Effect of excessive cement in prestressed concrete girder

C.V. Kand, T.P. Thite and S.M. Litake

DETAILS OF FLYOVER AND METHOD OF CONSTRUCTION

This flyover was on an important road with heavy traffic, had 46 spans and length of 1230 m viaduct. The width of flyover was 10.5 m and 8 m. In 10.5 m there were 10 precast prestressed girder and in 8 m width 6 girders. The L-section and cross section is shown in Figure 1.

Construction method

Precast pre-stressed multiple girders were cast at the ground at available places and towed to the site and lifted. The form work for deck slab fixed to precast girders and slab cast in situ.

Foundations, piers/abutments were cast in situ along with bearings and precast girders were launched. The girders were 3 spans continuous; after launching girders on individual spans, the continuity was given in the girders through a cross girder and continuous slab.

CODAL REQUIREMENT FOR MAXIMUM CEMENT CONTENT

- Section of IRC-21 2000 gives minimum cement content for PSC members as 400 kg/m^3 for up to M40 concrete vide table no. 5.
- MORT&H specifications for road and bridge works Fourth Revision of 2001 specify maximum cement content as 540 kg/m^3 as per clause 1703.2; however, the revised MORT&H specification for road and bridge works, Fifth Revision of 2013 has given the limit of 450 kg/m^3 as per clause 1703.3.
- Maximum cement content has been reduced from 540 to 450 kg/m^3

The main reason for reducing the cement content is, if there is more cement per cubic metre in concrete, it will cause shrinkage cracks. High grade cement (Grade 53) is generally used in rich concrete (mainly used for pre-stressed concrete). This cement consumption i.e. 450 kg/m^3 is used for a 80 storied building if they have used only 450 kg/m^3 of cement for M80 concrete; this was possible using admixtures and reducing water cement ratio to 0.3.

Maximum cement content is reduced since it was likely to cause shrinkage in concrete and that is why all the codes had reduced cement content from 540 to 450 kg/m^3. There is a belief among the engineers that if more cement is added, the strength will be improved. This is not correct.

In this flyover, minimum cement content was 11.2 bags i.e. 560 kg/m^3

THE PROBLEMS IN PRECAST GIRDER

One of the stacked girders was critically examined before towing and launching. Distresses were noticed in one girder (Figure 2). There were inclined cracks in the girder indicating either shear deficiency, shrinkage cracks or bad concrete. The surfaces of concrete were rough. This crack could not be ignored; the crack could be due to deficient concrete or deficient design. At the top surface of bottom bulb of girder, pockets due to air bubbles were seen. This could be due to trapped air.

LOAD TEST

It was decided to carry out detailed investigations, check the design in particular non tensile steel and compare this with similar girders, also to check tests results of concrete cube (Figures 3 and 4). Beside this it was also decided to

