ANALYSIS AND DESIGN
OF
TRANSFER TOWER STRUCTURE

By

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ANALYSIS AND DESIGN
OF
TRANSFER TOWER STRUCTURE

Major Project

Submitted in partial fulfillment of the requirements

For the degree of

Master of Technology in Civil Engineering
(Computer Aided Structural Analysis & Design)

By

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May 2008

CERTIFICATE

This is to certify that the Major Project - II entitled "Analysis & Design of Transfer Tower Structure" submitted by Mr. Sheth Devendra N. (06MCL016), towards the partial fulfillment of the requirements for the degree of Master of Technology in Civil Engineering (Computer Aided Structural Analysis and Design) of Nirma University of Science and Technology, Ahmedabad is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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ABSTRACT

Transfer tower is a framed structure which is used as a junction point in the conveyor belt system for conveying material. The geometry of the structure depends upon the conveyor systems like singular, multilayer or parallel. It also depends upon the different orientations of the conveyor belt and different elevation of the belt system. This report includes the analysis and design of the Transfer tower structure. The aim of this report is to find the economy and safety of the Transfer tower structure by using different arrangement of the conveyor system and using different materials as steel and concrete.

The Transfer tower is analyzed for various loads like conveyor loads due to Belt tension, Wind load, Eq. load, dead load and live load. The analysis and design of the structures are carried out by using STAAD-Pro and checked manually. The report includes the introduction of pile foundation and also includes the analysis and design calculation of pile cap and pile. Moreover this report also gives brief calculation and introduction about the connections design. The sample design calculation of moment resisting connection is also carried out.

The comparative study by using different material properties (steel and concrete) and cost comparison of the structures are also carried out for the Transfer tower structure.

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ABBREVIATION NOTATION AND NOMENCLATURE

A_s	surface area of pile
A_p	c/s area of pile
B	width of Pile cap
D	Diameter of Pile
F	Design wind load
f_s	Average unit skin friction
I	Importance factor
I_o	Pile moment of inertia
I_x	Moment of inertia about x axis
I_y	Moment of inertia about y axis
k	Constant
k_1	The probability factor
k_2	The terrain, height and structure size factor
k_3	The topography factor
L	Length of Pile cap
M	Moment on Pile group
M_x	Moments about x axes
M_y	Moments about y axes
n	Number of piles
Sa/g	Average response acceleration coefficient
P	Axial load on Pile group
p	Strength of joint
P_q	Permissible stress
p_z	Design wind pressure
Q_u	Ultimate bearing capacity of Pile
q_p	Bearing capacity of soil at depth L
q_u	Unconfined compressive strength of soil
R	Response reduction factor
s	Weld size
t	Throat thickness
t_f	Thickness of flange

t_w	Thickness of web
V_b	Basic wind speed
V_z	Design wind speed
W	Self weight of Pile cap
x	Distances from y and x axes to any pile
y	Distances from y and x axes to any pile
Z	Zone factor

1. INTRODUCTION

1.1 GENERAL

Owing to great variety of conveying machines available, differing as regards principle of operation , design features, means and direction of conveyance, a general classification of material handling equipment is well high impossible. To break a large study down in to several more simple components conveying machines have been classified according to their major distinctive features.

According to their principle of operation we discurn conveying machines of intermittent and continues action machines of intermittent action include a great variety of ground level and overhead rail and railess transport machines, manoeuvring and hauling equipment with cars and trucks overhead rail and cableways tractors and scrapers and some types of transfer equipments machines of continues action include various types of conveyors, pneumatic and hydraulic transport installation and some types of transfer equipments.

According to the types of material handled, the machines are divided in to conveying machines for bulk loads, unit loads or both bulk and unit loads
Continues machines may be classified;

a) According to the means by which motive power is transmitted to the load as,

1. Mechanical handling equipment
2. Gravity equipment
3. Pneumatic equipment
4. Hydraulic equipment in which the carrying medium is jet of water.

b) According to their purpose and principle of action as,

1. Stationary conveyors
2. Transfer equipment
3. Pneumatic handling equipment
4. Hydraulic handling equipment

Stationary conveyors are classified according to their design as machines;

1. With a flexible pulling member,
2. Without a pulling member

A feature all machines with a flexible pulling member have in common is that the load moves along the carrying run together with the pulling member. The flexible pulling member transmits motion to the mobile load carrying member (belt, apron, bucket, carriers, cars, etc.) and to the load carried by them. In certain designs the load glides (rolls) along stationary guide ways (for instance, a through). The load carrying members move along horizontal or inclined sections and are supported by traveling or stationary rollers or stationary guide ways.

1.2 CONVEYOR SYSTEM AND TRANSFER TOWER

In the conveyor systems the Belt conveyors are employed to convey a great variety of unit loads and bulk materials along horizontal or gently inclined paths and also to carry articles of light weight in line production from one operation to another. Belt conveyors are extensively used in all branches of industry and are the principal conveying devices used to mechanize handling operations in foundries, deliver fuel in power plants, for ground level and underground haulage of coal and ores in coal mining, transportation of grain and all sorts of unit loads in stores and grain elevators, for mechanization of handling operations in earth constructions and building work, between processing steps in the light and food industries, etc. Belt conveyors are often included in complicated installations such as transfer lines, handling bridges, girder elevators, etc. According to design, the belt conveyors are classified as stationary, portable and mobile conveyors.

Transfer tower is a framed structure which is used in conveyor belt system. It is used as a junction point to transfer the material from one conveyor belt to another conveyor belt in the conveyor system therefore it is also called as Junction House. There are different types of conveyor systems like, Singular, Parallel, and Multilayer conveyor system. The Geometry of the Transfer tower depends upon the Conveyor systems and different orientation of the belt.

In the Transfer tower the material is collected from the main conveyor belt and it transfers from main conveyor belt to shuttle conveyor system to different paths. Transfer tower accommodate the mechanical system like pulleys, drivers, idlers, belt, hopper, chute, belt cleaners, supporting system etc.

In industrial application the various types of conveyors are used shown below.

- Belt conveyors
- Apron conveyors
- Roller conveyors
- Flight conveyors
- Overhead conveyors
- Pneumatic conveyors
- Hydraulic conveyors
- screw conveyors
- Bucket elevator

1.3 OBJECTIVE OF STUDY

The objective of this report is to review the design of the Transfer tower (Junction house) and to determine the economical aspect and do the parametric study of the members of transfer tower by using steel and concrete as material for double and parallel belt conveyer systems.

1.4 SCOPE OF WORK

To understand the behavior and design of the Transfer tower conveyer belt supporting systems by using the different alternatives of steel/concrete options and study the economical aspect of the structure systems.

Parametric Study:

a) Review on base structure having isolated, combined and/or piling.
b) To frame the Design philosophy.
c) The conveyor systems are designed for:

1. Double layer system
2. Parallel system

The framing is designed by using following alternative:-

Sr. No.	COLUMNS	BEAMS
1	STEEL	STEEL
2	CONCRETE	CONCRETE
3	CONCRETE	STEEL

d) Analysis: For the system analysis and design STAAD-Pro software will be used as required.

- Analysis along with wind and earthquake load.
- Analysis in view of conveyor loading provisions.

e) Economics: To review with system.

f) Detailing of sample members with connections.

1.5 ORGANIZATION OF MAJOR PROJECT

The Major project is organized in following chapters.

Chapter 1 presents the introduction and background of the material handling structures and conveying systems. Chapter 2 presents brief literature review pertaining to structure and conveyor systems. In Chapter 3 the brief introduction of the Transfer tower (Junction house) structures and the functional requirement of the mechanical components in the conveyor systems. The load calculation details, geometry of structure and modeling of the Transfer tower structure (using STAAD Pro-2007) is given in the Chapter 4. The analysis and design of the Double conveyor Transfer tower structure with using different sectional properties and materials (Steel/Concrete). The comparative study of the different sections used in the design of column members is given in Chapter 5. The analysis and design of the members of the Parallel conveyor Transfer tower structure with using different sectional properties and materials (Steel/Concrete) is given in Chapter 6. Chapter 7 presents the classification Pile foundation, bearing capacity of soil and the analysis and

Design of the Pile cap and Pile group. Chapter 8 presents the introductory part of the different types of connections and sample calculations. The Design and Detailing of the moment resisting connection is also given in this chapter. Chapter 9 presents the comparative study of the different structures.

2. LITERATURE SURVEY

2.1 GENERAL

Material handling plays an important part in industrial economy. No modern industrial plant, be it a coal mine, power plants, metallurgical works, machine building works or textile factory would be conceivable without efficiently organized transport. According to different transferring equipment, the transfer system can be one independently or multi-conveyors or combined with other transfer equipments. The belt conveyor can be installed horizontally or aslope to meet the needs of different transfer lines.

Survey from various literatures such as different books and research papers has been carried out to support the present work. Literature survey has been carried out for mechanism of conveyer system.

2.2 LITERATURE REVIEW

- V. Afanasyev [1], gives description based on the various national code such as Indian (I.S:11592-2000), British standards, Russians standards and American standards. The book gives idea about conveying machines and some of the conveyors which are used in the industries. It gives description about the mechanical parts of the conveyer and show the different parts of the conveyer system.

- Wilbur G. Hudson [2], is based on different national codes such as Indian, British, Russian, American, and German. The book describes different conveyors with their schematic diagram and gives important tables for the design of conveyor components. It also gives description and design for the elevators and crushers units.

- Don Danemanis [3], describes the principal types of continuous conveying machines; conveyors, elevators, pneumatic and various auxiliary devices of conveying systems which in combination represent quite completely the modern means of complex mechanization in transporting materials-handling and storing operations. All types of conveying machines are described by a general scheme including their design, and operating principle.

- Jerzy Antoniak [4], present test on belt conveyors, characterized by considerable lengths and high capacities, complicated configurations of a conveyor route and equipped with driving systems of different type in which soft starting facilities were incorporated or not included. One of the objectives of the tests was to determine quantities of principal resistances to motion the results of which have been presented in this paper

- Dr.B.C.Punmia and A.K.Jain [6], gives the basic knowledge for the analysis and design of steel structures based on the Indian standards. Its reference is made for the analysis and design of truss structures.

- S.K.Duggal [8], is based on the Indian standards codes and gives the fundamental aspect of analysis and design, and also gives practical requirements such as safety, feasibility and economy of steel structures.

- IS 11592: 2000 [9], gives the guidance for the selection and design practice to be adopted for the belt conveyors. The standard gives the simple method of conveyor design calculations. The recommendations given in this standard shall be applied both to individual conveyors, as well as conveyor system consisting of more than one conveyor.

- A. spivakovsky and v. dyachkov [5], presents the general description of the conveying machines. It also contains the different chapters of the various types of the conveyors including belt conveyors system.

- H.J. Shah [16], gives the analysis and design of concrete structures with its detailing. Its reference is made for the design and detailing of pile.

- Joseph E. Bowels [17], gives the analysis of the different foundation. The different techniques for soil exploration are suggested by him. The different tests on soil are also shown.

- Ascalew Abebe and Dr. Ian GN Smith [18], has discussed about the types of piles, its classifications and design.

- James G. Colin [19], gives information and design of the timber pile. The different technique to save pile from decaying is also given.

- Buick Davison and Graham W Owens [20], has given analysis and design of steel structures with its connections details. Its reference is made for the design of steel structures.

3. TRANSFER TOWER STRUCTURE

3.1 GENERAL

Transfer tower is a framed structure which is used in the belt conveyor system. It is used as a junction point to transfer the material from one conveyor belt to another conveyor belt in the conveyor system. The transfer tower structure is used as junction point in the conveyor system therefore it is also known as "Junction house".

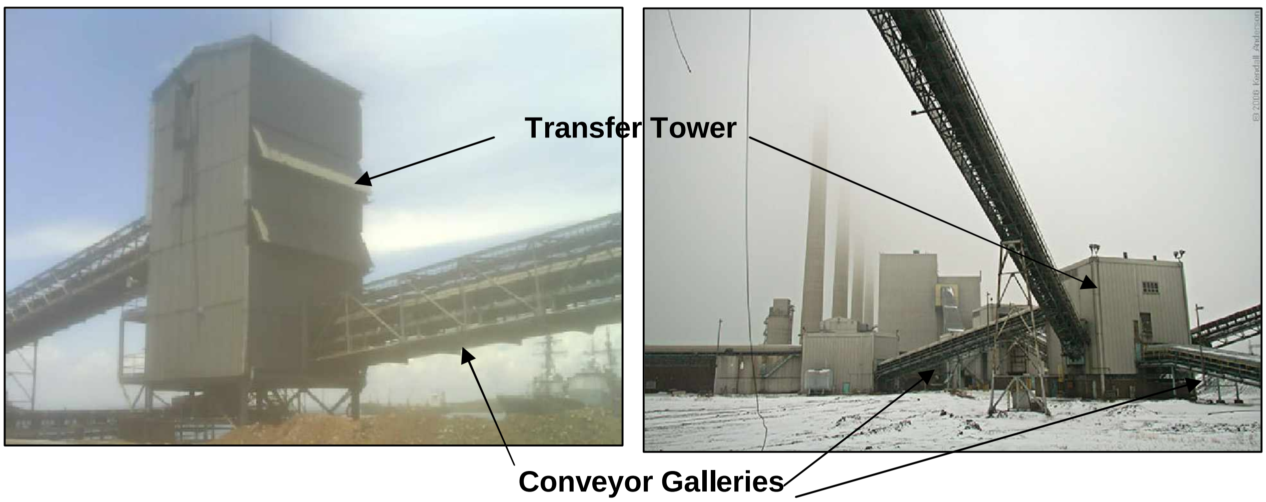
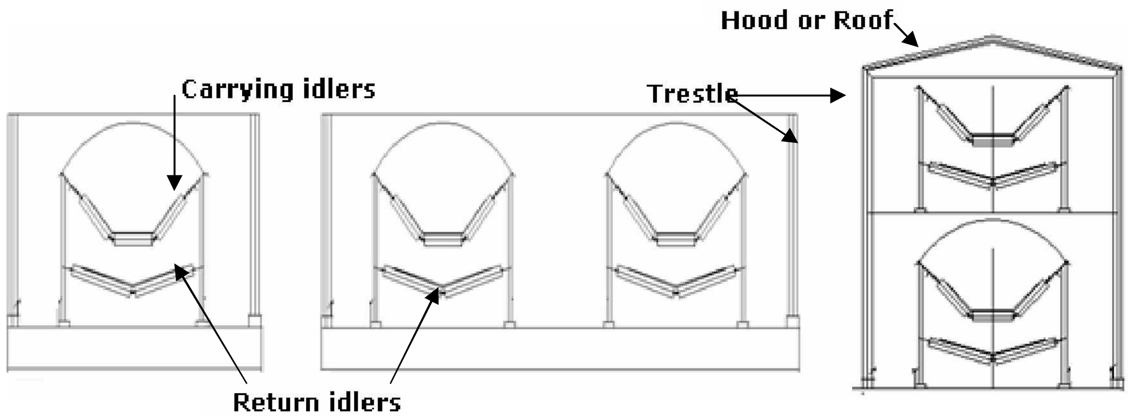


Fig. 3.1 Transfer Tower

The junction house accommodates different number of conveyor galleries as per requirement. According to the number of conveyor galleries in the conveyor system, the system can be divided mainly in three types. The arrangement of the number of conveyors galleries are shown in the Fig. 3.2.

- Singular conveyor system
- Parallel conveyor system
- Multilayer conveyor system



(a) Singular Conveyor (b) Parallel Conveyor (c) Double Conveyor

Fig. 3.2 Arrangement of Conveyor Systems

The Geometry of the Transfer tower depends upon mainly,

- Conveyor systems
- Different orientations of the conveyor belt
- Different elevation of the belt system

In the Transfer tower structure the material is collected from the main conveyor belt and it transfers from main conveyor belt to shuttle conveyor system to different paths. Transfer tower accommodate the various mechanical systems like pulley, drivers, hopper, chute etc.

The report includes the analysis and design of the J2 Transfer tower system. This total material handling system is located at the Dahej. The Fig. 3.3 shows that the flows chart of the total coal transfer conveyor system from the one location to the final stock system. This system consist of J1, J2, J4, J5, J6, J7, J12 and J1A, J2A junction houses and J1C1, J1AC1, J2C1, J4C1, J5C1, J6C1, J6C2, J7C1, J12C1, S1C1 conveyor galleries.

The flow of the material is starts from the J1C1 conveyor gallery and it ends at the S1C1 conveyor gallery. The capacity of the conveying system for transferring the coal as material is 4200 t/h. The material comes in the J2 Transfer Tower from the J1A Transfer Tower by the J2C1 conveyor Gallery. The distance between the J2 and J1A is about 2.4 Km.

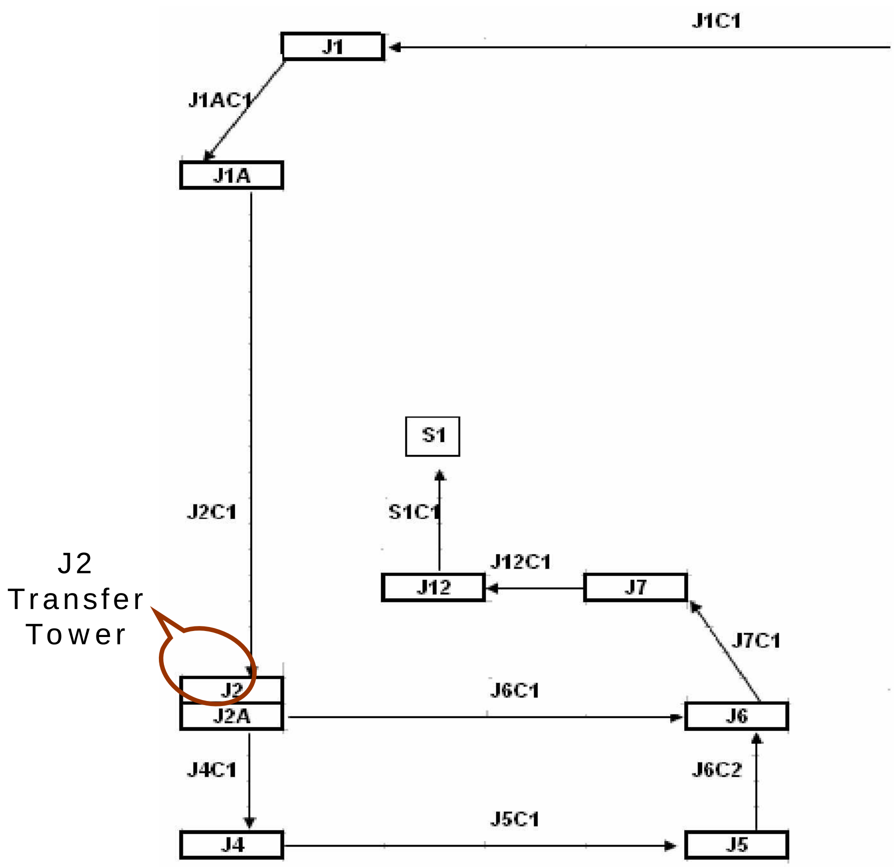


Fig. 3.3 Flow Chart of Conveyor System

3.2 COMPONENTS OF CONVEYOR SYSTEMS

In the conveyor system various types of mechanical components are used. Usually the belt conveyor is used for transporting coal as material in the system. It consists of a belt made up of layers of rubberized fabric, and is manufactured in widths capable of carrying a certain tonnage at certain speeds. The belt ends are spliced together, creating an endless loop which travels continuously between a head and tail pulley. The belt is supported on the top or carrying side by troughing rollers and on the bottom by straight or return idlers. It is normally driven by a motor connected to the head pulley shaft through a speed reducer. Proper load carrying tension is maintained by adjusting screw take-ups, or by gravity take-up counterweights. The basic components of the belt conveyor systems are shown in Fig. 3.4.

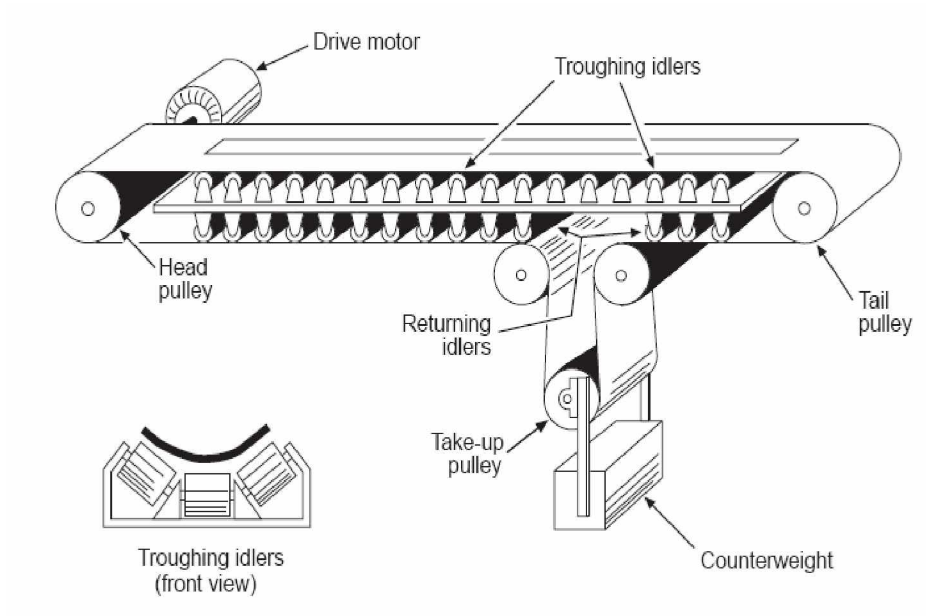


Fig. 3.4 Components of Belt Conveyor System

The detailed descriptions of various components of the Transfer tower conveyor systems are given below.

1. The Belts
2. The idlers - Carrying idlers and Return idlers
3. Shuttle conveyor
4. The pulleys
5. Take up
6. Belt cleaners
7. Conveyor frame
8. Magnetic pulley separator

(1) The Belts

In the belt conveyor system the belt is used as the continuous moving load carrying and tractive element. The following types of textile belts are employed in belt conveyors: camel hair, cotton, duck cotton and also rubberized textile belts of various types. Conveyer belt should meet the following requirements: low hygroscoposity, high strength, low own weight, small specific elongation, high flexibility, high resistivity to ply separation, long service life. Rubberized belt meet these requirements better than other types therefore generally preferred. The belt of a conveyor should have a high strength, low mass and low relative elongation, high elasticity (flexibility) longitudinally, and should resist properly alternate stresses appearing on multiple bendings in the belt on pulleys and rollers supports. It should also have a high wear resistance to abrasion by the conveyed material and conveyor elements and an ample resistance to the physico-chemical action of the load surroundings. The width of the belt is governed by lump size of material conveyed and the capacity requirement. The manufactured standard widths of belt are 300, 400, 500, 650, 800, 1000, 1200, 1400, 1600, 2000, 2500, and 3000 mm.

(2) The Idlers

The Idlers are used mainly conveyors handling bulk loads, less frequently unit loads,

According to their location on the conveyor. The idlers are classified as,

1. Carrying (upper) idlers.
2. Return (lower) idlers.

(I) (II) (III)

Fig. 3.5 Carrying and Return Idlers

I. The Carrying Idlers

The carrying idlers have generally three types of configurations,

- Five/three roll troughing idlers for troughed belts
- Two roll troughing idlers for troughed belts
- Horizontal carrying idler for supporting flat loaded belts

The Fig. 3.5 shows the three types of configurations in carrying idlers. The spacing of the idlers, diameter, and the design of the antifriction bearings are important factors in the design of a belt conveyor. If the spacing is excessive, the sag from idler to idler causes shock to the belt as it meets the rolls, shortening the life of the belt. Large diameter rolls reduce the abruptness of the bend as the belt rides the idler. The dust proof bearings are packed with lubricant by the manufacturer therefore no attention is required for long time.

II. The Return Idlers

The Return idlers which never contain more than single idlers is shown in Fig. 3.5 (III). Return idlers are subjected to the same severity as the carrying idlers, since they carry the empty belt, their spacing is doubled. There bearings and seals should be interchangeable with those of the carrying idlers, and the rolls should be so mounted in the hangers that they can be removed without disturbing the bearing adjustment.

(3) Shuttle Conveyor

Shuttle conveyor is the short length belt conveyor system which is used to feed from one belt to another which may be set at any point suited to desire point to discharge. Sometimes the reversing motor is used to provide adjustable stops which fix the limits of travel in either direction.

