CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 GENERAL

The use of composite construction in bridges have increased recently. However, detailed guidelines for the design of composite open web steel girder bridges are not available. The experimental study was conducted to ascertain the role of the composite deck in preventing the buckling of the top chord. The role of shrinkage strain was also taken into account as it may render the composite action doubtful. However, from the experiment, it was established that shrinkage cracking in the deck slab has little or no effect on the overall composite action and its load-deflection curve remains almost linear throughout. Load sharing between a deck slab and top chord was also calculated. Out of the total compressive force carried by the composite top chord, 72.0% force was carried by the RCC deck. In the RCC deck, 30.7% compressive force was carried by the reinforcing steel. Thus, the composite steel truss bridge offers a safe, economical and aesthetically appealing solution

Numerical analysis of the model was also done on STAAD.Pro.v8i. An attempt was made to calibrate the STAAD model so that the validity of the STAAD model results for the analysis of the composite bridges is upheld. It was found that STAAD satisfactorily analyzed the composite steel truss bridge for its bottom chord strains and the bridge deflection. As an example, a 60 m span bridge was analyzed as through type and deck type steel truss systems. The bridges were analyzed with composite and non-composite decks. Based on the experimental results and numerical analysis, the following conclusions are drawn.

Conclusions from experimental study

1. Shrinkage strain in M40 deck slab concrete is of the order of 0.0003. As per the STAAD analysis of the 30.0m span composite bridge, the flexural strain for the LL condition is 0.00019. Therefore, it may be apprehended that even under full live load conditions complete composite action may not take place. However, the load-deflection behavior of the composite model shows minor effect of shrinkage cracks in the beginning but at grater loading the effect is minimal.
2. At the common load of 44 kN, the ratio of deflections for the composite bridge model and the non-composite model is 0.59. Thus, a composite bridge is preferable from the serviceability consideration.
3. From the experimental study, it was observed that, the ultimate load at failure for the non-composite bridge model is 76.5 kN and for the composite bridge model, it is 196.2 kN. Therefore, the load-carrying capacity for the composite bridge is 2.56 times that of the non-composite bridge model.
4. The stiffness of the non-composite model is found to be 20 kN/mm, and for the composite bridge model, it is 37.2 kN/mm. Therefore, the stiffness of the composite bridge is 1.86 times the stiffness of the non-composite bridge, which may vary in relative sizes of the deck slab and the steel members.
5. The mode of failure for the non-composite bridge model is sudden due to buckling of the top chord members at a stress of 234.6N/mm^2. The failure mode for the composite bridge model is entirely changed to rupture of its bottom chord members at higher stress of 614.8N/mm^2. Thus, composite bridge design may permit higher reserve strength in comparison to the non-composite bridge.

6. At the central section of the model, load sharing by the deck slab is 72.0% and the remaining 28.0% is taken by the top chord member. At the failure, 30.7% of the total RCC deck compressive force is taken by the reinforcing steel in it.
7. Due to load sharing by the RCC deck along with the load taken by the steel top-chord member, maximum stress in the top chord member is limited to 168.0 N/mm^2, which is lower than the top chord buckling stress of 234.6 N/mm^2. Therefore, the buckling of the top chord compression member is entirely eliminated in composite bridges.
8. Strain in the deck slab significantly reduces from the maximum strain at the top chord member location of 0.00058 to the minimum strain in the middle of the two frames to 0.00026, which is reduced by 54.0%. The average strain near failure at the top of the deck slab is 0.00043.
9. Strain in the deck slab varies in the transverse direction with maximum strain at the truss locations. The average strain in the deck slab at the failure load of 196.2 kN is 0.74 times the maximum strain.
10. Shear studs may be designed for ultimate load conditions due to the rupture of the central bottom chord members. Spacing of the shear studs may be kept equidistant from shrinkage crack consideration. But, the concentration of longitudinal shear was observed near supports and over the joint. Due to this considerable spike near supports and joints, it is recommended that the design of shear studs may be carried out based on the shear forces in the studs found from the FEM analysis.

Conclusions from numerical study

11. In the STAAD model, the mesh size of the deck slab has little effect on the analysis results provided the aspect ratio of the elements is near one.

12. The composite bridge model failed at 196.2 kN. The variation of vertical deflection obtained from the experimental result closely tallies with the STAAD model results.
13. Strain in the steel bottom chord of a composite truss bridge, obtained from the STAAD analysis and the experimentally recorded strain closely tally. Thus, the STAAD model results for the bottom chord strain are calibrated.
14. In the top chord member, due to the combined effect of shrinkage cracks in the deck slab concrete and bending in shear connectors, the experimentally recorded strain is higher by about 100% than the STAAD analysis result. Therefore, while designing the composite section force in the steel component obtained from the STAAD analysis have to be doubled for design.
15. In the analyzed 60m span deck type bridge, stress is the top chord member at the mid-span is reduced by 48.4 % due to composite action of deck slab. Due to this, the chance of sudden buckling of the top chord members is also prevented in case of an overload.
16. In the analyzed through type bridge, maximum stress in the bottom chord at the mid-span decreases by 45.3% for the composite case.
17. Vertical deflection in the service condition for the through type bridge decreases from 95.1 mm to 88.36 mm by 7.1%. Similarly, it decreases from 91.16 mm to 82.75 mm by 9.2% for deck type bridges.
18. The horizontal deflection of the bridge for the composite through type decreases by 88 % and by 29 % for the deck type bridge under seismic load. The maximum defection in the deck type bridge for seismic case was observed at the deck location, which is elevated from the support. Similarly horizontal deflection of the

bridge for the composite through type decreases by 71.3% and by 29.13% for the deck type bridge under wind load.

The deck slab, while preventing buckling of the steel members, shares a significantly high proportion of the compressive force in the top members of a deck type bridge. The composite deck also significantly increases the horizontal stiffness of the bridge resulting in a more economical design of the bridge. Vertical deflection of the composite bridges is also lower in comparison to the non-composite bridges, resulting in their better serviceability.

6.2 FUTURE SCOPE OF STUDY

In the present study, a lab experiment is conducted to find out the role of composite deck in avoiding the buckling of the deck slab. It was also found that shrinkage cracks do not affect the composite action. The failure of the model shifted from buckling of the top chord to rupture of bottom members. From the study presented, the following areas of research can be further explored.

1. The strength of the composite bridge depends on the rupture of the bottom chord. An experimental and numerical study is needed, where high strength steel cables are used along with the bottom chord members.
2. Study of performance of composite deck (especially in negative moment) in a continuous composite deck open web girder bridge is necessary.
3. Finite element analysis and experimental study of the shear connector under fatigue loading may be carried out.