CHAPTER 1

INTRODUCTION

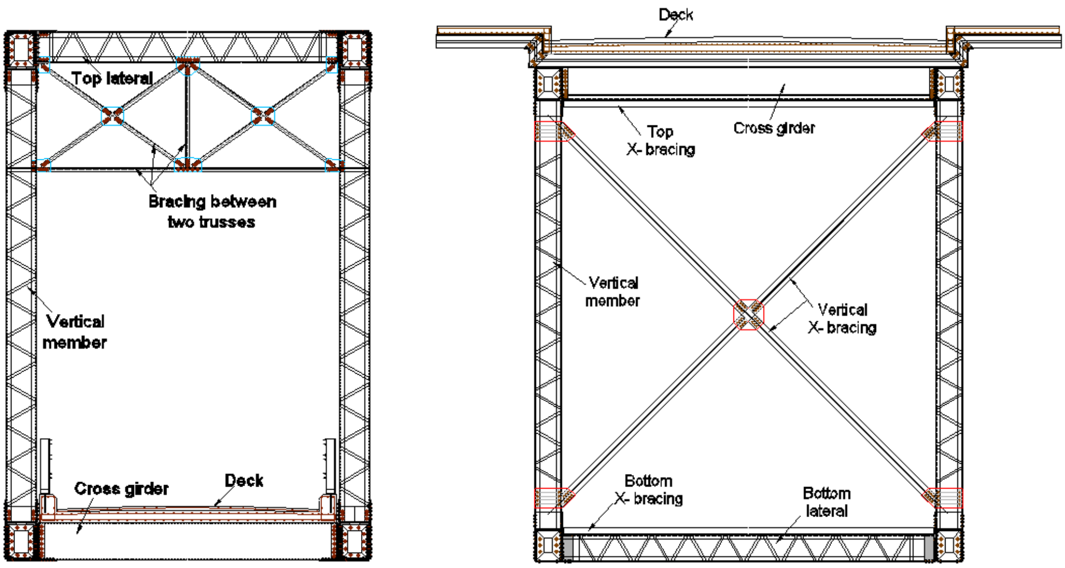
1.1 GENERAL

Bridge is a structure made with natural or manmade materials that provides passage over obstacles such as rivers, canals, valleys, rough terrain etc. Bridges are the most important part of the surface transportation system. Geometry of bridges depends on the site requirement and the nature of the terrain where the bridge is to be constructed.

Bridges can be categorized in several different ways depending on structural elements and the materials used. Classification of bridges also depends on how the forces of tension, compression, bending, torsion and shear are distributed through their structure. On the basis of force transfer mechanism, bridges are classified as Beam Bridge, Truss Bridge, Cantilever Bridge, Arch Bridge, Tied Arch Bridge, Suspension Bridge and Cable-Stayed Bridge.

A truss bridge or open web girder bridge is a bridge whose superstructure is composed of a truss and connecting elements form triangular units. Elements forming the triangular units are called as members of truss. Members of truss predominantly carry axial tensile or compressive forces. Truss bridges were popularly constructed throughout the world in 19th and 20th century and they became a common type of bridge built from the 1870s through the 1930s. Even today construction of truss bridges is in practice mostly in hilly areas.

Truss bridges or open web girder bridges are most commonly used bridges and found satisfactory from small spans of 10m to large span of 300m. Truss bridges of 50m to 60m spans are most common. According to the manner of transference of live load to the bridge, these are classified into through type (Figure 1.1.a) and deck type (Figure1.1.b) truss bridges. In the case of deck type truss bridges, the floor of the bridge is supported at the top chord joints of the truss. In a through type truss bridge, the floor of the bridge is supported at the bottom chord joints of the truss. Typical cross sections of through type bridge and deck type bridge are shown in Figure 1.1.



a. Through type bridge b. Deck type bridge

Figure 1.1 Typical cross sections of through and deck type bridges

Due to analysis constraints, earlier truss bridges were analyzed as planar pin jointed structure. But with the invention of computers, analysis and size of structure are no more a problem. Members of a truss are connected at the ends with the help of rivets, bolts or weld. These connections are actually rigid connections and not pin connections as required for pin jointed truss. Therefore, it has now become more relevant to analyze bridge trusses using space frame approach.

In Indian steel bridge design code IRC:24-2010, in absence of rigid space frame analysis, it is suggested to assume that all truss members are frictionless pin jointed and all loads including self weight of members are applied at joints. But, in actual practice it is not possible to construct truss joints as pin joints due to multiple rows of rivets or welding. Therefore, 3D rigid space frame analysis of truss bridges should be carried out to get actual axial forces and bending moments in truss members. In 3D rigid space frame analysis it is possible to get six types of forces at each node of truss member, and therefore, apart from checking members against buckling, all members must be checked for interaction ratio due to axial force and bending moments.

1.2 FAILURE OF BRIDGES

In the past a number of steel truss bridges have failed during various stages of construction or in service condition. The most common causes of bridge failure include: overstress of structural elements due to section loss, design defects and deficiencies, long-term fatigue and fracture, failures during construction, accidental impacts from ships, trains and aberrant vehicles, lack of inspection and unforeseen events. The failures have been partial, or total collapses have taken place. Historical events and selected case studies demonstrate the causes of different type of failure of bridges. There is a need to understand the conditions giving rise to past failures and ways to avoid such failures so that loss of life can be avoided. Future design codes can make use of the deficiencies identified in order to develop guidelines for safe practice. If failures are interpreted correctly, a great deal of information for correct analysis, anticipated behavior, detailed design, and construction can be obtained to help formulate accurate design guidelines.

