

REQUEST FOR PROPOSALS

Investigation of Fatigue Performance of Double Tee Flanges

Project:

The PCI Technical Activities Council and Research and Development Council have identified the fatigue performance of double tee flanges in parking garages as an industry priority. A further description of the research objectives is provided in the attached Research Project Statement.

Proposer Qualifications:

Proposers shall have demonstrated experience in the analysis and testing of precast and prestressed concrete structural systems. The principal investigator shall be experienced in research project management. Research facilities shall be available to conduct the testing required to accomplish the objectives stated in the attached Research Project Statement.

Proposal Requirements:

The Proposal shall include identification of the agency, the Principal Investigator, all staff, and partners that will provide work to the Project, including complete contact information. It shall further include a description of qualifications and related experience of the research team relevant to the Project and describe available testing facilities.

The Proposal shall include a description of the proposed work plan to demonstrate an understanding of the problem, include conceptual details of any proposed test setup, present a research plan to meet the objectives in the attached Research Project Statement, and include a detailed schedule for planning, testing, and reporting results.

The Proposal shall include a total lump sum budget and provide a breakdown of costs aligning with the research plan. As applicable, the Proposal shall include letters of support for the proposing agency and Project from precast concrete fabricators or other project contributors, and provide documentation of support for any planned in-kind contributions or matching funds for the research. PCI limits university indirect costs to 15 percent for funded projects per Board resolution. A sample PCI Research and Testing Agreement is attached and will be used as the contract form for the project. Any exceptions to terms of the agreement shall be noted in the proposal.

Proposals shall be submitted no later than **4:00pm Central Time on December 15, 2023** in electronic .pdf format to technical@pci.org. Questions regarding the Project may be sent to the same address.

Proposal Review:

Proposals received by the stated deadline will be reviewed by an Industry Advisory Committee composed of representatives from the Research and Development Council. The committee will recommend the selection to the Council for final project award. PCI anticipates final selection will be in **February 2023**. PCI reserves the right to reject all proposals.

Attachments:

Research Project Statement
Sample PCI Research and Testing Agreement

RESEARCH PROJECT STATEMENT

Investigation of Fatigue Performance of Double Tee Flanges

Background:

Section 5.13.1 of the 8th Edition PCI Design Handbook (2017) states the following:

Double-tee flanges are subjected to concentrated point loads in numerous applications, with parking structures being the most common. There are several approaches to performing these designs, including yield-line theory, influence charts, and an effective-width analysis. All of these methods appear to be conservative when compared with actual load tests (Aswad and Burnley 1991; Steele 2003; Botros et al. 2016). When considering concentrated loads on cantilevered flanges, the effective-width approach usually produces satisfactory results without the need to additionally refine the analysis. This approach requires the use of an influence angle extending back to the flange-to-stem interface in order to determine an effective resisting section. The flange reinforcement is designed based on one-way bending of a cantilever. This approach neglects plate behavior, which explains why load tests have shown it to be conservative. However, it typically results in a reasonable design. The research suggests that an influence ratio of 3:1 results in an effective width consistent with crack patterns from actual load tests.

The transverse design moments must be resisted by structural reinforcement, such as welded-wire reinforcement or reinforcing bars. Handbook Example 5.13.1.1 illustrates this for a uniform load and Example 5.13.1.2 illustrates this for a concentrated load. Fibers, which are sometimes used to control shrinkage cracks, do not transfer loads and, therefore, cannot be used to replace structural reinforcement. This is particularly important for structural toppings over precast concrete components. The reinforcement in these toppings cannot be replaced with fibers. It is good practice to reinforce the unsupported corners of double tees with a minimum of one no. 4 L-bar. Because double tees are prestressed units, the longitudinal reinforcement in the flange does not need to satisfy minimum shrinkage and temperature reinforcement.

The distribution of 3:1 was a generalization of the work by Botros et al. (2016) where flanges were subjected to concentrated loads until failure and the resulting crack pattern was used to determine the effective influence area. Gamble (2017) has suggested that concentrated loads should be reconsidered and changed to more realistic values and distributions. Gamble also notes *“The PCI Handbook treatment of the concentrated load case needs to be returned to something similar to the sixth edition example [which was 45 deg. distribution], as the seventh edition example has load-spread values that are indefensible on any rational analysis basis [which was 60 deg. distribution]—especially when compared with the results of elastic plate theory solutions or when compared to realistic multi-wheel loadings.”* Gamble suggests a series of four 2 kip wheel loads at 5 ft – 3 ft – 5 ft spacing to represent two cars passing in a parking garage. The commentary to ASCE/SEI 7-16 provides the following regarding the specified concentrated load for parking garages: *“In view of the large load effect produced by a single heavy vehicle (up to 10,000 lb (44.48 kN)), the current*

concentrated load of 2,000 lb (8.90 kN) should be increased to 3,000 lb (13.34 kN) acting on an area of 4.5 in: × 4.5 in: (0.11 m × 0.11 m), which represents the **load caused by a jack in changing tires** (emphasis added).”