(4) The Pulleys

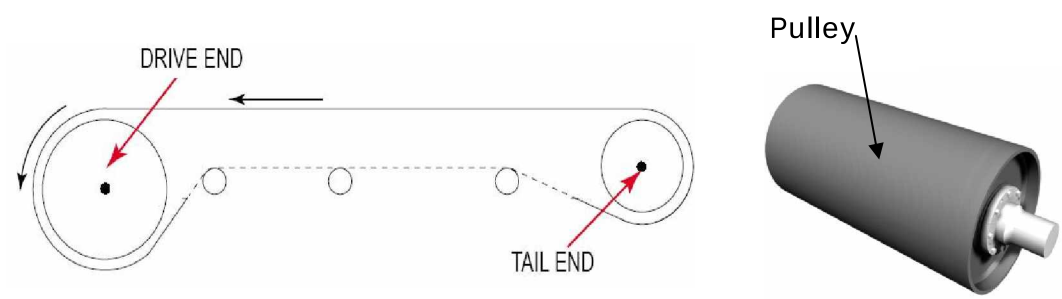


Fig. 3.6 Drive Pulley and Tail Pulley

The Pulleys are the main component of the conveyor belt system. The Fig. 3.6 shows that the driving pulley and tail pulley. The diameter of the pulley is selected based on the percentage of tensile force (ratio between the working tensile force and maximum allowable tensile force of the selected belt). The Pulleys may be straight faced or have a crown on the pulley face. The driving pulleys are cast iron or welded of sheet steel. The crown serves to keep the belt centered. In the lighter tension range the power may be transmitted to the belt through a flat face cast iron or steel pulley. A pulley with crown face should not be used as it would cause uneven stress across the belt. For greater tensions, the pulley is legged with rubber securely bolted or riveted to the rim, and a snub pulley is provided to increase the arc of contact with the belt.

(5) Take Up

Take up are the main unit of the conveyor system for carrying the load initially on track. The choice of take up and their location has to be decided depending on the configuration and length of the conveyor and available space. But acceleration and braking of conveyors have certain effects on the take up.

The main functions of the take up are;

- Ensuring adequate tension of the belt leaving the drive pulley so as to avoid any slipping of the belt,
- Permanently ensuring adequate belt tension at the loading point and at any other point of the conveyor to keep the troughed belt in shape and limit belt sag between carrying idlers,

Generally two types of take ups are used in the conveyor system;

a) Fixed take up devices that are adjusted periodically and

b) Automatic Take up device (constant load type)

(6) Belt Cleaners

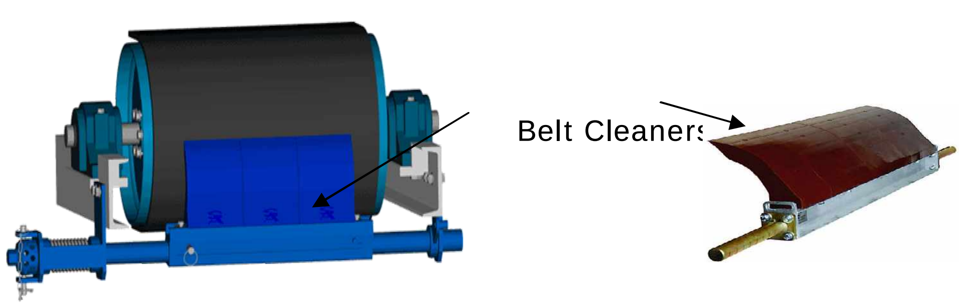


Fig. 3.7 Belt Cleaners

It is necessary to clean the belt when drive pulleys make contact with dirty side of the belt on the return run. This is especially the case when handling materials which are likely to pack on the belt, such as sticky and wet materials. The actual cleaning in scraper devices is performed by a strip of technical rubber facing a hinged bar or in the case of brushes, by rigid bristles or 1.0 to 1.2 mm Capron fiber facing the generating line of cylindrical brush face. The belt cleaners are mounted near the discharge pulley and scatter falls into the discharge spout.

(7) Conveyor Frame

In the belt conveyor system the belt is supported by the conveyor frame. The arrangement of the supporting belt on the conveyor frame is shown in Fig. 3.8. The total arrangement of the belt supporting system is also known as the conveyor galley.

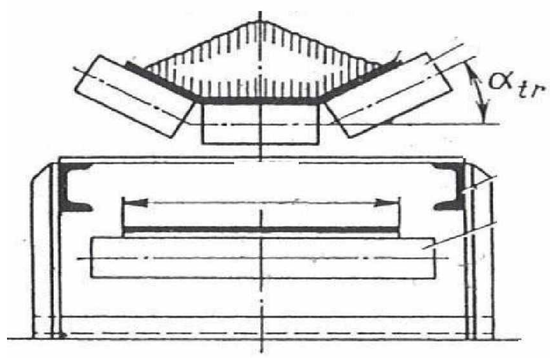


Fig. 3.8 Conveyor Frame

The supporting structure of the conveyor frame intermediate section is usually electric welded of profiled rolled stock, angle iron or channel bar, and consists of longitudinal beams, uprights and cross-pieces. The height of the frame is usually 400 to 500 mm; the spacing between the uprights is 2 to 3.5 m.

(8) Magnetic Pulley Separator

Magnetic pulley is one of the main components of the coal transfer belt conveyor system. The Fig. 3.9 shows the arrangement of the Magnetic pulley separators in the drive units.

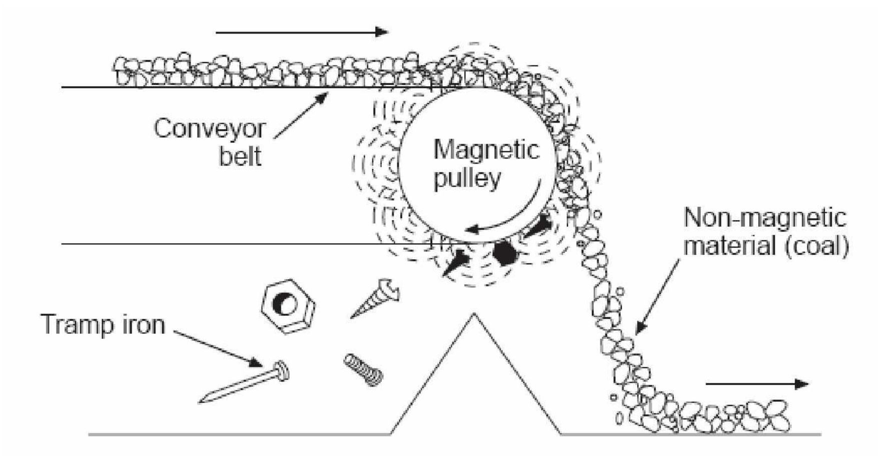


Fig. 3.9 Magnetic Pulley Separators

Either before or after the coal goes through the breaker, it passes over a magnetic pulley or separator which removes the tramp iron, dropping it into a tramp iron collector. After the coal passes through the breaker, it is delivered to the bunkers, to storage, or to the hammer mill crushers.

3.3 BELT TENSION

3.3.1 General

Belt tension is the tension required so that a given belt conveyor or belt elevator system will operate properly in its environment. This means minimum belt tension is great enough so that the belt conforms to the crown on any crowned pulley or pulleys. It also means that minimum belt tension is great enough so that the belt does not slip relative to the drive pulley under the most demanding conditions which can be expected.

3.3.2 Minimum Belt Tension

The force required to drive a belt conveyor or belt elevator usually is transmitted from the drive pulley to the belt by means of friction between the pulley surface and the belt surface. The force required to restrain a down-hill regenerative conveyor is transmitted in exactly the same manner. In order to transmit the right amount of power to drive the conveyor or elevator system at rated speed and under full load, there will be a difference in the tension in the belt as it approaches and leaves the drive pulley. This difference in tension is supplied by the driving power source and is known as Effective Tension (TE).

Excessive belt tension changes the characteristics of a rubber contact drum; it makes a soft wheel act harder and decreases the effectiveness of the serrations. Excessive belt tension can also lead to belt failure. It can cause the belt joint to mark the work piece, and can cause tracking problems. But the leading problem caused by excessive belt tension is the generation of heat. Excessive heat often leads to premature loading of the belt and wear on flexible belts

To achieve minimum belt tension: Start by the shutting off the conveyor and tensioning the belt until there is no “play” between the edge of the belt and the crowned pulley. Push against the belt to find out if there is any play. If more than one pulley has a crown, check the edge of the belt on each of the pulleys. If there is any play, tighten the belt until the play is eliminated. At this point the belt is in proper minimum tension.
Now operate the belt conveyor system under the most adverse conditions it will encounter and observe if there is any slippage between the drive pulley and the belt. If there is, more tension is required.

Determination of belt tension: by subjective evaluation is extremely difficult. Even the most experienced development and maintenance engineers can’t do it, except by accident. To know the exact tension of belt, use the belt as a stress/strain gauge. Start with the belt in a totally relaxed condition. Draw a line perpendicular to the belt center line; then draw another, perpendicular to the belt center line, exactly 100" away. Suppose now the given belt will stretch 1% at full rated load and go through the procedure of the proper minimum belt tension. Now if it is satisfied that the system will not encounter any slippage at worst conditions stop the conveyor and measure the two base lines again. It will find that the 100" dimension has grown. If it has grown to perhaps 100.25" this means the belt has been stretched 0.25% which is 1/4 of the 1%. Therefore, 0.25% means that you have achieved 1/4 of the rated belt tension. The two lines are no longer parallel to one another. They will assume a "parenthesis-like" shape, reflecting the kind of pulley crown or crowns employed in the system. If positive crowns are used, it will note that the center of the belt has been stretched a good bit more than the edges of the belt. To arrive at an average belt tension, it needs to choose the points at which to measure the measurement.

4. MODELING OF THE STRUCTURE IN STAAD Pro-2007

4.1 GENERAL

Transfer tower (Junction House) is a frame structure. The conveyor loading (mainly the belt tension at the drive pulley) is most important part of the Transfer tower design. Any error in load assessment will make the Transfer tower design erroneous. It becomes important for a designer to calculate the loads accurately on the Transfer tower so that the design becomes safe and economical. In the load combinations the wind load or earthquake load plays a vital role. The correct assessment of wind or Earthquake will lead to proper load assessment and reliable design of Transfer tower structure.

Structures shall be designed such that they are economical, safe and meet the functional & service requirements of the technological process for which they are designed.

4.2 LOAD CALCULATION

This Transfer tower structure is used to transfer the material (coal) from main conveyor to another belt. The location of the site for this conveyor system is Dahej. The material comes in the J2 Transfer Tower from the J2C1 conveyor Gallery. The length of the conveyor Gallery is about 2.4 km. The capacity of the system is for transferring the material is 4200 T/h.

- The loads for which the conveying structure must be designed can be classified into the following categories:
    1. Dead (Permanent) loads.
    2. Live (Operating) loads.
    3. Wind loads.
    4. Earthquake loads.
    5. Conveyor loads.

4.3 LOADS

The following loads and any dynamic effects resulting from them should be considered in the development of the design loading conditions.

4.3.1 Dead Loads (DL)

Dead loads are the weights of the structures and any permanent equipment and appurtenant structures, which do not change, with the mode of operation.
Dead loads should include the following;

1. Self weight of the complete structure with flooring, finishing, fixtures, partitions, wall panels, and all equipment supporting structures
2. Weight of the equipment.

Loads given in IS: 875 (part-I) shall be made use of for unit weight of materials.
For structural design the density of material (coal) is taken as 12 kN/m^3.
The following Dead loads shall be adopted for design of buildings/structures.

- Self weight of the structures
- Load on shuttle railing = 3.0 kN/m
- Dead load of flooring

Thickness of flooring	=	175 mm (R.C.C.)		
Self weight of flooring	=	0.175 x 25	=	4.38 kN/m^2
Finishing load	=	0.42 (assumed)	=	0.42 kN/m^2
		Total load	=	4.80 kN/m^2

4.3.2 Live Loads (LL)

Live loads are the weights of the structures which changes with the mode of operation. The loads considered shall not be less than that specified in IS: 875 (Part-II). Imposed loads should include the following;

1. Live loads, dust loads, cable trays, small pipe racks/hangers,
2. Minor equipment loads, Erection loads, Operation/maintenance loads, etc.

The following minimum live loads shall be adopted for design of Transfer tower structures in the belt conveyor system.

a) Flat roofs of Junction houses → Accessible roof: 1.5 kN/m^2
Non-accessible roof: 0.75 kN/m^2

b) Floors of Junction → 5 kN/m^2

c) Equipment loads → as per actual

d) Live load on Conveyor belt → 1.6 Design weight of material carried over the belt

e) Access platform and stairs → 5 kN/m^2

f) Dust load

Flat roof of Junction Houses : 0.75 kN/m^2

Floors at Junction house and gallery : 1 kN/m^2

Ø Impact Factor:

Impact factor due to moving hoists shall be,

- For electrically operated hoist : 1.2
- For hand operated hoists : 1.1
- For floor beams directly supporting drive Machinery like drive pulleys (head and tail end), Motor, gear boxes, etc. : 1.5

4.3.3 Wind Loads (WL)

The design wind load shall be calculated as per provisions of IS: 875 (Part-III).

Basic wind speed (V_b): for the project site at Dahez = 44 m/sec

Design wind speed (V_z): The basic wind speed shall be modified to include the following effects to get design wind velocity at any height.

$$V_z = V_b \, k_1 \, k_2 \, k_3 = 47.08 \text{ m/s}$$

Where,

k_1 = 1.07 (probability factor)

k_2 = 2 (terrain, height and structure size factor)

k_3 = 1 (topography factor)

Class of building structures = class C

Design wind pressure (P_z): The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity.

$$P_z = 0.6\ V_z^2 = 1.595\ KN/m2$$

Design wind load (F): The wind load F, acting in a direction normal to individual structural element or cladding unit is,

$$F = (C_{pe} - C_{pi})\ A\ P_d \quad = 1289.50\ kN$$

Where,

C_{pe} and C_{pi} = external and internal pressure coefficient,

A = surface area of structural element or cladding unit,

P_d = design wind pressure.

The calculated design wind pressure for the double layer conveyor Transfer tower is 1.595 kN/m2 and for parallel conveyor transfer tower is 1.50 kN/m2.

4.3.4 Earthquake Loads (EQL)

The Design for seismic loads shall be done in accordance with IS: 1893–2002. The The location of the site is Dahej and the seismic zone for this is III (0.16). The other parameters are considered for the double layer conveyor transfer tower structure.

The Seismic Zone	:	III. (0.16) (Dahej)
Response reduction factor	:	5 (Steel frame)
Importance factor	:	1.5
Rock and soil site factor	:	2 (medium soil)
Damping ratio	:	2
Period in X direction	:	0.83 sec (= 0.085 $h^{0.75}$)
Period in Z direction	:	0.83 sec (= 0.085 $h^{0.75}$)

4.3.5 Conveyor Loads

The junction house consists of double conveyor system. The capacity of the system for coal transfer is 4200 T/h and the length of the belt conveyor between two junction houses is about 2.4 km. At the end of the belt conveyor the drive units are arranged. According to the belt tension concept the driving pull is calculated on each drive pulley. The belt tension depends upon various factors. Some following major factors which are important for calculation of the belt tension;

- Transferring material capacity
- Material transfer velocity
- Bulk density of material
- Width of belt
- Speed of belt
- Weight of belt
- Frictional coefficients
- Slope of conveyor
- Pulley c/c Length of belt

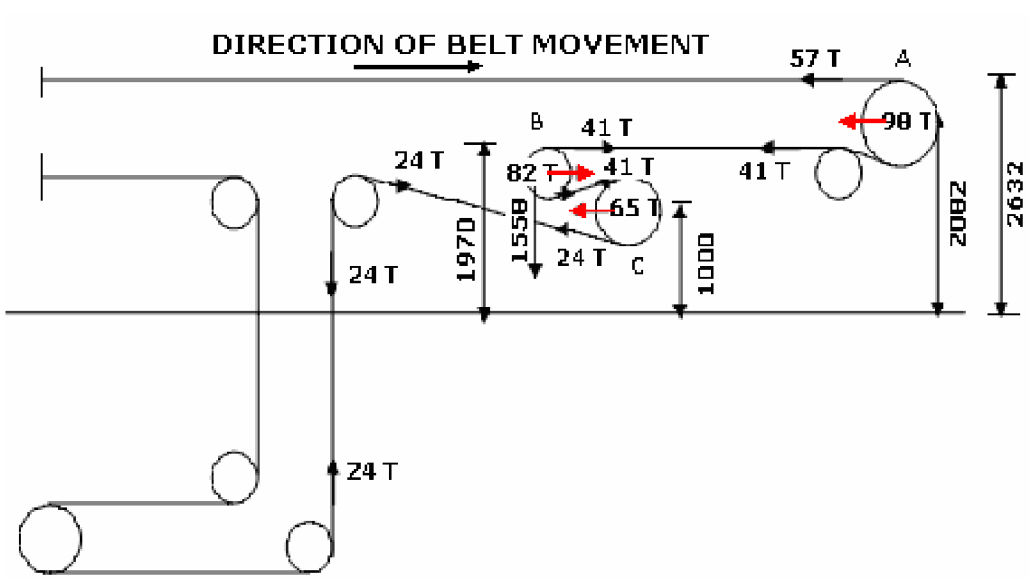


Fig. 4.1 Belt Tension Loads

In the modeling of the Transfer tower structure using STAAD Pro, the forces are calculated by the belt tension concept. The Fig. 4.1 shows that the forces developed in the drive pulley at A, B, and C. The pull load (forces) at A is 98 T, at B is 82 T, and at C is 65 T.

For the calculation of the belt tension force the impact factor is taken as 1.3.

At A,	Pull = 98 T	= 980 kN
	Force	= 637 kN (980/2 x 1.3)
	Moment	= 1325 KNm
At B,	Pull = 82 T	= 820 kN
	Force	= 533 kN (820/2 x 1.3)
	Moment	= 831.5 kNm
At C,	Pull = 65 T	= 650 kN
	Force	= 422.5 kN (650/2 x 1.3)
	Moment	= 422.5 kNm

4.4 LOAD COMBINATIONS

The structure shall be designed the load combination as per IS: 875 (Part – V)/IS: 1893. The safest junction house would be the one which is designed to withstand the worst loading condition but for economy combined with reliability, the probable combinations of loads are likely to occur.

For the calculation of load, the considered live load is more than 3 kN/m^2, however according to the codal provision 50 percentage live load is taken in load combinations. The worst load combinations due to dead load, live load, equipment load, wind load/seismic load, belt tension etc. shall be considered as follows:

a) DL $\pm$ LL

b) DL $\pm$ LL $\pm$ WL or DL $\pm$ 0.5 LL $\pm$ EQL

Note: Equipment load shall be considered under Live Load.

4.5 DEFLECTION

The deflection of various structural members shall not impair the smooth working of conveyor system and junction Houses shall not exceed the following limits.

a)	Conveyor galleries of the structures	:	Span/500
b)	Floor/roof beams of the Junction House and Walkway beams of the conveyor galleries	:	Span/325
c)	Floor beams directly supporting drive Machinery, Motor and Gear boxes	:	Span/500
d)	Monorail track beams	:	Span/500
e)	Frames of Junction towers and secondary Crusher house	:	Height/1000

4.6 MODELING AND ANALYSIS IN STAAD PRO 2007

STAAD Pro is the most popular structural engineering software product for 3D model generation, analysis and multi-material design. It has an intuitive, visualization tools, powerful analysis and design facilities and seamless integration to several other modeling and design software products. The software is fully compatible with all Windows operating systems but is optimized for Windows XP. For static or dynamic analysis of bridges, Embedded structures (tunnels and culverts), pipe racks, steel, concrete, Aluminum or Timber buildings, Transmission Towers, Stadiums or any other simple or complex structure, STAAD Pro has been the choice of design professionals around the world for their specific analysis needs.

4.6.1 Geometry of Transfer Tower (Junction House)

The arrangement of the conveyor galleries and flow of the transfer system in the Transfer tower system are shown in Fig. There are two conveyor galleries are shown in the system. The gallery 1 is at +26183 lvl and the gallery 2 is at +21250 lvl. The material is transferred from gallery 1 to the shuttle conveyor system at +19500 lvl and from gallery 2 to the shuttle conveyor system at +15800 lvl. The belt tension device is arranged at +23000 lvl. The arrangements of the total conveyor Transfer tower system are shown in the different views in appendix C.

Conveyor systems: 1. Double layer conveyor system

2. Parallel conveyor system

Ø Double layer conveyor system

The Double layer conveyor supporting structure contains the two conveyor galleries and the conveyors galleries are arranged on above other.

Length = 37 m, Width =10 m, Height = 21.83 m

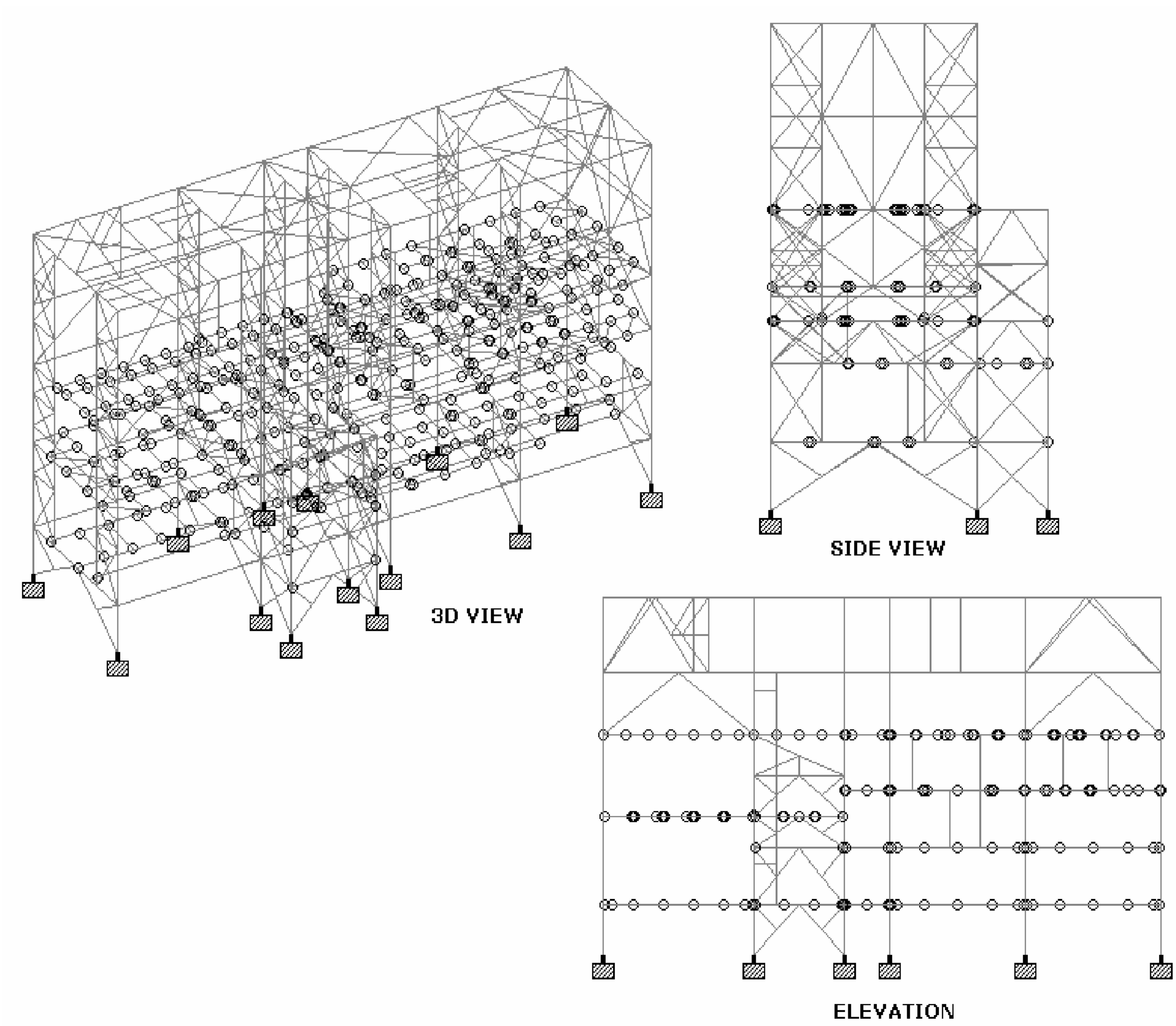


Fig. 4.2 Geometry of structure for Double layer conveyor system

In this double conveyor transfer tower system the shuttle conveyors are arranged in the different levels. There are six frames in X direction and two frames in Z direction in the structure. The Fig. 4.2 shows the sample arrangement and geometry of the double layer conveyor system

Ø Parallel conveyor system

The Parallel conveyor supporting structure contains the two conveyor galleries and the conveyor galleries are arranged side by side/parallel and share the same floor level for the supporting system.

