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"Investigation on the uses of steel as a sustainable construction material in Bangladesh."

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ABSTRACT:

In the context of rapid urbanization in Bangladesh, overpopulation in Dhaka city increasingly carries out chaos, inequalities, environmental degradation, opens spaces loss, socio-economic tension, and spontaneous settlements and sprawl. These crisis situations put to the forefront sustainable urbanization as a priority issue for urban development with reference to the globalization technology. Now a day's sustainability is a worldwide prior concern which is at the top of the construction agenda and steel is increasingly proving its value for meeting the challenges ahead. That's why we put our focus on steel construction and its relative valuable features over RCC. Steel has a high strength to weight ratio. This means that steel framed buildings have smaller foundations, which are a major contributor to a building's environment footprint. Steel's long-spanning capability not only improves functionality but also offers better flexibility for change of use through the building's life. Considering all these advantages we have done investigation the use of steel as a prime construction material with respect to Bangladesh. We have discussed the production of raw materials from SBRI (Ship Breaking and Recycling Industry). We have also described industrialized building system (IBS) for rapid construction, different types of members and connections used in single and multi storied buildings. The beam to column connection, column to foundation connection etc are mainly focused here. Fire, acoustic and seismic performance of steel building, vertical and horizontal extension for economical accommodation solution is also described in this work.

KEYWORDS: *Sustainability, SBRI, IBS, Steel, Fire, Connections.*

01. INTRODUCTION:

Bangladesh is a developing country, centralized in the capital city Dhaka, home of 16 million people and assumed to be 20 million by the year 2015. Main obstacle for rapid development is population explosion. An unplanned Dhaka city has already got population density of 23,029 per km^2. With an annual urbanization rate: 3.5%, every year nearly half of a million people move to Dhaka city and it has no infrastructure to accommodate its current residents. Almost 45 percent of Dhaka's population lives in informal settlements with substandard living condition.

Due to centralization, Dhaka controls 60 percent of the country's money transaction; most of the industries are situated in or close to Dhaka which draws rural people to seek employment here. Growing economy induce industrialization, which demands quicker and sustainable development of infrastructure to ensure accommodation and employment for new residents.

A way to cope with this crisis is to improve existing accommodation facilities and long-term planning and sustainable development of industries and other infrastructures.

So far majority of our construction practice is concentrate on RCC. As a result we need massive amount of bricks by destroying our fertile lands with mentionable amount of carbon emission through our conventional brick kilns. In addition, our cement manufacturing plants are also responsible for this.

Global warming is an obstacle to substantial development; due to this phenomenon tropical and low lying countries like Bangladesh are worst victim. Global warming is responsible for rising sea level; as a result we are losing living land area. As it is not possible to stop carbon emission of the developed countries, we should reduce carbon emission for our green future as much as we can through sustainable concern.

To meet the construction requirement, steel could be an ideal solution like other developing countries. Nowadays Steel buildings are gradually making a strong hold in Bangladesh's construction sector, as around 16 companies construct over 100 such buildings every tear on average.

Cost-effectiveness, rapid construction, lightweight, high resale value and less vulnerability than RCC buildings are some advantages of Steel buildings.

02. SUSTAINABILITY OF STEEL STRUCTURE:

"Sustainable design" has become the popular buzzword in design and begins with the design intent.

Sustainable development has been defined by the Brundtland Commission (1987) as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs.' Sustainable design describes a design philosophy that values the natural environment as an integral factor in creating new products or modifying old ones. The term often refers to the movement in the architecture and engineering industries towards buildings that incorporate the local environment and take advantage of natural resources such as sunlight, wind patterns, and geographic location to minimize the impact of building on the local, regional, and global environment (*The World Bank, Report December 2010*). Sustainable building designs consider larger settlement and industrial development patterns and attempt to make them healthier, less wasteful, and with fewer impacts on the natural environment through site choice, building design, choice of building materials, and building operations. Sustainable designs try to maximize overall efficiency with surrounding resources, such as transportation, as well as energy efficiency, habitat preservation and restoration, natural and renewable energy sources, water conservation, recycled, local, and non-toxic materials, and healthy and productive interiors.