Naito et al. (2019) examined fatigue life of flange-to-flange connectors and include Figure 10 with a histogram and a lognormal probability density for vehicular weights based on data from 2001 and earlier.

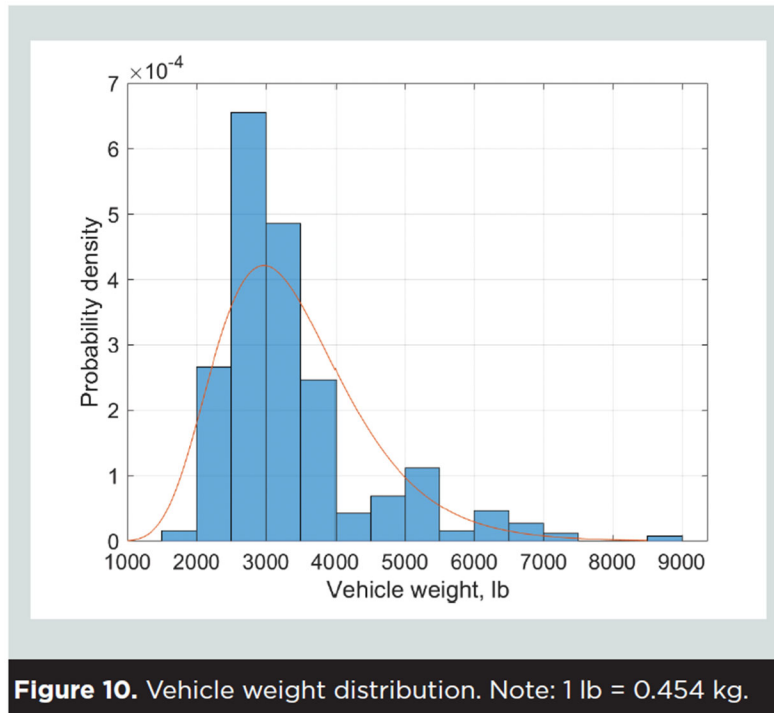


Figure 10. Vehicle weight distribution. Note: 1 lb = 0.454 kg.

Updated information from currently available production vehicles is needed to evaluate design loads for parking garages. Available information suggests electric vehicles may be more than 1,000 lbs. heavier than their internal combustion engine equivalents due to battery weight. Updated information on the distribution of vehicle weights will be used to determine the design load for the fatigue testing rather than the 3,000 lb. load from a jack.

Testing of double tee flanges subjected to point loads should demonstrate effective engagement of the flange reinforcement in load resistance. To achieve this, pre-cracking of the flange adjacent to the stem interface with stone-splitting wedges has been shown to effectively crack the section and engage the reinforcement.

Research Objectives:

The *prime* objective of the research shall be to investigate the fatigue performance and load distribution of double tee flanges subjects to concentrated loads. The findings from this work shall include recommendations on the design and detailing of double tee flanges and flange-to-flange connections.

The testing required for the prime objective should also be taken as an opportunity to simultaneously examine other **secondary** objectives that can improve the cost-effectiveness and safety of double tee flanges. Secondary objectives to consider include:

- 1) Determining appropriate vehicular loading criteria for the design of parking garages based on current market data and expected market trends for vehicles
- 2) Evaluating the performance of flange-to-flange welded connection details for fatigue resistance, including post-test examination of connectors;
- 3) Evaluating the relationship between flange-to-flange connector spacing and load distribution between adjacent flanges.

Minimum Testing Requirements

This project is anticipated to include at least two fatigue tests on one set of two double-tees: one test along one joint and one test on the other joint after rotating the tees. Prior to testing, a portion of the flange-stem interface near the concentrated loads should be pre-cracked to simulate a load event causing cracking prior to testing for fatigue performance. The test will be expected to subject the flanges to a minimum of 2,000,000 load cycles at intensities determined with the PCI Industry Advisory Committee. After fatigue testing, the double-tee flanges shall be subjected to concentrated load tests near midspan and the end in accordance with ACI CODE-437.2 to evaluate load-distribution and capacity of the flange sections.

