Mechanical Enhancement Of Composite Decks

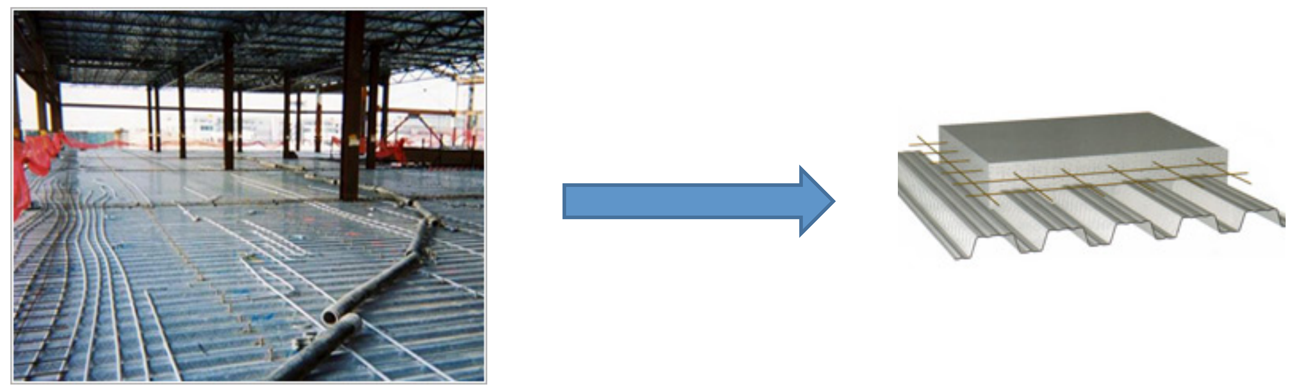
Civil Engineering

Students: Chris McComb, EIT and Bianca Rodriguez
Advisors: Fariborz Tehrani, Ph.D., PE, PMP

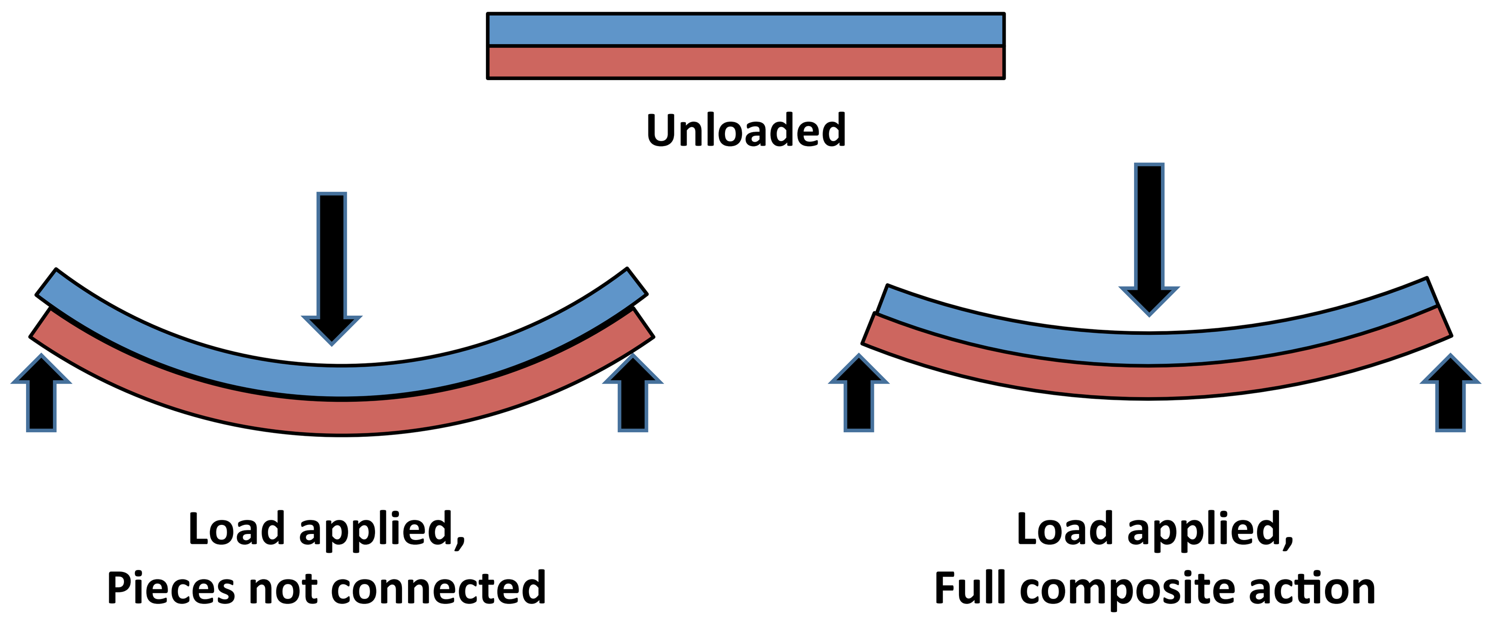
FRESNO STATE
Lyles College of Engineering