Steel can be recycled repeatedly without any degradation in terms of properties or performance in quality (*N.,Oxford University Press*). Steel construction has excellent low waste credentials during all phases of the building life cycle. It generates very little waste, with the byproducts of steel production widely reused by the construction industry. Any waste generated during manufacture is recycled. There is virtually no waste from steel products on the construction site (*Bachmann, France, 2002*).

Steel has enabled our modern way of life. It has helped lift societies out of poverty, spurring economic growth, and continues to do so around the world today. Iron, steel's precursor, fueled the industrial revolution starting in 1750, enabling manufacturing equipment in factories and rail transport. Modern steelmaking was developed 150 years ago with the invention of the Bessemer process allowing for the affordable mass-production of steel (an iron alloy). This set off a second industrial revolution, and sustained economic growth.

Steel is industrially produced under controlled conditions. There is little or no construction waste. By-products such as blast furnace slag cement and gas can be reused. Continuous innovation in production techniques and methods has provided a permanent reduction in energy used and emissions. The increasing use of used steel (scrap) in the production of new steel creates less and less need for the raw materials iron ore and coal. Currently over 80% of all steel beams are made from scrap.

03. COST ESTIMATION- STEEL STRUCTURE VS REINFORCED CEMENT CONCRETE (RCC) STRUCTURE:

The total cost of project is divided into four major construction activities such as, foundation, column, beam and slabs construction. Figure 07 and Figure 08 indicate distribution of material and construction cost for these activities, respectively, for each type of building. Same aspect is presented as % of total cost of project in Table 2.

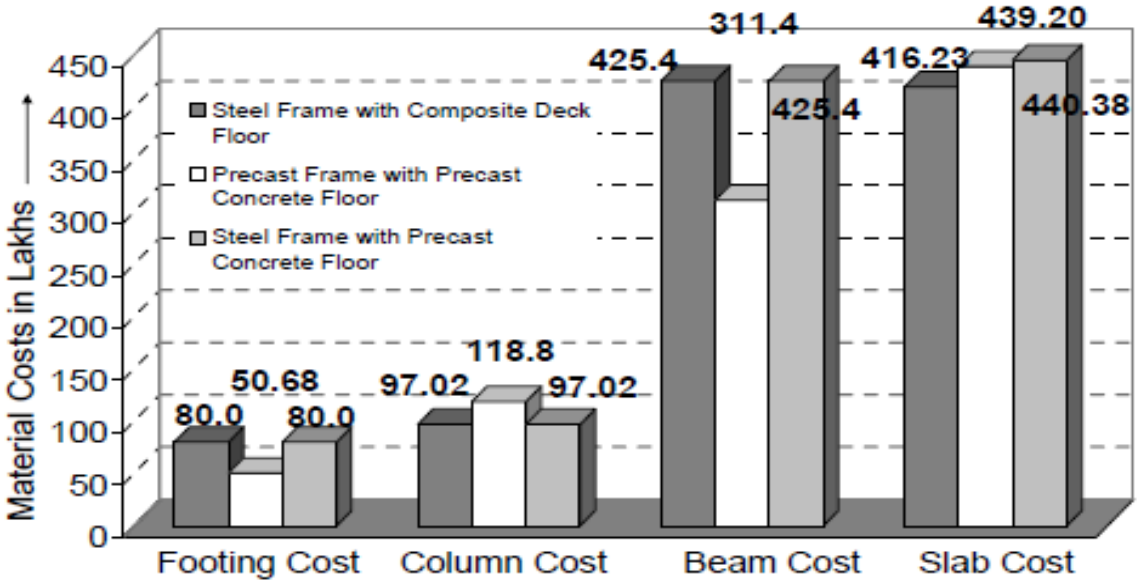

Figure 01: Material Cost of Buildings.

