



## COST ANALYSIS OF STEEL CONCRETE COMPOSITE STRUCTURES IN BANGLADESH

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### ABSTRACT

Steel-concrete composite construction has gained wide acceptance world wide as an alternative to pure steel and pure concrete construction. However, this system is a relatively new concept for the construction industry in Bangladesh. Reinforced concrete members are used in the framing system for most of the buildings since this is the most convenient & economic system for low-rise buildings. However, for medium to high-rise buildings this type of structure is no longer economic because of increased dead load, less stiffness, span restriction and hazardous formwork. Steel-concrete composite frame system can provide an effective and economic solution to most of these problems in medium to high-rise buildings. An attempt has been made in this study to explore the cost effectiveness of composite construction for medium to high-rise buildings in Bangladesh. A cost versus number of story curve shows that for low-rise buildings RCC frame system is cheaper than composite system. However, for buildings with number of stories greater than 15, composite construction becomes economic than RCC construction.

**Keywords:** Reinforced concrete; composite; structures; construction; columns; cost comparison; economic.

### 1. INTRODUCTION

An important and economic combination of construction materials is that of steel and concrete, with applications in medium to high-rise buildings as well as bridges. Steel-concrete composite system has several advantages over traditional reinforced concrete or steel structures: these include high strength-to-weight ratios, structural integrity, durable

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finishes, dimensional stability and sound absorption. These advantages have led to a substantial increase in the use of composite construction all over the world in recent years. However, in a developing country like Bangladesh this innovative technology is not practiced widely. Most of the buildings constructed in Bangladesh so far are low rise structures which are not economically favorable for composite construction point of view. Due to increased land price and population growth medium to high-rise structures are gaining popularity and approvals from Government. In Bangladesh reinforced concrete members are mostly used in the framing system for most of the buildings since this is the most convenient & economic system for low-rise buildings. However, for medium to high-rise buildings this type of structure is no longer economic because of increased dead load, less stiffness, span restriction and hazardous formwork. Steel-concrete composite frame system can provide an effective and economic solution to most of these problems in medium to high-rise buildings. An attempt has been made in this study to explore the feasibility of composite construction in Bangladesh for medium to high-rise buildings.

## 2. OBJECTIVE AND SCOPE OF THE STUDY

The objectives of this study are,

1. To provide a brief description to various components of steel concrete framing system for buildings.
2. To investigate the cost effectiveness of steel-concrete composite frames over traditional reinforced concrete frames for building structures.

Since composite construction is a relatively new concept for Bangladesh, a brief introduction to composite building system will certainly help the design engineers to familiarize themselves with the components of this system. To fulfill the second objective of a typical commercial building with a floor area of 7720sft is selected for this study. Design and estimation of the cost of the building superstructure only is conducted with similar floor pattern but variable heights likely 6 storied, 12 storied, 18 storied and 24 storied buildings. Structural analysis for the buildings with reinforced concrete framing system as well as with steel-concrete composite framing system is performed using ETABS finite element software. Cost of the building superstructure is estimated for the two framing systems in the context of Bangladesh.

## 3. STEEL-CONCRETE COMPOSITE FRAME SYSTEM

### 3.1 Composite floor system

Steel-concrete composite framing system, as shown in Fig. 1, comprises of composite columns and steel-concrete composite floor deck system. Composite floor system consists of steel beams, metal decking and concrete. They are combined in a very efficient way so that the best properties of each material can be used to optimize construction techniques.

The most common arrangement found in composite floor systems is a rolled or built-up steel beam connected to a formed steel deck and concrete slab (Fig. 2). The metal deck

typically spans unsupported between steel members, while also providing a working platform for concreting work. The composite action of the metal deck results from side embossments incorporated into the steel sheet profile [1]. The composite floor system produces a rigid horizontal diaphragm, providing stability to the overall building system, while distributing wind and seismic shears to the lateral load-resisting systems [1].

