Extending Application of SDCL Steel Bridge System to ABC Applications in Seismic Regions

Ramin Taghinezhad[1], Atorod Azizinamini[2]
[1]Ph.D. Candidate, [2]Professor and Chair
Department of Civil and Environmental Engineering, Florida International University, Miami, FL

www.abc-utc.fiu.edu

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INTRODUCTION

Recently a new steel bridge system, referred to as "Simple for Dead Load and Continuous for Live Load (SDCL)" has gained popularity in non-seismic areas of the country. The SDCL bridge system advances the bridge construction to elimination of expansion joints and bolted connections. Accordingly, it results in many advantages including: higher service life and lower inspection and maintenance costs comparing to conventional bridge construction methods.

In SDCL system, the girders are spliced over the pier. Girders are placed spanning directly from pier to pier (or abutment to pier) within each span. The individual spans are simply supported when the deck is cast. Once the deck is in place, reinforcing steel cast into the deck provides continuity of the tensile forces for live load and superimposed dead loads (weight of barrier and future wearing surfaces) only. The compressive component is transferred by steel blocks. An example of the typical SDCL connection detail is shown in Figure 1.

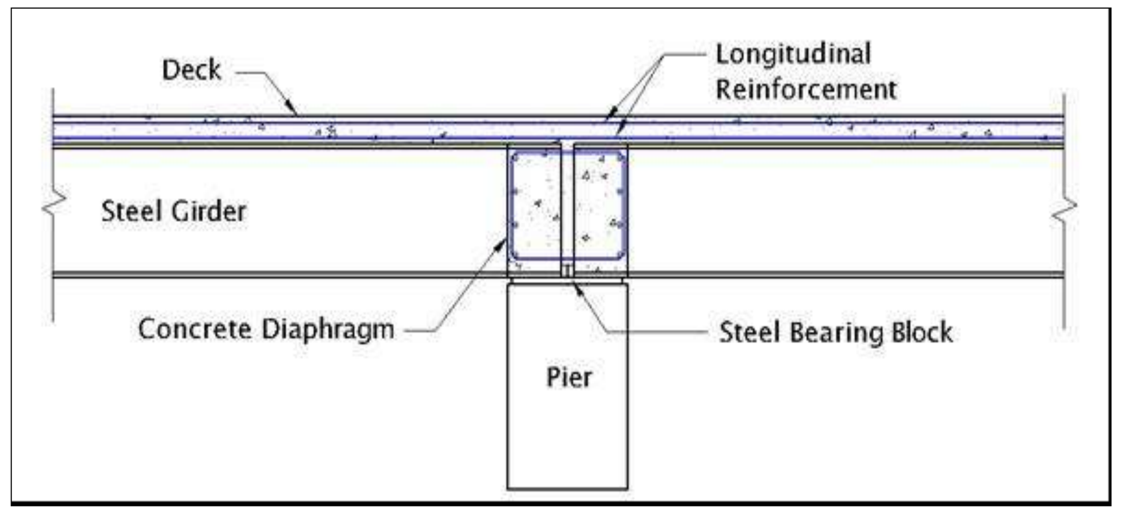

Fig. 1. Simple for Dead and Continuous for Live Detail

The SDCL system is also best suited for accelerating the construction process. An ABC implementation of the SDCL method includes: building individual spans off site, transporting them to the final location and then joining the spans over the middle piers to create continuity for live load. Another version of the system which utilizes adjacent beam technology can significantly reduce the onsite construction activities.

PURPOSE OF THE RESEARCH

To-date no research studies have been conducted to extend the applicability of SDCL system to seismic regions, either for conventional or ABC. The main objective of this research is to extend the application of SDCL to high seismic areas. This project is Phase I of an envision effort that will culminate in development of set of details and associated design provisions that will allow use of SDCL in high seismic areas.

This project, as Phase I, is concentrating on developing suitable details through mainly, numerical analysis. It is envisioned that in Phase II of the project, experimental tests will be carried out to verify the validity of the design recommendation.

PROPOSING ALTERNATIVE CONNECTION DETAIL FOR SEISMIC REGIONS

❑ THE NECESSITY OF USING A NEW CONNECTION

In the case of non-seismic application, the connection over the middle supports are mainly subjected to negative moment. i.e. the bottom flanges of the girders transfer, mainly compressive force into concrete diaphragm. Therefore the bottom flanges of the girder inside the concrete diaphragm does not need to be positively connected and the current detail is sufficient. However, in the case of seismic application it was determined that the bridge girders over the middle support could be subjected to positive moment. i.e. bottom flanges will be subjected to tension and try to pull out of the concrete diaphragm.