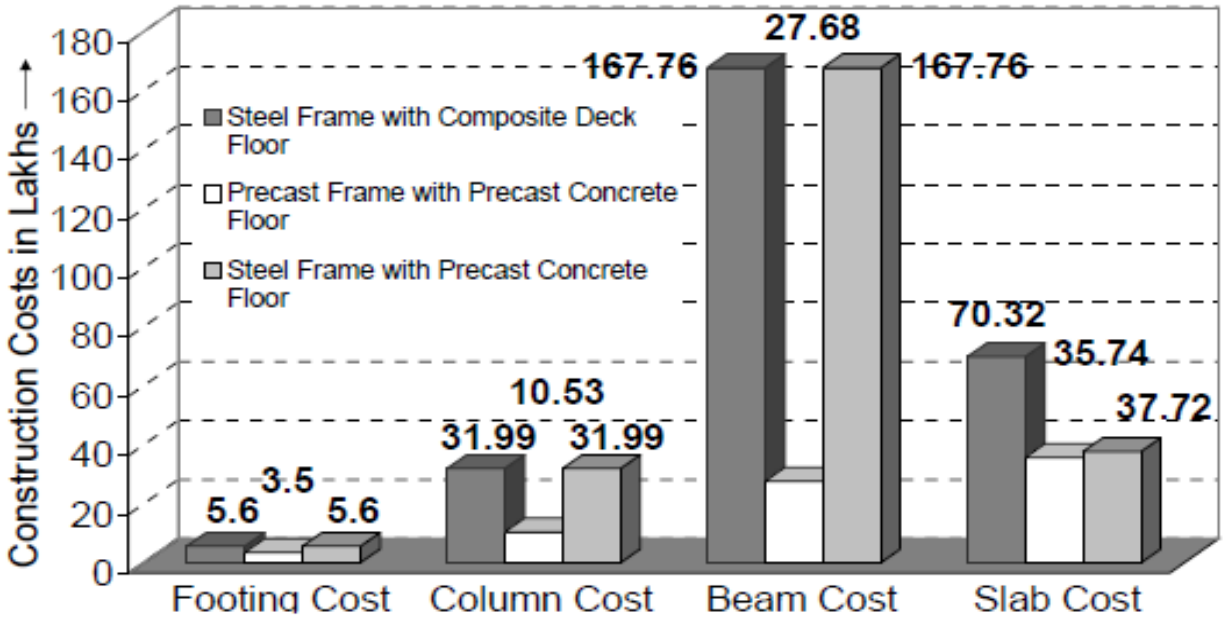

Figure 02: Construction Cost of Buildings

Structural Elements	Material and Construction cost as % of total cost of projects		
	Steel frame with precast Concrete floor	Precast concrete frame with precast concrete floor	Steel frame with precast Concrete floor
Foundation	7	6	7
Column	10	12	10
Beam	45*	34	46*
Slab	38	48	37

Table 1: Percentage of total cost of projects.

It is observed that for the steel frame with composite floor building and steel frame with precast concrete floor structure, the maximum material cost is associated with beams and slabs material while maximum construction cost with erection of post-tensioned beam. For precast frame with precast concrete floor structure, the maximum material cost is associated with slab and beams material and maximum construction cost with erection of slab panels.

Table 3 shows, the percentage increase in material and construction cost of structural elements for other two buildings as compared to steel frame with composite deck floor. The negative values indicate that extra cost is required for it. For precast structure, the total percentage of cost savings are associated with, beam cost (42.83%), footing cost (36.27%), and slab cost (2.38%) and the cost of column is slightly extra by only 0.25% compared to steel frame with composite deck floor. Similarly the percentage of cost savings are associated with beam cost (42.83%), footing cost (36.27%), and a little saving in slab cost as 1.64% as compared to steel framed with precast concrete floor structure.

As compared with steel framed with composite deck floor, the total cost saved through precast frame with precast concrete floor construction is about 23.10%, and the cost saved through steel framed with precast concrete floor construction is only 0.52%. The cost saved for precast frame with precast concrete floor is about 22.70% as compared to steel frame with precast concrete floor. The costs for foundations and costs of columns for all this type of building is least amount as evaluated with cost of beam and slabs construction. The cost of large span post-tensioning composite steel beam affect on the total project cost, project cost increased by 11% of total cost of projects. The reduction in total cost of steel building is attributed to cost of steel being higher than concrete.

Sr. No.	Structural Elements	Precast Concrete Frame with Precast Concrete Floor (%)			Steel Frame with Precast Concrete Floor (%)		
		Material Cost	Construction Cost	Total Cost	Material Cost	Construction Cost	Total Cost
1	Foundation	36.68	36.88	36.27	0	0	0
2	Column	-22.44	67.08	-0.25	0	0	0
3	Beam + PT Beam	26.80	83.50	42.83	0	0	0
4	Slab	-2.80	48.80	2.38	-6.05	45.99	1.34

Table 2: Percentage Increase in Cost Compared to Steel Frame with Composite Deck Floor.