Composite action increases the load carrying capacity and stiffness (i.e. reduces the deflection) by factors of around 2 and 3.5 respectively. The concrete forms the compression flange – the steel provides the tension component and shear connectors ensure that the section behaves compositely. During construction, the beam is designed to resist concrete dead load and the construction load (to be treated as a temporary live load). At the composite stage, the composite strength and stiffness of the beam should be utilized to resist the full design loads. Successful composite beam design requires the consideration of various serviceability issues, such as long-term deflections and floor vibrations. Beam spans of 6 to 12 m can be created giving maximum flexibility and division of the internal space. Composite slabs use steel decking of 46 to 80 mm depth that can span 3 to 4.5 m without temporary propping [2]. Slab thicknesses are normally in the range 100 mm to 250 mm for shallow decking, and in the range 280 mm to 320 mm for deep decking. Composite slabs are usually designed as simply supported members in the normal condition, with no account taken of the continuity offered by any reinforcement at the supports [2].

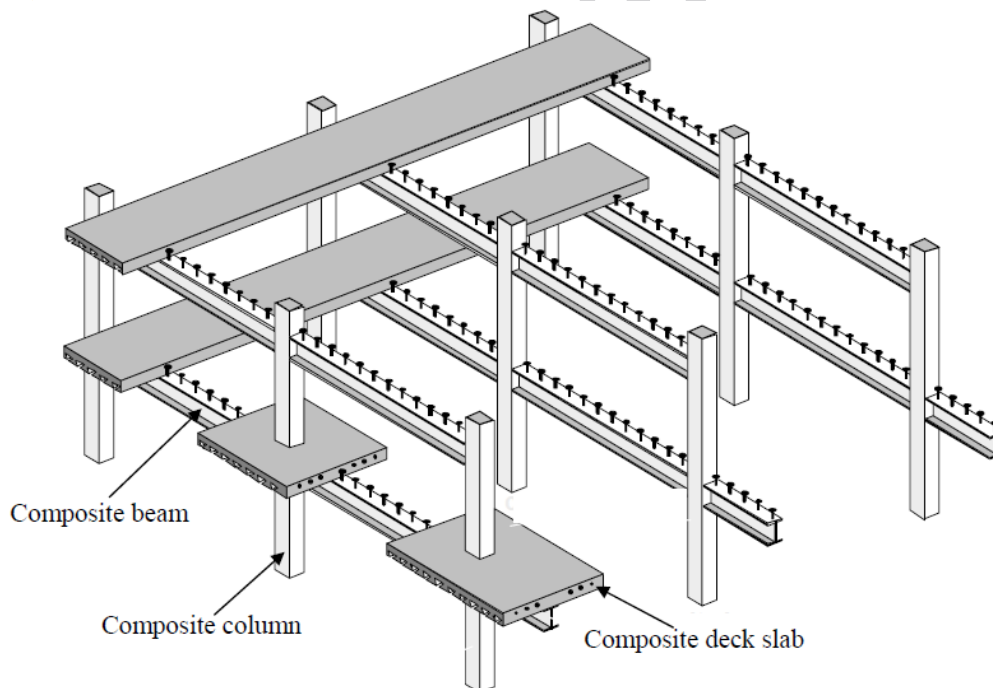


Figure 1. Steel-concrete composite frame

### 3.2 Composite columns

Composite columns have large load carrying capabilities, small cross sections and good fire protection properties. They are well known to possess high axial strength and flexural

stiffness. The confinement of concrete by steel increases its compressive strength and ductility. They can be constructed in a great variety of different forms. Two types of composite columns commonly used are: concrete filled tubes (CFT) and fully encased composite (FEC) columns (Fig. 3(a) and 3(b)). Both of these composite systems have limitations such as limited cross-sectional dimensions of standard shapes (CFT), requirement of extensive formwork and additional reinforcing steel (FEC columns) and complex beam-to-column connections. These limitations have indirectly imposed restrictions on the use of composite columns.