Past failure studies have shown that failures occur due to a variety of reasons. The primary causes of failure and the numerous secondary causes contributing to failure need to be investigated. Primary effects may not all be dangerous by themselves, but when combined with secondary effects, their cumulative action can trigger a collapse. It is important to understand both the mechanics and mechanism behind a failure and the applicable theory of yielding and fracture so that structural integrity is maintained and future designs are made safer.

Lessons from failures in past may be treated as learning experiences, because when a bridge collapses it might have certainly been pushed the existing knowledge to the limit in some way. Therefore, structural collapses in general, and particularly bridge collapses, which are often most spectacular, have a significant effect on the development of the knowledge of structural action and material behavior and has spurred research into particular fields (Z. Šavor, *et. al.*, 2011).

Steel girder bridges especially truss bridges are more susceptible to failure as compared to other bridges. K. Wardhana and F. C. Hadipriono (2003) carried out a statistical study of failure of 500 bridges in USA from 1989 to 2000. In their study it is found that the dominant types of failed bridges were the steel beam/girder and steel truss bridges, with 145 (29%) and 107 (21%) occurrences, respectively. These failed bridges constitute over 50% of the total bridge.

1.3 COMPOSITE TRUSS BRIDGE

Composite construction of RCC floors with trusses is common in case of building construction, and with steel plate girders in case of composite plate girder bridges. Not much literature is available for composite steel truss bridges. Despite unavailability of proper design guidelines and design standards for composite truss bridges, various types of composite truss bridges have been constructed in the World. In India through type truss bridge construction is most popular, and construction of deck type composite steel truss bridges is not in practice. Hence further research in this area is required to avail benefits of the composite construction.

Trusses are efficient structural systems, since the members experience essentially axial forces and hence the materials are fully utilized (R. P. Johnson, *et. al.*, 2001). Steel as a structural material is equally strong; both in tension and compression, and the truss members are fully stressed, hence steel trusses are more efficient. They tend to be economical to support loads over larger span lengths. However, the members in the compression chord of the simply supported steel truss (top chord) may prematurely buckle before the stresses reach the material strength. In this context composite action of the RCC slab with the truss compression chord becomes useful and prevents its buckling. A reinforced concrete or composite deck floor is required in bridges to provide a flat surface. Using it as a part of the compression member in truss system is an economical proposition. Concrete has a lower strength compared with steel and hence requires larger cross section to sustain a given compression. Consequently, the concrete floor slab used as a part of the compression chord of the truss is not vulnerable to buckling failure. Further, concrete can more economically carry compression. Thus, in a composite truss system the relative merits of steel and concrete as construction materials are fully exploited. It is one of the most economical systems in longer span bridge construction. Composite truss systems are structurally efficient and economical. Considering functional and structural efficiency and economy, it is only natural that composite steel-concrete trusses are a popular choice for medium span bridges. Shear transfer between the steel truss and concrete deck slab is mobilised usually using shear studs.

Composite truss bridges are generally not designed in India. The first composite double deck railway truss bridge under construction in India is Bogibheel bridge across river Brahmaputra in Assam. Using shear connectors, if the deck slab is made composite with the top chord compression members of a simply supported truss bridge, then lateral buckling of the top chord members can be prevented, and it can support more load at the limit state of collapse. Therefore, possibility of design of composite steel truss bridges is explored and detailed design procedure with examples is presented.

Continuous span composite truss bridges do not have full advantage of the composite action, as negative moment at the support is approximately twice the positive moment at the mid span, and it causes tension in the deck slab. Because of this cracked deck slab at the supports does not contribute in composite action. Cases of existing continuous composite bridges in the World are compared with the objective of establishing their usefulness in mountainous regions like Himalaya. Therefore, continuous composite bridges are not recommended due to above reasons. Simply supported composite truss bridge is further studied for its suitability.

1.4 MOTIVATION

Steel truss bridges are found to be very suitable between 30.0m to 100.0m spans in mountainous regions like Himalaya in India. These bridges are light in weight and therefore, are also suitable for highly seismic areas like in Himalaya where most of the area lies in most severe seismic zone-V. Failure of Chauras bridge in Uttarakhand, India in the year 2012, claiming six lives with it, demanded investigation for the causes of failure, and further research and innovation in the area of design of steel truss bridges. Therefore, the research work on analysis, design and construction of steel truss bridges was taken up on the following aspects.

In the present study failure analysis of Chauras bridge in Uttarakhand, India is carried out at collapse stage. Few design shortcomings has been found in the design and construction. 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 research new concept of composite truss bridge and its design guidelines are introduced in addition to the design guidelines available for design of truss bridges. Design of shear studs for composite steel truss bridge is carried out using different codes and proposed guidelines. Comparative study has been carried out for through type, deck type, semi deck type and under slung truss bridges in the terms of deflection and steel off take. A new type of configuration, semi deck type truss, is presented which is found to be advantageous over other type of truss configurations.

1.5 ORGANISATION OF THESIS

The present thesis is divided in seven chapters. General introduction of truss bridges and their different configurations, and design aspects of composite truss bridges are discussed in Chapter 1. The Chapter 2 gives the literature review on failure of bridges and recent developments in composite truss bridge construction. Scope of present study is also given in this chapter. In Chapter 3, a case study of failure of Chauras bridge and strengthening of Garudchatti bridge is presented. Design guidelines for design of composite truss bridges are proposed in Chapter 4. in Chapter 5, analysis and design of shear studs for composite truss bridge is carried out. Comparative study of different type of truss configurations for three different spans is presented in Chapter 6. Suitability of use of HTS in composite truss bridge is also presented. The conclusions drawn out of the present work and the future scope of works are summarised in Chapter 7.