04. SHIP BREAKING INDUSTRY AND STEEL AVAILABILITY IN BANGLADESH:

Ship breaking is a process of dismantling an obsolete vessel's structure for scrapping or disposal. Ship breaking activities are being practiced in the coastal areas of Bangladesh due to fulfill the increasing demand of raw materials for re-rolling mills and other steel construction purposes. Ship breaking activities of Bangladesh initiated in 1969.

The ship breaking and recycling industry (SBRI) converts end-of-life ships into steel and other recyclable items. SBRI provides more than half of Bangladesh's steel supply.

According to ship breakers in Chittagong, approximately 85 percent of a ship is recyclable steel in the form of directly re-roll able steel (75 percent) and melting scrap (10 percent).

Fig 03: Ship breaking activities in Bangladesh are concentrated in Sitakund (Bhatiary to Barwalia), just north of Chittagong city on the Bay of Bengal.

As per reports, at present, as many as 60-80 large ships are dismantled, in as many as 32 ship-breaking yards every year, (*Editorial, Daily Star, June 11,2004*).

The ship breaking section in Sitakunda, that meets 80 percent of the country's demand for steel, SBRI contributions in Bangladesh, 2008/2009:

Company Name	**Yearly Production**
National steel Consumption	8 million tons
National steel production	2.2-2.5 million tons
Scrap steel from ship breaking	Up to 1.5 million tons
Ship breaking steel's contribution to Production	50%
Ship-breaking-steel Contribution to Consumption	20-25%
No. of re-rolling mills	250 to 350
Scrap yards (total no.)	40 active
Estimated no. of workers in yards	22,000

Table 3

According to recent Financial Express report, the ship breaking industry is the "second largest employment generating section" in Bangladesh. Approximately 22,000 workers are directly employed by the ship breaking industry in Bangladesh, and as many as 2, 00,000 are employed indirectly through ancillary activities.

Fig 04: Ship breaking industry in Bangladesh.

05. Present condition of steel construction in Bangladesh:

Steel buildings are gradually making a strong hold in Bangladesh's construction sector, as around 16 companies construct over 100 such buildings every year on average.

The construction of steel building began for the first time with the inception of Chittagong Export Processing Zone in 1984. Now such building is a common scene in all the industrial areas.

Though the main purposes were to house industries and silos in these buildings at the initial stage, hotels, garment factories, restaurants, garage and schools are now constructed with steel.

"It takes six to seven month to construct a 5-storey steel building, while for a conventional RCC (reinforced cement concrete) building it requires not less than two years," said M Akkas Ali, managing director of Multi-Concept Steel Building Products that has made 2.2 million sq ft areas of steel building during its lifetime.

Lightweight is another advantageous point. If designed accurately, weight of a steel building becomes 20% to 30% lower than any RCC building. When the RCC buildings have no resell value because it is not possible to shift from one place to another, it is very easy for a steel building to dismantle and shift, enabling it to get 80% resale value of its original cost.

06. Steel Construction Practices in Bangladesh:

As we investigated several construction sites to know about the practices of steel construction in Bangladesh, we tried to find out the process and design methods of steel construction especially residential and commercial building. We have learnt from here that our construction sector follows the international standard to construct a steel infrastructure to maintain a quality with respect to other developed countries. We also learnt that what types of connection are used in our construction, steel quality, steel formation, bracing system, decking profile, precaution measures in fire and seismic behavior etc.

Fig 05: Commercial building.

Fig 06: Residential building.

07. Pedestrian foot over bridge in Bangladesh:

Pedestrian footbridges are needed where a separate pathway has to be provided for people to cross vehicle roadway or some physical obstacle. Most pedestrian bridges are located in urban areas and designed intended to carry, primarily pedestrians, bicyclists and light maintenance vehicles over divided highways, expressways and freeway systems.

Fig 07: Typical view of foot over bridge.

Types of Pedestrian Foot-Over Bridge: A wide variety of structure types are available and each type is defined by the super structure used.

08. Steel Connections or Joints used in Bangladesh:

As our work focuses on multiple purposes of steel and various aspects of construction of the steel building, hence in the review of literature we mainly emphasize on the connection of the steel building *(Stanley, "Steel building-Analysis & Design").* Connection is very important and vital part of any kind of steel construction. Here we have discussed various standard forms and types of connections and members which are extensively used in steel construction around the globe (*AASHTO. 2008*). Classification of Connection: According to any individual or in combination with some of the components given below:

a. Pins
b. Rivets
c. Bolts (Shop or Site)
d. Welds (Shop or Site)

a. Pins: Pins are generally smooth large diameter fasteners that are not threaded. These fasteners are not very common.