Length = 37 m, Width = 20 m, Height = 16.82 m

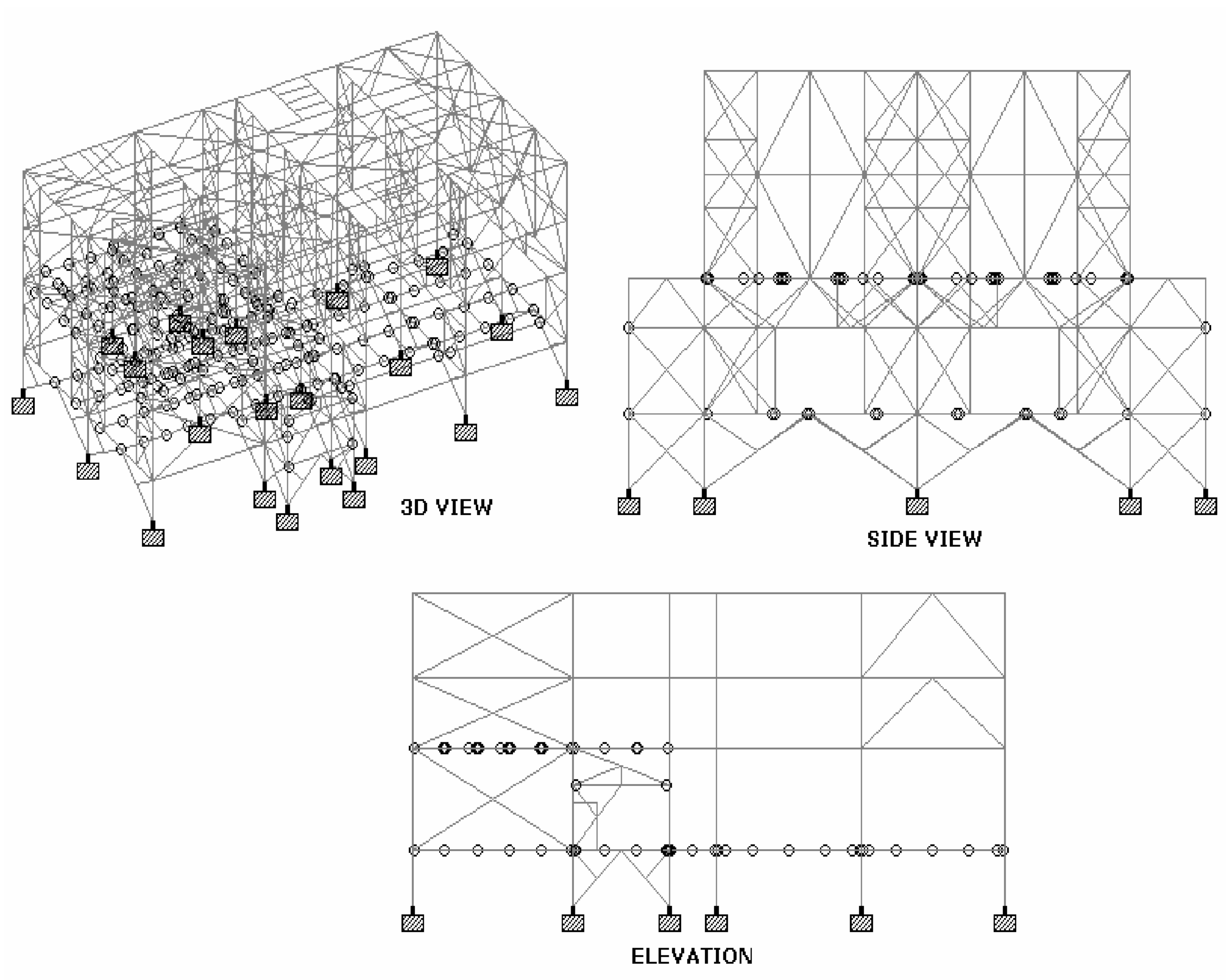


Fig. 4.3 Geometry of structure for Parallel conveyor system

In this parallel conveyor transfer tower system the shuttle conveyors are also arranged in the same levels. There are six frames in X direction and three frames in Z direction in the structure. The Fig. 4.3 shows the sample arrangement and geometry of the Parallel conveyor system.

4.6.2 Application of Loads on the Structure

(1) Dead Loads

Dead loads are the weights of the structures and any permanent equipment and appurtenant structures, which do not change, with the mode of operation.
For the modeling of structure the dead loads are taken as the floor loads.

- Total load on flooring = 4.80 kN/m^2
- Load on shuttle railing = 3.00 kN/m

(2) Live Loads

Live loads are the weights of the structures which changes with the mode of operation. The given live loads are considered for the modeling of the structure.

- Load on flooring = 5.00 kN/m^2
- Load on shuttle railing = 2.50 kN/m

(3) Conveyor Loads

According to the belt tension concept the tension load is calculated on each drive pulleys arranged in the structure. The Fig. 4.4 shows the application of belt tension load and Fig. 4.5 shows the forces applied on the each drive pulley as nodal loads at particular nodes.

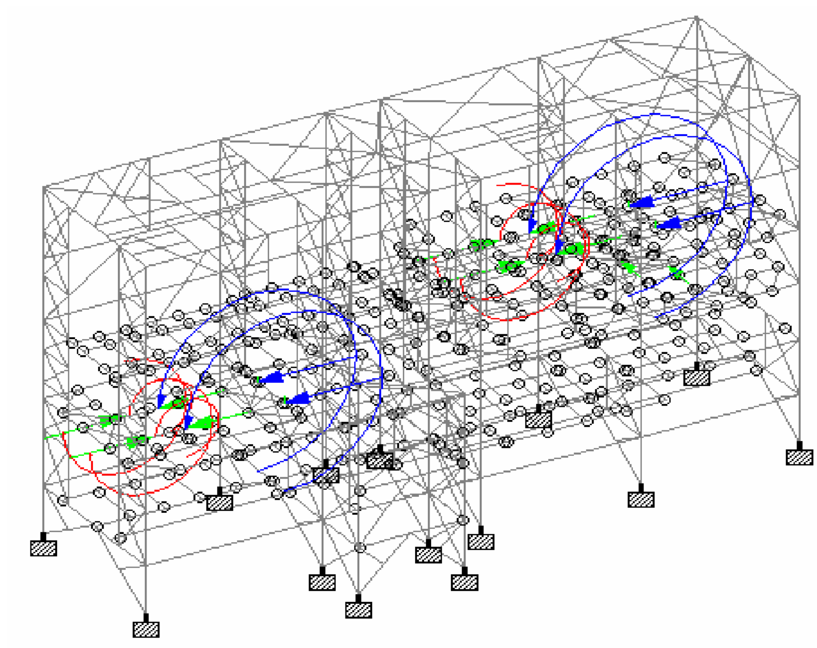


Fig. 4.4 Conveyor Loads at Drive pulleys

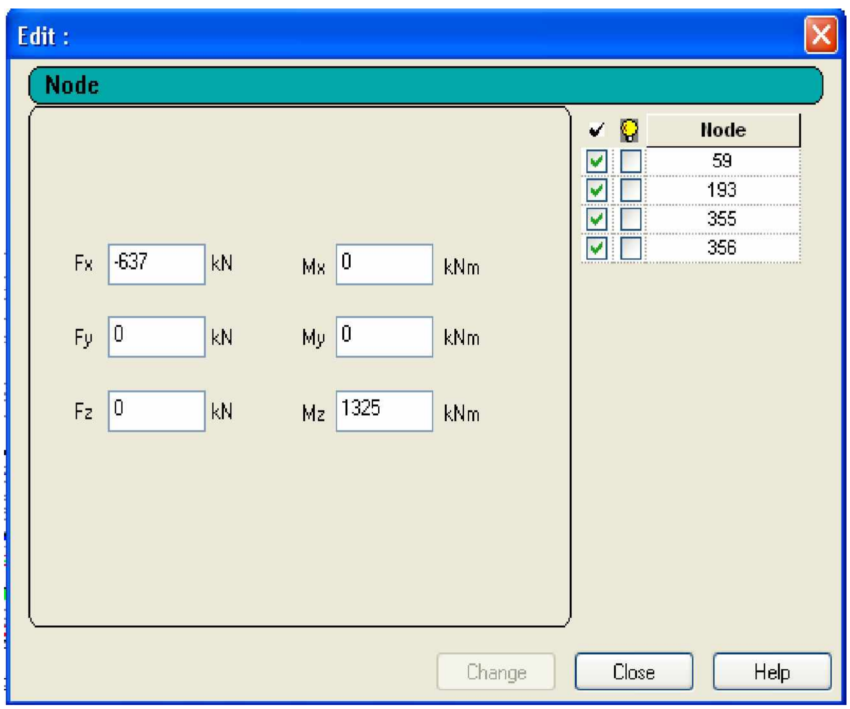


Fig. 4.5 Application of Conveyor Loads in STAAD Pro

(2) Wind Loads

The parameters for the wind load calculation are considered as per 4.3.3. The Fig. 4.6 shows the application of wind force to the structure in the STAAD Pro.

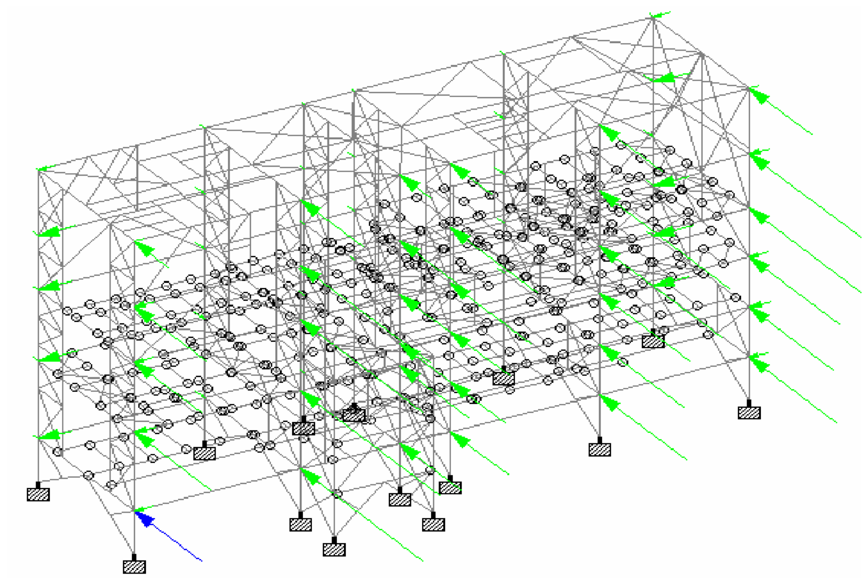


Fig. 4.6 Application of Wind Load in STAAD Pro

(3) Seismic Loads

The application of the seismic loads on the structure is applied directly in STAAD Pro by selecting the code IS: 1893 – 2002 and giving the necessary parameters.

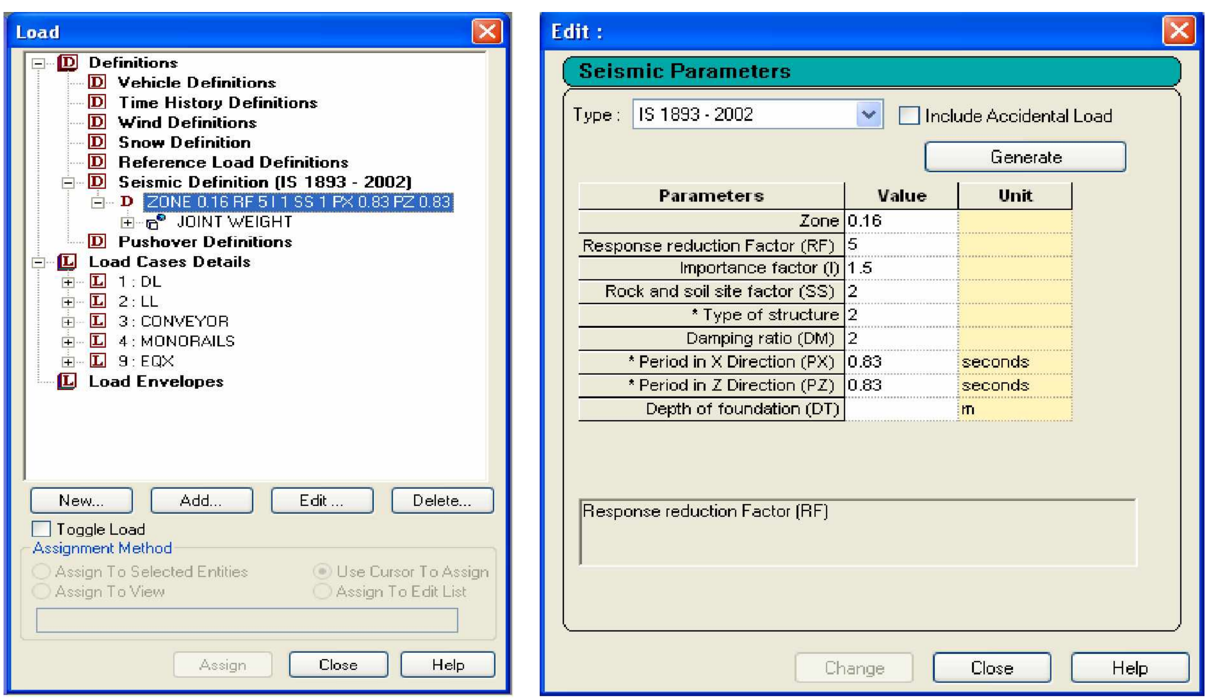


Fig. 4.7 Application of Seismic Loads in STAAD Pro

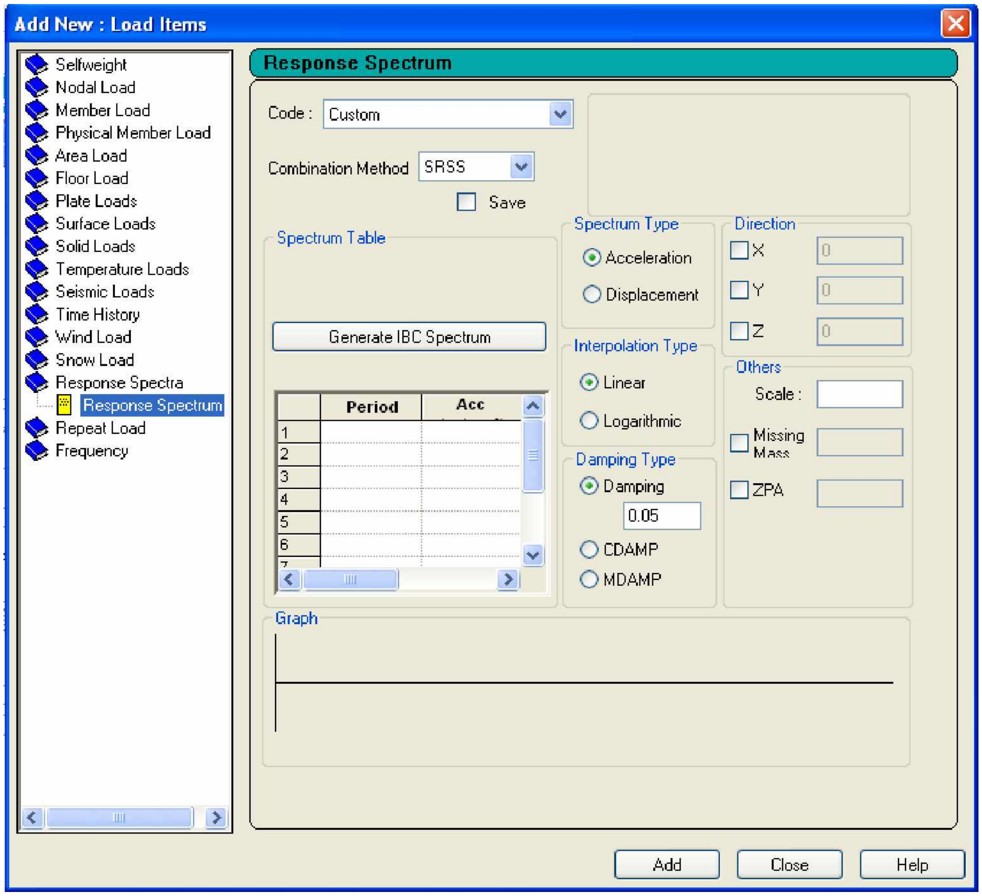


Fig. 4.8 Response spectrum in STAAD Pro

4.6.3 Resonance of the Structure

Resonance: When the frequency of the external excitation is equal to the natural frequency of a vibrating body, the amplitude of vibration becomes excessively large. This concept is known as resonance.

Frequency of the machine:

Machine frequency = 1500 rpm

= 1500/60

= 25 cycle/sec

There are six mode shapes considered and shown in the above table. The frequency and time period are also shown in the table. The frequency of the machine is 25 cycle/sec. The ratios of the structural frequencies to the machine frequency are < 0.8, and > 1.2.

Ø The first three mode shapes of the steel structure are shown in Fig. 4.9.

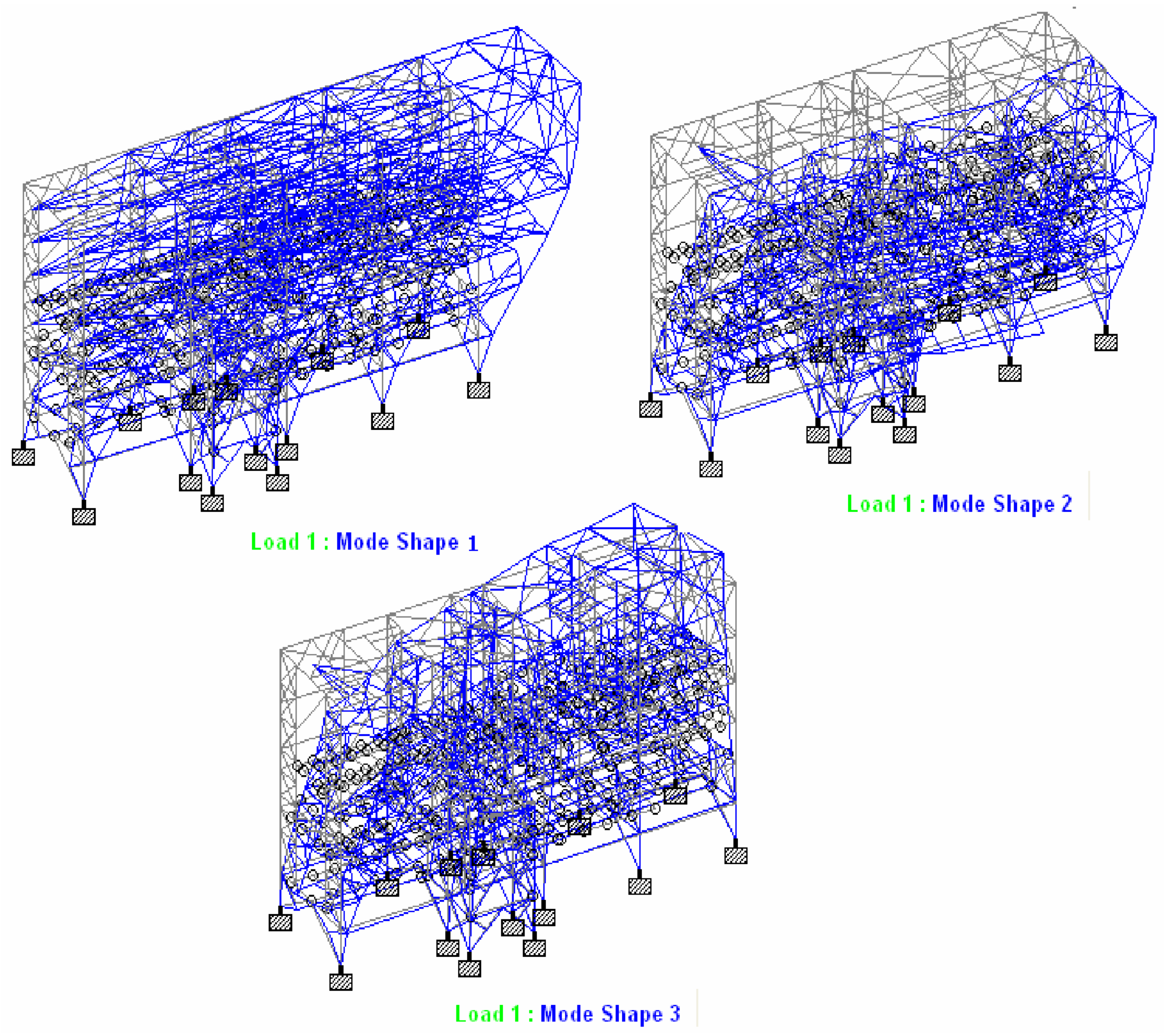


Fig 4.9 Mode shapes for Double conveyor steel structures

Table 4.1 frequencies of double conveyor structure

Mode	Frequency (cycle/sec)	Period (sec)	Ratio
1	2.872	0.3481	0.1148
2	3.252	0.3074	0.1300
3	3.377	0.2961	0.1350
4	4.333	0.2307	0.1733
5	4.426	0.2259	0.1770
6	4.983	0.2007	0.1993

Note:- For resonance, the ratio should be < 0.8, and > 1.2.

The Table 4.1 shows the frequencies of this structure and these frequencies are directly taken from the STAAD Pro results.

The first three modes shapes for the parallel conveyor steel Transfer tower structure are shown in Fig. 4.10. The Table 4.2 shows the frequencies of this structure and these frequencies are directly taken from the STAAD Pro results.

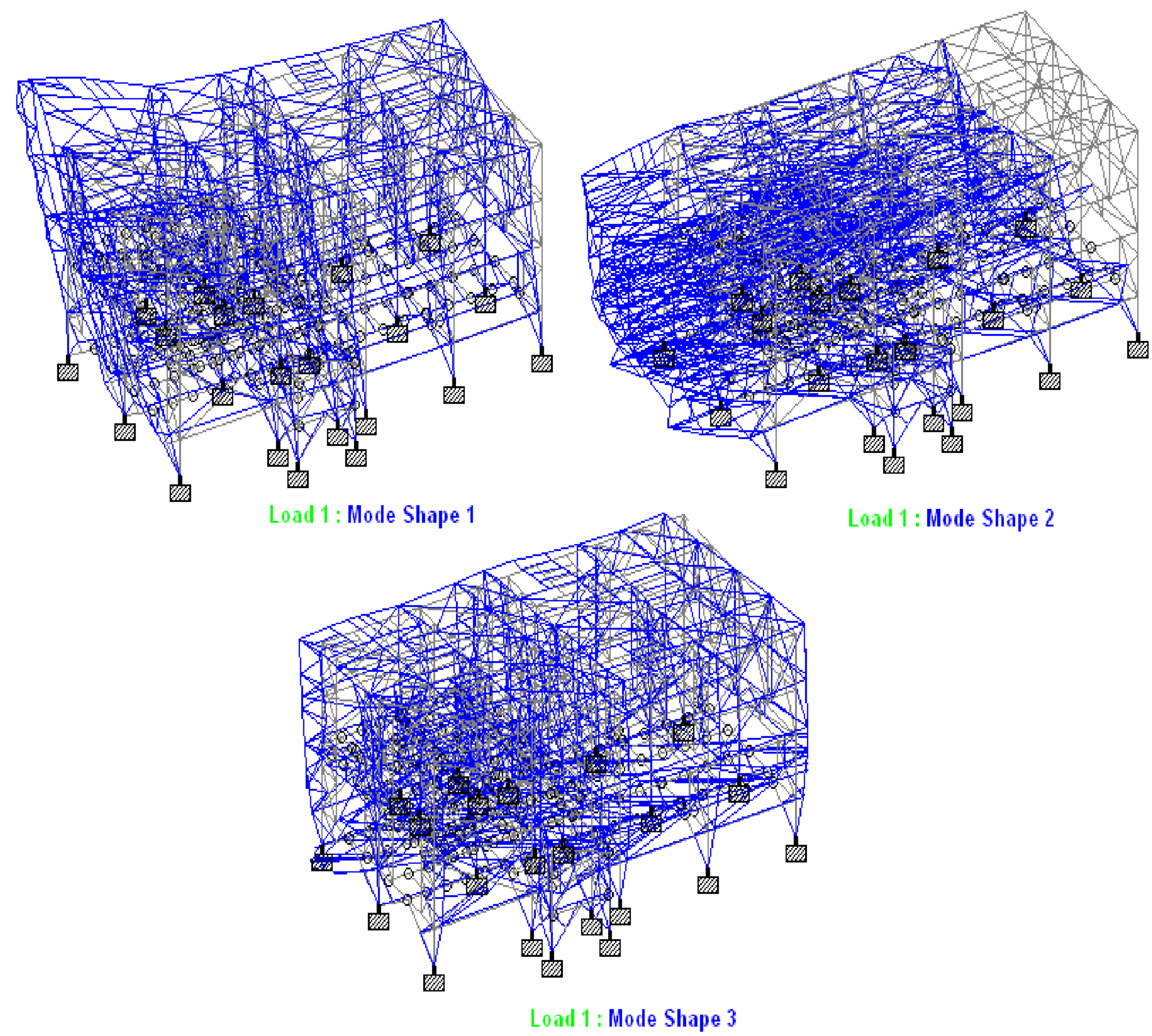


Fig 4.10 Mode shapes for Double conveyor steel structures

Table 4.2 frequencies of parallel conveyor system

Mode	Frequency (cycle/sec)	Period (sec)	Ratio
1	4.324	0.2312	0.1729
2	4.346	0.2301	0.1738
3	5.048	0.1980	0.2019
4	5.508	0.1815	0.2203
5	5.852	0.1708	0.2340
6	6.334	0.1578	0.2533

Note: For resonance, the ratio should be < 0.8, and > 1.2

4.6.4 Analysis and Design of Structures

The conveyor systems are analysed for:

1. Double layer conveyor Transfer tower system
2. Parallel conveyor Transfer tower system

The analysis and design of the double and parallel conveyor Transfer tower system are included in the next chapters. The chapters of double and parallel conveyor Transfer tower systems contain the analysis of the structure by using different materials as steel and concrete. The various design properties are used for the safety and serviceability of the structure.