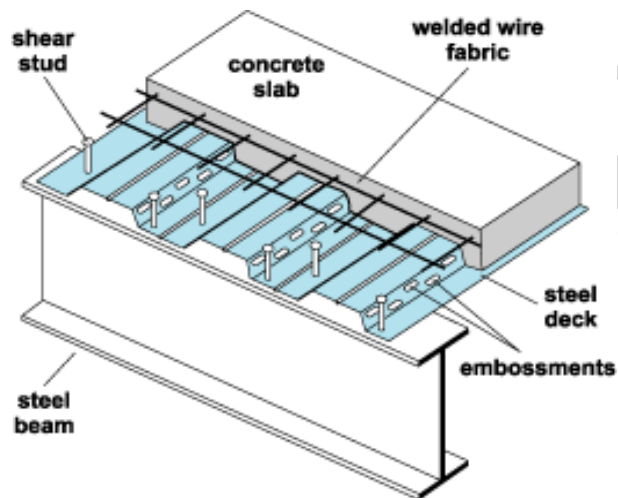


Figure 2. Composite floor system

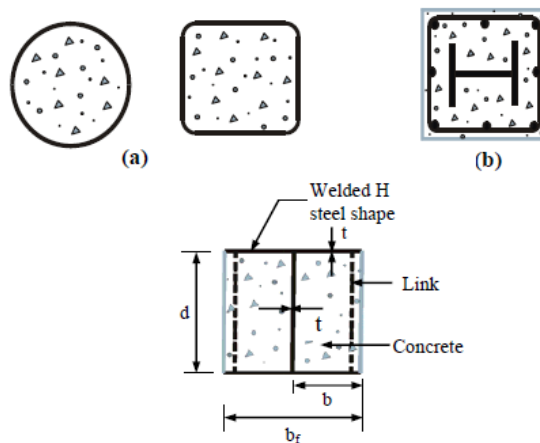


Figure 3. Common types of composite columns, (a) concrete filled tubes; (b) fully encased composite column; and (a) partially encased column

In Europe, in the early 1980s, PEC columns and beams were introduced using standard-sized rolled steel sections. In 1996, the Canam Group in Canada took the initiative to

propose a new type of composite column consisting of a thin-walled, welded H-shaped steel section, built-up from hot-rolled steel plate, with concrete infill cast between the flanges, as shown in Fig. 3(c). Transverse links are provided between the flanges at regular intervals to improve the resistance to local buckling. This new system has been termed the “partially encased composite (PEC) column,” since the steel section is only partially encased by the concrete. Additional reinforcement consisting of longitudinal and transverse rebars can be provided to improve the ductility of these columns under cyclic loading.

In PEC columns, since a built-up steel section is used instead of a standard shape, the designer has more flexibility when sizing the column cross-section. Moreover, thin steel plates are intentionally specified to obtain a more cost effective column by increasing the contribution of concrete in the load carrying capacity of the column. These factors have made PEC columns constructed with built-up shapes more attractive than those constructed with standard sections. Moreover, the high stiffness of the PEC column is expected to have beneficial effects for controlling the lateral deflection of buildings when used as a component of lateral load resisting systems and incorporating the use of high performance materials in the system. Extensive experimental and numerical research has been conducted on thin-walled PEC columns with built-up sections by several research groups [3-8] to investigate the behaviour of PEC columns fabricated with thin-walled built-up sections under various conditions of loading. The design guidelines are proposed based on these research works and are included in CSA S16-01 [9]. In the current study partially encased composite columns are used in the composite framed buildings as the load bearing element. The design of these columns is made according to the guidelines provided in CSA S16-01 [9].

### 3.3 Composite connections

For composite frames resisting gravity load only, the beam-to-column connections behave as they do when pinned before the placement of concrete. During construction, the beam is designed to resist concrete dead load and the construction load (to be treated as a temporary live load). At the composite stage, the composite strength and stiffness of the beam should be utilized to resist the full design loads. For simple frames consisting of bare steel columns and composite beams, there is now sufficient knowledge available for the designer to use composite action in the structural element, as well as the semirigid composite joints, to increase design choices, leading to more economical solutions. Practical design guidelines for semicontinuous composite braced frames are given in Liew et al. [10]. Figure 4 shows two typical beam-to-column connections: one using a flushed end plate bolted to the column flange, and the other using a bottom angle with double web cleats. The connections to edge columns should be carefully detailed to ensure adequate anchorage of rebars [11]. Otherwise, they shall be designed and detailed as simply supported. In braced frames a moment connection to the exterior column will increase the moments in the column, resulting in an increase of column size. Although the moment connections restrain the column from buckling by reducing the effective length, this is generally not adequate to offset the strength required to resist this moment. For an unbraced frame subjected to gravity and lateral loads, the beam is typically bent in double curvature with hogging moment at one end of the beam and sagging moment at the other. The concrete is assumed to be ineffective

in tension; therefore, only the steel beam stiffness on the hogging moment region and the composite stiffness on the sagging moment region can be utilized for frame action.