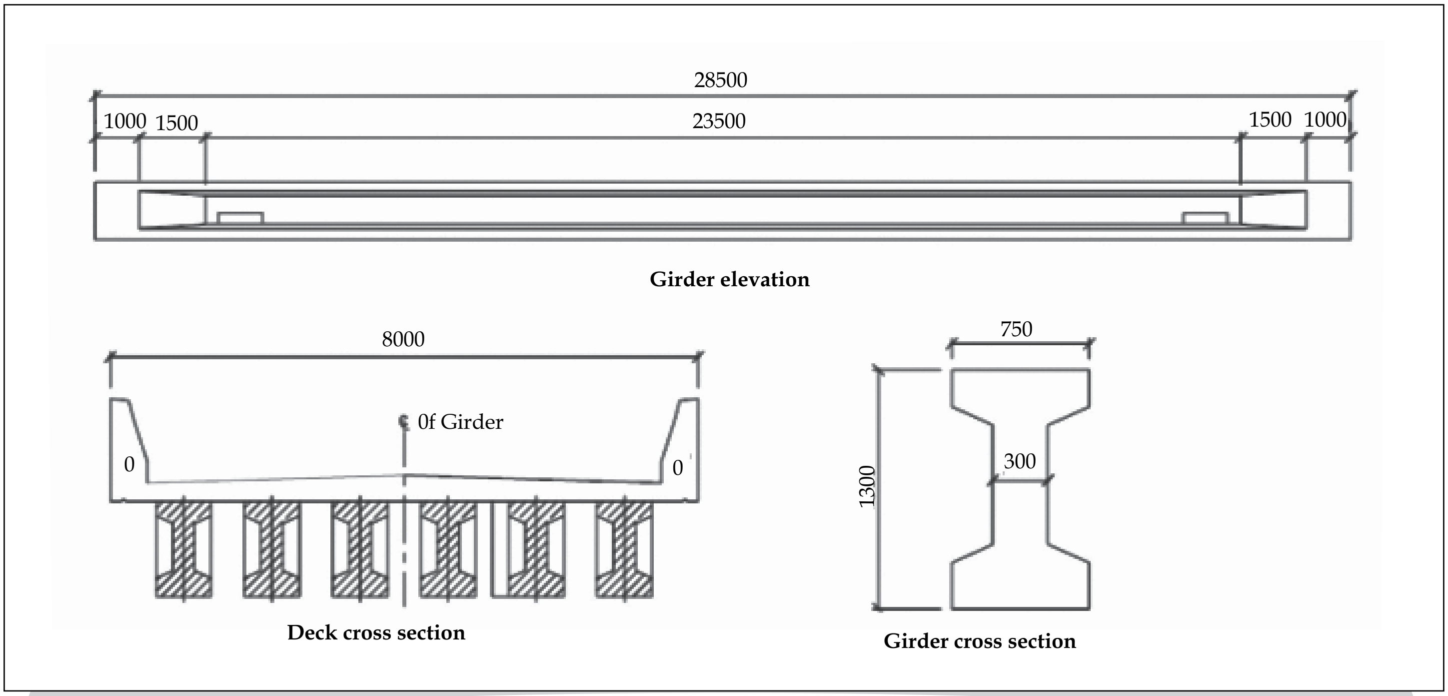

Figure 1. Girder details

Figure 2. Cracks in girder

test this girder for the load which is likely to be sustained by it during service. Each girder of 30 m length was provided with 4 HT cables (1 of 19T13 and 3 of 12T13). Such load test whereby maximum design stresses will be generated in the girder. Total test load was 22 tonnes.

The results of the deflections at the centre of the girder were taken with following sequence:

a. For no load condition at 1 Hr interval with deflection and temperature for 24 Hrs.

b. Placing the load 25% at a time, take the readings wait for two hours add further load and again take the reading.

c. Full load placed for 24 Hrs and readings were taken.

d. Quarter load was removed after 3 Hours and intermediate readings of deflections were taken.

e. Similarly readings were also taken 24 hours on removal of load.