4.7 SUMMARY

Chapter presents the brief introduction of various types of loads and calculation of loads acting on structure for analysis. The analysis of structure is carried out by the STAAD Pro. The application of the loads in STAAD Pro is also carried out.

5. DOUBLE CONVEYOR TRANSFER TOWER STRUCTURE

5.1 GENERAL

The Double layer conveyor supporting system contains the two conveyor galleries and the conveyors galleries are arranged on above other shown in Fig. 5.1. The above conveyor supports on the roof the below conveyor. The roof of below conveyor is floor for above conveyor. The loads of the above conveyor are transferred form floor or floor beam.

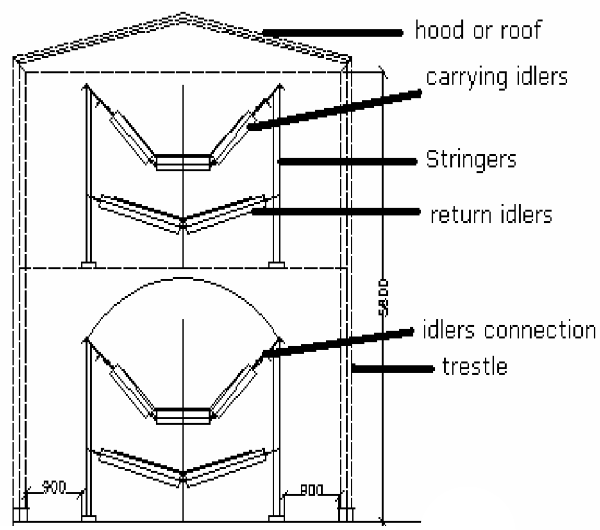


Fig. 5.1 Double Layer Conveyor Systems

The conveyor systems are designed for: Double layer conveyor system

The framing is designed by using following alternative:

Sr. No.	COLUMNS	BEAMS
1	Steel	Steel
2	Concrete	Concrete
3	Concrete	Steel

The modeling of the Double conveyor transfer tower structure is carried out in chapter 4. The structural drawings of the structure are attached in appendix C.

5.2 STEEL STRUCTURE

The Fig. 5.2 shows the full three dimensional view of the structure containing all the members as steel as material. The Fig. shows the elevation, side view and 3D view of the double layer conveyor system of the structure.

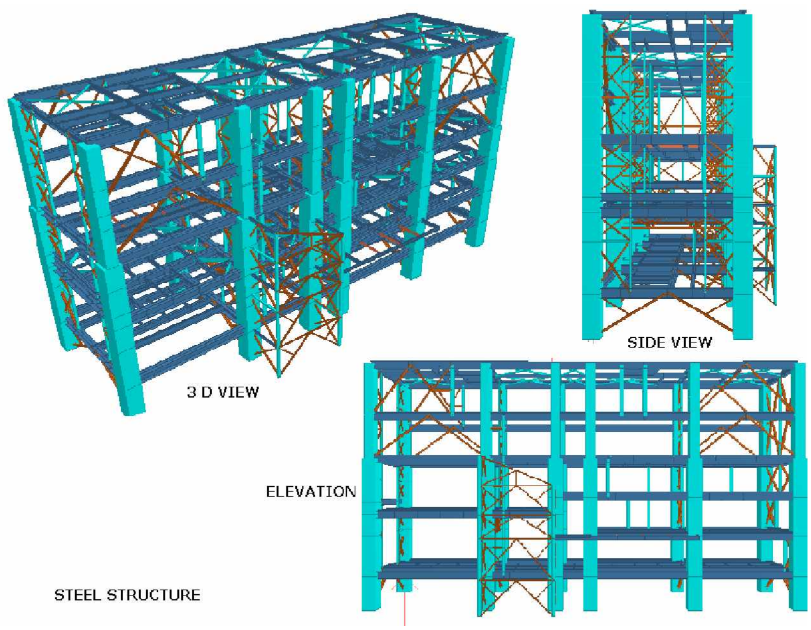


Fig 5.2 Steel Structure

5.2.1 Member Properties of the structure

The assumed member properties of the structure are given below in the Table 5.1. The table contains the certain standard sections and certain built up sections for the double layer and parallel conveyor structure.

Table 5.1 Steel Member Properties

Sr. No.	Mark	Profile	Section	
1	C1		flange web	PL 800 X 32 PL 1136 X 20
2	C1A		flange web	PL 800 X 32 PL 1136 X 20
3	C2		ISMB 250	
4	B1		flange web	PL 720 X 36 PL 800 X 20

5	B2	I	flange web	PL 600 X 32 PL 736 X 16
6	B3	I	flange web	PL 550 X 32 PL 686 X 16
7	B4	I	flange web	PL 500 X 32 PL 636 X 16
8	B5	I	flange web	PL 450 X 25 PL 600 X 12
9	B6	I	flange web	PL 400 X 25 PL 550 X 12
10	B7	I	flange web	PL 350 X 20 PL 510 X 10
11	B8	I	flange web	PL 300 X 20 PL 460 X 12
12	B9	I	flange web	PL 250 X 20 PL 410 X 10
13	B10	I	flange web	PL 200 X 16 PL 368 X 8
14	B11	I	ISMB 600	
15	B12	I	ISMB 500	
16	B13	I	ISMB 450	
17	B14	I	ISMB 400	
18	B15	I	ISMB 350	
19	B16	I	ISMB 300	
20	B17	I	ISMB 250	
21	B18	I	ISMB 200	
22	B19	[	ISMC 300	
23	B20	[	ISMC 200	
24	B21	[	ISMC 150	
25	B22	[	ISMC 100	

26	MR1		ISMB 450 PL 130 X 20
27	MR2		ISMB 400 PL 120 X 12
28	BR1		2 / L 150 X 150 X 20
29	BR2		2 / L 150 X 150 X 16
30	BR3		2 / L 150 X 150 X 12
31	BR4		2 / L 130 X 130 X 12
32	BR5		2 / L 130 X 130 X 10
33	BR6		2 / L 110 X 110 X 12
34	BR7		2 / L 110 X 110 X 10
35	BR8		2 / L 100 X 100 X 8
36	BR9		2 / L 90 X 90 X 8
37	BR10		2 / L 90 X 90 X 6
38	BR11		2 / L 75 X 75 X 6
39	BR12		2 / L 65 X 65 X 6
40	BR13		2 / L 50 X 50 X 6
41	BR14		2 / L 90 X 90 X 6
42	BR15		2 / L 65 X 65 X 6
43	BR16		L 100 X 100 X 6
44	BR17		L 90 X 90 X 6
45	BR18		L 75 X 75 X 6
46	BR19		L 65 X 65 X 6
47	SP1		ISMB 250
48	SP2		ISMB 200

49	SP3	[	ISMC 150
50	RB	][	2 / ISMC 150
51	TV	┐	L 50 X 50 X 6
52	R1	[	ISMC 200
53	R2	[	ISMC 150
54	R3	[	ISMC 125
55	P1	[	ISMC 200
56	P2	[	ISMC 150
57	P3	[	ISMC 125
58	TBR1	┐	L 75 X 75 X 8
59	RBR	┐	L 100 X 100 X 6
60	FBR1	[	ISMC 300
61	FR	┐	L 90 X 90 X 6
62	SA	┐	L 50 X 50 X 6

5.2.2 Built up Sections

There are various standard sections are generally used. But if the standards sections are not satisfied for design then built up sections are used. The certain typical built up cross sections of compression members are as follows.

Since the permissible compressive stress for a compression member increase with decrease in l/r ratio, the section should be proportioned to have the largest radius of gyration. A circular pipe has best cross section in this regard as its radius of gyration is highest for a given cross sectional area and is equal in all directions. However in actual practice this section is not preferred due to difficulty in joining with other members. Fig. 5.3 shows various types of cross sections generally used for compression members.

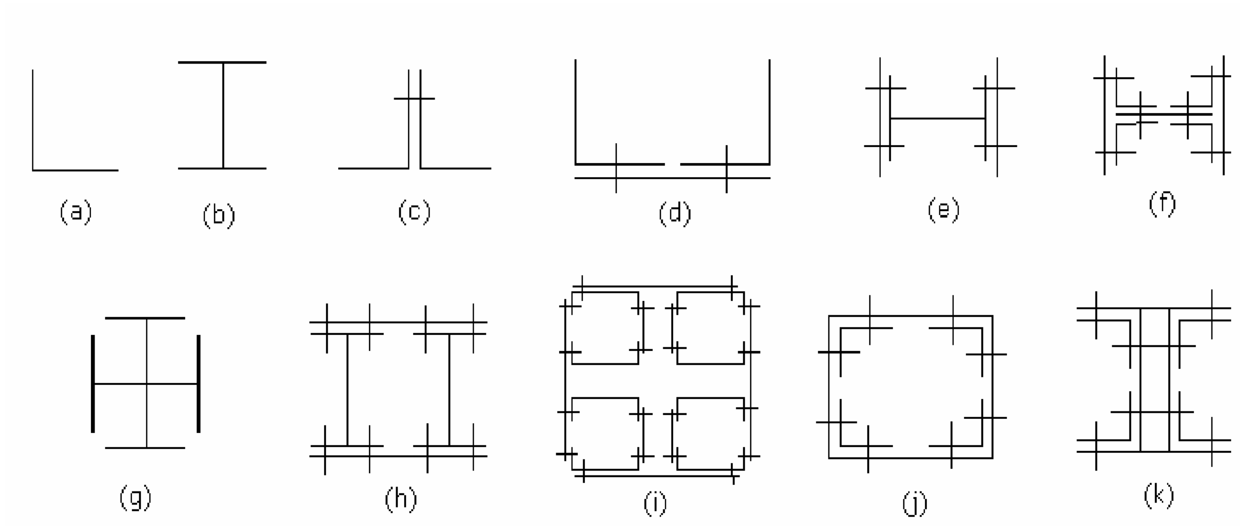


Fig. 5.3 various forms of compression members

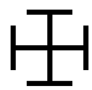
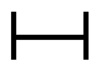
Single angle section is the simplest type of compression member and in roof trusses and as bracing in plate girder and built up columns. Single section is not economical as its radius of gyration is small about the minor principle axis and the allowable loads are further lowered due to eccentricity of the connections.

For compression members of I sections SC section, are most suitable as the difference between the radii of gyration about the two axis is the smallest. However, sometimes it is also desirable to have the column section stronger in the directions where more deflections are expected. Fig. 5.3 [(c) through (k)] shows the various built up cross sections used for compression members by using cover plates (shown by firm lines) and lacings (shown by dotted lines) along with rolled angle, channel and I-sections. Double angle section is frequently used for roof trusses and for braces in plate girder bridges. The built up section using two I section should be made by using an I section other than the SC section as its works out to be more economical. The double channel section (Fig. 5.3 (i)) is generally used in bridges and building frames. It has lacings provided on one side to facilitate the entry of gusset plate for end connections. Very heavy column sections can be made by using angle, channels, plates etc.

5.2.3 Various assumed Column Properties

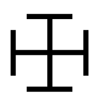
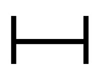
Generally the standard sections are used as column members in the general structures, but in heavy industrial structures the loads transfers from floors to columns are very heavy therefore the Built Up sections are used. Some typical built up sections are used for the design of the column members. The properties of this built up sections are shown below tables.

(A) Cross column section (1200 mm x 1200 mm)

1.	C1		Flange 800 mm x 32 mm
			Web 1136 mm X 20 mm
2.	C1A		Flange 800 mm x 32 mm
			Web 1136 mm X 20 mm

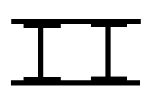
The cross section area of this section is approximately 1474.4 cm^2

(B) Cross column section (900 mm x 900 mm)

1.	C1		Flange 600 mm x 28 mm
			Web 844 mm X 16 mm
2.	C1A		Flange 600 mm x 28 mm
			Web 844 mm X 16 mm

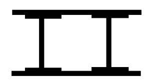
The cross section area of this section is approximately 940 cm^2

(C) 2-ISMB 600 + Plate (1150 mm x 25 mm)

1.	C1		2 ISMB 600
			PLATE 1150 mm X 25 mm

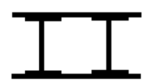
The cross section area of this section is approximately 887.4 cm^2

(D) 2-ISMB 600 + Plate (1150 mm x 20 mm)

1.	C1		2 ISMB 600
			PLATE 1150 mm X 20 mm

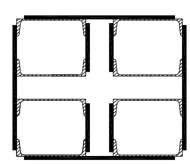
The cross section area of this section is approximately 772.5 cm^2

(E) 2-ISMB 600 + Plate (1150 mm x10 mm)

1.	C1		2 ISMB 600
			PLATE 1150 mm X 10 mm

The cross section area of this section is approximately 542.0 cm^2

(F) 8-ISMC 300 + 4-Plate (650x16) + 4-Plate (250x16)

1.	C1		8 ISMC 300
			OUTER PLATE 650 mm X 16 mm
			INNER PLATE 250mm X 16 mm

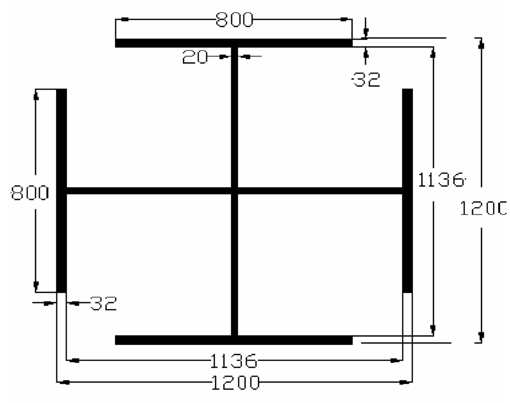
The cross section area of this section is approximately 941.12 cm^2

5.2.4 Results of the used Steel Sections

The below sections are used for the design columns. The table shows the c/s area of the section and steel take off of the structure using this section as column. The table also shows the deflections of the structure at boundary conditions (fixed and hinge) at levels where the conveyor is passing through structure. The permissible deflection of the structure at level 21.25 m is 8.450 mm and at level 26.183 m is 13.383 mm.

A. Original Structure 1200 mm X 1200 mm Column size

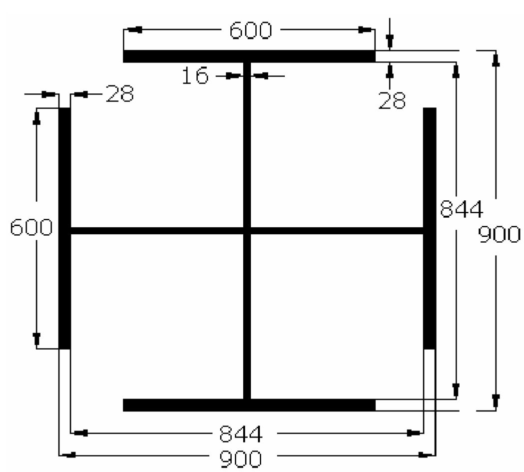
The Fig. shows the built up section of 1200 mm x 1200mm. This section contains the two web plates (1136 mm x 20 mm) and four flange plates (800 mm x 32 mm).



Area	1474.4 cm2	
Deflection (mm)	FIXED SUPPORT	HINGE SUPPORT
21.25 m Lvl.	6.10	12.01
26.183 m Lvl.	8.90	15.95
Take off (Weight)	5649.82 kN	

B. Original Structure 900 mm X 900 mm Column size

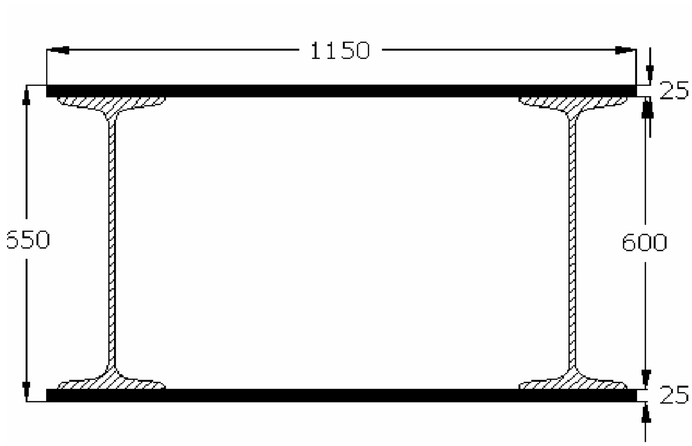
The Fig. shows the built up section of 900 mm x 900 mm. This section contains the two web plates (844 mm x 16 mm) and four flange plates (600 mm x 28 mm).



Area	940 cm2	
Deflection (mm)	FIXED SUPPORT	HINGE SUPPORT
21.25 m Lvl.	9.11	16.20
26.183 m Lvl.	13.61	20.00
Take off (Weight)	4783.04 kN	

C. 2-ISMB 600 + Plate (1150x25)

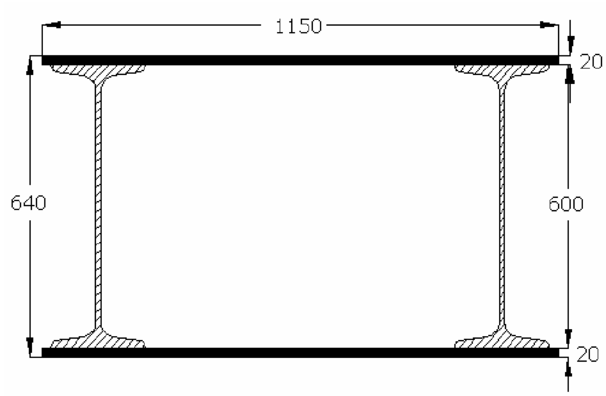
The Fig. shows the built up section of 2-ISMB 600 + Plate (1150 x 25). This built up section contains the 2-ISMB 600 and two plates (1150mm x 25mm). The c/c distance between the two I sections is 900 mm.



Area	887.4 cm2	
Deflection (mm)	FIXED SUPPORT	HINGE SUPPORT
21.25 m Lvl.	7.04	13.38
26.183 m Lvl.	10.20	17.05
Take off (Weight)	5040.00 kN	

D. 2-ISMB 6OO + Plate (1150x20)

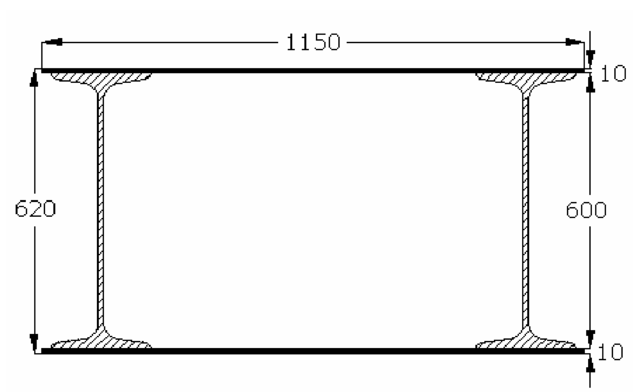
The Fig. shows the built up section of 2-ISMB 600 + Plate (1150 x 20). This built up section contains the 2 ISMB 600 and two plates (1150mm x 20mm). The c/c distance between the two I section is 900 mm.



Area	772.5 cm2	
Deflection (mm)	FIXED SUPPORT	HINGE SUPPORT
21.25 m Lvl.	7.43	13.80
26.183 m Lvl.	10.75	17.50
Take off (Weight)	4811.73 kN	

E. 2ISMB 6OO + Plate (1150x10)

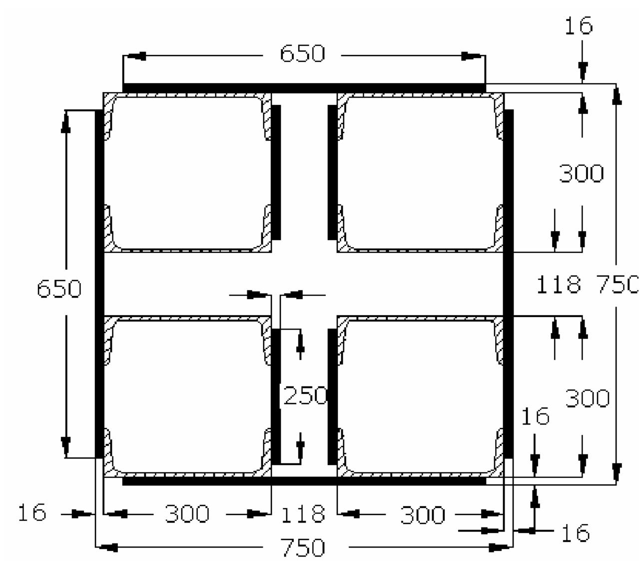
The Fig. shows the built up section of 2-ISMB 600 + Plate (1150 x 10). This built up section contains the 2 ISMB 600 and two plates (1150mm x 10mm). The c/c distance between the two I sections is 900 mm.



Area	542 cm2	
Deflection (mm)	FIXED SUPPORT	HINGE SUPPORT
21.25 m Lvl.	8.46	14.90
26.183 m Lvl.	12.01	18.76
Take off (Weight)	4348.18 kN	

F. 8-ISMC 300 + 4-Plate (650x16) + 4-Plate (250x16)

The Fig. shows the built up section of 8-ISMC 300 + 4-Plate (650x16) + 4-Plate (250x16). This built up section contains the 4 ISMC 300 and four outer plates (650mm x 16mm) and four inner plates (250mm x 16mm).



Area	941.12 cm2	
Deflection (mm)	FIXED SUPPORT	HINGE SUPPORT
21.25 m Lvl.	7.91	15.86
26.183 m Lvl.	12.80	19.60
Take off (Weight)	5356.27 kN	

5.2.5 Comparison of the Sections

The Fig. 5.4 shows the comparison of the steel take off of the various assumed sections of the column members.

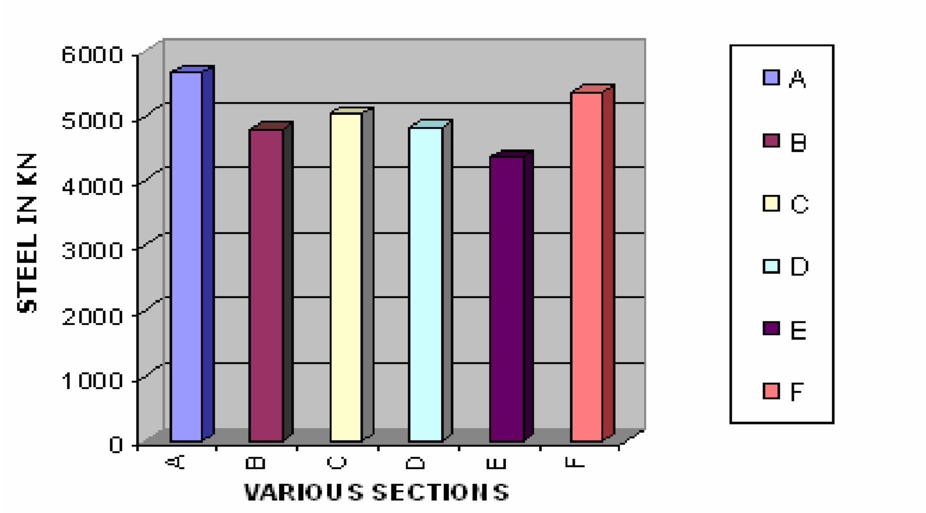


Fig. 5.4 Comparison of Sections

Table 5.2 Results of used Steel Sections

Notation	Used Sections in Double Layer Conveyor system	Steel Take Off
A	COL.1200 x 1200 mm	5649.82 kN
B	COL. 900 x 900 mm	4783.04 kN
C	2-ISMB 600 + PL (1150 x 25)	5040.00 kN
D	2-ISMB 600 + PL (1150 x 20)	4811.73 kN
E	2-ISMB 600 + PL (1150 x 10)	4348.18 kN
F	8-ISMC300 + 4-PL (650x16) + 4-PL (250x16)	5356.27 kN

5.2.6 Cost Comparison of the Sections

The Fig. 5.5 shows the cost comparison of the steel take off of the various considered sections of the column members.