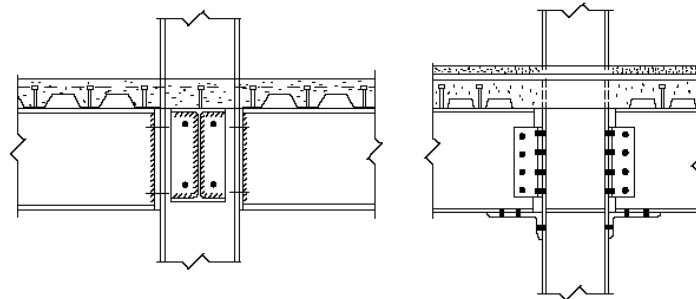


Figure 4. Typical composite connections

### 3.4 Advantages of composite construction

Steel–concrete composite construction has gained wide acceptance world wide as an alternative to pure steel and pure concrete construction. In composite construction steel and concrete are arranged to produce an ideal combination of strength, with concrete efficient in compression and steel in tension. This type of construction renders the following advantages in comparison to steel only or concrete structures.

1. Increased strength for a given cross sectional dimension.
2. Increased stiffness, leading to reduced slenderness and increased buckling resistance.
3. Good fire resistance and corrosion protection in case of concrete encased columns.
4. Significant economic advantages over either pure structural steel or reinforced concrete alternatives.
5. Identical cross sections with different load and moment resistances can be produced by varying steel thickness, the concrete strength and reinforcement. This allows the outer dimensions of a column to be held constant over a number of floors in a building, thus simplifying the construction and architectural detailing.
6. Erection of high rise building in an extremely efficient manner.
7. Formwork is not required for concrete filled tubular sections.
8. More usable area than RCC structure because of less cross sectional area.

## 4. METHODOLOGY

A typical commercial office building has been chosen for the feasibility study of steel–concrete composite construction in Bangladesh. A typical floor plan of the building is shown in Fig. 5. The design and analysis of the structure is conducted with four different heights of the building. The finite element software ‘ETABS’ is used to carry out the structural analysis for both RCC framed and composite framed buildings. The design of the reinforced concrete buildings are performed using BNBC 1993 [12] & ACI 318-99 [13] codes. In designing the RCC framed buildings–two way beam supported slab is selected as the gravity

load resisting system whereas beam-column frame combined with RCC shear wall is used as the lateral load resisting system.

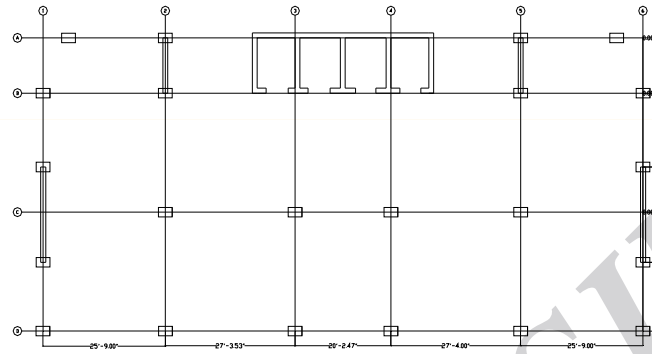


Figure 5. Typical floor plan

The steel concrete composite frame system is designed using AISC-LRFD (2005) code [14]. Partially encased composite columns used in the current study are designed according to CISC 2009 [15] code. For the composite framed buildings gravity load is transferred through the steel-concrete composite floor system and steel plate shear walls are used to carry the lateral loads acting on the building. After designing the buildings material cost of the superstructure is estimated for both reinforced concrete members and steel-concrete composite members. The cost for construction and supervision for the two framing systems are also conducted for the buildings with four different heights. The total costs of the buildings with RCC and composite framing system are included in Table 1. Figure 6 shows graphical representation of this table which presents the cost versus number of story curve. The discussion on the results is included in the subsequent section.

