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Cast-in-Place Piling Properties

Prepared for
WHRP Geotechnics
Technical Oversight Committee

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Topic/Problem Statement: Document literature from 2000 to the present relevant to the strength of cast-in-place piling, steel structural support tubes filled with concrete. LRFD standards include both steel and concrete strength in design calculations that assume a certain level of composite action. New WHRP research will develop methods for determining actual CIP concrete compressive strength and composite action and strength of CIP members.

Keywords: Pile, cast-in-place, CIP, LRFD, load, composite, steel, concrete, bearing, strength.

Summary

We found eight published articles and presentations from 2000 through 2006, but no research in progress on CIP piles, composite action in pile bearing, and related topics. Of the eight, four originate in 2004 conference proceedings, and one article each in the years 2006, 2005, 2001 and 2000. All articles we found were from academic journals and conference proceedings except for the TRB-published article in 2006.

Citations

Results are listed chronologically, with the most recent citations shown first. Links to online copies of cited literature are provided when available. Contact the WisDOT Library to obtain hard copies of citations.

Title: Evaluation of full-sized cast-in-place pile capacity with artificial defects
Author(s): Gyungja Jung, Oh Sun Kwon, Sung Jun Jung, Myoung Mo Kim
Date: 2006
Source/URL: *Transportation Research Record No. 1975*, 2006: 10-20.
Description: 11 pp.
Contents: Cast-in-place piles in the field are likely to have unintended defects during construction, such as soft bottom, segregation of concrete, and contraction or enlargement of the cross section. The effect of defects in cast-in-place piles on the pile's resistant behavior was evaluated. Four piles with artificial defects of soft bottom, concrete segregation, and contractions of the cross section by 10% and 20%, respectively, as well as one sound pile, were constructed simultaneously. Static load tests, load transfer measurements, and integrity tests were performed for the piles. In addition, three-dimensional numerical analysis was conducted to analyze the effect of the contraction defect

on the pile's resistant behavior. For the pile with the defect of concrete segregation, integrity tests and load transfer measurements showed that the pile strength was reduced by more than 50% in the section of the weak zone having the defects. For the piles that contained the defect of asymmetric contraction of the cross section, the measured strain in the defective section was lower than that in the section without the defect, and three-dimensional numerical analysis showed that the defect increased the axial stress in the section of the defect. Crosshole sonic loggings were conducted before and after static load tests. The difference in the loggings between the prestatic and poststatic load tests indicated the growth of defects as the piles were loaded.

Title: Response of 0.6 m cast-in-steel-shell pile in liquefied soil under lateral loading
Author(s): T.J. Weaver, S.A. Ashford, K.M. Rollins
Date: January 2005
Source/URL: *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 131 (1), January 2005: 94-102.
Description: 9 pp.
Contents: This paper presents results from a full scale lateral load test on a 0.6 m cast in steel shell (CISS) pile in sand liquefied by controlled blasting. Lateral loads were applied by a hydraulic actuator to simulate seismic inertial forces. The CISS pile was instrumented to provide the data necessary for backcalculating lateral soil resistance and displacement. Details of the pile instrumentation and testing procedure are described. Results from three simplified analyses are presented, where liquefied soil resistance was accounted for by modifying standard static curves and compared to measured test results. Limitations of the simplified methods are discussed. Test results show the blast induced liquefied sand did not provide resistance to lateral pile movement at displacements up to 50 mm. At displacements of sufficient magnitude, a phase transformation in the sand occurred resulting in a reduction in pore water pressure, and increased lateral soil resistance.

Title: Limit state design of CIP post-tensioned concrete box girder bridges
Author(s): Toorak Zokaie
Date: 2004
Source/URL: *Proceedings of the 2004 Structures Congress*, 2004: 51-58.
Description: 8 pp.
Contents: The cast-in-place post-tensioned box girder bridge has been a popular bridge type in the western United States, particularly in the state of California. This type of construction allows for an efficient and cost-effective alternative, while being a very aesthetically pleasing structure. While post-tensioning provides the required service strength, the monolithic pier construction enhances the seismic performance of the bridge. Due to the relatively high torsional rigidity, these bridges have typically been designed as a unit, rather than individual girders. The LRFD specifications have introduced several changes that affect the design of this type of bridge. These include live load application, live load distribution factors, live load reduction due to skew, loss of prestress and post-tension, partial prestressing, and revised load factors and load combination Limit States. As the implementation of the LRFD continues for this type of bridge, the effect of the new specifications needs to be understood. This paper will present some of the key issues affecting the CIP box girder bridges. Analytical results comparing the AASHTO Standard and LRFD specifications will be presented to high light their differences.