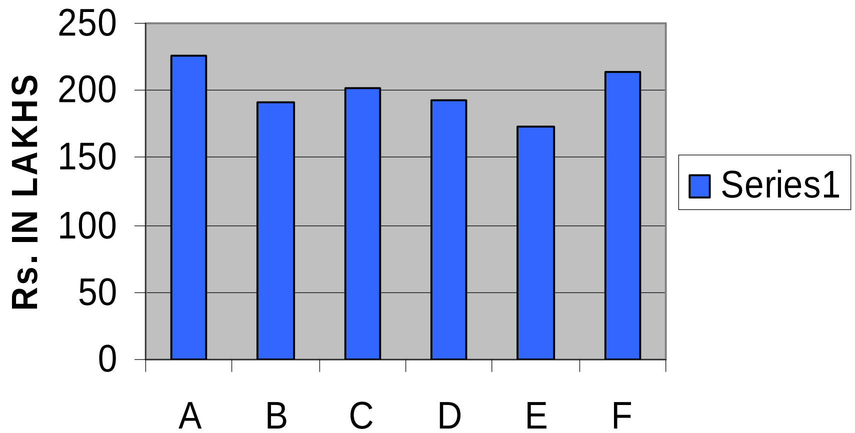


Fig. 5.5 Comparison of sections

Table 5.3 Cost comparison of the assumed steel sections

NOTATION	Take Off (kN)	RATE (Rs. IN LAKHS)
A	5649.82	225.99
B	4783.04	191.32
C	5040.00	201.60
D	4811.73	192.46
E	4348.18	173.92
F	5356.27	214.25

5.3 CONCRETE STRUCTURE

The Fig. 5.6 shows the full three dimensional view of the structure containing all the members as concrete as material. The figure shows the elevation, side view and 3D view of the double layer conveyor system of the structure. Here the levels of the floors in the structure are a constraint and the head room of the each floor is fixed. The loads comes to the load carrying members are very heavy therefore the sizes of the beam members will increase. It means the total height of the structure will increase, but the floor level is constraint, therefore it is not possible to get proper head room between the floors. For these reasons, these types of structures are not useful by using concrete as material.

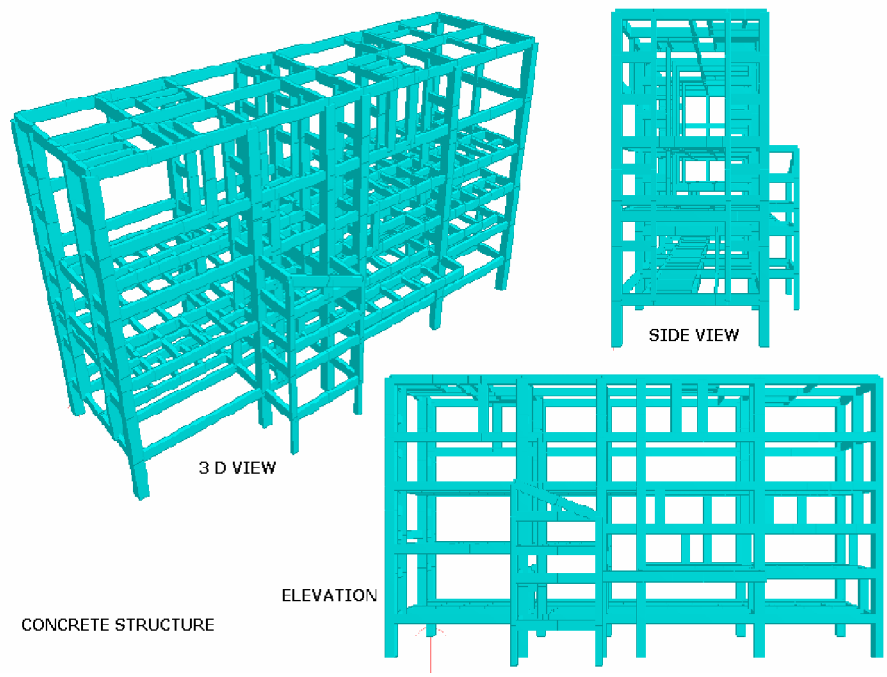


Fig. 5.6 Concrete Structure

5.3.1 Member Properties of Structure

The assumed section properties of the members for the double layer conveyor system of the concrete structures are given below Table 5.4.

Table 5.4 Member Properties of concrete structure

SR NO.	MARK	SECTION
1.	C1	900 mm X 900 mm
2.	C2	400 mm X 400 mm
3.	B1	450 mm X 600 mm
4.	B2	450 mm X 600 mm

The column size is 900 mm x 900 mm is used for the main columns of the structure. The c/s area of this column section is 8100 cm2. The deflections of the Transfer tower structure at different boundary conditions (fixed conditions and hinge conditions) are shown below table at levels where the conveyor is passing through structure.

Column	900 X 900 mm	
Area	8100 cm2	
Deflection (mm)	FIXED SUPPORT	HINGE SUPPORT
21.25 m Lvl.	8.60	15.70
26.183 m Lvl.	13.33	20.91

5.3.2 Material Take off of Members

Total volume of concrete = 880.41 m3

Total weight of steel = 535.15 KN

5.3.3 Limitations of the Concrete Structure

Generally this type of structures is constructed with using the steel as material. The certain limitations of the concrete Junction House structures are given below.

- The levels of the floors in the structure are a constraint.
- The depth of the beams increases with using the concrete as material in compare to the steel structures, the higher depth of the beam consume the more headroom area and therefore can’t get proper or sufficient headroom.
- The construction of concrete junction house is time consuming while steel junction house structure is faster to fabricate.

5.4 COMPOSITE STRUCTURE

The Fig. 5.7 shows the full three dimensional view of the structure containing all the column members as concrete and remaining all members are steel as material. The figure shows the elevation, side view and 3D view of the double layer conveyor system of the structure.

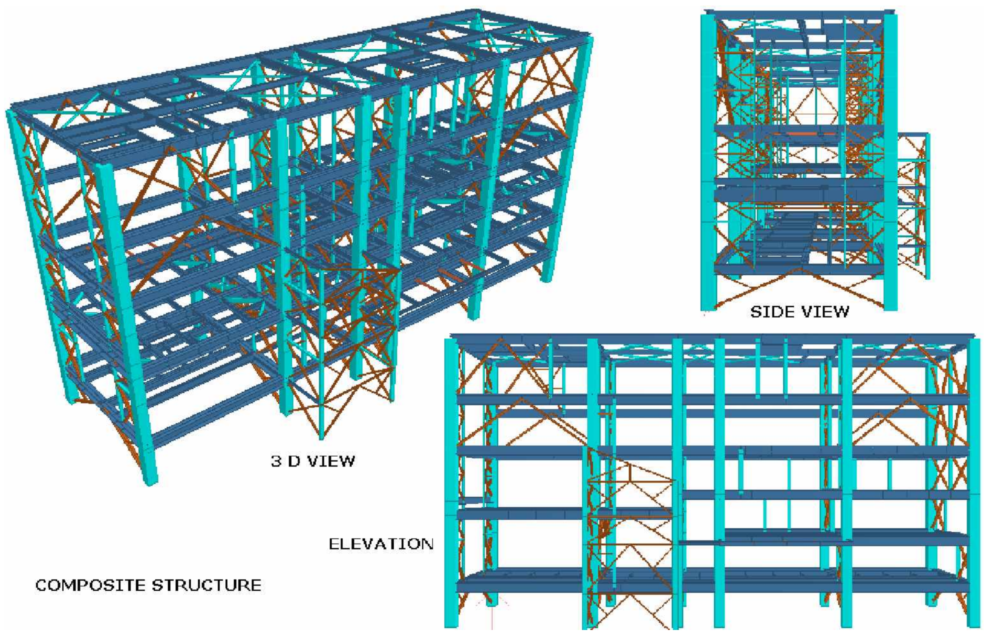


Fig. 5.7 Composite Structure

The above Fig. 5.7 shows the all members are steel remaining the main column members. The column size is 700 mm x 700 mm is used for the main columns of the structure. The c/s area of this column section is 4900 cm2. The deflections of the Transfer tower structure at different boundary conditions (fixed conditions and hinge conditions) are shown below table at levels where the conveyor is passing through structure.

Column	700 X 700 mm	
Area	4900 cm2	
Deflection (mm)	FIXED SUPPORT	HINGE SUPPORT

21.25 m Lvl.	10.01	17.11
26.183 m Lvl.	14.01	21.52

5.4.1 Material Take off of Members

- Ø MATERIAL TAKE OFF FOR CONCRETE MEMBERS

  Total volume of concrete = 156.62 m3

  Total weight of steel = 108.12 kN

- Ø STEEL TAKE OFF FOR STEEL MEMBERS

  Total weight of steel = 3269.35 kN

5.5 ANALYSIS RESULTS

Column Forces

The member forces of the structure due to various structural loads are shown below. The column orientation and no. of the structure are shown in Fig. 5.8. The column forces are also shown in the Table 5.5.

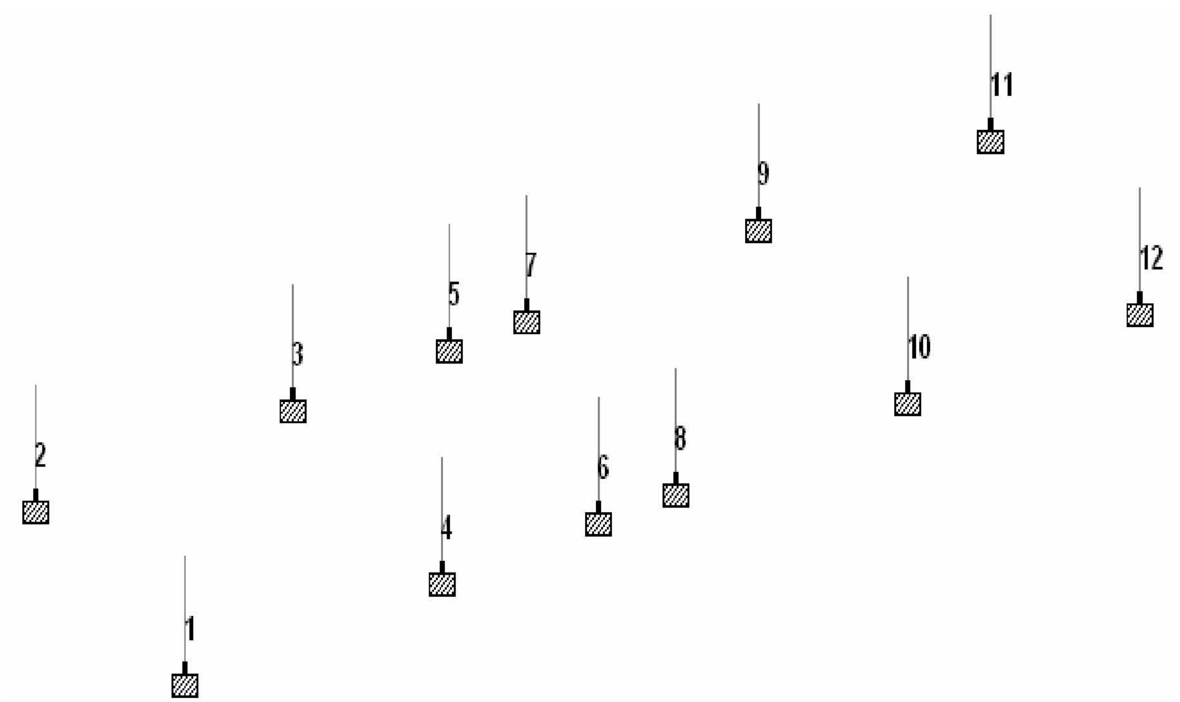


Fig. 5.8 Orientation and Column numbers in double conveyor

Table 5.5 Column Forces in Double Layer Conveyor

Beam	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1	1136.23	-205.65	41.05	-0.00	-442.11	-1090.37
2	1371.12	-256.18	100.47	-0.03	-510.61	-1248.25
3	1893.70	-264.12	151.69	0.00	-570.32	-1163.39
4	1496.97	-230.94	62.55	-0.01	-567.00	-1005.11
5	1306.81	-280.51	113.13	-0.01	-543.60	-1175.65
6	1010.57	-238.00	69.49	-0.00	-571.13	-1017.43
7	1218.59	-307.46	142.62	-0.02	-597.04	-1170.48
8	1032.96	-257.68	60.22	-0.02	-601.04	-1008.29
9	2684.24	-293.35	212.88	-0.02	-908.62	-1198.52
10	2131.79	-247.04	102.22	-0.01	-917.32	-1021.00
11	1257.83	-256.85	207.04	-0.01	-966.72	-1230.21
12	771.92	-212.54	146.34	-0.01	-985.40	-1028.77

SUPPORT REACTION

The orientation and node no. are shown in the Fig. 5.9. The support reaction results are shown in the Table 5.6.

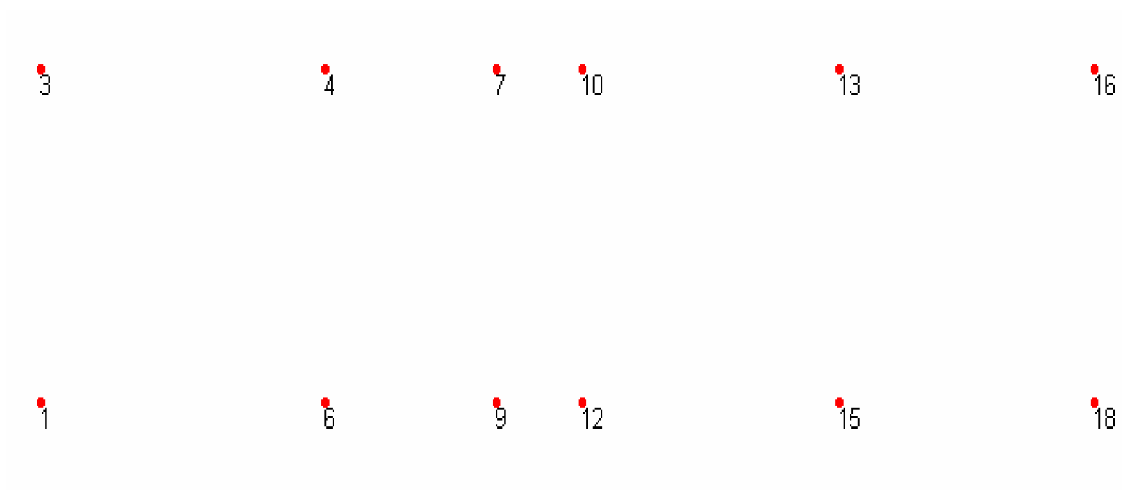


Fig 5.9 Node no. of support members in Double conveyor structure

Table 5.6 Support Reaction in Double Layer Conveyor

Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1	**205.65**	**1184.04**	**-122.50**	**442.11**	**-0.00**	**-1090.37**
3	256.18	1468.26	261.27	510.61	-0.03	-1248.25
4	264.12	2080.10	460.65	570.32	0.00	-1163.39
6	230.94	1609.76	-224.71	567.00	-0.01	-1005.11
7	280.51	1427.12	312.54	543.60	-0.01	-1175.65
9	238.00	1062.21	-107.54	571.13	-0.00	-1017.43
10	307.46	1369.63	393.06	597.04	-0.02	-1170.48
12	257.68	1115.59	-162.66	601.04	-0.02	-1008.29
13	293.35	3003.91	748.04	908.62	-0.02	-1198.52
15	247.04	2254.89	-207.84	917.32	-0.01	-1021.00
16	256.85	1434.91	500.88	966.72	-0.01	-1230.21
18	212.54	821.89	166.10	985.40	-0.01	-1028.77

5.6 SUMMARY

This chapter presents the brief introduction of the double layer conveyor transfer tower structure. The analysis and design is carried out by using different materials (steel/concrete). There are various option used in the design of the steel structure. The comparisons of the steel take off of the various sections are also carried out.

6. PARALLEL CONVEYOR TRANSFER TOWER STRUCTURE

6.1 GENERAL

The Parallel conveyor supporting system contains the two conveyor galleries and the conveyor galleries are arranged side by side/parallel and share the same floor level for the supporting system shown in Fig. 6.1. Similarly as double layer conveyor system the conveyor load is transferred from floor or floor beans to the supporting system.

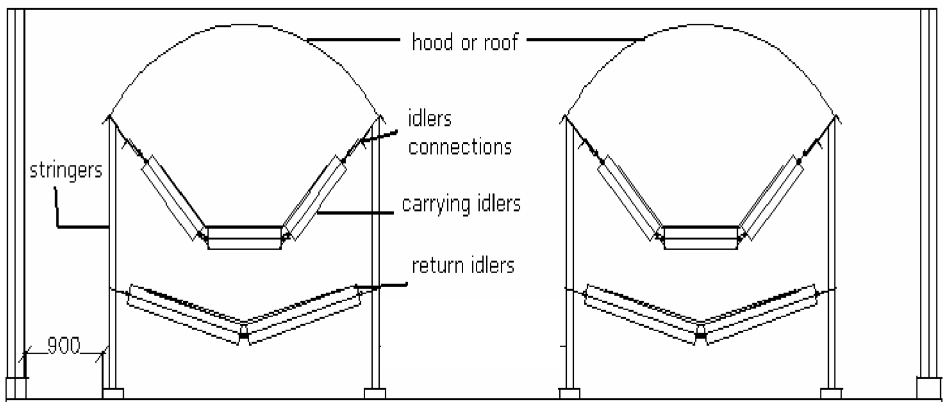


Fig. 6.1 Parallel Conveyor Systems

The conveyor systems are designed for: Parallel conveyor system

The framing is designed by using following alternative:

Sr. No.	COLUMNS	BEAMS
1	STEEL	STEEL
2	CONCRETE	CONCRETE
3	CONCRETE	STEEL

The modeling of the Parallel conveyor transfer tower structure is carried out in chapter 4. The structural drawings of the structure are attached in appendix C.

6.2 STEEL STRUCTURE

The Fig. 6.2 shows the full three dimensional view of the structure containing all the members as steel as material. The figure shows the elevation, side view and 3D view of the double layer conveyor system of the structure.

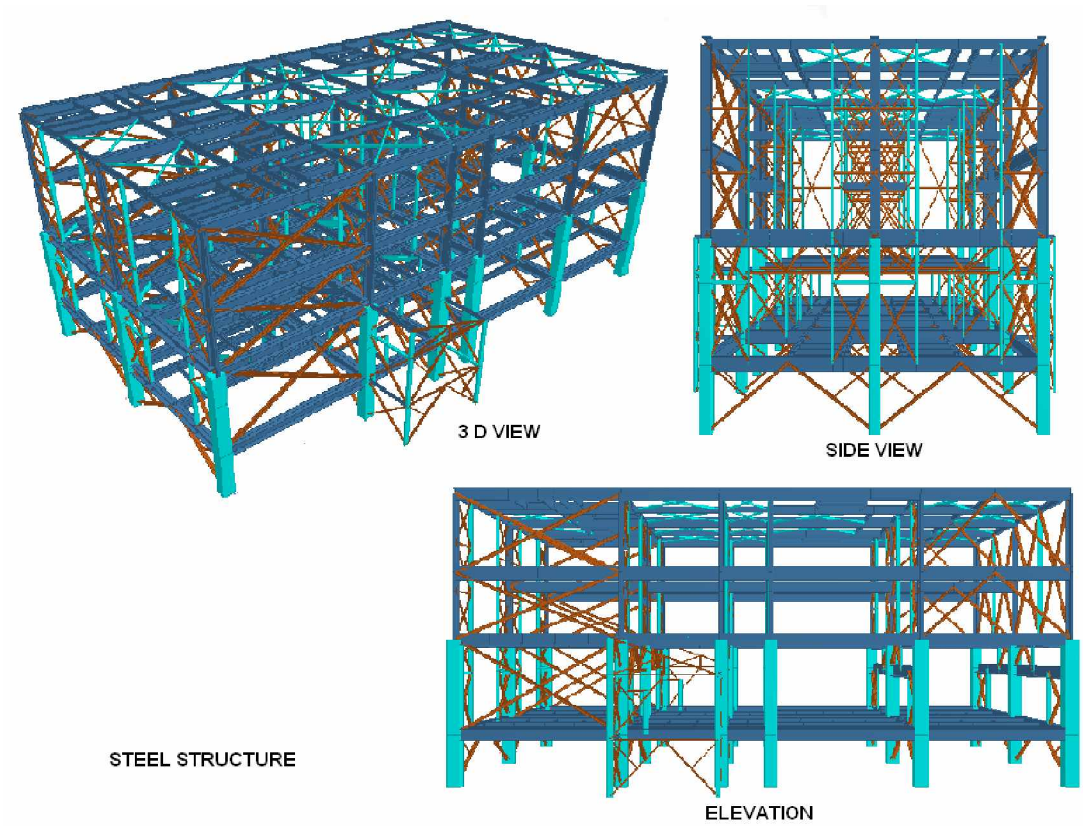


Fig. 6.2 Steel Structure

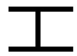
6.2.1 Member Properties of Structure

The assumed member properties of the structure are given in the Table 5.1 in chapter 5. The table contains the certain standard sections and certain built up sections for the structure.

6.2.2 Various Column Properties of Structure

Generally the standard sections are used as column members in the general structures, but here the loads transfers to the columns are very heavy therefore the standards sections are not satisfied. Because of heavy loads a typical built up section is used for column members. The properties of this built up sections are shown below in table.

(1) 2-ISMB 600 + Plate (750x16)

1.	C1		2 ISMB 600
			PLATE 750 X 16 mm
2.	C1A		ISMB 600

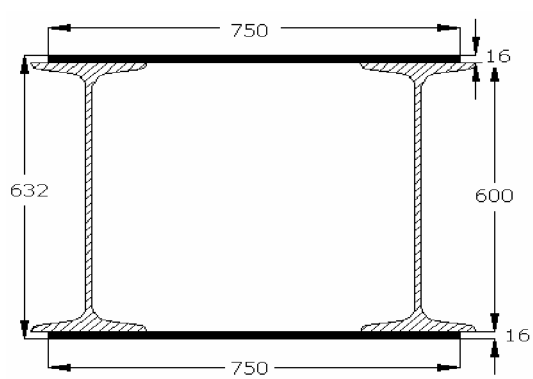
The cross section area of this section is approximately 552.42 cm^2

6.2.3 Result of the used Steel Section

The below section is used for the design of column. The table shows the c/s area of the section and steel take off of the structure using this section as column. The table also shows the deflections of the structure at boundary conditions (fixed and hinge) at levels where the conveyor is passing through structure. The permissible deflection of the structure at level 21.25 m is 8.450 mm.

1. 2ISMB 6OO + Plate (750x16)

The Fig. shows the built up section of 2-ISMB 600 + Plate (750 x 16). This built up section contains the 2-ISMB 600 and two plates (750 mm x 16 mm).



Area	552.42 cm2	
Deflection (mm)	FIXED SUPPORT	HINGE SUPPORT
21.25 m Lvl.	5.59	10.32
Steel Take off	4778.57 KN	

6.3 CONCRETE STRUCTURE

The Fig. 6.3 shows the full three dimensional view of the structure containing all the members as concrete as material. The Fig. shows the elevation, side view and 3D view of the double layer conveyor system of the structure. Here the levels of the floors in the structure are a constraint and the head room of the each floor is fixed. The loads comes to the load carrying members are very heavy therefore the sizes of the beam members will increase. It means the total height of the structure will increase, but the floor level is constraint, therefore it is not possible to get proper head room between the floors. For these reasons, these types of structures are not useful by using concrete as material.