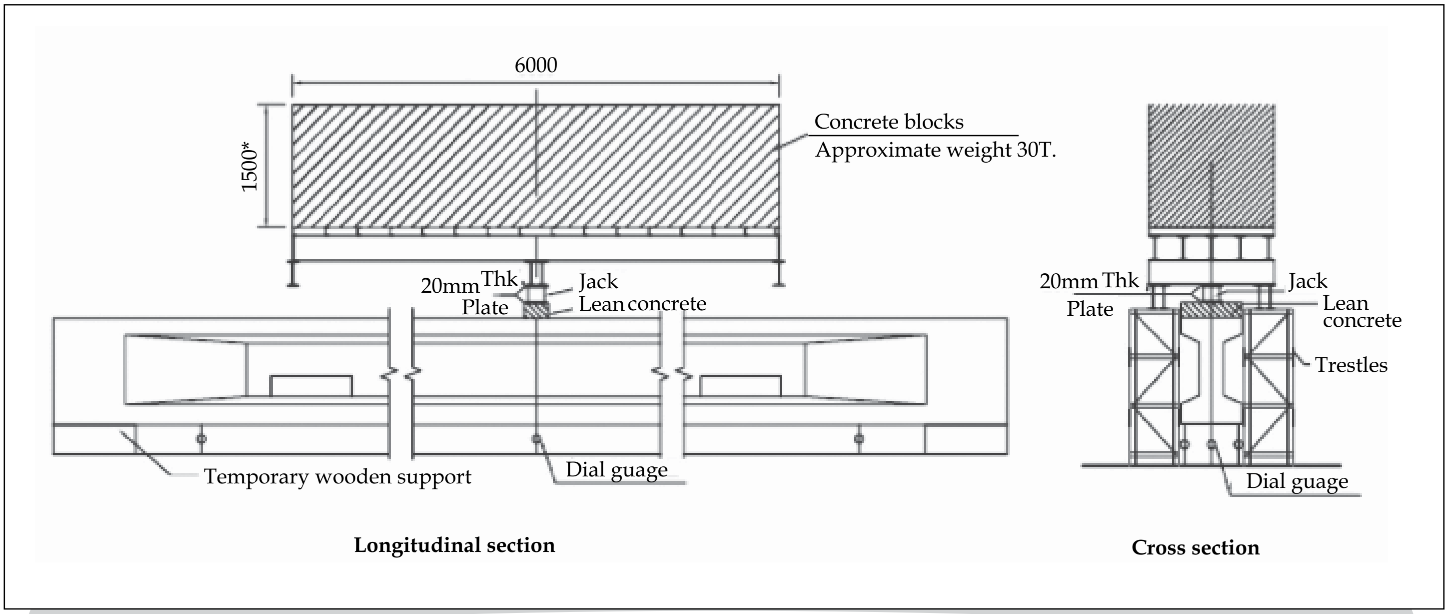

Figure 3. Girder load test

Figure 4. The loading arrangement during girder load test

Figure 5. The measurement arrangement during girder load test

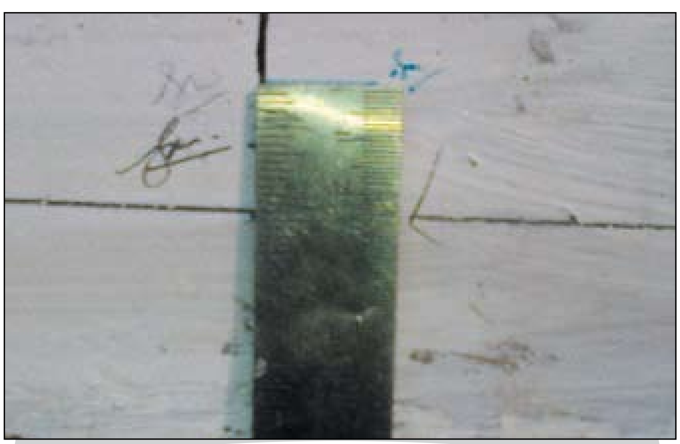

Figure 6. Maximum deflection after 24 hrs of girder loading

Figure 7. Residual deflection after 24 hrs of girder unloading

Figure 8. Combination of ultrasonic & rebound hammer test showing girder concrete strength as 54.0 N/mm^2

The maximum deflection was 26.19 mm against a theoretical deflection of 26.74 mm. The recovery of deflection was 23.41 mm i.e. 89% which is more than 85% prescribed for deflection test of pre-stressed girders. This recovery showed that the prestressed concrete girder had behaved very well, this high recovery also indicated more than adequate flexibility in the structure; this also showed that the surface cracks were not due to any design deficiency. These appeared to be perhaps due to extra cement provided in this structure.

ABOUT SHRINKAGE IN CONCRETE

Page 340 of the Book "Concrete Technology- Theory and Practice" by M. S. Shetty gives various types of shrinkages. Following important points are noteworthy:

- Volume change is one of the most detrimental properties of concrete, which affects the long term strength and durability of concrete. To practical engineers the aspect of volume change in concrete is important from the point of view that it causes unsightly cracks in concrete. When such cracks occur, the moisture and the water during rainfall are likely to enter the concrete and can cause corrosion of steel.
- As shrinkage is an inherent property of concrete, it demands greater understanding of the various properties of the concrete which influence its shrinkage characteristics. It is only when the mechanism of all kinds of shrinkage and factor affecting the shrinkage are understood and the engineer will be in better position to control and limit the shrinkage in the body of concrete.
- In this case it not a plastic shrinkage. It can be termed as drying shrinkage. Just as the hydration of cement is an everlasting process the drying shrinkage is also an everlasting process, when the concrete is

Figure 9. Cone failures

subjected to drying condition. Most of it occurs in 28 days, but some continues thereafter.

The test has proved that the strength of concrete is not reduced and which was the earlier fear.

ANCHORAGES

The anchorages of pre-stressed cables were also seen (Figure 5). Some of these were damaged at various locations which indicate that the concreting of the anchorages was not done properly. The argument which was usually forwarded by the site staff is that, there is lot of steel in the anchorage zone and that is why concreting is not proper. This was not correct. What actually happened was, it was difficult to compact the concrete by pin vibrators at anchor alone and it was necessary to use surface vibrators at anchorage zones or use 16 mm rods to compact the concrete at anchorage zone manually. Thus careless handling of anchorages was the only cause. If form vibrators are not available, compaction of cement concrete could be done manually by 16 mm rods.

PRECAUTIONS IN PSC BRIDGES

- The cement content in concrete of any strength may be limited to 450 kg/m^3. With this content, concrete strength up to M80 can be achieved by reducing water cement ratio and using admixtures like silica fume.
- Strength of the concrete with additional cement is not reduced.
- There is no objection for using fly ash. It is being used in many bridges. The fly ash must be tested before use.
- Concreting of anchorages should be done more carefully, form vibrators should be used and if necessary, consolidation by 16 mm rods can also be done.
- Cracks in the girder after the load test are substantially closed. However, epoxy paint on cracked girder appears necessary.

C.V. Kand PhD holds a B.E. Civil from College of Engineering, Pune; M.Sc. (bridges) from Surrey University, U.K.; PhD from International University, Ceylon. He has more than 32 years experience in government service in design and construction of bridges and 26 years experience as a private consultant in buildings and bridges. He has published more than 100 technical papers in various journals including Indian Road Congress and The Indian Concrete Journal. He is presently the Chairman of C.V. Kand Consultants Pvt. Ltd., Pune.

Tanaji P. Thite holds a B.E. Civil and M.Tech (structures) from VNIT, Nagpur. He has more than five years experience in bridge design. He is a Design Engineer at C.V. Kand Consultants Pvt. Ltd., Pune.

Sadanand Litke holds a B.E. Civil; M.E. (geotech); M.Tech (structures). He is a Junior Engineer at Pune Municipal Corporation. He has more than three years experience in bridge construction and seven years in water supply engineering.