Table 1: Comparison of cost between RCC structure and composite structure

| Story | Cost of R.C.C. Structure (Tk.) | Cost of Composite Structure (Tk) | % difference |
|-------|--------------------------------|----------------------------------|--------------|
| 6     | 2,38,86,780                    | 2,83,58,945                      | 19           |
| 12    | 5,52,73,408                    | 5,73,02,982                      | 4            |
| 18    | 8,52,57,890                    | 8,22,23,379                      | -4           |
| 24    | 13,49,85,000                   | 11,57,43,510                     | -14          |

### 5. DISCUSSION ON RESULTS

The cost of RCC building and composite building for different storey heights as presented in Table 1 indicates that for low rise buildings RCC structure is economic as compared to

composite structure. As the story number increases the difference in cost between RCC and composite structure reduces. After certain limit the cost of RCC structure exceeds the cost of composite structure. This limit of storey number is 15 as observed in the cost versus number of storey curve (Fig. 6). For buildings with no of storey above 15 RCC construction is costlier than composite construction. For 18 storied and 24 storied building the cost of RCC structure exceeds the cost of composite structure by 4% and 14% respectively. A bar chart showing the comparison of cost between RCC and composite buildings for variable story numbers is presented in Fig.7.

From Fig. 6 it is obvious that increase in the number of story results in increased cost for RCC construction as compared to composite construction. This increase in cost for RCC construction with respect to composite construction increases exponentially with the number of storey of the building. In the cost estimation for building structures in current study only the material and construction cost for the superstructure of the typical commercial building is considered. No savings in the construction time for the erection of the composite structure is included. As compared to RCC structures, composite structures require less construction time due to the quick erection of the steel frame and ease of formwork for concrete. Including the construction period as a function of total cost in the cost estimation will certainly result in increased economy for the composite structure.

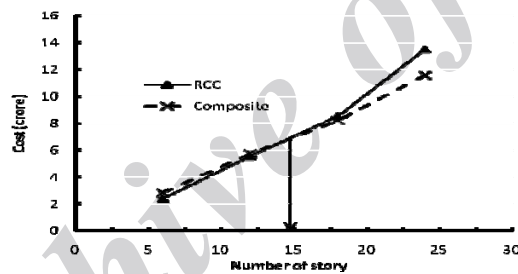


Figure 6. Cost versus number of storey curve for composite and RCC building

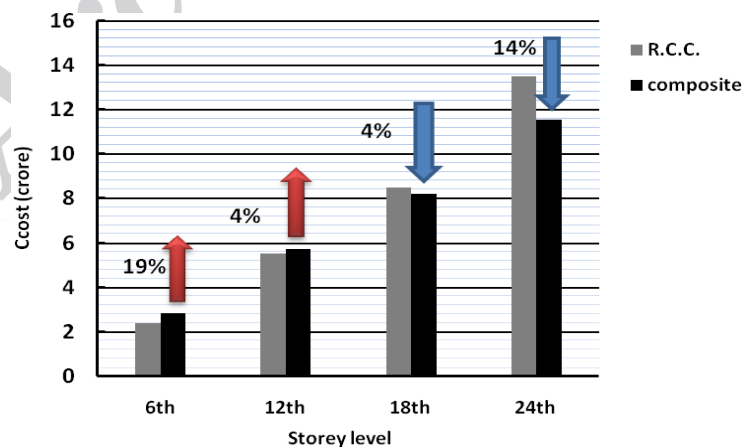




Figure 7. Cost comparison bar chart

## 6. CONCLUSIONS

Steel-Concrete Composite frame system and its components are described to provide a brief introduction to composite construction. From the literature provided and considering the advantages of composite structure, it is clear that this type of construction can provide a satisfactory solution for the strength and serviceability requirements of commercial as well as residential buildings in Bangladesh. This paper also presents a feasibility study of composite structures in the current construction industry of Bangladesh. This was performed by comparing the cost of RCC buildings with that of composite buildings. The number storey for each building type was varied to identify the effect on cost of these two different types of construction for low, medium and high rise buildings. The results show that RCC construction is better for low rise buildings (below 15 stories). For medium to high rise buildings steel concrete composite frame system is a better choice over reinforced concrete frame system from both economy & serviceability point of view. For high rise buildings constructed with composite frames cost decreases due to the use of smaller cross sectional element, use of less steel, use of less formwork for concrete, low labour cost etc. Steel-concrete composite frame system can be an economically viable solution for high-rise buildings in Bangladesh.

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