KSU-14-04

I. Research Project Title: KDOT Column Expert: Ultimate Shear Capacity of Circular Columns using the Modified Compression Field Theory

II. Research Problem Statement: The extreme event requirement as a limit state set by AASHTO LRFD makes it necessary to develop the actual capacity of concrete sections to accurately design them to withstand the extreme load events. For confined sections subjected to combined axial force and uniaxial bending moment, the actual ultimate *flexural* capacity is found using the earlier versions of KDOT Column Expert. Accordingly, it is necessary to develop a computer program that evaluates the section capacity in shear by generating accurate shear-moment interaction diagrams for each level of axial force and compares them to the available experimental results. This analysis can prove useful to estimate the existing capacity of damaged bridge piers when subjected to truck impacts. It is also desirable to have a reliable analysis tool that can be used to assess the actual shear capacity of the pier when developing a repair action. Experimental evidences have shown that the modified compression field theory can capture the actual shear capacity of the section very accurately. In addition, the dowel action of the longitudinal bars acting in tension can contribute to increasing the shear capacity, a factor often neglected by design codes of practice.

The nonlinear axial load-strain and uniaxial moment-curvature response of *reinforced concrete circular section* combined with shear forces is very involved. It is important to note that accurate results are guaranteed when the axial load and bending moments are proportional since loading path dependence is avoided. Rasheed and Abd El Fattah have developed a framework for columns that imposes proportional axial force and uniaxial bending moment on circular sections and iterates to obtain the corresponding deformation parameters. However, this procedure needs to be extended to the general case of shear-moment-axial force interaction.

III. Research Proposed/Research Objectives: The objective of this proposed research is to develop a detailed analysis procedure that can be used by KDOT as an effective analysis and design tool to determine the actual ultimate shear capacity of reinforced concrete circular columns subjected to axial force and uniaxial bending moment simultaneously. The proposed software will introduce the following:

1. Shear force-bending moment interaction diagrams for each level of axial force based on the actual capacity according to the modified compression field theory.
2. Design shear force-bending moment interaction diagrams for each level of axial force based on the ϕ factors of AASHTO LRFD procedure.
3. Mapping of demand shear force, bending moment and axial force points on the shear capacity interaction diagrams to visually show their correlation.

Fig. 1 shows a schematic sketch of the type of results obtained from the analysis of circular concrete columns. The modified compression field theory-based model for combined shear force- bending moment and axial compression will be extended. The second stage of the work will involve the development of an algorithm capable of plotting the ultimate and the design interaction diagrams in 2D and 3D spaces, Fig. 1a-b. By selecting the axial load level of the case being analyzed from the 3D surface, the conventional 2D plot of the shear-moment is generated. This software will be benchmarked, during the third stage, against existing experimental, numerical and computational data and will form the sixth version of **KDOT Column Expert**. The fourth stage will be to extend the GUI (Graphics User Interface) to generate all the possible interaction diagrams graphically and map all possible demand sets of data on them while furnishing all the material properties available to the user and required by the analysis in a graphical menu built into the program. Once the axial load demand level of data is entered, the shear-moment interaction diagram is locked at that axial force height level when plotting the 2D interaction diagram, Fig. 1b.

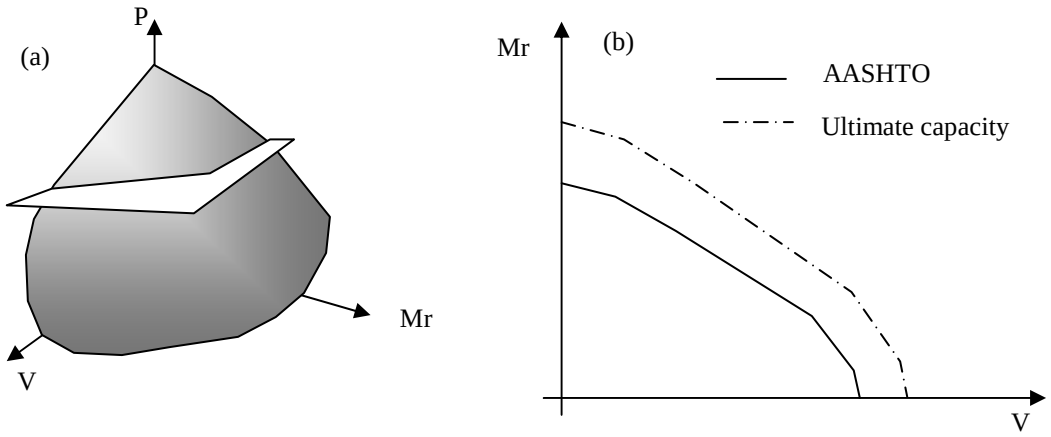

Fig. 1 Column shear interaction diagrams (a) 3D surface. (b) Specific interaction diagram cut.

The specific tasks of this proposed project will be developed after the project is approved and in consultation with the KDOT-assigned project monitor.

IV. Estimate of Funding and Research Period:
Estimated project duration: 24 months (starting May 2013)
Estimated budget: $ 61,000

V. Urgency and Payoff Potential: The research should have a high priority. It is inevitable to have a detailed analysis tool that accounts for the actual ultimate shear capacity of bridge piers. The developed and benchmarked software ***KDOT Column Expert*** for analyzing circular and rectangular bridge piers, under flexure, is currently used by the Bridge Design Office and its consultants to perform routine design and analysis.

VI. Implementation Strategy: The software developed in this study will be available for immediate implementation by the Bureau of Design at KDOT, just like earlier versions of ***KDOT Column Expert***.

VII. Project Personnel: This project will be carried out under the direction of **Hayder Rasheed**, Principal Investigator and **Asad Esmaeily** Co-principal Investigator in close cooperation with the Bureau of Design. One Ph.D. student in civil engineering will also work on this project.

Hayder Rasheed holds a Ph.D. in Civil/ Structural Engineering from The University of Texas at Austin. His areas of specialty are structural engineering/mechanics, FRP composites and concrete behavior. He is particularly interested in the structural performance of concrete and FRP besides other structural applications. He is a registered Professional Engineer ***in Wisconsin***.
Asad Esmaeily received his Ph.D. degree in Civil/Structural Engineering, M.S. degree in Electrical Engineering and also M.S. degree in Structural Engineering from the University of Southern California. As a **CalTrans senior bridge engineer** for close to a year, he worked on **the seismic retrofit/replacement of the new bay-bridge** before joining Kansas State University. He is a registered Professional Engineer (**PE, California**).

VIII. Submission Information:
November 30, 2012
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