Preface

In the past a number of steel truss bridges have failed during various stages of construction or service condition. Sudden failure or collapse of bridge is always a catastrophic disaster as such type of collapse does not give any precautionary warning. Possibility of sudden collapse of truss bridges has always been due to buckling of non-redundant critical compression members. Unlike compression members, tension members do not usually fail suddenly since they experience noticeable elongation and can take stress up to ultimate stress beyond the yield stress. Behavior of tension and compression members under loading is completely different and therefore, compression members need a different approach for their design. In case of truss bridges, failure of gusset plates connecting members of truss, and buckling failure of compression members are the most happening failures. A first step towards understanding and quantifying the risk of bridge failures can be provided by acquiring knowledge on possible failure mechanisms of existing structures and the root causes of collapse. There is a need to understand the conditions giving rise to past failures and ways to avoid such failures sothat loss of life and property can be minimized.

Sudden collapse of 190m long Chauras Bridge on Alakanada River, Uttarakhand, India, which was a three span (40m+110m + 40 m) continuous deck type truss bridge, took place during casting of the deck slab after successful launching of the truss in the year 2012. Chauras bridge collapsed due to buckling of one of its top chord compression member. Sudden collapse of the bridge claiming six lives with it indicates that steel girder bridges must also be checked at the limit state of strength.

In the present research work, failure analysis of Chauras bridge is carried out to find the cause of failure of truss bridge and its preventive measurement for existing or future construction of steel bridge. As per Indian and European Standards, in addition to 1.1 material safety factor and 1.5 load factor used for compression and tension members in limit state of serviceability design. As per Indian and European Standards, 1.1 material safety factor and 1.5 load factor used for compression and tension members in limit state of serviceability design. It is recommended that additional load factor of 1.5 (both for dead and live loads) for laterally unsupported compression members, and no additional load factor for tension members and joints, should be used for checking the design of steel truss bridges at the limit state of strength.

On the same design of Chauras bridge, Garudchatti bridge at Dugadda was constructed first and opened to traffic, but excessive vibrations and lifting of end supports under live load condition were observed. Failure of Chauras bridge led to the serious concerns in the minds of people and technocrats about the safety of Garudchatti bridge also, because it was constructed using the same design of Chauras bridge. Therefore, it was decided to strengthen and carry out load testing of Garudchatti bridge before reopening to the traffic.

In the present work, analysis of Garudchatti bridge are presented to identify structurally unsafe members for most severe live loads given in IRC:6-2010 code, and recommendations for strengthening of the critical members. The critical compression members were strengthened by welding additional channel sections. RCC anchor blocks were constructed to restrict lifting of end supports under live load. After strengthening, load testing of the bridge was performed to ensure the safety of the bridge. The bridge is now reopened for traffic. In the past a number of bridges have collapsed during load testing. In case of any shortcoming in the design or overloading during load testing, compression members of the truss may suddenly buckle and cause collapse of the bridge. Therefore, it is not advisable to load test steel truss bridges which do not have adequate margin beyond the service load condition.

Structural steel and concrete materials can be combined in different ways to highlight the art of structural engineering in bridge design. Composite action in trusses may be explored to produce variety of design solutions. Composite action of RCC deck with steel truss is advantageous as top chord compression members of the truss are laterally supported with the help of shear studs and prevents their buckling.

In the present research work behavior of composite truss bridges is discussed from basic principles of mechanics. The stresses developed in the deck slab and steel truss members are highlighted in view of composite action in steel truss bridges. Due to shrinkage strain of 0.0003 in deck slab concrete after its casting, complete composite action between RCC deck and steel truss is not possible. Effect of shrinkage strain on composite action is discussed in detail. Unlike simply supported composite truss bridges, in continuous composite truss bridges, deck slab is in tension at supports due to hogging moment at intermediate support locations. In addition to the shrinkage strain, tensile strain due to hogging moment causes more tensile cracks and hence composite action between RCC deck and steel truss is not possible in hogging moment zone. Therefore, simply supported composite truss bridges are more advantageous than continuous composite truss bridges. An innovative design procedure of composite steel truss bridge considering all above mentioned criterions has been proposed in this research work. Design guidelines for design of composite truss bridge in service condition, for overload condition and at ultimate collapse are proposed. Also, based on these proposed design guidelines, a comparative

study of 90.0m span composite and non composite simply supported deck type truss bridge is carried out.

In the present research work an innovative semi deck type truss bridge is designed on the basis of design proposed guidelines. Till today no semi deck type truss bridge is constructed in the world. The design of shear studs using different codes is compared. FEM analysis of the bridge is carried out to get the total longitudinal shear in shear studs. The shear studs are designed for a 42.0m span semi deck type truss bridge using different standard design codes. Finally, based on the design comparison of shear studs using different codes and FEM analysis, few design recommendations are given for the design of shear studs for composite truss bridges.

Finally, comparative study has been carried out on the basis of proposed design guidelines for truss bridges of span 30.0m and 90.0m having four different configurations viz. through type, deck type, semi deck type and under slung truss. Analysis and design of the above mentioned bridges are performed in service load condition for (DL+LL) case, and at overload condition for 2.25 x(DL+LL) case. Also an attempt has been made to compare the design results of a 90m span deck type truss bridge using structural steel of grade E250 and high tensile steel (HTS) of grade E410. It is observed that deck type composite truss bridges using HTS are lightweight and found advantageous in earthquake prone areas.

Keywords: *Failure analysis, Load factor, Composite truss bridge, Shear studs, Shrinkage, Design guidelines, Semi deck type bridge*