❑ NEW PROPOSED CONNECTION FOR SEISMIC REGIONS

The proposed connection is similar to non-seismic detail, except that it uses high strength bolts to positively connect the girder ends, more dowel bars which goes from the column into the concrete diaphragm and more closed stirrups (Figure 2).

Fig. 2. The proposed connection for seismic region.

RESEARCH METHODOLOGY

To evaluate the behavior of the proposed connection during seismic event, series of nonlinear analyses were carried out. A series of nonlinear analysis were carried out to comprehend:

a) Force transfer mechanism for the envisioned connection detail for seismic areas

b) Numerically identify, as best as possible, the modes of failure.

One of the challenging point in achieving the two objectives listed above was the type of loading that the model should be subjected to. Series of prototype bridges were designed based on Caltrans recommended design provisions and were subjected to various ground motions. However, one could question such approach to establish the demand side, as outcome may change based on the details of the prototypes and ground motions used. Therefore it was decided to subject the model to three different types of loading as following:

- Pushing down the ends of the girders
- Pushing up the two ends of the girder
- Pushing up one end of girder and pushing down the ends of other girder

NUMERICAL STUDY

The proposed connection was modeled by nonlinear finite element program to study its behavior in more detail and develop information that could be used to advance the proposed detail. Commercial finite element software package, ANSYS 16, was used for the finite element modeling. The finite element model consisted of the steel girder, concrete slab, concrete diaphragm, bolts, bars and steel details such as stiffeners.

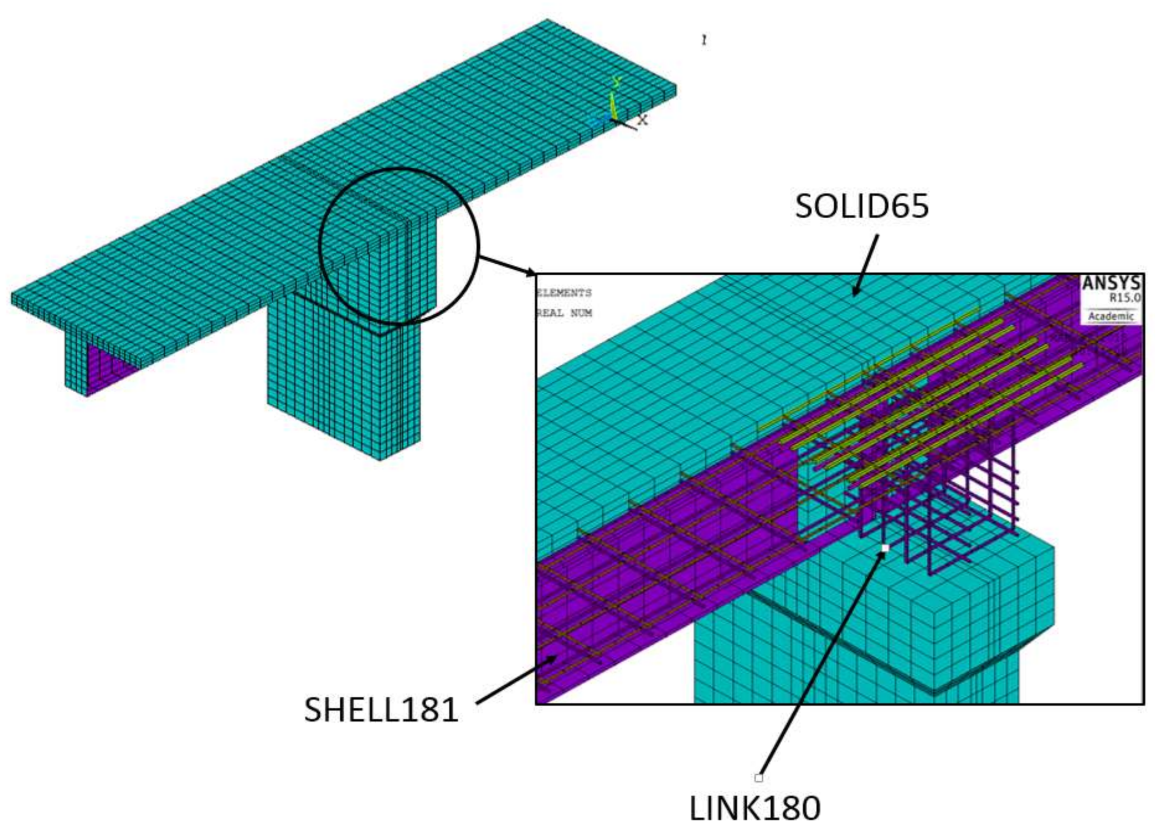

Fig. 3. Finite element model in ANSYS.

