Title:	Development of Knowledge in the Application of Strut-and-Tie Modeling
The Problem:	There are gaps in knowledge for applying strut-and-tie modeling. TxDOT designs can significantly benefit, if these knowledge gaps can be filled. There have been no tests performed where there are three orthogonal directions of tension ties, such as would occur above a drilled shaft in tension where a column is supported on a four-drilled shaft footing. When there is one direction of tension, the strength of the concrete is reduced; when there are two orthogonal directions of tension at a node, the strength of the concrete is reduced further. It is logical to assume that where there are three orthogonal directions of tension, the strength of the concrete is reduced further still. Until physical testing is done, the current practice may be underestimating the strength of these nodes. A finite element model was developed to show that a hooked bar creates significant nodal stresses. The tighter the radius of the bend, the higher these stresses are. While the AASHTO LRFD Bridge Design Manual does not specifically require checking the stresses in this type of node, it is good engineering practice. Often when you have hooked reinforcement, there are multiple mats of reinforcing, as often seen on cantilevered bents. There have been no attempts at determining the stress effects of nested hooked bars. Designing based on the current state of practice may lead to over stressing these areas. Currently, AASHTO LRFD does not provide any benefit to the confinement provided by the presence of passive confinement reinforcement for the nodal capacities. Confinement increases the capacity of concrete, so it is logical to assume passive confinements could increase the capacity of the nodes. TxDOT could see a reduction in the size of members designed using strut-and-tie modeling (footings and cantilevered bents), saving cost on cubic yardage of concrete. Furthermore, AASHTO LRFD limits the spacing of crack control reinforcing to d/4. This is the limit of the current research. Additional research could show that crack control reinforcing could be spaced wider, saving cost on reinforcing steel.
Technical Objectives:	The researchers shall address the following: 1. Determine the nodal efficiency factor of a node where there are three orthogonal directions of tension ties. 2. Determine the nodal stresses due to hook bars, especially nested hook bars. 3. Determine how the presence of passive confinement reinforcing should adjust the confinement modification factor. 4. Determine if the current d/4 limit on the spacing of crack control can be exceeded. 5. Provide guidance on the spacing limits. 6. Conduct physical testing, or finite element models, or a combination of both. 7. Provide guidance on modifications to AASHTO LRFD to incorporate findings. The expectation of this project is that the end product will obtain a TRL level 5.
Desired Deliverables:	1. Technical memorandum for each task completed. 2. Monthly progress reports. 3. Value of Research (VoR) that includes both qualitative and economic benefits, to be included in the final research report. 4. Research report documenting the findings of the research, including a comprehensive test report, and design guidance on modifications to AASHTO LFRD Specifications and the TxDOT Bridge Design Manual. 5. Project Summary Report.

Proposal Requirements:	1. Utilize the “Proj/Agre” and “PA_Form” templates located at the TxDOT RTI website. 2. Proposals will be considered non-responsive and will not be accepted for technical evaluation if they are not received by the deadline or do not meet the requirements stated in RTI's University Handbook, which is also located at the RTI website. 3. Proposals should be submitted in PDF format, 1 PDF file per proposal. File name should include project name and university abbreviation. 4. This project will be tracked during the life of the project using a Technology Readiness Level (TRL) scale. For more information about the use of a TRL, click.