DESIGN POLICY
LONG PILE BENTS

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A recent practice of designing pile bents for ratios of height to unsupported length of near 20 is resulting in some unsafe designs. The basis for this practice lies in the AASO code which fails to adequately define length and end restraint effect. A provision for long columns is made in AASHO 1.5.9 formulas (4) and (6) using the ratio of unsupported length to least lateral dimension. No mention is made of the relationship between effective[1] length and unsupported length and the fact that effective length may be greater than unsupported length. It is my recommendation that revisions be made to the AASHO code in this respect.

Columns may fail due to elastic instability (buckling) prior to material failure. This was recognized by Euler over 200 years ago. Long reinforced concrete columns subject to eccentric loads were first analyzed by Broms and Viest[2] in 1958. In this paper formulas were developed which give the load and moment at buckling. From these formulas graphs of ultimate loads were developed and compared to test data with good results. Column shape was recognized by Hromadik[3] and extended to sections other than rectangular. A later paper by Broms and Viest[6] gave a design approach to long columns. This paper was the basis for the 1963 ACI code and 1969 AASHO provisions for long columns.

The design formulas proposed by Broms and Viest which were later incorporated in the codes were based on a column hinged at both ends without translation and a safety factor of 2. The Commentary[1] on the ACI code gives an excellent discussion of length effects. Attention is directed to figure 4, cases 1 and 2. In case 1, where column ends are held against displacement, the effective length equals the unsupported length. In case 2, where resistance to displacement depends on column stiffness, the effective length is greater than the unsupported length.

The condition where we use rocker or roller type shoes, which permit rotation and displacement will allow the case 2 condition to develop. It has been assumed in the past that a fixed condition exists at some distance below ground. What actually exists is a point of maximum movement about one fourth the penetration length of the pile with curvature extending below the point[4]. Unless translation is prevented at the top of the pile, effective length could be greater than twice the unsupported length which is the case of a flagpole or gin pole.

Pile bents must be limited to cases where displacement is prevented by superstructure or where the unsupported length is less than 12. The following systems are assumed to give sufficient resistance to displacement to allow effective length to be assumed equal to unsupported length:

1. Slab spans fixed to two bents.
2. I-beam spans on Type B shoes.
3. I-beam spans fixed at both ends.
4. Separated batter pile bents.

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If it is necessary to use a system not meeting the above stated requirements the allowable load must be reduced by a factor similar to equation (9-5) in the ACI Code[5]. Such an equation reduced the allowable load to about 30% of the short column load for an L/D of 12 as compared to 94% by the AASHP formula.

The common use of prestressed piles has resulted in service load stresses controlling the design of these piles. The buckling consideration does not eliminate the need to check allowable stresses.

References:

1. Commentary on Building Code Requirements for Reinforced Concrete (ACI 318-63) American Concrete Institute publication SP-10.

2. Broms and Viest, ultimate Strength Analysis of Long Hinged Reinforced Concrete Columns, ASCE Proceedings paper 1510, January 1958.

3. Discussion by J. J. Hromadik of the paper, reference 2.

4. M. T. Davisson, Lateral Load Capacity of Pile, Highway Research Record No.333, Pile Foundations.

5. ACI Standard Building Code Requirements for Reinforced Concrete (ACI 318-63), June 1963.

6. Broms and Viest, Design of Long Reinforced Concrete Columns ASCE Proceedings Paper 1510 July 1958.

U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

SUBJECT: Use of Unpainted Steel, AASHO M222, on Federal-aid Projects	FHWA NOTICE

February 19, 1971

The memorandum supersedes our memorandums of October 10, 1967, and March 8, 1970, and Circular Memorandums of October 4, 1966, and January 16, 1968, relative to the use of this material on Federal-aid projects.

Our previous restriction relative to use of AASHO M222 material, in part, was based upon questionable economic comparisons with painted steel and upon our concern over the durability of the material in an unpainted state. In light of more recent information relative to initial and maintenance painting costs, and current mill prices for this material, it has now been determined that unpainted M222 material can be economically justified.

Additionally, a sufficient number of unpainted structures have now been built as experimental projects, upon which to base an evaluation of the durability. This evaluation is not yet complete and will depend upon continued maintenance inspections and reports as required under those experimental projects previously established.

Until such time as this evaluation or other manifestations indicate otherwise, unpainted steel conforming to AASHO M222, which is the same as ASTM A588 but with impact testing added, may be used without further justification for structures on Federal-aid projects provided the following conditions are met:

1. The locality and environment must be such that atmospheric or other contaminants will not adversely affect the development or effectiveness of the desirable dense oxide coating.

2. Roadway drainage must be prevented from falling or collecting on this material through use of a drainage collection system, a completely closed deck, or application of paint to areas exposed to deck runoff.

3. The esthetics of the structure appearance must have been given careful consideration, with due regard for both the metal work and the supporting structure, and each State should evaluate the consequences resulting from possible unsightly staining of concrete surfaces, as well as other facilities or public involvement under the structure. These considerations alone may greatly outweigh the improved structural appearance.

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Unpainted steel used for main members subject to tension or to reversals of stress should conform in all respects to AASHO M222. For compression members, the impact requirements of Section S1 may be waived.

Unpainted steel for secondary or nonstress-carrying members should conform to AASHO M222, with the impact requirements of Section S1 waived, or to AASHO M161 (ASTM A242). A242 members should be used only for riveted or bolted construction unless the weldability of the steel is established in accordance with Paragraph 102(b) of the American Welding Society Specifications for Welded Highway and Railway Bridges. The waiver of impact requirements for these members permits the use of standard angles, channels, etc., from stock, for which impact data is generally not available.

When steel for a project is procured under AASHO M222 with impact tests for information only, and the test results show impact values of less than the specified 15 foot-pound at +40ºF for any lot, the material in this lot will not be rejectable, but it shall be used only for compression members. If it is not possible to use all the material in compression members, it shall be the FHWA policy to require that the remainder of the lot be normalized or replaced with new steel. The costs of relocation, heat treatment for normalizing, or replacement are eligible for Federal-aid funding at the project reimbursement ratio.

The steel producers have offered an alternate procedure for heat qualification of impact properties. This procedure requires one impact test of the thickest and of the thinnest material of each heat and/or product furnished. The extra for heat lot testing has been quoted as $5 per ton. Heat lot impact testing, if preferred by the State, is acceptable.

Some states are specifying the impact test as a requirement for acceptance, believing that the reduced risk of failure from brittle fracture justifies the extra cost. This extra cost is acceptable for Federal-aid participation.

Welded construction should conform in all respects to the requirements pertaining to ASTM A588 steel (unpainted) in the current edition of the American Welding Society Specifications for Welded Highway and Railway Bridges except as modified by current Bureau of Public Road Circular Memorandums or FHWA Notices. As of the date of this Notice, the current edition of the AWS Specifications is D2.0-69 and the applicable memorandums are as follows:

Circular Memorandum dated February 16, 1970, entitled "Recommendations Relating to the 1969 Edition of the American Welding Society Specifications for Welded Highway and Railway Bridges, AWS D2.0-69.

Circular Memorandum dated June 15, 1970, entitled "Revisions to the 1969 Edition of the American Welding Society Specifications for Welded Highway and Railway Bridges."

Satisfactory weldability data have been submitted to the Federal Highway Administration by the producers of Grades A, B, C, F, and G. If a contractor proposed to furnish either Grade D or Grade E, the State should require the producer to submit information on weldability before the order is placed. Grade designations, however, should not be specified in the contract documents prepared for the design.

M. F. Maloney, Director
Office of Engineering