Fig 08: Typical pinned connection we found at our site investigation.

Pins are always placed perpendicular to the load direction and are in shear. Since pins are not threaded, they do not clamp the connection members together and, consequently, do not enable friction based force transfer between the connected members (*Joints in Steel Construction, Silwood Park*).

b. Rivets: A rivet is a permanent mechanical fastener. In the past, hot-driven rivets were extensively used in structural joints. Nowadays riveting has completely been replaced by welding or bolting, expect in some historical refurbishments.

Fig 09: Typical riveted connection.

c. Bolts: The benefits of bolt connection-

-Suitable for primary and secondary steelwork connections.
-Suitable for virtually any type of section.
-No welding, on-site drilling or tapping required.
-Fast, cost effective and simple installation,
-Available in a range of protective coatings, or stainless steel throughout.

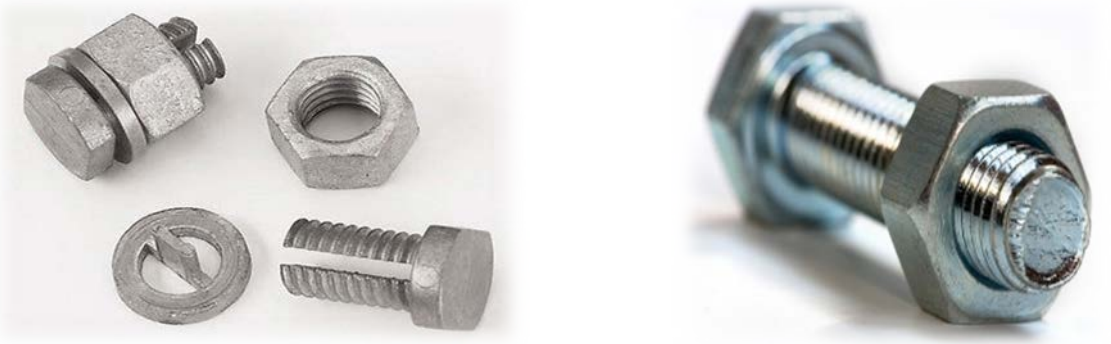

Fig 10: Typical bolted connection.

d. Welds: Welding is the process of joining two pieces of metal by creating a strong metallurgical bond between them by heating or pressure or both.

Fig 11: Welding connection we found at our site investigation.

It is distinguished from other forms of mechanical connections, such as riveting or bolting, which are formed by friction or mechanical interlocking. It is one of the oldest and reliable methods of joining.

Another Classification of Connection:

01. According to the type of connecting medium used-
a) Bolted connections.
b) Welded connections.
c) Bolted-Welded connections.

02. According to the type of structural elements that made up the connections-
a) Single-plate-angle connections.
b) Double-web-angle connections.
c) Top and seated-angle connections.
d) Seated beam connections, etc.

03. According to the type of members the connections are joining-
a) Beam-to-beam connections.
b) Column-to-column connections.
c) Beam-to-column connections.
d) Hanger connections.

04. According to the type of internal forces the connections are expected to transmit-
a) Shear (semi rigid, simple) connections.
b) Moment (rigid) connections.
c) Shear and Moment connections.