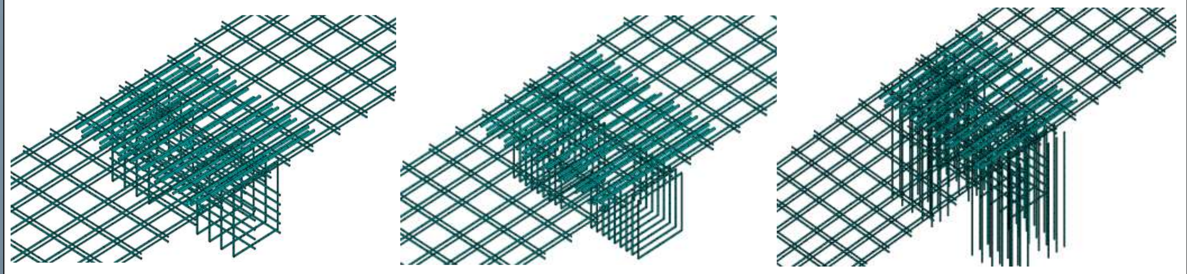

Fig. 4. Three different models for stirrups and dowel bars

FINITE ELEMENT RESULTS

▪ MOMENT-DRIFT UNDER PUSH-DOWN FORCES

Figure 4 compares moment-drift for current SDCL connection and proposed connection for seismic regions. Results show bolts increased the moment capacity of connection under push-sown forces. Top bolts help to deck bars and bottom bolts help to steel block to carry tensile and compressive forces respectively. Finite element results indicate yielding of the top bolts prior to crushing of the bottom concrete.

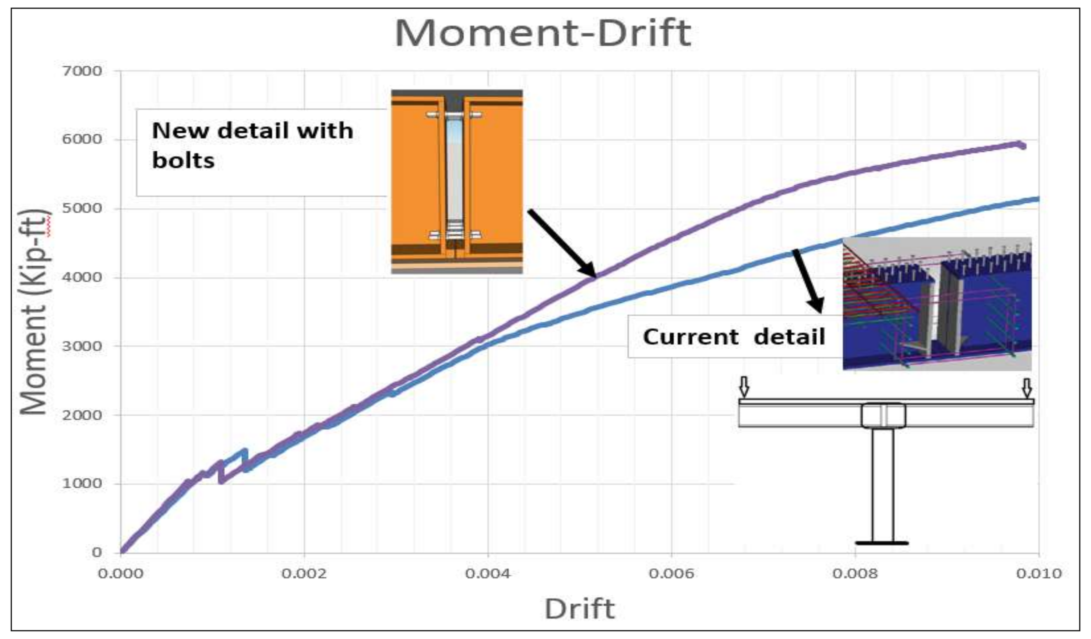

Fig. 4. Moment-drift under push-down forces

❑ MOMENT-DRIFT UNDER PUSH-UP FORCES

The connection over the pier is subject to positive moment under vertical component of earthquakes . This loading was modeled by applying two push-up forces. The finite element analysis was performed for models with different bolt sizes, closed stirrups and dowel bars volume ratio (Figure 5).