It is envisaged that the test setup will consist of two parallel full-length (60 ft) double-tees with a set of two concentrated loads, representing the two tires of a vehicle crossing the joint, located near midspan. However, proposals containing innovative and less expensive setups that can still provide the information required to achieve the prime objective are welcome. Details for the flange-to-flange connections, including type and spacing, shall be determined after discussion with the PCI Industry Advisory Committee. In addition, proposals shall describe any actions to be taken as part of each test setup to investigate one or more of the secondary objectives described previously.

Scope of Work

1. Develop the test setup and design components for testing in accordance with the background information and minimum testing requirements for review by the Industry Advisory Committee.
2. Perform testing and data collection.
3. Prepare interim reports and presentations for the Industry Advisory Committee.
4. Perform appropriate analysis of data collected to support the development of design requirements and revisions to industry standards and/or handbooks.
5. Prepare final report of test program for review by the Industry Advisory Committee and final approval by the Research and Development Council.

Deliverables

Interim Reports: Provide interim reports and presentations at 6 month intervals to the Industry Advisory Committee on the progress of the work, including testing or analysis completed since the prior report. Interim reports to remain confidential with Industry Advisory Group.

Final Report: Provide final report of test program including appropriate background information, details of the test setup and procedures, all test results, summary and discussion of results, and recommended design requirements. Final report is expected to be published on the PCI website. Recommended design requirements are expected to include:

1. Support for maintaining or increasing the current requirements for concentrated loads in parking garages in the IBC and ASCE 7;
2. Rationale for maintaining or changing the recommendations on load distribution in 5.13.1 of the 8th Edition PCI Design Handbook;
3. Changes recommended for the design of flange-to-flange connectors, which may include spacing, welding, or other details to improve performance;

Publications: Provide summary paper(s) for publication in the *PCI Journal*.

Duration:

The project is anticipated to be completed within 12 months.

Budget:

The Research and Development Council has allocated up to \$100,000 for this project.

Payments to the successful agency will be made according to the following schedule:

Initial 40% of lump sum cost upon notice to proceed

Additional 20% of lump sum cost after submission of interim report

Additional 30% of lump sum cost after submission of draft final project report

Final 10% of lump sum cost, plus any authorized additional costs, upon acceptance of final project report and receipt of article submission for PCI Journal

References

- Aswad, A., and G. Burnley. 1991. "Point Load Tests on Double Tee Flanges." *PCI Journal* V. 36 No. 4 (July–August): pp. 66–73.
- Botros, A.W., G. Lucier, S. Rizkalla, and H. Gleich. 2016. "Behavior of Free and Connected Double-tee Flanges Reinforced with Carbon-fiber-reinforced Polymer." *PCI Journal* V. 60 No. 5 (September-October): pp. 49–68
- Gamble, W. 2017. "Analysis and Design of Double-T Flanges." *Concrete International* V. 39 No. 10 (October): pp. 43-47
- Naito, C., R. Hendricks, and A. Osborn. 2019. "Flange-to-flange double-tee connections subjected to vehicular loading, part 2: Fatigue life assessment" *PCI Journal* V. 64, No. 2 (March-April): pp. 23-38
- Stanton, J.F. 1983. "Point Loads on Precast Concrete Floors." *Journal of Structural Engineering* V. 109, No. 11: pp. 2619-2637
- Steele, S. 2003. "Point Load Tests and Flange Reinforcement in Double tees." Master thesis. Pennsylvania State University.

SAMPLE RESEARCH AND TESTING AGREEMENT

THIS RESEARCH AND TESTING AGREEMENT (the "Agreement"), effective as of the ___ day of _____, 20__ (the "Effective Date"), is by and between Prestressed Concrete Institute, an Illinois not-for-profit corporation located at 8770 W. Bryn Mawr Ave, Suite 1150, Chicago, IL 60631 (hereinafter referred to as "PCI") and _____ (hereinafter referred to as "University").

In consideration of the premises, the mutual covenants herein contained and intending to be legally bound, the parties hereto agree as follows:

Article 1 – Definitions

- 1.1 "Project" shall mean the performance of the scope work as defined in the research proposal entitled _____ and dated _____. The scope of work is incorporated herein by reference as set forth in full in attachment A.
- 1.2 "Agreement Term" is from the Effective Date through _____ [date].
- 1.3 "Principal Investigator" shall mean the individual(s) identified as such in the research proposal for Project, who is/are the University faculty and/or staff member(s) responsible for supervision and administration of the Project.
- 1.4 "Intellectual Property" shall mean individually and collectively all inventions, improvements, copyrights, patents, proprietary information or discoveries that are conceived or made (i) by University or (ii) jointly by PCI and University in performance of Project.
- 1.5 "Report" shall mean the periodic or final summary of work performed by University related to the Project.
- 1.6 "Material Breach" for the purpose of this Agreement shall mean any event, situation, condition, or lack of performance in accordance with the work plan defined in Attachment A which causes the Project to be significantly modified, delayed or cancelled.
- 1.7 "Completion of Work" shall mean the completion of goals, objectives and other measurements as defined in Attachments A.
- 1.8 "Acceptance of Final Paper" shall mean the acceptance by PCI of the final deliverables defined in Attachment A at its sole discretion. The intent shall be a judgment of the quality of the deliverable and not a judgment on the results of the research.

Article 2 – Conduct of Project

- 2.1 University shall use reasonable efforts to commence the Project promptly after the Effective Date.
- 2.2 In the event that the Principal Investigator becomes unable or unwilling to continue Project, and a mutually acceptable substitution is not available, University and/or PCI shall have the option to terminate said Project, subject to the provisions of Article 8, by giving written notice to the other party of such termination.
- 2.3 PCI shall promptly provide University with such information or documents of whatever form or nature, or undertake such actions, as University may reasonably require in order to conduct the Project.

Article 3 - Reports and Conferences

- 3.1 Project reports will be provided by University to PCI as set forth in the Project proposal and a final report will be submitted by University at the conclusion of the Agreement Term or earlier termination of this Agreement.
- 3.2 PCI shall have the right to reproduce, publish, and disseminate any written reports or deliverables delivered to PCI by the University pursuant to this Agreement. Ownership and copyright for such reports or other materials shall vest in PCI.
- 3.3 During the Agreement Term, representatives of University will meet with representatives of PCI at such reasonable times and places as set forth in the Project proposal to discuss the progress and results of, as well as ongoing plans or agreed upon changes in the Project.

Article 4 – Compensation and Expenses

- 4.1 It is agreed to and understood by the parties hereto that except as may be otherwise agreed by the parties in writing, total costs to PCI for the Project hereunder shall not exceed the sum of _____ (\$_____). Payment to University shall be made by PCI according to the following schedule:

[as defined in the project RFP]

- 4.2 University shall retain title to all equipment, materials, and supplies purchased and/or fabricated by it with funds provided by PCI under this Agreement unless otherwise stated in Attachment A.

Article 5 – Publicity and Use of Name

- 5.1 Neither party shall be allowed to use the name of the other party or its representatives in any advertising regarding the Project without the prior written consent of the other party. The University shall identify PCI as the sponsor in any publicity, advertising or news release regarding the Project. PCI shall be allowed to use the name of the University and the Principal Investigator for announcements of the project and for Project updates to the PCI membership and such announcements and updates shall not be considered advertising.

Article 6 - Publications

- 6.1 University may catalog and place reports of the Project in the University library and may issue publications based on the Project. The research results not proprietary to PCI, as agreed by PCI, may be used in University research and education programs. University shall provide PCI the opportunity to review any report or publication and will, upon the request of PCI, withhold publication for up to 90 days.

Article 7 – Intellectual Property

- 7.1 Title to all Intellectual Property developed in the course of performance of the Project, whether or not protectable by patent, trade secret, or copyright, shall reside in the party whose personnel conceived the subject matter and diligently pursued reducing the subject matter to practice, and such party may perfect legal protection therein in its own name and at its own expense. Jointly made or generated Intellectual Property shall be jointly owned by the parties unless otherwise agreed in writing.

Article 8 – Agreement Term and Termination

- 8.1 This Agreement shall become effective upon the Effective Date and shall continue in effect for the Agreement Term unless sooner terminated in accordance with the provisions of this Article. The parties hereto may, however, extend the Agreement Term for additional periods as desired under mutually agreeable terms and conditions which the parties shall reduce to writing and sign.
- 8.2 Either party may terminate this Agreement upon thirty (30) days prior written notice in the event of a Material Breach by the other party of any term or provision hereof, provided such breach remains uncured at the end of said thirty (30) day period. Such notice of a breach shall include a reasonable description of the facts surrounding the alleged breach and a proposed course of action to cure said breach, if applicable.
- 8.3 PCI shall pay the University any costs which have accrued or been encumbered up to the actual date of termination under this Article and shall not be relieved of the obligation to pay such costs because of termination under this Article.
- 8.4 Termination of this Agreement by either party for any reason shall not affect the rights and obligations of the parties accrued prior to the effective date of termination of this Agreement.
- 8.5 No termination or expiration of this Agreement, however effectuated, shall release the parties hereto from their respective rights and obligations under Articles 3, 5, 6, 7, 8, 9, 10, 12, 13, 16, and 17, which such Articles shall survive in their entirety any termination or expiration of this Agreement.

