large number of the concepts covered in CE 441 this semester. It was very interesting to see a real world application and actually get to observe the steel and concrete reach maximum stress and strain before going into failure. It is also very important to understand how certain research and testing with real world applications is completed. This project definitely gives us an advantage when entering the industry."

"The project was useful in showing us with hands-on experience how a concrete beam reacts to an increasing load, and ultimately fails. The experience of recognizing cracks forming and the significance of where and when they occur can only be helpful in the future. It was also interesting to observe the tension and compression reinforcement as it reached its yield strain. Testing of the reinforced concrete beam was helpful in creating a better understanding of reinforced concrete design."

"The experiments performed in the lab allowed hands on learning approach. This is helpful for students with different learning styles and allows for experimental results, not only showing the expected deflection and nominal moment capacity but through a linear observation of the failure mode. The inclusion of structural experiments in a structures design class can greatly enhance a student's retention."

a: Rebar Cutting

b: Rebar Assembling

c: Formwork Construction

d: Concrete Pouring

e: Concrete Vibrating

f: Surface Smoothing

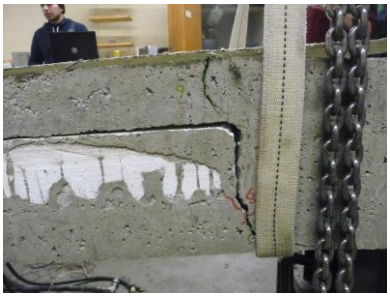
g: Constructed Panels

h: De-molded Panels

i: Test Setup

j: Panel Testing

k: Panel Failure



l: Failure Mode

Figure 7: Students' Participations