Construction Tolerances—Prestressed Concrete

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•THE MANUAL for Inspection of Prestressed Concrete was prepared by a joint committee composed of members of the AASHO Committee on Bridges and Structures and representatives of the Prestressed Concrete Institute. Its purpose is to provide uniform inspection procedures for the manufacture of bridge members. Some of the state highway departments have also developed their own manuals which, when coupled with special specification provisions and appropriate project drawings, comprise the contract documents for specific projects (Fig. 1).

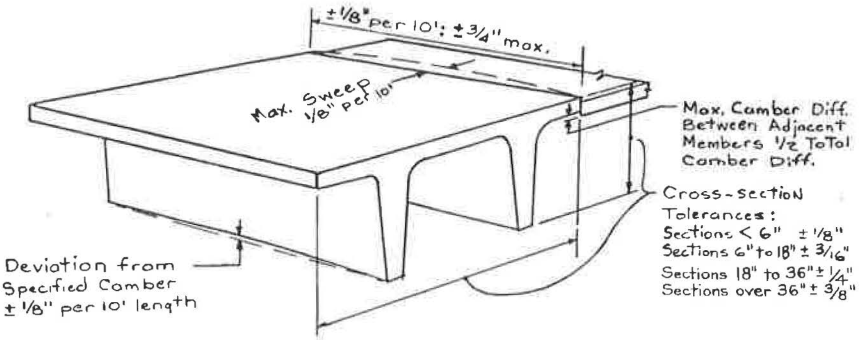

Figure 1. Dimensional tolerances.

Bill Dean of Florida, Chairman of the Joint AASHO-PCI Committee which prepared the Manual, said,

> Regarding the tolerances as published; first, they were not considered by the committee to be sacred and next, they must be applied with judgment and understanding. . . . During preparation of the manual the subject of inclusion of a table of dimensional tolerances was proposed several times. During our two-day meeting, in which the text of the manual was finalized, we had for reference tolerance tables prepared by several states and by some producers. Each tolerance dimension as listed, was brought up, considered and agreed to by the full committee.
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> To my best knowledge, this table of tolerances has been given a wider distribution than any published heretofore. It is not surprising that some objections have developed and some suggestions for improvement have been made . . . .
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> To sum up: The published tolerances are not to be considered as forever binding. This represented the best judgment of the committee members at the time the manual was published; improvements and modifications will surely be developed; any set of dimensional tolerances should be applied with judgment and some understanding of member functions.

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The general feeling among interested engineers appears to be that tolerances should be a guide to promote minimum requirements throughout the industry as well as an indication of a reasonable standard of performance and should not be a hindrance in obtaining more exacting workmanship. They should not be regarded as rigid and sacred. Specific job conditions may require separate tolerances, either closer or more liberal.

Specific portions of the table of tolerances contained in the AASHO-PCI Manual have been commented on by various bridge engineers and prestressers. Joseph Kirby, Bridge Engineer, North Dakota State Highway Department, states:

> Plus or minus camber tolerances could allow too great a difference between adjacent beams while a gradual change from a plus tolerance on one side of a structure to a minus tolerance on the other side could be satisfactory. Tolerances should therefore be specified in relation to the group of beams and not individually (unless an extremely small tolerance is specified).

On the same subject, H. B. Schultz, Engineer of Bridges, Wisconsin State Highway Commission, states:

> I hope that generally manufacturing procedures will improve to the extent that the tolerance for camber may be reduced. This should be possible as more producers adopt external vibration, thus making it possible to compact concrete that is uniformly of a very low slump.

Comments were received from C. A. Pestotnik, Bridge Engineer, Iowa State Highway Commission, as follows:

> We have had a problem with prestressed beams at bearing seats. Although the bearing area at each end of a beam may be a flat, true plane and normal to the web, we have found beams with a slight twist that results in edge bearing at one or both ends of the beam when placed on the bridge seats.

He further recommends a change in the tolerance table: "Bearing Plate or Bearing Area Deviation from plane: We prefer $\pm 1/32''$ rather than $\pm 1/16''$." On the camber problem, Mr. Pestotnik says,

> Recently, we have conducted a limited investigation to measure the initial centerline camber of thirty-four identical 100′ pretensioned prestressed concrete beams. In order to minimize the effect of creep, the cambers were measured as soon as the prestress was released. The camber readings thus obtained were consistent, and in close agreement with the calculated cambers. These beams are now being erected and their cambers will again be checked in the spring of next year (1964) prior to the placement of concrete floor slab. From our past experience, the "final" cambers were far from consistent even for identical beams. We wholeheartedly support the idea of additional research concerning cambers in order to enable the designer to predict the camber more accurately and to establish more appropriate tolerance values.

Several prestressers in Wisconsin have suggested that the horizontal alignment tolerance for box beams and slab sections should be liberalized somewhat for members more than 40 ft long. It was suggested that an increase from 3/8 in. to 1/2 in. for lengths from 40 to 60 ft be considered and from 1/2 in. to 3/4 in. for lengths greater than 60 ft. From the same group comes the suggestion that the "head out of square" tolerances for prestressed piling be increased from 1/16 in. in 12 in. to 1/8 in. in 12 in.