09. Classification Based on Shape:

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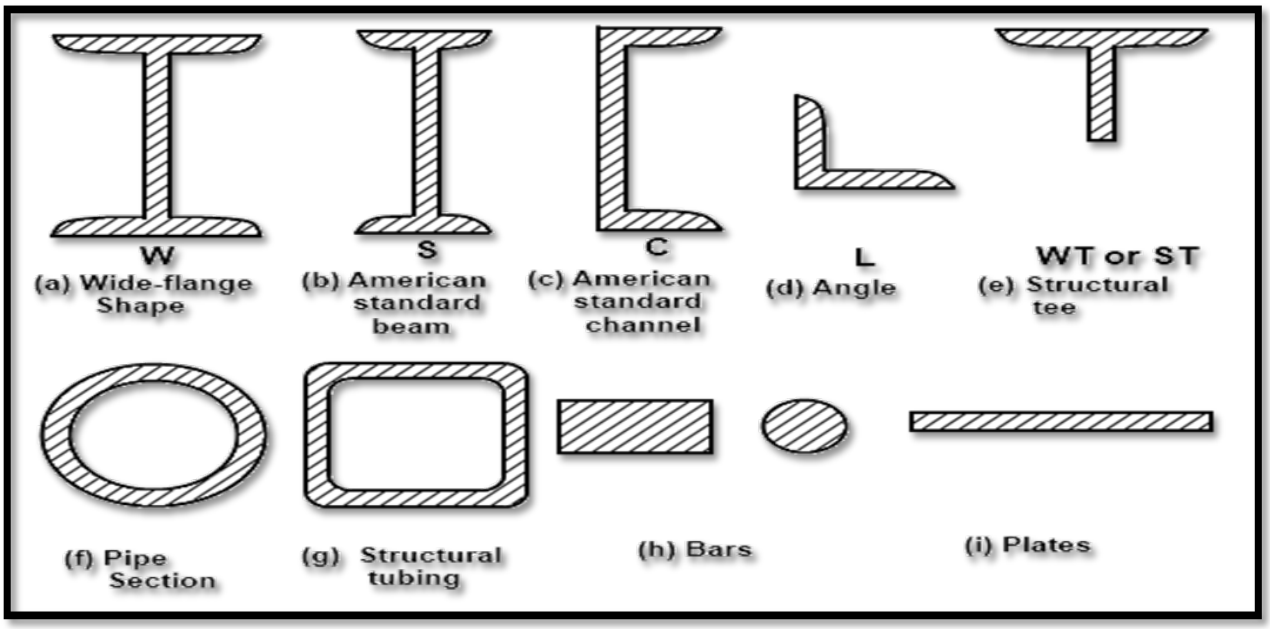

Fig: 12

1. Classical Skeleton framing
2. Steel truss
3. Rigid frames
4. Arches
5. Domes
6. Cable supported Roofs
7. Classical system supported by beams, girders and columns.
8. Beams: W or S shapes, Channel shapes for roof purling.
9. Columns: generally W shapes