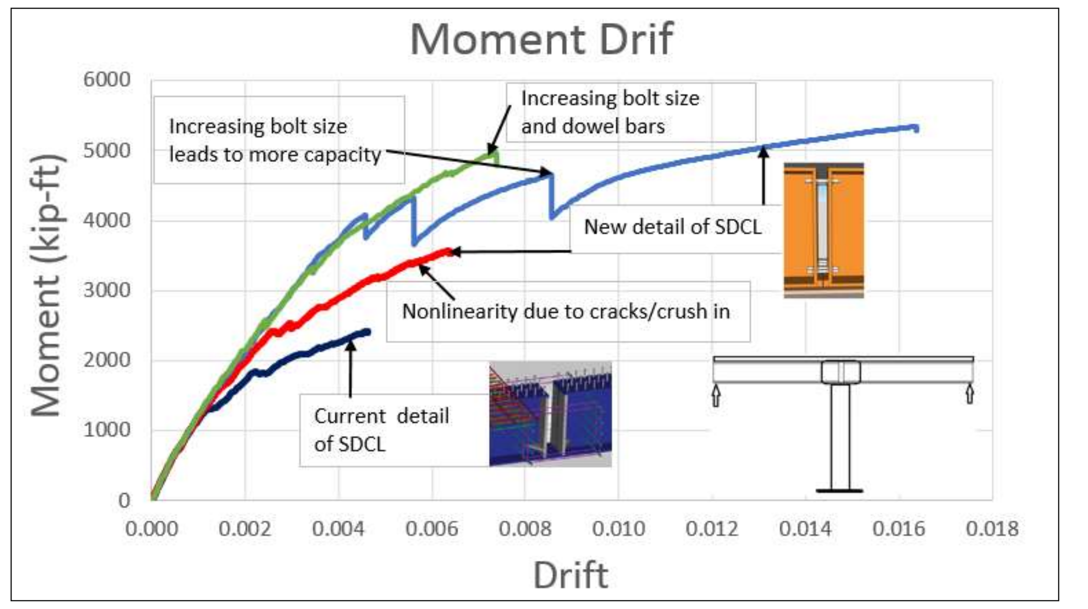

Fig. 5. Moment-drift under push-up forces

❑ MOMENT-DRIFT UNDER MOMENT REVERSAL

The deflection of the bridge under longitudinal seismic loads was simulated with two inverse loads at two ends of the girders. As shown in Figure 5, the results indicate bolts don't increase the capacity of the system while dowel bars at two sides of the concrete diaphragm have major effect on the capacity of the system.

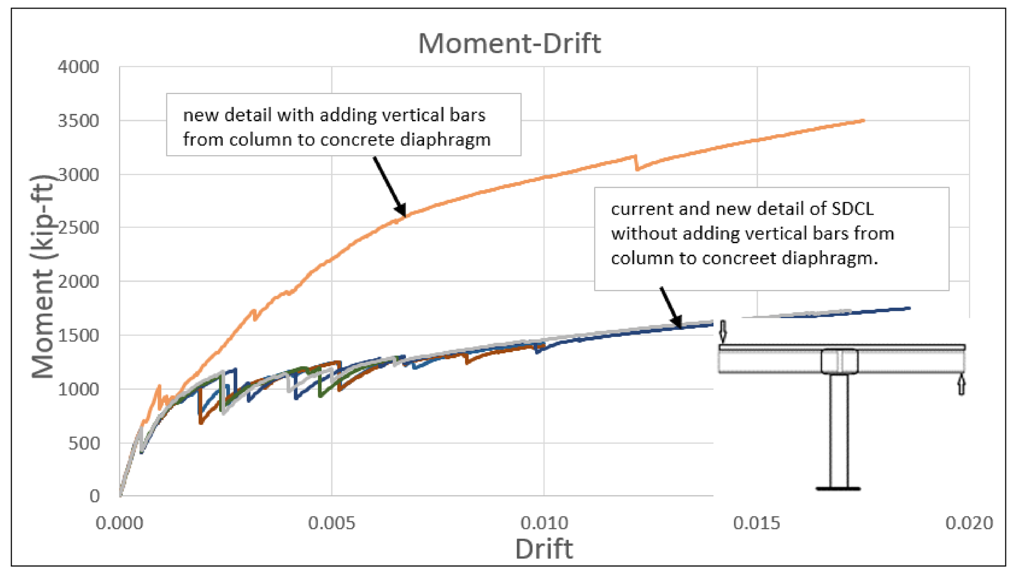

Fig. 5. Moment-drift under push-up forces

PRELIMINARY CONCLUSIONS

At this point we are still modifying and further refining the envisioned detail and it is too early to recommend a detail for testing. What we have learned is that, for integral option (where superstructure and substructure are monolithic. practiced mainly in west coast), significantly more closed stirrups needs to be placed in the concrete diaphragm and further a good connection between super and substructure needs to be developed to prevent early failure of concrete diaphragm when it is subjected to moment reversal.

REMAINING TASK

The remaining task in this project includes getting feedback about the new proposed connection detail, using drop-down bent cap or combined bent cap and concrete diaphragm from DOT engineers. The feedbacks will help to improve and finalize the detail and probably doing some component test. The numerical study is planned to be done by September and component test for cyclic loads is to be done by December.