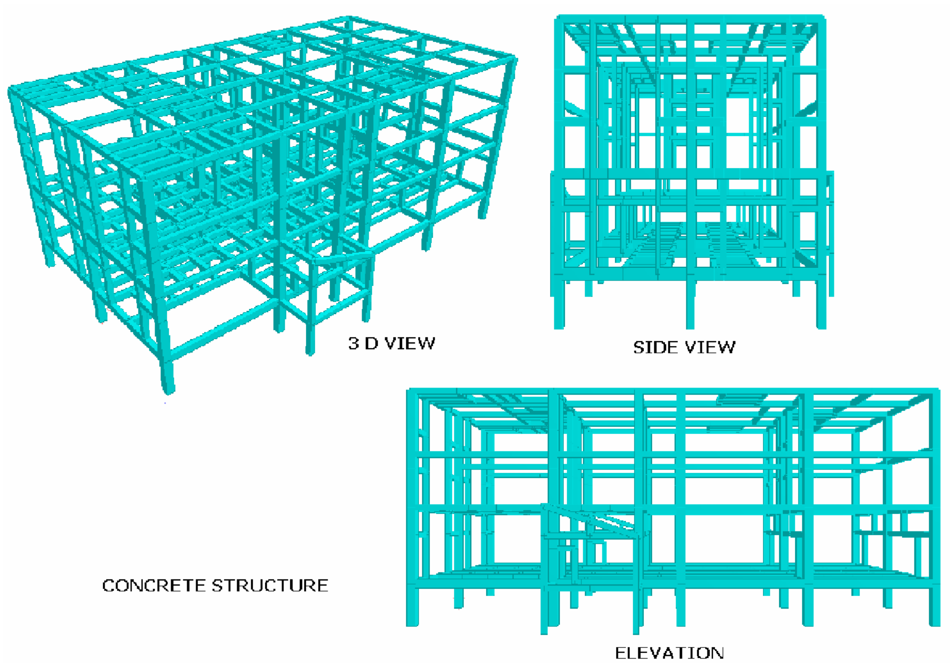


Fig 6.3 Concrete Structure

6.3.1 Member Properties of Structure

The assumed section properties of the members for the double layer conveyor system of the concrete structures are given below Table 6.1.

Table 6.1 Member Properties of Concrete Structure

SR NO.	MARK	SECTION
1.	C1	900 mm X 900 mm
2.	C2	450 mm X 600 mm
3.	B1	450 mm X 850 mm
4.	B2	450 mm X 600 mm

The column size is 900 mm x 900 mm is used for the main columns of the structure. The c/s area of this column section is 8100 cm2. The deflection of the Transfer tower structure at different boundary conditions (fixed conditions and hinge conditions) is shown below table at level where the conveyor is passing through structure.

Column	900 x 900 mm	
Area	8100 cm2	
Deflection (mm)	FIXED SUPPORT	HINGE SUPPORT
21.25 m Lvl.	9.01	15.12

6.3.2 Material Take Off Members

Total volume of concrete = 1138.38 m3

Total weight of steel = 660.61 kN

6.3.3 Limitations of the Concrete Structure

Generally this type of structures is constructed with using the steel as material. The certain limitations of the concrete Junction House structures are given in 5.3.3.

6.4 COMPOSITE STRUCTURE

The Fig. 6.4 shows the full three dimensional view of the structure containing all the column members as concrete and remaining all members are steel as material. The Fig. shows the elevation, side view and 3D view of the Parallel conveyor system of the structure.

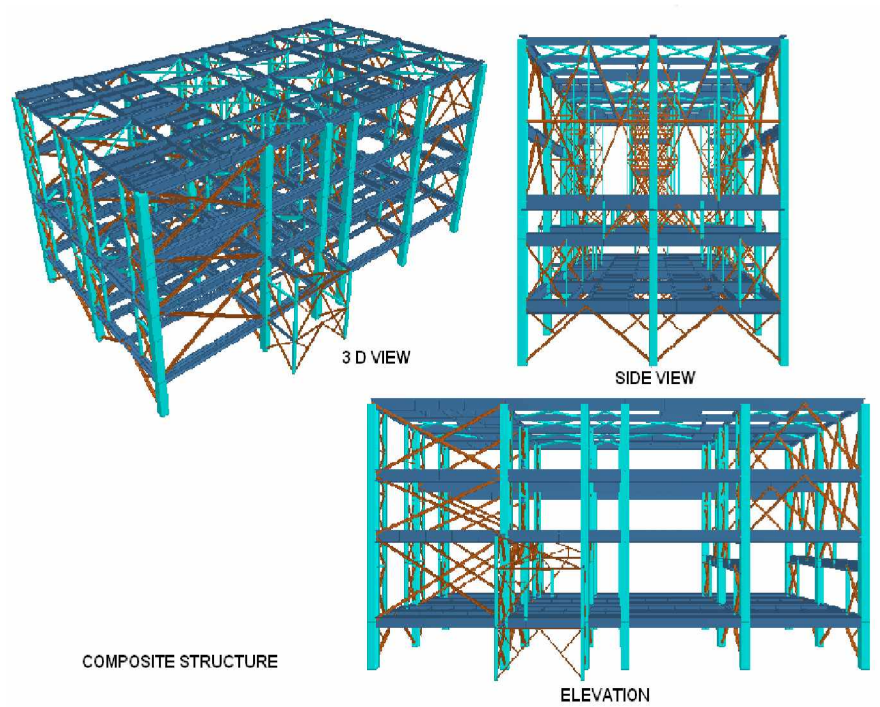


Fig. 6.4 Composite structure

The above Fig. shows the all members are steel remaining the main column members. The deflections of the Transfer tower structure at different boundary conditions (fixed conditions and hinge conditions) are shown below table at levels where the conveyor is passing through structure.

Column	1000 x 600 mm	
Area	6000 cm2	
Deflection (mm)	FIXED SUPPORT	HINGE SUPPORT
21.25 m Lvl.	7.50	15.4

6.4.1 Material Take Off Members

- MATERIAL TAKE OFF FOR CONCRETE MEMBERS

  Total volume of concrete = 120.49 m3

  Total weight of steel = 96.85 kN

- MATERIAL TAKE OFF FOR STEEL MEMBERS

  Total weight of steel = 2242.83 kN

6.5 ANALYSIS RESULTS

After the analysis of the structure the forces in each member is taken from the STAAD Pro. The column forces and the support reactions of structures are given below.

Column Forces

The orientations and no. of column are shown in Fig. 6.5. The column forces are shown in the Table 6.2.

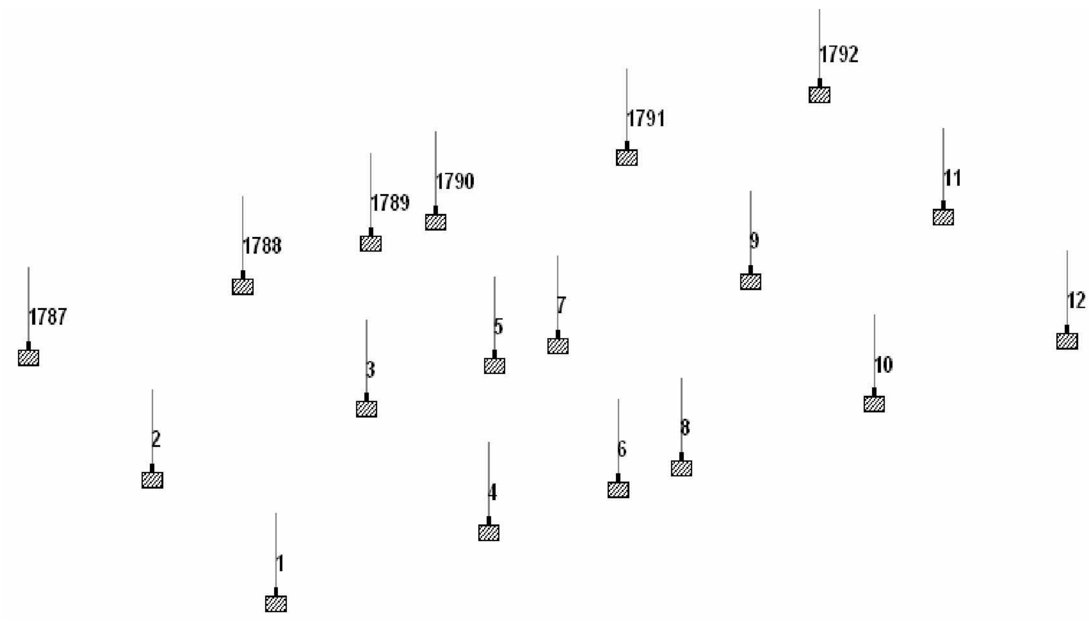


Fig. 6.5 Orientation and Column numbers in Parallel conveyor

Table 6.2 Column Forces in Parallel Conveyor Transfer tower

Beam	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1	1081.94	-41.68	169.04	0.00	-366.86	-133.86

2	1952.58	23.73	297.32	-0.00	-602.44	113.55
3	1952.71	66.69	340.65	0.00	-584.60	151.59
4	880.94	-99.84	235.37	-0.00	-385.64	-188.40
5	703.16	23.59	244.65	-0.00	-462.01	80.21
6	346.46	-40.05	153.60	-0.00	-288.77	-96.17
7	730.98	45.84	264.73	-0.00	-468.47	108.80
8	332.81	-58.32	150.54	-0.00	-278.47	-114.78
9	1210.14	124.78	209.59	-0.00	-404.87	267.12
10	715.09	-119.92	123.18	-0.00	-243.04	-263.85
11	679.66	74.51	127.09	0.00	-329.72	185.40
12	416.33	-65.16	86.70	-0.01	-207.58	-173.39
1787	1162.20	42.89	193.58	0.00	-416.84	145.52
1788	935.00	106.75	262.90	0.00	-435.51	210.37
1789	350.46	42.11	177.37	0.00	-331.47	109.46
1790	373.23	62.49	171.60	0.00	-317.56	134.91
1791	735.05	127.47	139.98	0.00	-276.53	290.90
1792	476.33	69.79	97.88	0.01	-235.34	193.76

Support Reaction

The orientation and node no. are shown in the Fig. 6.6. The support reaction results are shown in the Table 6.3.

Fig. 6.6 Node no. of support members in Parallel conveyor

Table 6.3 Support Reaction in Parallel Conveyor

Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1	180.85	1140.11	-212.91	-133.86	0.00	-366.86
3	320.94	2052.17	168.17	113.55	0.00	-602.44
4	340.65	2099.72	243.46	151.59	0.00	-584.60
6	235.37	971.06	-331.40	-188.40	0.00	-385.64
7	244.65	809.11	153.54	80.21	-0.00	-462.01
9	153.60	409.10	-178.57	-96.17	-0.00	-288.77
10	264.73	852.04	186.52	108.80	-0.00	-468.47
12	150.54	421.78	-219.67	-114.78	-0.00	-278.47
13	209.59	1365.94	455.61	267.12	-0.00	-404.87
15	123.18	854.64	-374.59	-263.85	-0.00	-243.04
16	150.70	774.06	314.51	185.40	-0.00	-329.72
18	98.51	506.63	-225.17	-173.39	-0.01	-207.58
852	205.39	1230.04	214.27	145.52	-0.00	-416.84
853	262.90	1047.22	348.40	210.37	0.00	-435.51
854	177.37	416.18	184.42	109.46	0.00	-331.47
855	171.6	467.77	230.76	134.91	0.00	-317.56
856	139.98	880.89	389.17	290.90	0.00	-276.53
857	109.68	572.35	237.56	193.76	0.01	-235.34

6.6 SUMMARY

This chapter presents the brief introduction of the Parallel conveyor transfer tower structure. The analysis and design is carried out with using steel and concrete as material. The analysis and design is also carried out composite structure with using concrete column and steel beams. The comparisons of the material take off are also carried out for the structures.

7. PILE FOUNDATION

7.1 GENERAL

If the good soil is available at a higher depth (more than 3 m) below the ground, pile foundations are economical. Piles transfer the loads from the column to the hard soil by bearing and to the surrounding soil by friction. In water logged areas and in grounds with filled up soils, piles can be advantageously used to provide safe foundations for any type of structure. Pile foundations can be used to support building columns, underground and overhead tanks, transmission towers carrying loads with large eccentricity, to support retaining walls, marine structures and many others. In general, pile foundations are adopted as a common solution for poor and problematic soils.

Pile foundations are the part of a structure used to carry and transfer the load of the structure to the bearing ground located at some depth below ground surface. The main components of the foundation are the Pile cap and the Piles. Piles are long and slender members which transfer the load to deeper soil or rock of high bearing capacity avoiding shallow soil of low bearing capacity. The main types of materials used for piles are Wood, steel and concrete. Piles made from these materials are driven, drilled or jacked into the ground and connected to pile caps. Depending upon type of soil, pile material and load transmitting characteristic piles are classified accordingly.

7.2 FUNCTION OF PILES

As with other types of foundations, the purpose of pile foundations is:

- To Transmit a foundation load to a solid ground
- To Resist vertical, lateral and uplift load

A structure can be founded on piles if the soil immediately beneath its base does not have adequate bearing capacity. If the results of site investigation show that the shallow soil is unstable and weak or if the magnitude of the estimated settlement is not acceptable a pile foundation may become considered. Further, a cost estimate may indicate that a pile foundation may be cheaper than any other compared ground improvement costs.

In the cases of heavy constructions, it is likely that the bearing capacity of the shallow soil will not be satisfactory, and the construction should be built on pile foundations. Piles can also be used in normal ground conditions to resist horizontal loads. Piles are a convenient method of foundation for works over water, such as jetties or bridge piers.

7.3 CLASSIFICATION OF PILES

Piles can be classified in the following ways:

- Ø On the basis of Material:
  - Timber
  - Steel
  - PCC
  - RCC
  - PSC
  - Composite
- Ø On the basis of Method of Construction:
  - Driven (displacement) precast piles
  - Driven (displacement) cast in situ piles
  - Bored (replacement) precast piles
  - Bored (replacement) cast in situ piles
- Ø On the Basis of Sectional Area:
  - Circular
  - Square
  - Tubular
  - Octagonal
  - H-section
- Ø On the Basis of Mode of Load Transfer:
  - End bearing piles
  - Friction piles
  - Bearing cum friction piles
- Ø On the Basis of Size of Piles:
  - Micro (Mini) Piles (<150 mm)
  - Small diameter piles (>150 mm, < 600mm)
  - Large diameter piles (>600 mm)

- On the Basis of Inclination of Piles:
  - Vertical piles
  - Raker (batter piles)

7.4 DRIVEN AND CAST IN SITU PILES

Driven Piles

Driven piles are considered to be Displacement piles. In the process of driving the pile into the ground, soil is moved radially as the pile shaft enters the ground. There may also be a component of movement of the soil in the vertical direction. The advantages and disadvantages of the driven-cast in situ piles are given below:

Advantages:

- Driving tube driven with closed end to exclude ground water.
- Length can easily be adjusted to suit varying level of bearing stratum.
- Formation of enlarged base does not destroy or reduce shaft skin friction.
- Enlarged base can be possible.
- Materials in pile not governed by handling or driving stresses
- Noise and vibration can be reduced in some types by driving with internal drop-hammer.

Disadvantages:

- Concrete in shaft liable to be defective in soft squeezing soils or in conditions of artesian water flow where withdraw able-tube types are used.
- Concrete cannot be inspected after installation.
- Length of some types limited by capacity of piling rig to pull out driving tube.
- Displacement may damage fresh concrete in adjacent piles, or lift these piles, or damage adjacent structure.
- Noise and vibration due to driving may be unacceptable.
- Can not be used in river or marine structures without special adaptation
- Can not be driven with very large diameters
- End enlargements are of limited size in dense or very stiff soils.

7.5 ANALYSIS AND DESIGN OF PILE FOUNDATION

7.5.1 Loads on pile groups

The pile groups carry the loads from the columns. Thus they are subjected to the axial loads, moments and horizontal loads. The pile cap is assumed to be rigid. This means that it may tilt under the action of loads and moments but will not bend. This assumption simplifies the calculation of loads on each pile. The loads are discussed as follows.

(a) Axial loads on a group of vertical piles

Let P be the axial load on the column and w be the self weight of the pile cap. The total load on the pile group is P + W. the column is placed on the symmetrically arranged pile group so that the load is axial on the pile foundation. As the pile cap is rigid it will transfer equal loads to each pile. If n is the number of piles, the load (axial force F) on each pile due to axial load

$$F_a = \frac{P+W}{n}$$

If the number of piles is decided, the load in each pile is found from the above equation. Conversely, if the capacity of the pile is given, number of symmetrically arranged piles can be determined.

(b) Moment on a group of vertical piles

The pile cap is assumed to be rigid which rotates about its centroidal axis under the action of the moment. Thus the piles located nearer to the centroidal axis have no significant effect of the moment whereas the piles located farther from the centroidal axis are more loaded due to moments. For symmetrically loaded pile group subjected to axial force and biaxial moment,

$$F_{\max} = \frac{P+W}{n} \pm \frac{Mx_n}{I_y} \pm \frac{My_n}{I_x}$$

P = axial loads on pile group,
W = self weight of pile cap,
M = moment on the pile group,
n = number of piles,
Ix & Iy = moment of inertia about x & y axis

(c) Horizontal load

The resistance to horizontal load from the column can be provided by friction, adhesion and passive pressure of surrounding soil. How ever in case of poor soil, it is necessary to see that the horizontal load is resisted by the piles. In cases of jetties and wharves, the piles are clear between deck and sea bed. Such piles must be designed to resist horizontal load.

(d) Design of a pile

The maximum axial loads in piles of a pile group from various applied loads for a selected arrangement of piles is determined by the calculation. The soil design of the pile consists of determining the diameter and length of the pile using soil properties of the site. Structurally the pile may be designed as a reinforced concrete column subjected to axial load, moment and shear. If the pile is adequately supported throughout by soil, the length of pile may be designed as short column.

7.5.2 Soil Bearing capacity for Pile foundation

The capacities of soil at Dahej for different depths are given in below Table 7.1. These capacities of soil are useful to find out the length of the piles.

Table 8.1 Capacity of Soil

Thickness of strata (m)	Description of strata	Notation	Capacity of soil (T)
0-2	Dark brown med. Dense fine sand	SP-SM	20
2-3	Dark brown dense fine silty sand	SM	20
3-5	Dark grey stiff med. plastic silt and clay	CI	20
5-7	Dark grey med. Dense fine silty sand	SM	30
7-8	Dark grey very stiff sandy clayey silt	CL	30
8-12	Dark grey very stiff med. Plastic silt and clay	CI	40
12-15	Brown very stiff plastic silt and clay	CH	40

15-19	Brown very stiff med. Plastic silt and clay	CI	60
19-21	Brown very stiff plastic silt and clay	CH	80

As the capacity of the pile is known therefore the length of the pile is calculated by the following formula.

$$Q_u = q_p \times A_p + f_s \times A_s$$

Q_u = Ultimate bearing capacity of pile

q_p = Bearing capacity of soil at depth L (9 x Cu)

f_s = Average unit skin friction (∞ x Cu)

A_s = Surface area of pile (π x d x L)

A_p = c/s area of pile (π/4 x d x d)

7.5.3 Structural Design of pile

For piles, minimum concrete grade shall preferably be M20. The concrete cover to the main reinforcement shall be not less than 50 mm. in case of aggressive environment; the larger cover may be adopted. Projected reinforcements at the top of the pile are required to have proper bonding with pile cap. In case of driven piles, the top concrete of pile shall be stripped for required bond length (the cast length of the pile is accordingly adjusted). The piles in a group are so adjusted that the centroid of the column section and that of pile group coincide. The minimum area of longitudinal reinforcement within the pile haft shall be 0.4 percent of the sectional area calculated on the basis of outside area of the casing of the shaft (bored piles).

Handling stresses:-

Piles have large lengths. They suffer handling stresses (pre cast driven piles) due to self-weight during positioning, lifting and erection the piles.

Main Reinforcement:-

The main reinforcement is designed for axial load, shear and moment as the case may be. The pile is considered as fixed at the base (good soil or rock) and at the top (rigid pile cap). Therefore, the effective length of the column may be considered as l_{ef} = 2/3 x l. The minimum are of longitudinal reinforcement within the pile shaft shall be 0.4 percent of the sectional area calculated on the basis of outside area of the casing of the shaft (bored piles). In case of driven piles, the minimum reinforcement is based on handling stresses which ultimately depends on the length of the pile.

Ties:-

The minimum lateral reinforcement shall be 0.2% of the gross volume of the pile with a spacing not exceeding b/2 where b is the minimum lateral dimension of the piles. The ties for end lengths of pile equal to 3b shall be reinforced by 0.6% of the gross volume. The spacing of ties from end length to the internal portion shall be gradually increased. If the pile is required to penetrate a hard strata the end lengths are additionally reinforced with reinforcement in the form of helix.

7.5.3 Pile cap

The pile caps may be designed by assuming that the load from column is dispersed at 45' from the top of the cap up to the mid-depth of the pile cap from the base of the column or pedestal. The reaction from piles may also be taken to be distributed at 45' from the edge of the pile up to the mid-depth of the pile cap. On his basis, the maximum bending moment and shear forces should be worked out at critical sections.

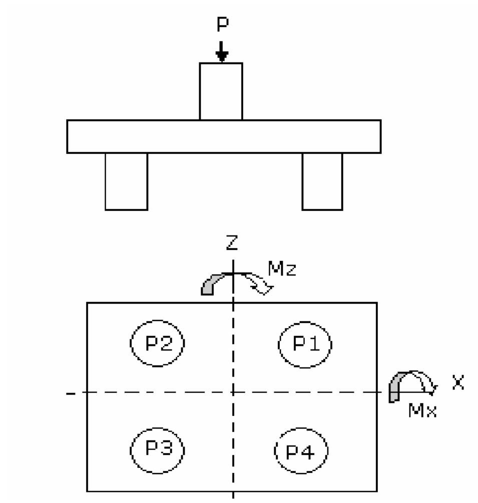


Fig. 7.1 Forces in Pile cap

The method of analysis and allowable stresses should be in accordance with IS: 456-2000. Unless a single pile is used, a cap is necessary to spread the vertical and horizontal loads and any overturning moments to all the piles in the group.

The cap is usually of reinforced concrete, poured on the ground unless the soil is expansive. Caps for offshore structures are often fabricated from steel shapes. The pile cap has a reaction that is a series of concentrated loads (the piles); and the design considers the column loads and moments, any soil overlying the cap (if it is below the ground surface), and the weight of the cap.

The assumptions for a conventional pile cap design are as follows:

1. Each pile carries an equal amount of the load for a concentric axial load on the cap; or for n piles carrying a total load Q, the load Pp per pile is

$$P_p = \frac{Q}{n} \qquad \text{..... (1)}$$

2. The combined stress equation (assuming a planar stress distribution) is valid for a pile cap non centrally loaded or loaded with a load *Q* and a moment, as

$$P_p = \frac{Q}{n} \pm \frac{M_y x}{\sum x^2} \pm \frac{M_x y}{\sum y^2} \qquad \text{..... (2)}$$

Where, Mx & My = moments about x and y axes, respectively

x, y = distances from y and x axes to any pile

$\sum x^2, \sum y^2$ = moment of inertia of the group, computed as

$$I = I_0 + Ad^2 \qquad \text{..... (3)}$$

But the moment of inertia of pile IQ is negligible, and the A term cancels, since it is pile load desired and appears in both numerator and denominator of Eq. (2). The assumption that each pile in a group carries an equal load may be nearly correct when the following criteria are all met:

1. The pile cap is in contact with the ground.
2. The piles are all vertical.
3. Load is applied at the center of the pile group.
4. The pile group is symmetrical and the cap is very thick (or rigid), usually about 1.8 to 2 m thick for plan dimensions of 2 to 3 m and depending on pile spacing.

In a practical case of a four-pile symmetrical group centrally loaded, each pile will carry one-fourth of the vertical load regardless of cap rigidity (or thickness). With a fifth pile directly under the load, cap rigidity will be a significant factor.
Pile cap shall be deep enough to allow for necessary anchorage of the column and pile reinforcement:

- The pile cap should normally be rigid enough so that the imposed load could be distributed on the piles in a group equitably.
- In case of a large cap, where differential settlement may be imposed between piles under the same cap, due consideration for the consequential moment should be given.
- The clear overhang of the pile cap beyond the outermost pile in the group shall normally be 100 to 150 mm, depending upon the pile size.
- The cap is generally cast over 75 mm thick leveling course of concrete. The clear cover for main reinf. in cap slab shall not be less than 60 mm.
- The pile should project 50 mm into the cap concrete.

7.5.4 Design of Pile foundation

7.5.4.1 Design of Pile cap

The design of pile foundation for the transfer tower structure is given below. The support reaction of the column members are given in the table below.

