Prestressing steel girder bridges

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Prestressing Steel Girder Bridges

La précontrainte des ponts à poutres métalliques

Vorspannung von Stahlfachwerkbrücken

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The technique of prestressing steel girder bridges and structures is of recent origin and has attracted the attention of many structural engineers. There are two purposes for which this technique is utilised in steel girder bridges, viz., 1. for strengthening existing bridges to enable them to carry loads that are havier than the design loads, and 2. for the design of new bridges by prestressing the members and thereby effecting economy. Both these aspects have been covered in the papers presented to the Association. The strengthening of existing railway bridges is, in my opinion deserving of serious consideration in many countries on account of the increase in present-day loads and speeds as compared with the design loads. Unfortunately, not much experimental evidence of the results of prestressing, especially on the durability of prestressing in the case of riveted structures, is yet available. For instance, it would be interesting to know whether:

1. The actual stresses developed in the structure agree with the calculated stresses.
2. Any records have been kept which would make it possible to determine the effect of vibrations and the loss of prestress due to slip at rivets, creep etc., in course of time.
3. Any records have been kept of the increase in camber due to prestressing and the loss of camber in course of time, especially in railway bridges which are subjected to heavy vibrations.

Just as a loaded bridge girder develops secondary stresses due to restraining action at the joints, an important consequence of prestressing would be that the initial prestressing would develop secondary stresses in the chord and web members, having an opposite sign to that which would occur under normal loads. Therefore, an important advantage of prestressing would be the elimination, or reduction, of secondary stresses. According to the British and American codes of practice the secondary stresses need not be considered if the ratio of depth to length of members is kept within certain limits. In the B.S. Specification it is 1/12 for chord members and 1/24 for web members, and in the AREA

Specification it is 1/10. In the case of heavily loaded girders, for instance, the girders in bridges carrying double or multiple tracks, the members are sufficiently rigid and the limiting ratio of depth/length cannot always be maintained, with the result that the secondary stresses are bound to the appreciable. For instance, in the open-web girders of the deck type supported at the top chord level, as used in the double track, 150 ft. spans, for the new Yamuna Bridge at Delhi (India), the length/depth ratio is as much as about 7,5. If in such cases the limits mentioned above had to be maintained, the depth would have to be reduced. The value of l/r for compression members would increase even more, thereby reducing the permissible axial stress. Unter such conditions, according to the British Code, the girders have to be designed taking into consideration the secondary stresses. Here, prestressing will have a distinct advantage in reducing the secondary stresses and reducing the areas of members, required for direct stresses under service loads, so that the effect of secondary stresses can be ignored and higher axial stress permitted in compression. It would be interesting to know whether this effect of structural prestressing on the secondary stresses has been studied.

While dealing with secondary stresses, it may interest the members to know that on the Indian Railways, a method to eliminate secondary stresses by pre-deforming the girders was developed and is now a standard practice. Briefly, the method is as follows:

1. The change in length of each member under full service load is calculated, and to ensure that the length of the floor system of a span shall be constructed to its nominal dimensions, i. e., to avoid changes in lengths of floor and the bracing system between the chords which carry the floor system, a further change in length is applied in the length of all members equal to

$$\frac{\text{change in length of loaded chord}}{\text{length of loaded chord}} \times \text{length of member}$$

   In through spans, this change will be an increase while in the case of deck spans a decrease in the lengths of all members.

2. The actual manufactured lengths of members are the nominal lengths altered as above.

3. The positions and directions of gauge lines of all connection holes in the main gussets and also those in chord joints and the machining of ends are according to the nominal dimensions.

4. The bottom chord is first laid on camber jacks and the required camber is given.

5. The web members are then fitted to the bottom chord and the top chord is also placed in position. The holes at the top end of web members and the top chord joints will obviously not correspond.

6. The members are strained into position and riveted up with the permanent gussets.

This method of pre-deforming the girders was developed during the design of the Wellingdon Bridge near Calcutta (span 350 ft.) in 1930. The method although apparently elaborate, is not difficult to apply in practice and does not entail any appreciable cost. Subsequently, tests were conducted by Dr. Nicols, on the girders of the Nerbudda Bridge (span 282 ft.) to determine the efficiency of the method. A full report of the tests appears in the Proceedings of the Institution of Civil Engineers, London (1937), in Paper No. 507 "Prestressing Bridge Girders". Tests were also conducted on the girders of a small span (150 ft.) Wunna Bridge for the same purpose. In the new girders for the combined rail-road bridges across the Ganga and the Brahmaputra, spans 400 ft., designed by Messrs. Freeman, Fox and Partners of the U.K., the effect of pre-deformation was taken into consideration. These girders were erected by the cantilever method and as the method of pre-deforming, given above, could not be followed, it was a matter of doubt as to whether the required pre-deformation could be achieved. Elaborate tests were recently conducted on the Brahmaputra Bridge also to determine the secondary stresses during erection. It was found that pre-deformation could be achieved only to the extent of about 30% in the case of the girders of the Brahmaputra bridge erected by the cantilever method and of 40% in the other two girders erected on camber jacks. The full theoretical pre-deformation obviously could not be achieved which could be attributed to tolerances in manufacture and fabrication. In the girders of the Brahmaputra bridge the members were of high-tensile steel and consequently were sufficiently slender, so that secondary stresses were not of much consequence. The Nerbudda and Wunna bridge girders were of mild steel and deformation stresses in some members were as high as 50% of the primary stresses, and at one or two points they were even higher.

Hence, the elimination of secondary stresses may be necessary and desirable under certain circumstances and this can be done either by pre-deforming the girder by the method given in the Indian Railway Code of Practice for Steel Bridges or by prestressing the girders by the methods recently developed.

Summary

The report points out an important advantage of the prestressing of open web girders in eliminating secondary stress and thereby, in some cases, permitting higher axial stresses in compression. An alternative method of reducing secondary stresses by pre-deforming the girders, as adopted in Indian Railways, is mentioned, and the respective tests are described.

Résumé

Cette communication met en évidence le considérable intérêt qui s'attache à la précontrainte des poutres à treillis du fait de l'élimination des contraintes secondaires et, par voie de conséquence, de l'accroissement parfois possible des contraintes axiales de compression. On se réfère également à un autre moyen permettant de réduire les contraintes secondaires et qui consiste à réaliser une déformation préalable des poutres, solution que les Chemins de fer de l'Inde ont adoptée. Les essais correspondants sont décrits.

Zusammenfassung

Der Bericht behandelt einen wichtigen Vorteil der Vorspannung von Stahlfachwerkträgern: Die Möglichkeit der Ausschaltung von Nebenspannungen, womit in einigen Fällen eine bessere Materialausnützung erreicht werden kann. Eine Methode zur Verringerung der Nebenspannungen durch Vorkrümmung der Träger, wie sie bei den Indischen Staatsbahnen im Gebrauch ist, wird zusammen mit zugehörigen Versuchen beschrieben.