Carl E. Thunman, Jr., Assistant Engineer of Bridge and Traffic Structures, Illinois Division of Highways, comments as follows:

For example, some individuals wanted very close camber controls on prestressed I-beams as they felt that high cambers and variable cambers resulted in the necessity of either increasing the thickness of the cast-in-place slab or required that the top of the beam be embedded excessively into the slabs. Others were willing to accept a more liberal camber control on I-beams due to the fact that they detailed their structures, allowing for camber; and maintained a constant depth cast-in-place slab by providing a variable depth fillet between the top of the beam and the bottom of the slab. This is just one example; however, I think it serves to point out that the details of each particular application of a precast prestressed member control to some extent acceptable tolerances . . . .

In determining tolerances we have tried to select tolerance limits which are practical to attain with conventional methods and equipment used by the prestressed concrete industry and at the same time recognize the effect of such tolerances on our use of the products. Following are some of the items which were considered in determining tolerances.

The effect of the tolerance limits in cross-sectional dimensions was evaluated to determine how much variance would affect the structural properties of the member. The effect of the accuracy of the prestressing force was investigated to determine the behavior of the beam at extreme ranges of tolerance. Incidentally, with specification writers now considering allowable tension in the precompressed tensile zone of prestressed concrete bridge members, I feel that the question of accuracy of the prestressing force becomes more significant than ever before. While admittedly the magnitude of the prestressing force has little or no effect on the ultimate capacity of the prestressed member, it does have a pronounced effect on the magnitude of the cracking load, and, consequently, on the behavior of the member since the member does lose stiffness at and beyond the cracking load. With the trend in specifications going toward allowable tensions under full design loads, I feel that the accuracy of the prestressing force assumes more significance than previously.

The effect of dimensional tolerances on the problems arising in incorporating a precast element into the final structure in the field was given consideration. For example, the effect of tolerance in overall length of the beam on positioning the beam on the substructure unit and the effects of allowable tolerance in the width of the beam on the overall lay-up width of adjacent box beams were considered.

Such things as the effect of allowable tolerance on the final function of the structure and the aesthetic effect were also taken into consideration.

Mr. Kirby of North Dakota says about post-tensioned beams:

If camber is post-tensioned beams is adjusted during construction by varying the prestress force, the limits of this variation from the planned amount shall be ± 5%. Uniform camber in beams is dependent upon a uniform concrete mix and accurate placing and tensioning of prestress steel. Varying the prestress force within limits will offset these inaccuracies making beams more closely resembling the design requirements.

From the inspection standpoint there is another approach which has been discussed in an exploratory manner and may have some merit or at least bear further investigation and study. A possibility exists of establishing primary ranges of the tolerance which when specifically met would provide unqualified acceptance of work along with establishing secondary ranges for qualified acceptance subject to correction by the contractor or penalty to the contractor for noncritical departures from specified tolerances. Adequate inspection of the fabrication and casting procedures in a prestressers plant facility will normally provide the basis for a determination of structural soundness of any prestressed concrete beam produced, whether or not the construction dimensional tolerances prescribed are complied with. However, the average inspector is occasionally faced with the situation wherein a particular beam has been found to exceed the allowable dimensional tolerance in noncritical physical characteristics, but in all respects is structurally sound. Of course, this is the situation that requires good judgment and understanding of the member function. This situation could be easily handled if a secondary range of allowable tolerances was specified which would provide the possibility of correction or the acceptance of a penalty by the contractor for a noncritical departure from the specified tolerances.

A corollary to the establishment of a secondary range of allowable tolerances has been used in recent months by a consulting structural engineer of Albuquerque, New Mexico, Fred J. Fricke:

> When an approved Laboratory 28-day Test and supplementary core boring of concrete of a certain pour fails to meet the strength of concrete required, and subsequent investigation by the engineer indicates that such low value concrete can be used in the structure a penalty of $10. per yard of such concrete poured will be assessed against the contractor; the contractor to have the option of paying the penalty or replacing the low value concrete.

Discussion with this engineer has revealed that the clause is bringing desired results and he intends to use it until a better solution appears. The citing of this example is not intended to imply recommendation of a similar approach but merely to show that action is being initiated by some engineers to try to solve the problem.

The premise of establishing primary and secondary ranges of tolerance in connection with prestressed concrete needs further study, but it does offer possibilities that can be explored.

In summary, based on contact with many engineers who have used the Manual for Inspection of Prestressed Concrete since its publication, it is evident that it has become the standard for the industry, particularly with regard to the tolerance limits established. To date PCI has published two manuals dealing with inspection and tolerances, and it is our aim to continue to review and revise this latest manual to improve the standard. It appears that in some areas which I have mentioned (bearing areas of beams, horizontal alignment of long beams, accuracy allowances in measuring prestressing force, and end squareness of prestressed piling), further consideration, review, and analysis may be needed. To this end the background information and data collected and developed in the preparation of this paper will be furnished to the Joint AASHO-PCI Committee for evaluation. It has become apparent that the general area of camber, and particularly differential camber, needs considerable additional detailed study to arrive at more representative and realistic construction tolerances. The Technical Activities Committee of the Prestressed Concrete Institute already has this as an agenda item and will have several committees working in this area of responsibility. It is hoped that the results of these studies will soon be available for the highway bridge program.