F_y (kN)	F_x (kN)	F_z (kN)	M_x (kNm)	M_z (kNm)
1184.00	205.00	-122.00	442.00	-1090.00

For the design of the pile cap the assumed properties are:

Thickness of Pile cap (t) = 0.70 m
Width of Pile cap (B) = 2.70 m
Length of pile cap (L) = 2.70 m
Diameter of Pile (D) = 0.60 m

The final forces of pile are given below.

Table 7.2 Pile forces

Pile No.	Final forces in pile
1	789 kN
2	104 kN
3	591 kN
4	-94 kN

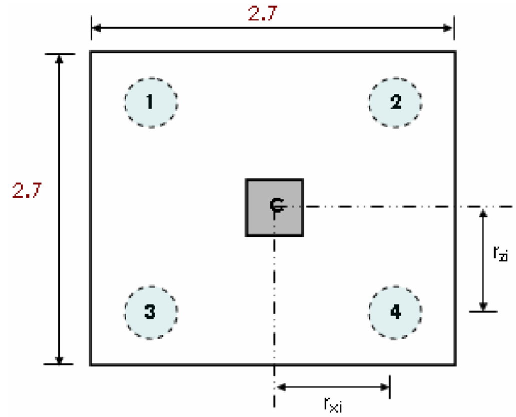


Fig. 7.2 Pile numbers

The detailed calculation of pile forces and the pile cap design is given in appendix C. The detailing of the pile cap design is shown in Fig. 7.3.

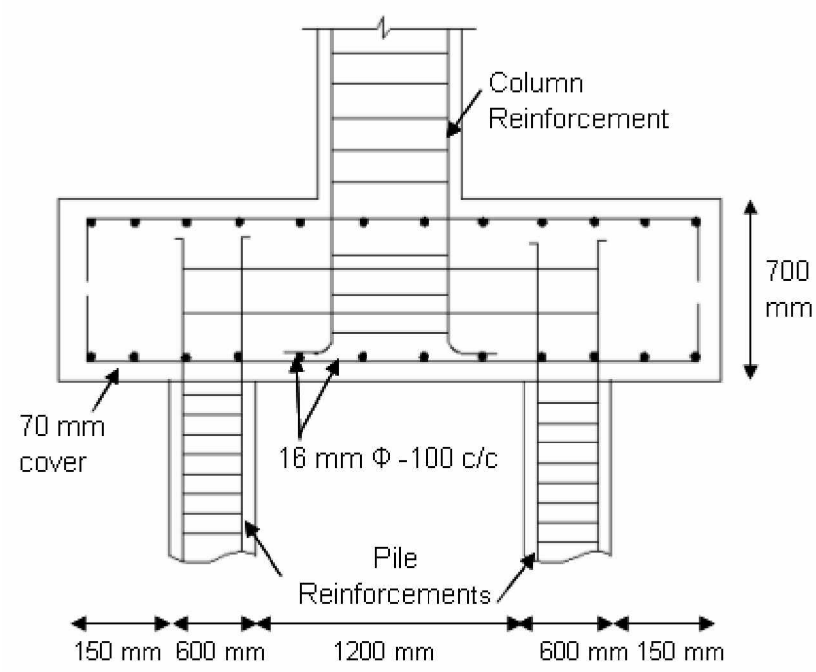


Fig. 7.3 Detailing of Pile cap Design

7.5.4.2 Design of Pile

The design of pile for the calculated pile forces are given below.

The forces and the parameters for circular pile design are given below.

Pile load (force in pile)	= 789 KN
Pile diameter	= 0.6 m
Pile length	= 21 m

Provided no of Piles = 4

The pile design is carried out as per the design sheet given in the appendix B. The design detailing of the pile is given below Fig.7.4.

Provided main steel = 10-25 mm Φ

Provided Lateral ties = 8 mm Φ 300 c/c

Top length (3D) = 8 mm 35 c/c (0.6% gross volume)

Bottom length (3D) = 8 mm 55 c/c (0.6% volume of ties)

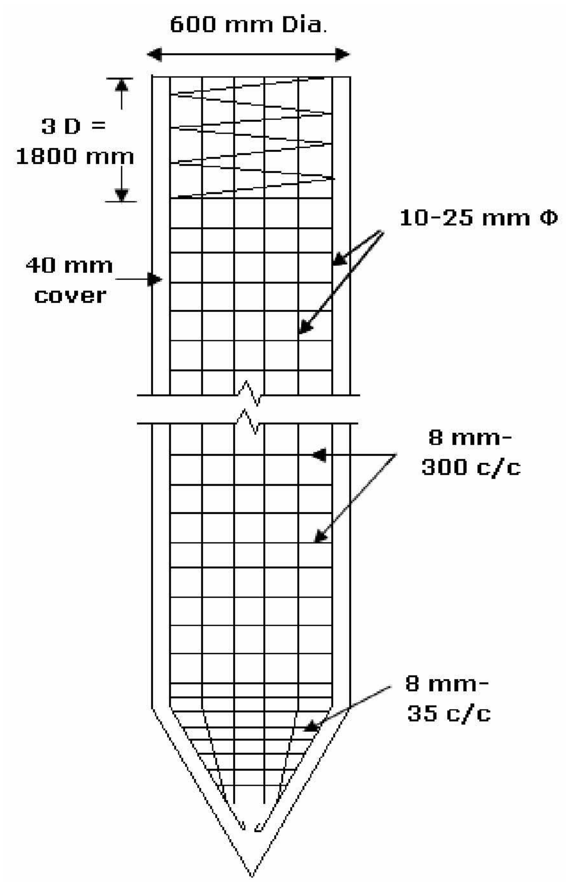


Fig. 7.4 Detailing of Pile Design

7.6 SUMMARY

This chapter presents the brief description about the pile foundation design. For the design of the pile foundation the group of pile is used. In this group of piles, four numbers of piles are used for design. The length of the pile is carried out from the capacity of the soil condition. The analysis and design of the pile cap and pile with detailing are given.

8.1 GENERAL

Steel sections are manufactured and shipped to some standard lengths, as governed by rolling, transportation and handling restrictions. However, most of the steel structural members used in structures have to span great lengths and enclose large three-dimensional spaces. Hence connections are necessary to synthesize such spatial structures from one-and two-dimensional elements and also to bring about stability of structures under different loads. Thus, connections are essential to create an integral steel structure using discrete linear and two-dimensional (plate) elements.

A structure is only as strong as its weakest link. Unless properly designed, the connections joining the members may be weaker than the members being joined. However, it is desirable to avoid connection failure before member failure for the following reasons:

- To achieve an economical design, usually it is important that the connections develop the full strength of the members.
- Usually connection failure is not as ductile as that of steel member failure. Hence it is desirable to avoid connection failure before the member failure.

Therefore, design of connections is an integral and important part of design of steel structures. They are also critical components of steel structures, since

- They have the potential for greater variability in behavior and strength,
- They are more complex to design than members, and
- They are usually the most vulnerable components, failure of which may lead to the failure of the whole structure.

Thus designing for adequacy in strength, stiffness and ductility of connections will ensure deflection control during service load and larger deflection and ductile failure under over-load. Hence, a good understanding of the behavior and design of joints and connections in steel structures is an important pre-requisite for any good design engineer. This chapter gives an overview of the design of connections in steel structures.

8.2 TYPES OF CONNECTIONS

Connections are normally made either by bolting or welding. Bolting is common in field connections, since it is simple and economical to make. Bolting is also regarded as being more appropriate in field connections from considerations of safety. However, welded connections which are easier to make, more efficient.

8.2.1 Bolted Connections

Two types of bolts are used in bolted connection. The most common type is bearing bolts in clearance holes, often referred to as ordinary bolts or black bolts. They are popular since they are economical, both in terms of material and installation costs. The force transfer mechanism under shear is as shown in Fig. 8.1 (*a*). The force is transferred by bearing between the plate and bolts at the bolt holes. The bolts experience single or double shear depending upon the plate configuration. The failure may be either by shearing of the bolts or bearing of the plate and the bolt.

The main disadvantage of bearing type of bolted connections is that the elements undergo some slip even under a small shear, before being able to transfer force by bearing. This is due to clearance between the bolts and the holes. Such a slip causes increased flexibility in the lower ranges of load and unexpected joint behavior in some situations. In such cases high strength friction grip (HSFG) bolts are used. In HSFG bolted joints, high strength bolts (8G or 10K grade) are pre-tensioned against the plates to be bolted together, so that contact pressure is developed between the plates being joined Fig. 8.1 (*b*). When external shear force is applied, the frictional resistance to slip between the plates prevents their relative slip. These bolted joints achieve higher stiffness in shear because of frictional resistance between the contact surfaces. Only when the externally applied force exceeds the frictional resistance between the plates, the plates slip and the bolts bear against the bolt holes. Thus even after slip, there is a reserve strength due to bearing.

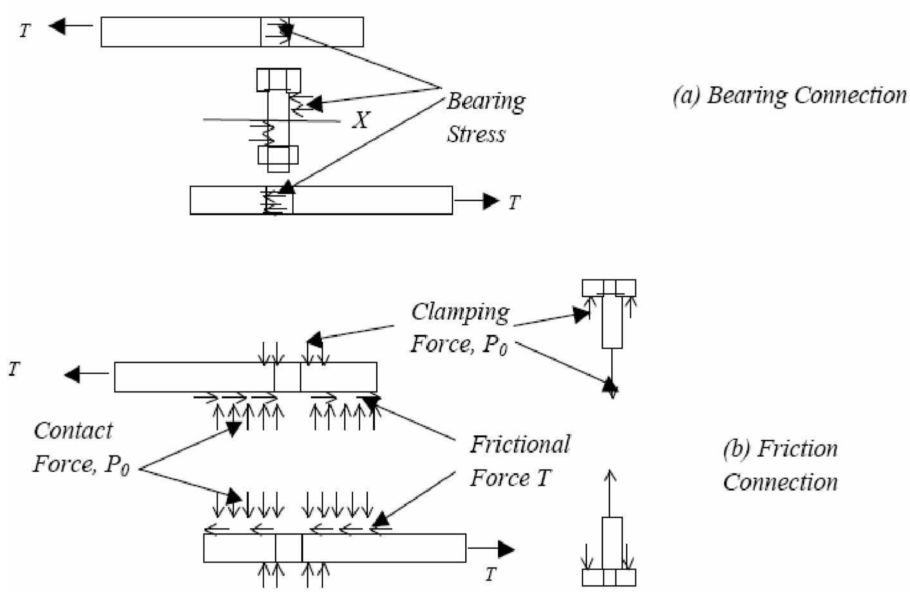


Fig. 8.1 Bolt shear transfer mechanism

The HSFG bolts are expensive both from material and installation points of view. They require skilled labour and effective supervision. Due to their efficient force transfer mechanism they have become very popular recently. Moreover, their performance is superior under cyclic loading compared to other forms of jointing.

8.2.2 Riveted Connections

Riveted joints are very rare in modern steel construction practice. The behavior and design of riveted connections are very similar to bearing type of bolted constructions. Since structural rivets are driven hot, the rivet shank expands to fill the hole while being driven. Hence, while calculating rivet strength, the hole diameter and not the nominal rivet diameter is used. Due to this, the slip in riveted joints is less than in bearing type of bolted joint. Further, in the process of cooling, the rivet shank length reduces, thereby causing some clamping force, as in HSFG. Riveting has been traditionally limited to railway bridges in India.

However, with the introduction of HSFG bolts, which are better suited under cyclic loading than rivets, their use is discontinued even in railway bridges in most countries.

8.2.3 Welded Connections

Welded connections are direct and efficient means of transferring forces from one member to the adjacent member. Welded connections are generally made by melting base metal from parts to be joined with weld metal, which upon cooling form the connection. The welded connections in a majority of the cases may be categorized as fillet weld or butt (or groove) welds as shown in Fig.8.2.

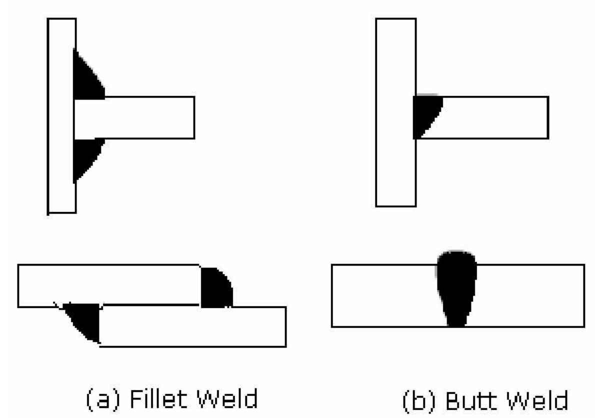


Fig. 8.2 Typical Welded Connections

8.2.3.1 Fillet welds

The fillet weld is done for members which overlap each other. For such joints the critical stress is shear stress. They are also subjected to direst stresses but these are not much importance. To all external appearances, the concave fillet weld seems to be larger than the convex weld.

Following terms are used while designing a fillet weld as follows:

(1) size of filet weld:

The minimum size of the fillet weld should not be less than the values given in the below Table 8.1.

Table 8.1 Minimum size of fillet weld

Thickness of thicker part	Minimum Size
Up to and including 10 mm	3 mm
Over 10mm up to and including 20 mm	5 mm
Over 10mm up to and including 20 mm	6 mm
Over 10mm up to and including 20 mm	8 mm first run 10 mm minimum

(2) Throat of fillet weld:

The effective thickness of throat is calculate as,

Throat thickness = K x fillet size

(3) Effective length of fillet weld:

The effective length of a fillet weld is equal to its overall length minus twice the weld size. The effective length of a fillet weld designed to transmit loading should not be less than four times weld size.

(4) Permissible stress and strength of fillet weld:

The fillet welds are designed for the shear stress at the minimum section, i.e. the throat of the weld. The permissible shear stress in the fillet weld is 108 Mpa. The shear strength of a fillet weld is given by the following equation:

$$P = P_q \times L \times t$$

Where,

P = strength of the joint

P_q = permissible stress

L = effective length

t = throat thickness = K x s

K = constant

s = weld size

The permissible stresses in shear and tension are reduced to 80% for field welds made during erection. The permissible stresses are increased by 25% if the wind or earthquake loads are taken into account. However, the size of the weld should not be less than the size required when the wind or earthquake load is considered or neglected. The merits and demerits of the fillet welds are given below.

The merits of the fillet welds are:

- No prior edge preparation is necessary,
- Simple, fast and economical to make, and
- Does not require very skilled labors.

The demerits of fillet welds are:

- Not appropriate to transfer forces large in magnitude,
- Poorer performance under fatigue loading, and
- Less attractive in appearance.

8.3.2.2 Butt welds

The strength of a butt weld is taken equal to the strength of parts joined if full penetration of the weld metal is ensured. A complete penetration of the weld metal can be ensured in the case of double-V, double-U, double-J and double-bevel joint. In the case of single-V, -U, -J and bevel joints, the penetration of the weld metal is generally incomplete and effective throat thickness is taken as (5/8) x thickness of thinner part connected. The change in thickness while joining unequally thick plates should be gradual. A tapper not exceeding 1 in 5 is provided when the difference in thickness of the parts exceeds 25% of the thickness of the thinner pare or 3 mm, whichever is greater. The merits and demerits of the butt welds are given below.

The merits of butt welds are:

- Easily designed and fabricated to be as strong as the member,
- Better fatigue characteristics, compared to fillet welds,
- Better appearance, compared to fillet welds, and
- Easy to detail and the length of the connection is considerably reduced.

The demerits of the butt welds are:

- More expensive than fillet welds because of edge preparation required,
- Require more skilled manpower, than that required for fillet welds.

8.3 MOMENT RESISTING CONNECTIONS

Connections which are designed to transmit end moments in addition to the end shears are called moment connections. Following may be the cases where consideration has to be given to the end moments:

A. The end reactions of the beam are eccentric, giving to end moments,
B. Girders subjected to wind forces in multistory buildings.

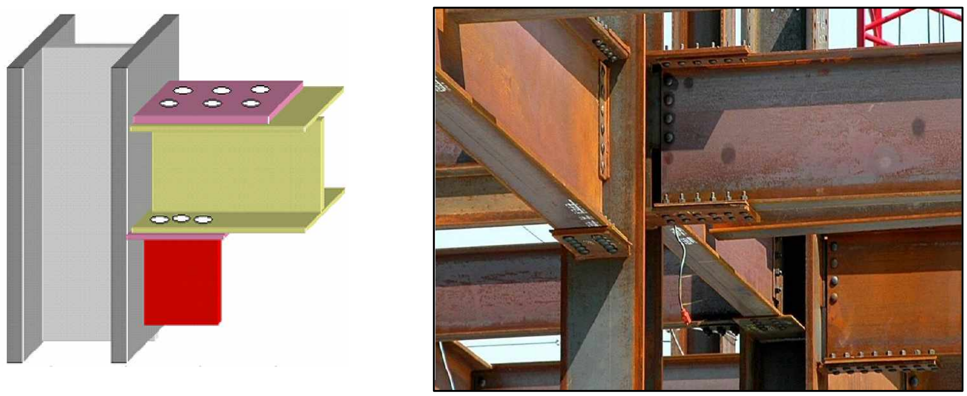


Fig 8.3 Moment Connections

Connections designed to resist the end moments should be able to develop that moment of resistance. Such connections are also termed as rigid connections. These do not permit any relative rotation between the beam and the column.

There are two types of moment connections are permitted:

1. Fully restrained (FR) connections
   - Have sufficient strength to transfer moments with negligible rotation between connected members,
   - The angle between connected members is maintained,

2. Partially restrained (PR) connections
   - Have sufficient strength to transfer moments, but the rotation between connected members is not negligible,
   - The angle between connected members may change,

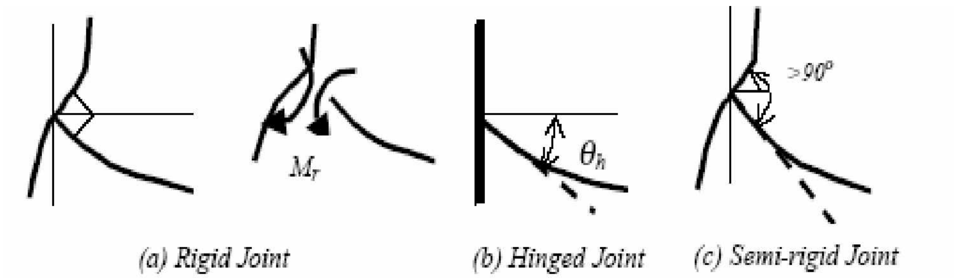


Fig. 8.4 Types of beam to column joints

Moment resisting connections between beams and columns in multistoried buildings are very common. These connections may be made using bolting or welding. Depending upon the type of joining method and elements used to make the joint, the flexibility of the joint may vary from hinged to rigid joint condition. The moment at the joint M may vary between rigid joint moments, M_r Fig. 8.4 (a), and zero value Fig. 8.4 (b) and the relative rotation between members at the joint, θ, may vary between zero Fig. 8.4 (a) and hinged joint rotation, θ_h Fig. 8.74 (b). In practice the joints are neither ideally hinged nor ideally rigid. In fact all the joints exhibit some relative rotation between members being joined Fig. 8.4(c).

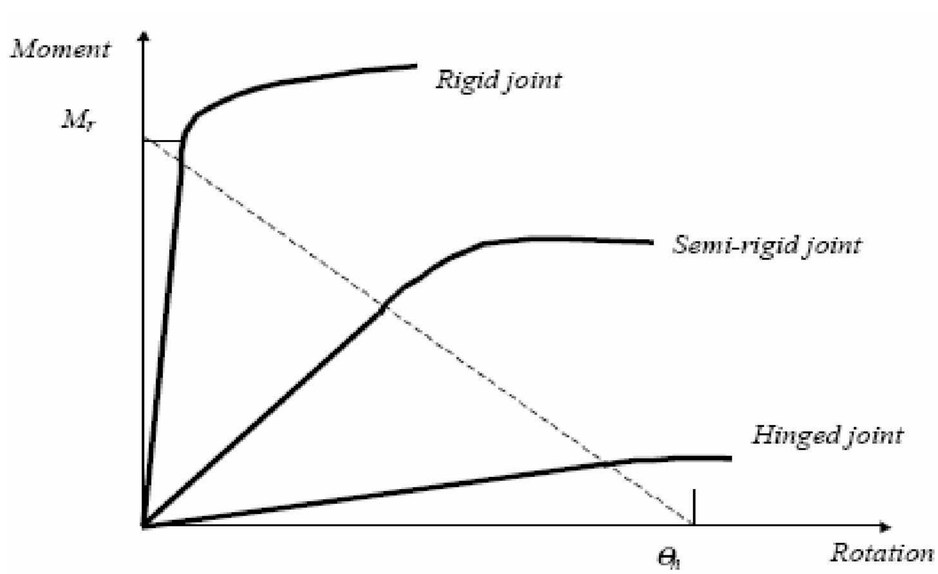


Fig. 8.5 Moment versus joint rotation

This is due to the deformation of elements in the joint. The moment versus relative joint rotation of different types of connections is shown in Fig. 8.5. Any joint developing more than 90% of the ideal rigid joint moment is classified as rigid and similarly any joint exhibiting less than 10% of the ideal rigid joint moment is classified as hinged joint; and the joint developing moments and rotations in between are referred as semi-rigid. Based on test results and theoretical studies, moment rotation relationship for different standard connections exhibiting semi-rigid behavior has been presented in literature.

8.3.1 Design of moment resisting connection

Moment resisting connections is provided where the value of the moment is higher. Here the results of forces of the beam section are taken from STAAD Pro.

The end reaction = 80 KN

Bending moment = 360 KN

The relevant properties of the sections are given below,

Beam: B4

Column: B – 900 mm x 900 mm

Table 8.2 Properties of sections

Properties	B4 (Beam)	B (Col.)
D (Depth of section)	700 mm	900 mm
B (Width of flange)	500 mm	600 mm
t_f (Thickness of flange)	32 mm	28 mm
t_w (Thickness of web)	16 mm	16 mm

The design results of connections are given below. The design sheet of the moment resisting connection is attached in Appendix B.

Provided top plate = 500 mm x 10 mm
(10 mm fillet weld)

Design seat angle = 200 mm x 20 mm x 12 mm
(10 mm fillet weld)

Provided stiffener plates = 200 mm x 10 mm (four numbers)
(10 mm Butt weld)

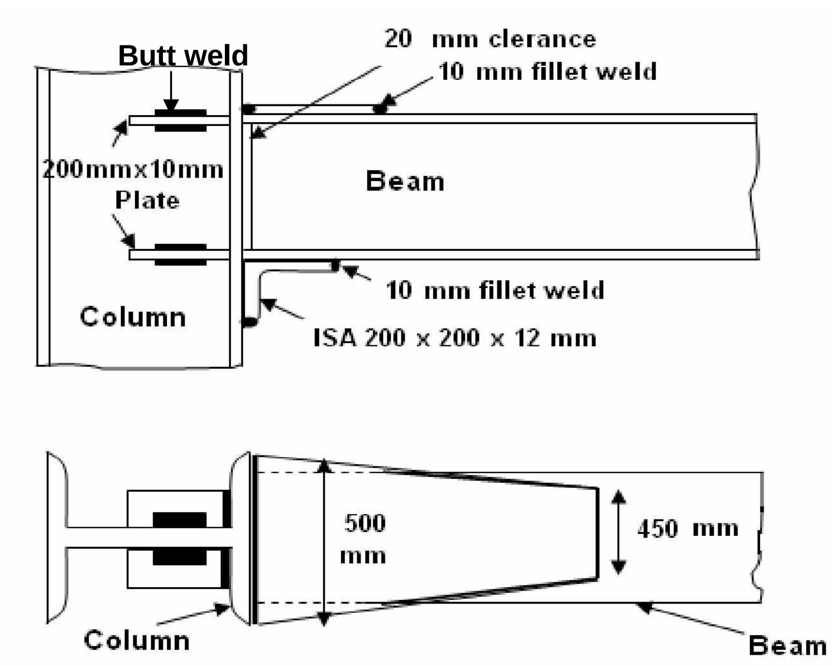


Figure 8.6 Detailing of moment connection

8.4 SUMMARY

This chapter presents the brief description about the connection design. The design of connections is an integral and important part of steel structures. Generally in an industrial structure welded connections are used. In this structure the moment resisting connections are used. Therefore the sample design calculation of the moment resisting connection is carried out with detailing.

9. SUMMARY AND FUTURE LINE OF ACTIONS

9.1 GENERAL

Junction house is acted upon by different loads like wind load, earthquake load, conveyor load, equipment load, construction load etc. The structure is analyzed for different types of loads. Moreover it is checked for the deflection to be within its permissible limit. It shall be designed for economy, safety and functional requirements of the process.