Title: A quality and safety issue for cast-in-place piles – 25 years of experience with low-strain integrity testing in Germany: From scientific peculiarity to day-to-day practice
Author(s): O. Klingmuller, F. Kirsch
Date: 2004
Source/URL: *ASCE Geotechnical Special Publication No. 125, Current Practices and Future Trends in Deep Foundations*, 2004: 202-221.
Description: 20 pp.
Contents: The German Committee for Dynamic Pile Testing (subcommittee of the Piling committee of the German Geotechnical Society - DGGT) reviewed the experience of its members with low-strain pile integrity testing. This review shows that about 2% of all cast-in-place concrete piles carried out in Germany have been tested and that signals of approximately 15% of the tested piles show a deviation from the ideal signal. Further evaluation revealed that only 5% of the tested piles had to be denominated as defective in the report and only 1% were subject to remedial measures. German experience and especially the assessment of piles according to the classification system as proposed in the "Recommendations for Dynamic Pile Testing" by the DGGT is described. Statistical data as well as illustrative case studies are given. The case studies comprise integrity test results in comparison with excavated piles and coring. The paper states the best practices and the fields of application of the low-strain integrity test method as well as shortcomings of the method when applied to certain pile system.

Title: Practical uses of dynamic load testing with increasing energy
Author(s): J.W. Beim
Date: 2004
Source/URL: *ASCE Geotechnical Special Publication No. 125, Current Practices and Future Trends in Deep Foundations*, 2004: 390-397.
Description: 8 pp.
Contents: Dynamic Load Testing of foundation piles was introduced in Brazil as early as 1981, to fulfill the need of the oil industry for quality control of offshore piles. Dynamic tests were first used on land projects in 1983. Since that time, thousands of piles have been tested using this technique. Local peculiarities like less conservative failure criterions and the prevalent use of restrike tests using drop hammers led to the generalized use of methods based on the application of blows with increasing energy. Theoretical studies of the behavior of piles subjected to blows with increasing energy were made and published by Brazilian engineers. Specific interpretation methods were developed, like the use of graphs relating RMX (Case Method Capacity) with DMX (maximum displacement during the corresponding blow). This paper describes how dynamic load tests with increasing energy are executed, and discusses its use for testing both driven and cast-in-situ piles. Examples are shown to illustrate the various conclusions that can be reached by using those methods.

Title: Applications of a simplified dynamic load testing method for cast-in-place piles
Author(s): Garland Likins, Brent Robinson, Mohamad Hussen
Date: 2004
Source/URL: *GeoSupport 2004: Innovation and Cooperation in the Geo-Industry*, 2004: 110-121.
Description: 12 pp.
Contents: Dynamic loading tests take advantage of the high impact load that a relatively small mass can generate by falling from a preselected height. For driven piles, where the readily available driving hammer itself is the loading apparatus, this test method is particularly convenient. The uniform geometry and material properties of driven piles makes pile load and motion measurements and their interpretation relatively easy. For drilled shafts, however, the testing effort is somewhat more involved because a ram with a weight equal to 1 to 2% of the test load must be available and dropped from heights of 1 to 3 m by using a crane. Additionally, potentially irregular shape and non-uniform material properties of cast-in-place pile tops make accurate force measurements more challenging. This paper further describes how the dynamic testing procedure has been simplified and made more accurate by the APPLE (Advanced Pile Proof Loader/Evaluator) method, which combines the force measuring device with the loading system. In effect, the pile top force is calculated from the product of measured deceleration and mass of the drop weight; motion is also measured at the pile top. The paper describes two tests, conducted on different field sites, and presents correlations that further verify the soundness of this approach. The authors conclude that high-strain dynamic testing of cast-in-place shafts is a well established method in contemporary foundation engineering practice. Advantages over other types of load testing include low cost, convenience and speed of testing, assessment of structural integrity in addition to bearing capacity and resistance distribution, and the ability to randomly test shafts after installation. The APPLE improves and simplified the high-strain dynamic testing process.

Title: A critical review of current LRFD provisions for composite members
Author(s): Roberta T. Leon
Date: 2001
Source/URL: *Proceedings of the Structural Stability Research Council, 2001 Annual Technical Session and Meeting*, 2001: 189-208.
Description: 20 pp.
Contents: The changes in strength design of load resistance factor design (LRFD) provisions for composite beams and columns are discussed. The composite systems designed based on ultimate strength concepts provide most economical and efficient floor systems for modern steel structures. The composite columns are attractive because their increased stiffness reduces building drift and improves stability of structure. The use of composite columns is hampered by over-conservatism of current design provisions.

Title: Analysis of lateral head movements of CIP piles
Author(s): Kyung-Soo Jeon, Jeong-Hwan Kim, Sung-Hwan Kim, Myoung-Mo Kim
Date: 2000
Source/URL: *Proceedings of Sessions of Geo-Denver 2000*, 2000: 254-268.
Description: 15 pp.
Contents: Prototype lateral load tests were performed on two sets of 4-400mm cast-in-situ concrete piles at two different locations to verify the validity of theoretical approaches for predicting pile head movements and the empirical relations between soil elastic moduli and N values for SPT. To this end, the load displacement curves

obtained from the lateral load tests are compared with Chang, Randolph, and p-y curve methods. For the linear methods, such as Change and Randolph, empirical constants are varied from 7 to 28 as suggested in various references. As of result of comparisons, it is know that the linear methods can predict the pile head movements within the usual range fairly well, if appropriate empirical values are adopted. The p-y curve method predicts the pile head movements consistently in a conservative way. On average, the predicted loads by p-y method for given pile head displacements are about 70% of the minimum values of the test results for the same displacements. For the prediction of ultimate lateral resistance of piles, it is found that Brom's method could give too small values compared to the actual ultimate resistances depending upon the types of soils where the piles are embedded.