Article 9 - Arbitration

- 9.1 In the event of any conflict or claim arising out of or relating to any provision of this Agreement or breach thereof, the parties shall make a good faith effort to resolve such conflict amicably between themselves, and if thereby failing, resolution by submission to mediation under the Construction Industry Mediation Rules of the American Arbitration Association, and if thereby failing, resolution by arbitration under the Construction Industry Arbitration Rules of the American Arbitration Association. The location of any mediation or arbitration shall be within the metropolitan area of Chicago, Illinois.

Article 10 - Disclaimer of Warranties

10.1 University disclaims any and all warranties, both express and implied, with respect to the services to be performed hereunder and any deliverables resulting therefrom, including their condition, conformity to any representation or description, the existence of any latent or patent defects therein, and their merchantability or fitness for a particular use or purpose.

Article 11 - Insurance

11.1 University shall carry the following insurance coverage with companies acceptable to PCI.

11.1.1 Commercial General Liability, including Contractual Liability and Completed Operations/Products Liability coverage, at the minimum limit of \$2,000,000 per project/ per occurrence (depending on degree of risk, other limits may be appropriate) and \$5,000,000 aggregate;

11.1.2 Automobile Liability at \$1,000,000 each accident.

11.1.3 Workers' Compensation at statutory limits and Employer's Liability coverage at a minimum limit of \$1,000,000;

11.2 Prior to commencement of the Project pursuant to this Agreement, University shall furnish PCI with proof of insurance, satisfactory to PCI in its sole discretion, evidenced by duly authenticated certificates of insurance, which certificates shall show the insurance type, amount, class of operations covered, effective dates, and dates of expiration of policies.

Article 12 – Independent Contractor

12.1 In the conduct of the Project hereunder, University and PCI are and shall remain independent contractors and nothing herein shall be construed to create a partnership, agency or joint venture relationship between the parties. Neither party is authorized or empowered to act as agent for the other for any purpose and shall not on behalf of the other enter into any contract, warranty or representation as to any matter. Neither party shall be bound by the acts or conduct of the other. Each party shall be responsible for wages, hours, and conditions of employment of its personnel during the term of, and under, this Agreement.

Article 13 - Governing Law

13.1 This Agreement shall be governed by and construed in accordance with the laws of the State of Illinois.

Article 14 - Notices, Invoices, and Payments

14.1 Notices, invoices, communications and payments hereunder shall be deemed made if given in writing and addressed to the party to receive such notice, invoice, communication or payment at the address given below, or such other address as may hereafter be designated by notice in writing:

If to Sponsor:

Precast/Prestressed Concrete Institute
8770 W Bryn Mawr Ave
Suite 1150
Chicago, IL 60631

If to University:

Article 15 - Force Majeure

15.1 In the event that either party is unable, wholly or in part, to carry out its obligations under this Agreement by reason of acts of God or public enemy, wars, insurrections, civil disturbances, epidemics, labor disputes, failure of government approval, accidents, failure of utilities, material shortages, fires, storms, floods and any other causes, whether of the kind enumerated herein or otherwise, not within the control of the party unable to perform, then the obligations of this Agreement shall be suspended during the reasonable continuance of any inability so caused.

Article 16 – Non-Discrimination

16.1 University and PCI shall not discriminate against any employee or applicant for employment because of race, color, sex, sexual preference, age, religion, national origin, disability, or because he or she is a disabled veteran or veteran of the Vietnam Era.

Article 17 - Assignment

17.1 This Agreement shall not be assigned by either party without the prior written consent of the other party hereto. This Agreement shall be binding upon and inure to the benefit of the respective successors and permitted assigns of the parties.

Article 18 - Agreement Modification

18.1 Any agreement to change the terms of this Agreement in any way shall be valid only if the change is made in writing and signed by a duly authorized representative of each party hereto.

Article 19 - Entire Agreement

19.1 This Agreement constitutes and expresses the entire agreement of the parties hereto with reference to the subject matter hereof, with all prior promises, undertakings, representations, agreements, understandings and arrangements relative thereto having been herein merged into this Agreement

IN WITNESS WHEREOF the parties have caused this Agreement to be executed, each by its duly authorized representative, to be effective as of the Effective Date defined herein.

UNIVERSITY:

PRESTRESSED CONCRETE INSTITUTE:

By: _____

By: _____

Title: _____

Title: _____

Date: _____

Date: _____