I. RESEARCH PROJECT TITLE

LRFD software for design and actual ultimate capacity of confined rectangular columns: Phase 1

II. RESEARCH PROBLEM STATEMENT

The problem of truck impact to reinforced concrete bridge piers is very common to State Departments of Transportation in Kansas and elsewhere. In such cases of pier impact with or without apparent damage, it is desirable to have a reliable analysis tool that can be used to assess the actual capacity of the pier prior to developing a repair action. It is widely known that AASHTO dictates the requirement of ignoring the contribution of confinement to the ultimate capacity of concrete columns. This is reflected on the column design interaction diagrams prepared by ACI 340 in the Design Handbook 17. This could be quite significant especially for columns under relatively high axial loads. The prediction of the actual ultimate capacity of confined concrete columns under a certain axial load level requires specialized nonlinear analysis.

The nonlinear moment curvature response of *reinforced concrete beam sections* is typically established based on the well-known incremental deformation procedure. The problem of determining the ultimate capacity of concrete columns is conceptually similar. However, the required solution procedure is different and more 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 has developed a framework for beam-columns that imposes proportional axial force and uniaxial bending moment on rectangular sections and iterates to obtain the corresponding deformation parameters. However, this procedure needs to be extended to the general loading of axial force and biaxial bending. The procedure is load-controlled in which the ultimate capacity is determined from failure strain limits. This may be performed by using the so called fiber model which is a 2D constant-strain element analysis of the cross section. The moment of the area concept will be extended to biaxial bending and the double curvature about the inelastic centroid axes will be monitored up to failure.

III. RESEARCH PROPOSED/RESEARCH OBJECTIVES

The objective of this proposed phase is to develop a detailed analysis procedure that can be used by KDOT as an effective analysis and design tool to determine the actual capacity of reinforced concrete rectangular columns. The proposed software will solve for the following:

1. Axial force-biaxial moment interaction diagrams based on AASHTO resistance factors.
2. Axial force-biaxial moment interaction diagrams based on the 0.003 concrete crushing strain limit, which is designated by unconfined ultimate analysis.

3. Axial force-biaxial moment interaction diagrams for the ultimate capacity of columns based on the actual confined concrete stress-strain behavior (Phase 2).

Fig. 1 shows a schematic sketch of the type of results anticipated. A new model will be developed for the realistic capacity analysis towards establishing expert software for the complete engineering of bridge piers. The new eccentricity-based model for combined biaxial bending and axial compression is proposed. The eccentricity will relate the resultant moment to the axial force. It will be plotted against the size of the compression zone for verification and further insights. The second stage of the work will involve the development of an algorithm capable of predicting the unconfined and the confined interaction diagrams in 3D space. By selecting the axis orientation of the resultant moment versus axial force from the 3D space, the conventional 2D plot is generated. By generating families of parallel interaction diagrams, conceptual or preliminary design will be made very easy. This software will be benchmarked, during the third stage, against existing experimental data and will form the first interactive tool for the design of piers using AASHTO LRFD. The fourth stage will be to build the GUI (Graphics User Interface) to make the software interactive and user friendly during Phase 2 of this project.

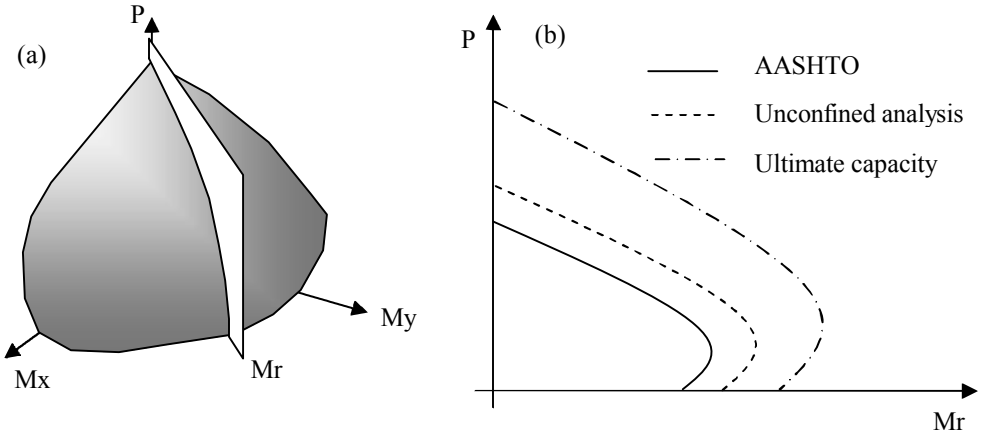

Fig. 1. Column interaction diagrams (a) 3D surface. (b) Specific interaction diagram cut.

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: 18 months (starting May 2009)
Estimated budget: $ 59,900

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 capacity to columns and bridge piers. The developed and benchmarked software will be used to assess the actual ultimate capacity of bridge piers subjected to truck impacts or those requiring capacity upgrade due to corrosion or overloads.

VI. IMPLEMENTATION STRATEGY

The software developed in this study will be available for immediate implementation by the Bureau of Design at KDOT.

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.

Asad Esmaeily holds a Ph.D. in Civil/ Earthquake Engineering from University of Southern California. He has more than 13 years of experience in the experimental and analytical studies on reinforced concrete structures, including software development, on bridges in general and bridge piers in particular. He is a registered Professional Engineer.

VIII. SUBMISSION INFORMATION

November 27, 2008

Hayder Rasheed, Ph.D., P.E.
Associate Professor
Department of Civil Engineering
Kansas State University
2118 Fiedler Hall
Manhattan, KS 66506
Tel. (785) 532-1589
Fax. (785) 532-7717
E-mail: hayder@ksu.edu