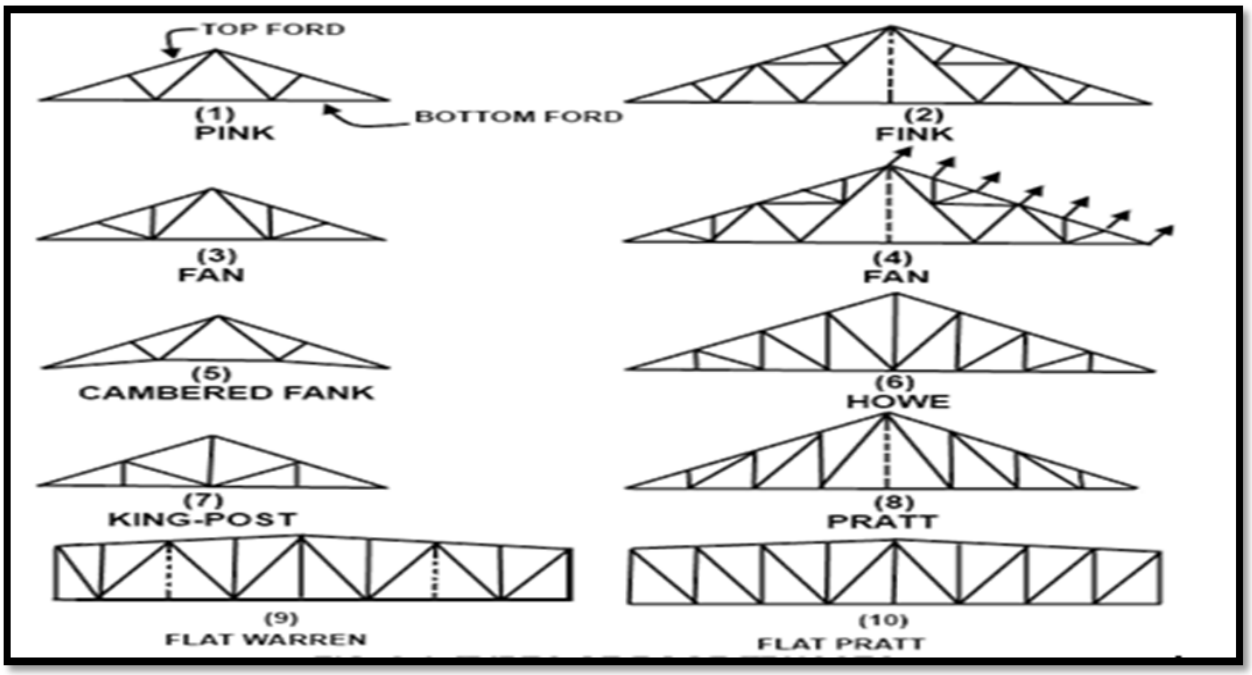

Fig: 13

Fig 14: Truss Bridge

Fig15: Built-up Members

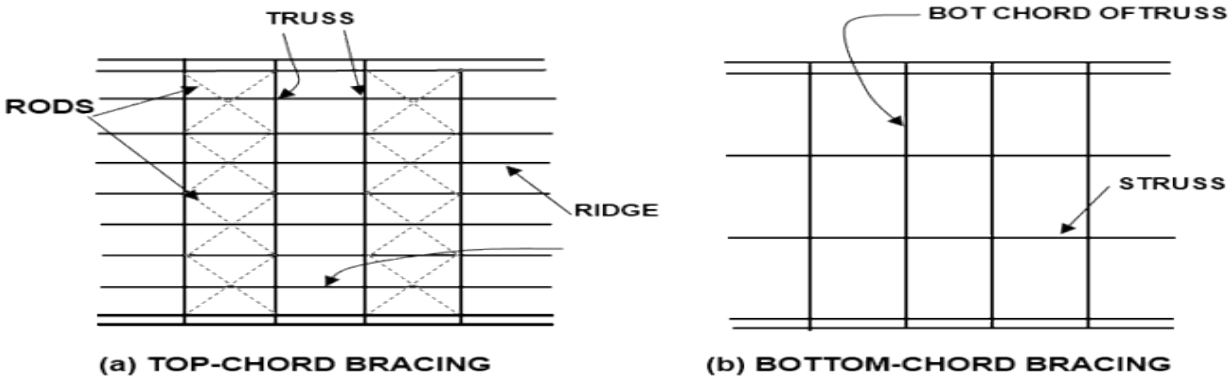

Fig: 16

Steel Trusses:

1. Triangular rigid structure
2. Most common double pitched roof trusses
3. Fink & Pratt.
4. Most common flat trusses: Pratt & Warren
5. No span limit
6. Often prefabricated
7. Used with wood or steel purlins to support the roof.
8. Bracing: if resting on masonry walls :
    i. Diagonal bracing in alternate bays
    ii. Continuous struts(angles, channels)

According to the type of structural elements that made up the connections:

Single plate connections: These connections made such that one plate is shop welded to secondary section (beam) and the angle is welded to Primary Section (column or beam) or single shear plate welded to secondary beam and bolted to Primary beam or column. The angle or plate will be bolted or welded after erection of the beam.

Double-web-angle connections: This connection is made with two angle welded or shop bolted to the web of secondary beam and after erection the angles are bolted or site welded to the primary member (beam or column) or both the angle are welded to the secondary beam and site bolted to the primary beam or column.

Top and seated-angle connections: This type of connection is generally used in case of moment connections. In this connection, two angles are provided at top and bottom of the beam to resist moment. The shear will be resisted by the web plate. This connection is generally used for lesser moments where heavy loads are not acting.

Seated beam connections: This type of connection is generally used in case of shear connections. In this connection, a seating angle will be provided at bottom of secondary beam which will be shop welded to the primary member. This is to facilitate easy erection of the secondary beam and this seating angle resists vertical shear coming from the beam.

10. CONCLUSION:

The purpose of our extensive research was to describe briefly the properties, advantages and other parameters of steel as a sustainable construction material in Bangladesh to meet countries growing construction requirements. It was found that steel is not yet widely popular in Bangladesh as a construction material. We tried to describe other parameters as a concept, on the basis of Bangladesh and neighboring foreign countries. However it can be said that construction practices of steel in Bangladesh is increasing day by day.

This paper covers all type of members and connection used world-wide and narrowed down some possible concept for our country. Bolted connections were found as common practices for beam column connection and column foundation connection.

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