Introduction

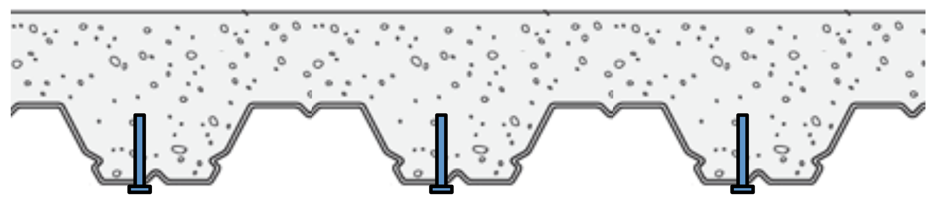
Many buildings make use of composite decks as either floors or roofs. A composite deck consists of concrete poured over a corrugated piece of light gage steel deck. In addition, steel rebar is cast within the concrete as reinforcement. A cross section of a typical composite deck is shown below.



Typically, the strength of the composite deck is calculated by only taking the steel rebar and the concrete into account – the light gage steel deck is disregarded. This is because the concrete is not mechanically connected to the steel deck. If the concrete could be mechanically connected to the steel deck, the strength and rigidity of the deck could be greatly increased (see below).

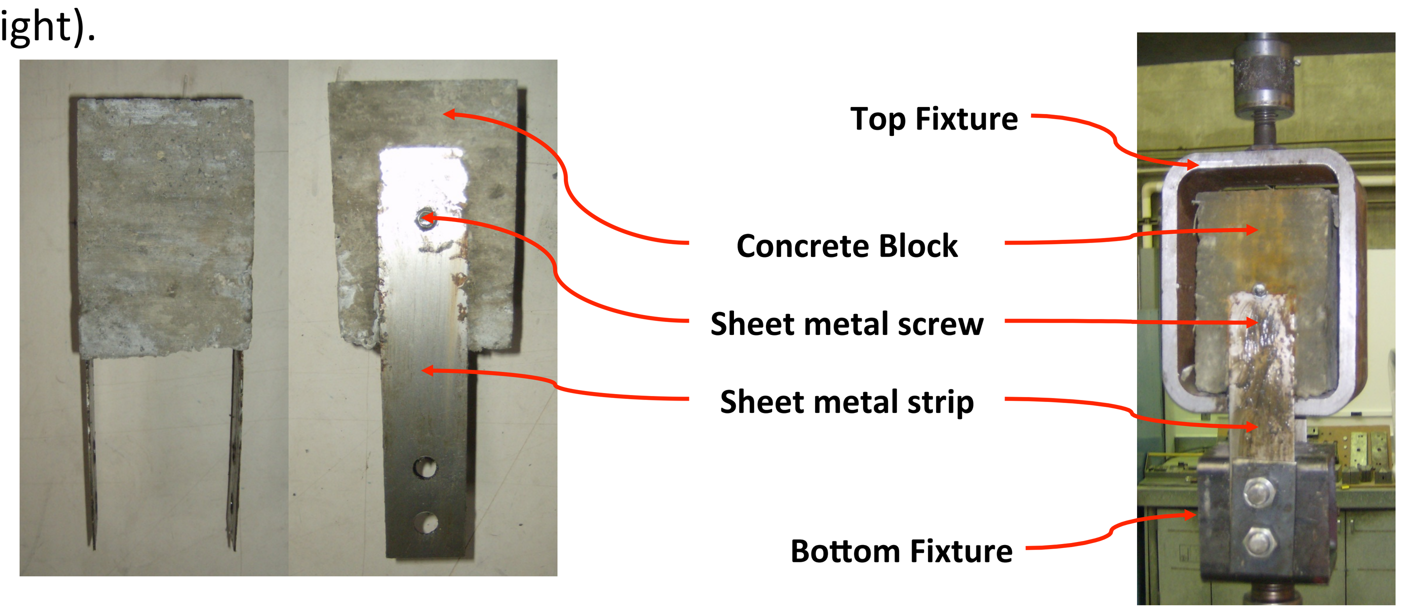


It is anticipated that the concrete can be anchored to the corrugated steel deck both economically and effectively by drilling sheet metal screws through the steel deck prior to placing the concrete (a cross section is shown below). Calculations indicate that this connection might prove so effective that steel reinforcement within the concrete (known as rebar) might be done away with entirely.

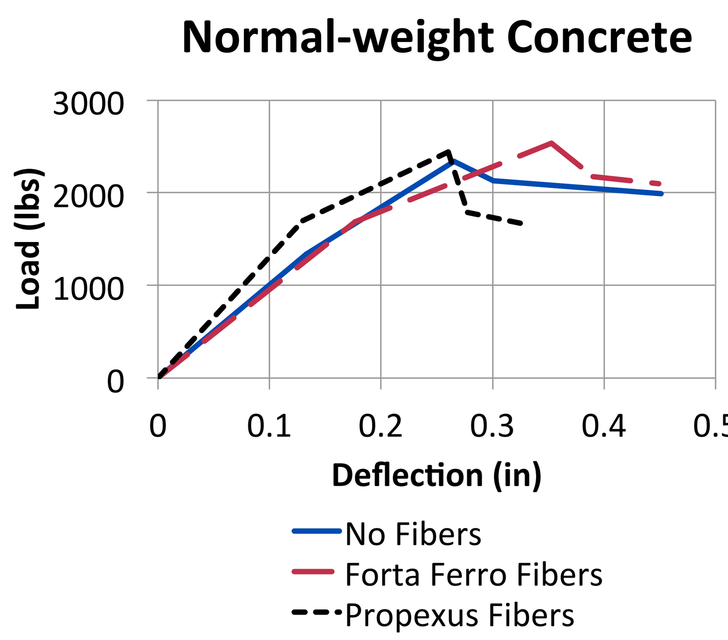


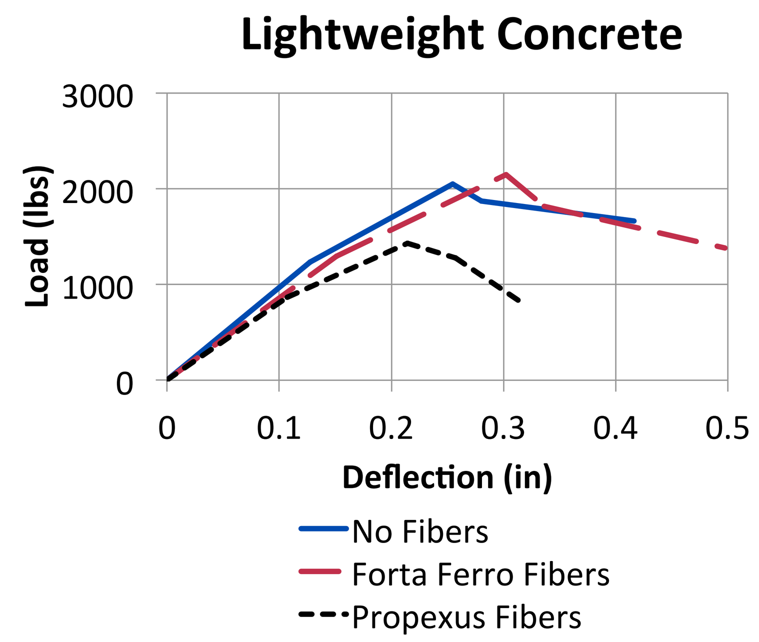
Experimental Validation of Connection Strength

Predicted values for the strength of the embedded sheet metal screw were based primarily on design equations from ACI 318. These design equations are typically meant for much larger embedded fasteners, and are typically very conservative. For that reason, it was deemed necessary to experimentally validate the strength of the connection. In all cases, the experimentally validated strength exceeded that predicted by ACI equations. The strength of the connections was tested with specimens as shown below (left). These specimens were loaded in tension using a hydraulically actuated machine (right).



A total of 6 different concrete mixes were used (both lightweight and normal-weight, using no fibers, Forta Ferro fibers, or Propexus fibers). For each mix, 5 identical specimens were constructed and tested. After the data was appropriately filtered, the curves shown below emerged. The graph on the left shows load as a function of deflection for normal-weight concrete, and the graph on the left shows the same data for lightweight concrete.

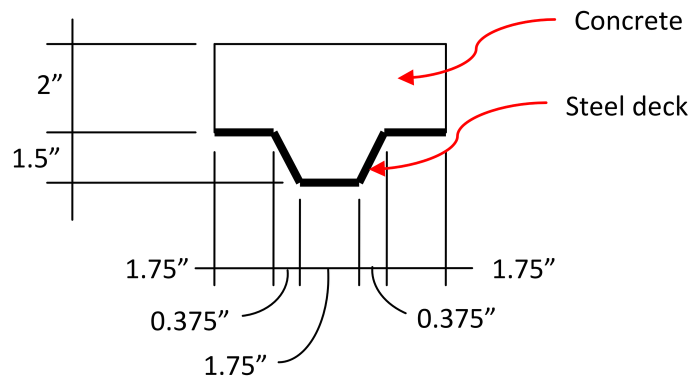




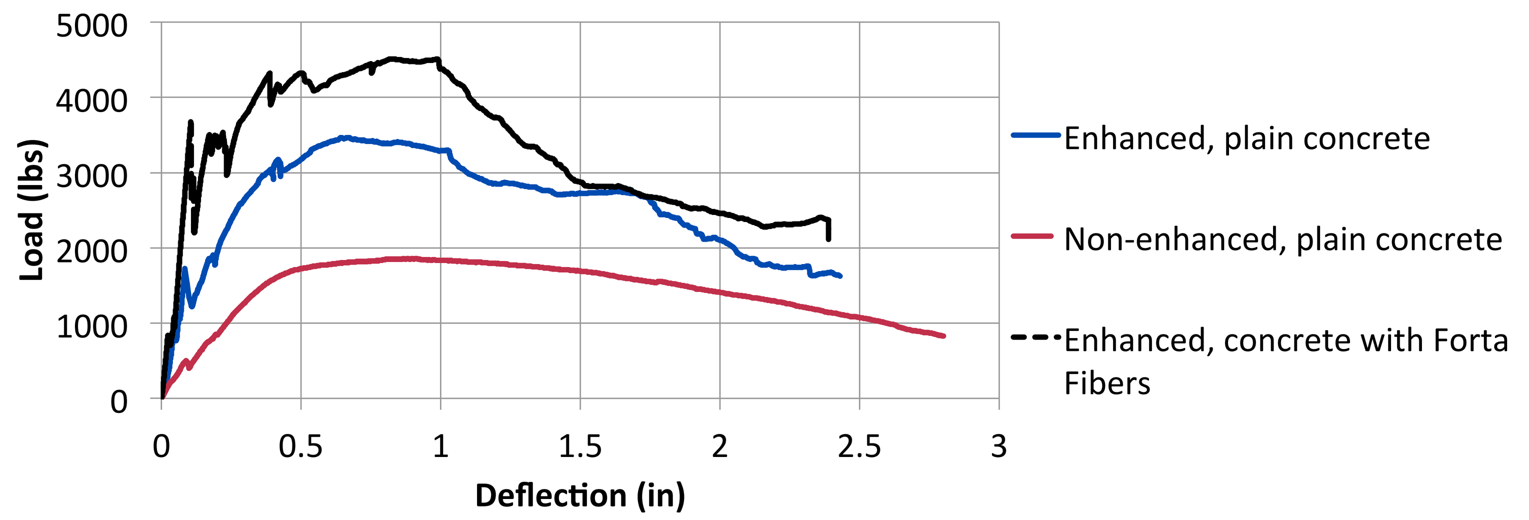
It is interesting to note that the Propexus fibers did not appear to increase the ductility or strength of the connection. In addition, specimens utilizing Forta Ferro fibers only achieved modest gains in ductility.

Experimental Validation of Enhanced Deck

Using the material stress-strain curves and the geometry of the section a moment-curvature plot was developed. This was accomplished by discretizing the cross-section into a series of horizontal strips, and then calculating the curvature and moment for various strain values. The moment-curvature relationship, along with the experimentally developed load-displacement curves for the shear connections, were used to calculate the expected strength of a unit-width of deck with a 33" simply supported span. Physical pieces of deck were then constructed and tested (figures at right).



The chart below shows typical curves for non-enhanced beams with plain concrete, enhanced beams with plain concrete, and enhanced beams with fiber reinforced concrete.



The full experimental and predicted results for the series of beams are shown in the table to the right. The low predicted value for the lightweight/Propex beams is due to the low measured strength of the embedded fasteners.

Aggregate Type	Fiber Type	Measured Strength (k-in)		Predicted Strength (k-in)	% Diff.
		Average	St. Dev.		
Plain Lighweight	None	10.3	0.4	9.4	-8.8%
Lighweight	None	22.1	2.2	22.0	-0.4%
Lighweight	Propex	24.8	0.9	17.1	-30.9%
Lighweight	Forta	26.2	0.4	24.0	-8.3%
Normal-weight	None	21.0	0.7	24.2	15.1%
Normal-weight	Propex	23.9	1.3	22.8	-4.8%
Normal-weight	Forta	23.1	1.7	24.3	5.3%

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Conclusions, Future Work, and Recommendations

This project aimed to increase the strength of composite decks by increasing the shear transfer between the two materials. The results presented, both analytical and experimental, indicate that this can be accomplished by the use of embedded sheet metal screws, driven through the steel deck prior to pouring the concrete. In addition, further gains can be realized with the addition of reinforcing fibers in the concrete. The experimental results match up well with an analytical model which allows the prediction of the ultimate strength of the deck. However, the calculation of the deflection of the deck is currently inaccurate. Further development of this model is recommended prior to attempts are publication so that the full performance of enhanced composite decks can be calculated. More experimental validation of the model is also recommended. The experimental validation offered here only used a single fastener size, single fastener spacing, and single deck type. All of these variables must be explored and tested to determine the limitations of the analytical model. This method might be of use in locations where increased deck strength is beneficial in a specific and relatively small area. However, if this method were to be used for entire floors or roofs, it would be necessary to affix the screws (or a similar projection) using an automated manufacturing process.