9.2 COMPARISON OF THE STRUCTURE

The cost comparison is carried out for the double and parallel conveyor transfer tower system with using the steel/concrete as material.

9.2.1 Comparison of Steel Structure

The Table 9.1 shows the take off of the double and parallel conveyor transfer tower structures. The Fig. 9.1 shows the weight comparison of the steel structures.

Table 9.1 Quantification Steel structures

STEEL STRUCTURE	WEIGHT (kN)
Double	4811.73
Parallel	4778.57

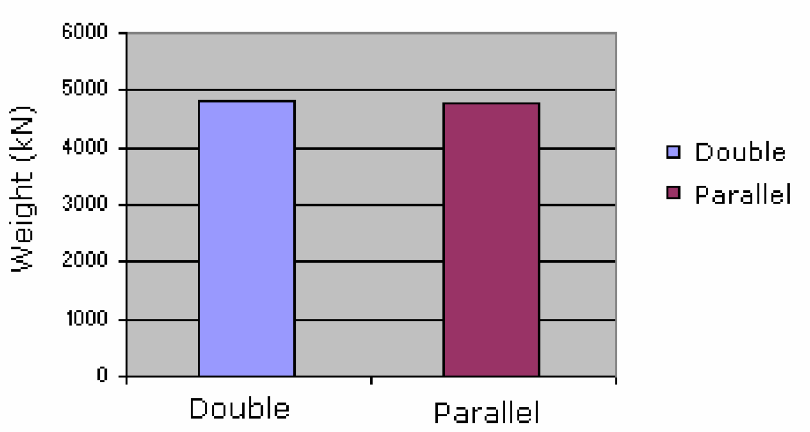


Fig. 9.1 Weight comparison of the steel structures

9.2.2 Comparison of the Concrete Structure

The Table 9.2 shows the concrete volume and steel take off of the double and parallel conveyor transfer tower structures. The Fig. 9.2 shows the comparison of the concrete structures.

Table 9.2 Quantification of concrete structures

CONCRETE STRUCTURE	CONC. (m^3)	STEEL (kN)
Double	880.41	535.15
Parallel	1138.38	660.61

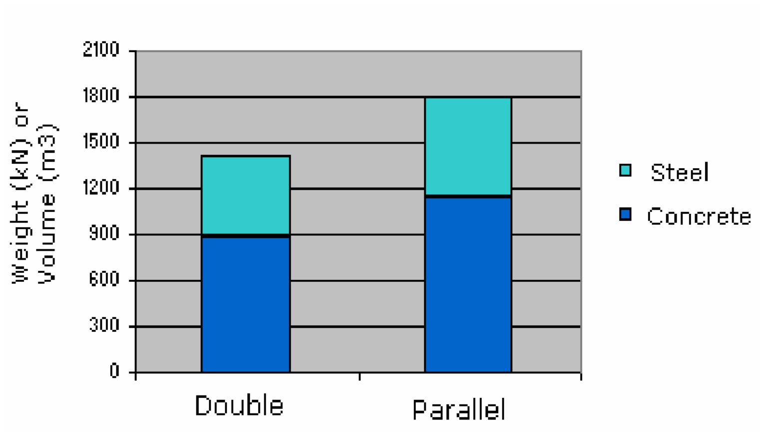


Fig. 9.2 Volume and weight comparison of concrete structures

9.2.3 Comparison of the Composite Structure

The Table 9.3 shows the concrete volume and steel take off of the double and parallel conveyor transfer tower structures. The Fig. 9.3 shows the comparison of the composite structures.

Table 9.3 Quantification of composite structures

COMPOSITE STRUCTURE	CONCRETE (m^3)	STEEL (kN) (Reinf. +members)
Double	156.62	3377.48
Parallel	120.49	2339.68

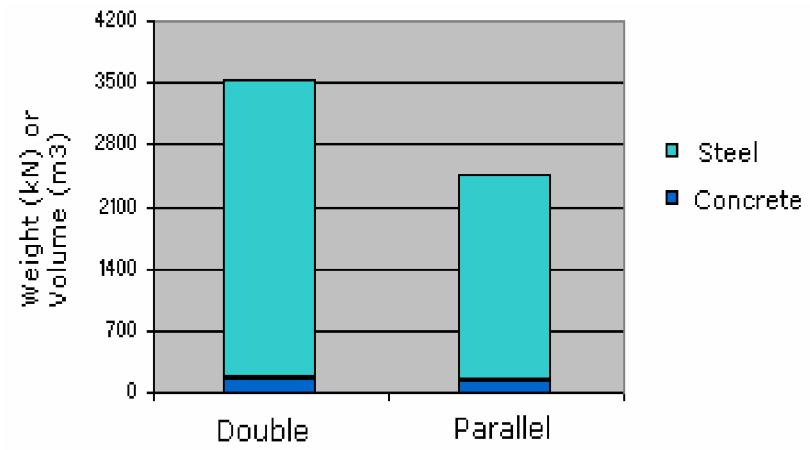


Fig. 9.3 volume and weight comparison of composite structures

9.2.4 Cost comparison of the Structures

The cost comparison of the double and parallel conveyor transfer tower structure with using the material as steel and concrete is shown in figure 9.4.

For the comparative study the rate of steel and concrete is taken as 40 Rs/kg and 3500 Rs/m3 accordingly.

Table 9.4 Cost comparison of structures

TYPE	COST IN Lakhs		
	STEEL	CONCRETE	COMPOSITE
Double	192.46	52.22	140.58
Parallel	191.14	66.26	97.80

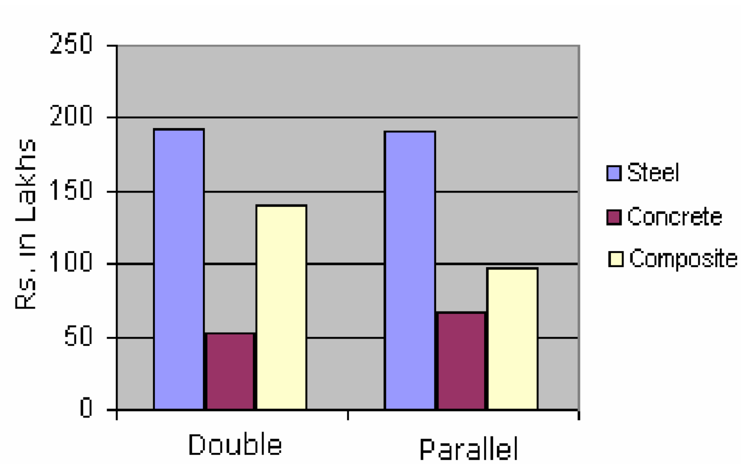


Fig. 9.4 Cost comparison of Structure

9.3 CONCLUSION

- The junction house is analyzed with the assumed sectional properties of members and it is designed in STAAD-Pro. All members have passed the design checks in STAAD-Pro.
- The DL+LL+WL combination is governing the design of major members, compared to DL+LL and DL+0.5 LL+EQ
- The concrete Transfer Tower is proved to be economical than steel and composite Transfer Tower, but steel is chosen for its durability and easy fabrication. Moreover steel Transfer Tower can be easily extended in future for its expansion.
- For the concrete tower of the same level as that of steel tower, the c/s of members is more and because of more headroom the weight and the space of the structure is also more and hence unfeasible.

9.4 FUTURE LINE OF ACTION FOR MAJOR PROJECT

The analysis and design of Transfer tower structure can be carried out by considering another orientation and geometry.

This structure can be analysed and designed by Multi layer conveyor galleries using different materials (Steel/Concrete).

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APPENDIX – A

List of Useful Websites

- www.conveyorchain.com
- www.cemanet.org
- www.hic-india.com
- www.ise.ncsu.eduwww.bandt.com
- www.martin-eng.com
- www.interroll.com
- www.pro-belt.comwww.tranterphe.com
- www.gujaratdirectiory.com
- www.kamandirect.com
- www.hasler-int.com
- WWW.KWSMFG.COM
- www.armax-conveyors.co.uk
- www.inventorypos.com
- www.conceptengineer.com
- www.sbe.napier.ac.uk/projects/piledesign/guide/index.htm

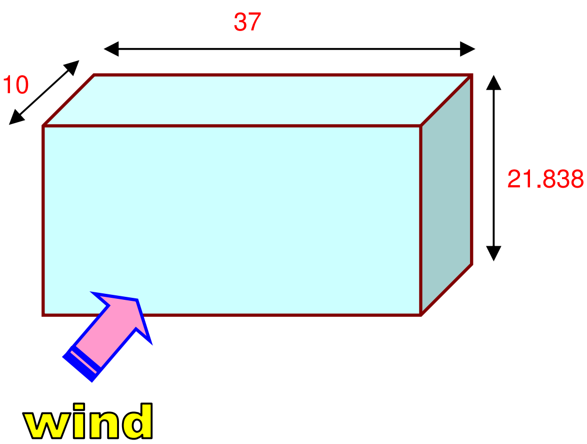
APPENDIX – B

Design sheets

- Ø Calculation of Wind Loads for Double layer conveyor system
- Ø Calculation of Wind loads for Parallel conveyor system
- Ø Design of Column
- Ø Design of Pile cap
- Ø Design of Pile
- Ø Design of Moment resisting connection

WIND LOAD CALCULATION FOR DOUBLE LAYER CONVEYOR STRUCTURE

Design pressure on wall



wind zone	**Vb**	**44**
Risk coefficient	**K1**	**1.07**
Terrain, Height and		
Structure size factor	**category**	**2**
	class	**3**
	K2	1
Topography factor	**K3**	**1**
design wind speed	**Vz**	**47.08**

height	**h**	21.838
width	**w**	10
length	**l**	37
	h/w	2.1838
	l/w	3.7

Permeability cpi **0.5**

External pressure ciefficients (cpe) for walls or rectangular cladding building
from Table 4, IS 875

Angle	A	B	C	D
0	0.7	-0.4	-0.7	-0.7
90	-0.5	-0.5	0.8	-0.1

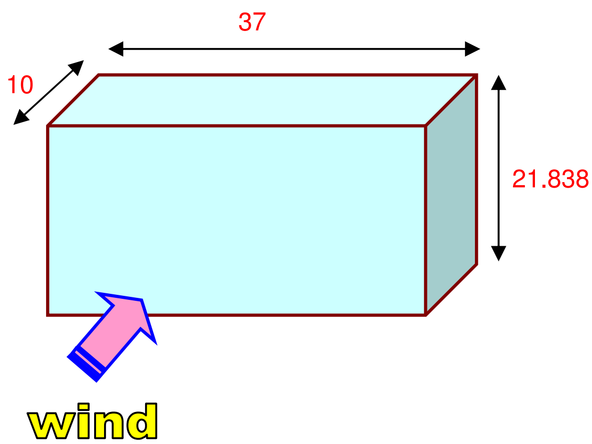
wind angle	cpi	(cpe - cpi) for surface			
		A	**B**	**C**	**D**
0	0.5	0.2	-0.9	-1.2	-1.2
	-0.5	1.2	0.1	-0.2	-0.2
90	0.5	-1	-1	0.3	0.4
	-0.5	0	0	1.3	0.4

		A	**B**	**C**	**D**
(cpe-cpi)	**max**	1.2	0.1	1.3	0.4
	min	-1	-1	-1.2	-1.2

Design wind pressure	**Pz (wind)**	1595.899	N/m2
0.6 Vz2	**Pz (lee)**	-1329.916	N/m2
Design force	**F (wind)**	1289.496	KN
	F (lee)	-1074.58	KN

WIND LOAD CALCULATION FOR DOUBLE LAYER CONVEYOR STRUCTURE

Design pressure on wall



wind zone	**Vb**	**44**
Risk coefficient	**K1**	**1.07**
Terrain, Height and Structure size factor	**category**	**2**
	class	**3**
	K2	1
Topography factor	**K3**	**1**
design wind speed	**Vz**	**47.08**

height	**h**	21.838
width	**w**	10
length	**l**	37
	h/w	2.1838
	l/w	3.7

Permeability cpi **0.5**

External pressure ciefficients (cpe) for walls or rectangular cladding building from Table 4, IS 875

Angle	A	B	C	D
0	0.7	-0.4	-0.7	-0.7
90	-0.5	-0.5	0.8	-0.1

wind angle	cpi	(cpe - cpi) for surface			
		A	**B**	**C**	**D**
0	0.5	0.2	-0.9	-1.2	-1.2
	-0.5	1.2	0.1	-0.2	-0.2
90	0.5	-1	-1	0.3	0.4
	-0.5	0	0	1.3	0.4

		A	B	C	D
(cpe-cpi)	**max**	1.2	0.1	1.3	0.4
	min	-1	-1	-1.2	-1.2

Design wind pressure	**Pz (wind)**	1595.899	N/m2
0.6 Vz2	**Pz (lee)**	-1329.916	N/m2
Design force	**F (wind)**	1289.496	KN
	F (lee)	-1074.58	KN

Design of Column

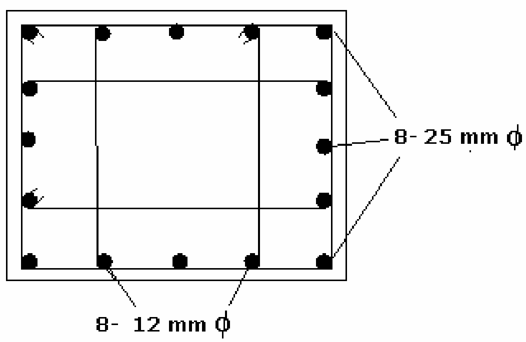
DESCRIPTION		RESULT					
Column as a compression member subjected to biaxial bending moment							
Max moment							
Column size							
Depth-y		**0.700**	m				
Depth-x		**0.700**	m				
Concrete grade	**fck**	**30**	N/mm^2				
Steel grade	**fy**	**415**	N/mm^2				
Axial force		**113.600**	T				
Torsion		**0.000**	T-m				
Moment -x		**44.200**	T-m				
Moment -y		**109.000**	T-m				
Equivalent moment Mx		44.200	T-m				
Equivalent moment My		109.000	T-m				
d'		**0.054**	m				
Design Forces							
Axial load Pu		**113.600**	**T**	Gross Area	**Ag**	490000	mm^2
Moment @ x- axis Mux		**44.200**	**T-m**	Area of steel	**As**	5880	mm^2
Moment @ y- axis Muy		**109.000**	**T-m**	Area of concrete	**Ac**	484120	mm^2
					Puz	8365770	N
UNIAXIAL MOMENT CAPACITY OF THE SECTION @ X-X AXIS							
Pu / Fck*b*D		0.077					
Assumed % of steel		**1.200**					
p/Fck		0.040					
d' / D		0.077					
Mu / Fck*b*D^2		**0.080**		(Refer chart-44,page-129, SP-16)			
Muxl		82.320	T-m				

UNIAXIAL MOMENT CAPACITY OF THE SECTION @ Y-Y AXIS

Pu / Fck*b*D	0.077		
Assumed % of steel	1.200		
p/Fck	0.040		
d' / D	0.077		
Mu / Fck*b*D^2	**0.080**		(Refer chart-44,page-129, SP-16)
Muyl	82.320	T-m	
Puz /Ag	17.07	N/mm^2	
Puz = Fac. * D-x * D-y/1000	836.577	T	
Pu / Puz	0.136		
Mux / Muxl	0.537		
Muy / Muyl	1.324		
αn	1.000		
$(Mux / Muxl)^{\alpha n}$ + $(Muy / Muyl)^{\alpha n}$	**1.861**	**Revise**	

$$\left(\frac{M_{ux}}{M_{ux1}}\right)^{\alpha n} + \left(\frac{M_{uy}}{M_{uy1}}\right)^{\alpha n} \leq 1.0$$

Detailing of Column



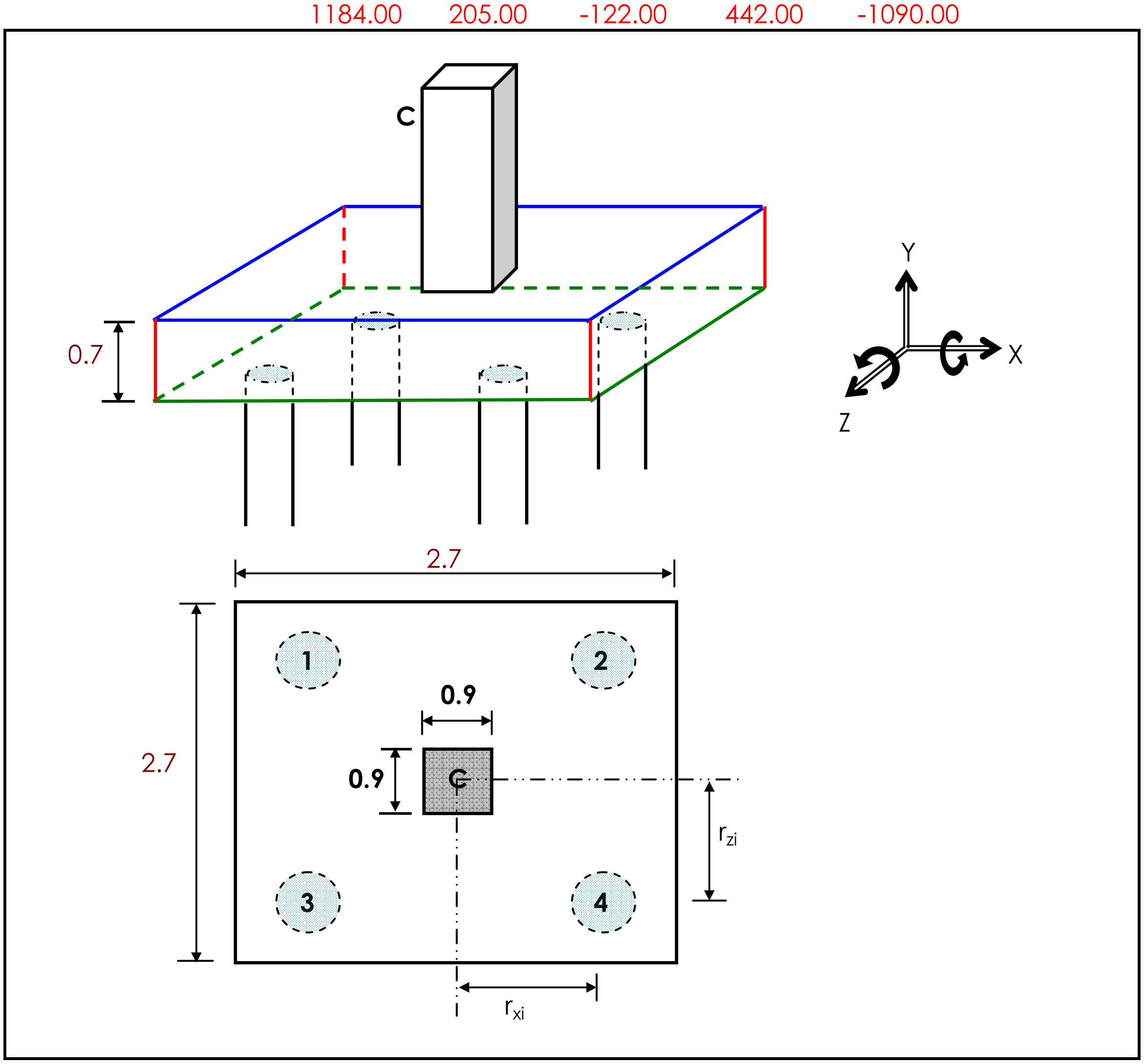
Area of steel required		5880	mm^2
Reinforcement provided	**4**	**nos**	**20**
	8	**nos**	**25**
	4	**nos**	**20**
Area of steel provided	**64.40**	cm^2	**O.K.**

REACTIONS FOR 4 PILES WITH A SINGLE COLUMN

THICKNESS OF PILECAP (T)	= 0.70	m
CLEAR COVER	= 0.075	m
WIDTH OF PILECAP (B)	= 2.70	m
LENGTH OF PILECAP (L)	= 2.70	m
WIDTH OF COLUMN (b)	= 0.90	m
DEPTH OF COLUMN (d)	= 0.90	m
f_{ck} FOR PILECAP	= 25	Mpa
f_y FOR PILECAP	= 415	Mpa
THICKNESS OF SOIL LAYER ABOVE PILECAP	= 0.60	m
UNIT WEIGHT OF SOIL ABOVE PILECAP	= 18.00	kN/m^3
CLEAR CANTILEVER FROM PILE	= 0.15	m
DIAMETER OF PILES	= 0.60	m

UNFACTORED REACTIONS AT COLUMN BASE

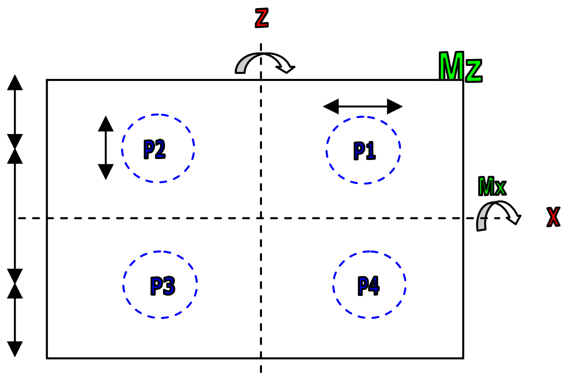
COLUMN	F_y (kN)	F_x (kN)	F_z (kN)	M_x (kN.m)	M_z (kN.m)
	1184.00	205.00	-122.00	442.00	-1090.00

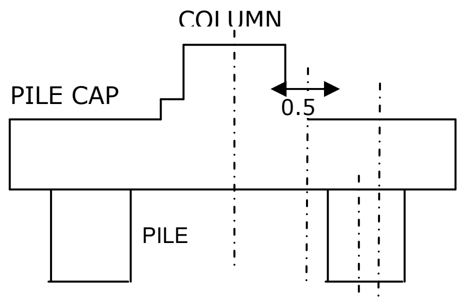


COLUMN	**C**	
MOMENT DUE TO SHEAR AT PILECAP BASE (M_X')	-85.40	kN.m
MOMENT DUE TO SHEAR AT PILECAP BASE (M_Z')	-143.50	kN.m
TOTAL BENDING MOMENT (M_X)	356.60	kN.m
TOTAL BENDING MOMENT (M_Z)	-1233.50	kN.m
TOTAL VERTICAL UNFACTORED FORCE	1390.31	kN

PILE NO.	**r_{xi} (m)**	**r_{xi}^2**	**r_{zi} (m)**	**r_{zi}^2**	**FINAL FORCES IN PILE (kN)**
1	0.900	0.81	0.900	0.81	**789**
2	0.900	0.81	0.900	0.81	**104**
3	0.900	0.81	0.900	0.81	**591**
4	0.900	0.81	0.900	0.81	**-94**
	Σr_{xi}^2 =	3.24	**Σr_{zi}^2 =**	3.24	

DESIGN OF PILE CAP





Axial load		**1184**	kN
moment in x direction		**442**	kNm
moment in z direction		**-1090**	kNm
fck		**25**	N/mm2
fy		**415**	N/mm2
Pile dia		**600**	mm
c/c distance between piles		**1.8**	m
Assume Pile cap width		2700	mm
Assume the thickness of pile cap		**700**	mm
Effective depth of pile cap		**630**	mm
pedestal size		**1000**	mm
column size		**900**	mm
vertical load moment due to moment	Mx	245.5556	kN
vertical load moment due to moment	Mz	-605.5556	kN
Total factored load between pile P1 and P4		1256.333	kN
Total factored load between pile P2 and P1		278.4	kN
Design factor load on two piles	Pu	1256.333	kN
BM in pile cap at section a-a		860.5883	kNm
Effective depth d is given by	d	303.9529	mm

(BM = 0.138 fck bd2)			
	The provided depth is ok		
Area of steel is given by	Ast	**4000**	mm2
BM=0.87 fy Ast(d-(fy ast/b fck))	1.015967		
enter the various value and get the value and it should near by one			
use dia of bars	Dia of bar	spacing	Area of bar
	16	100.48	200.96
Provide the dia bar and spacing	16	**100**	mm
Area of steel is provided	Ast	**5000**	mm2
(see the SP 16, Pg 230)			
Percentage of steel provided	Pt	0.293945	%
(Min 0.2 % steel provide)			
Provide distribution bar	**16**	100	spacing

SHEAR ONE WAY ACTION

Section for diagonal actioneill be tedsted at distance 0.5d from the face of pedestal	0.5d	315	mm
distence between pile face to pedestal face		100	
distence		385	
shear force by linear interpolation		806.1472	kN
Shear strength of M25 concrete for steel of	0.293945	%	
Shear strength	Tc	**0.34**	
(see IS 456:2000, Pg 73)			
Nominal shear stress	Tv	0.473925	N/mm2

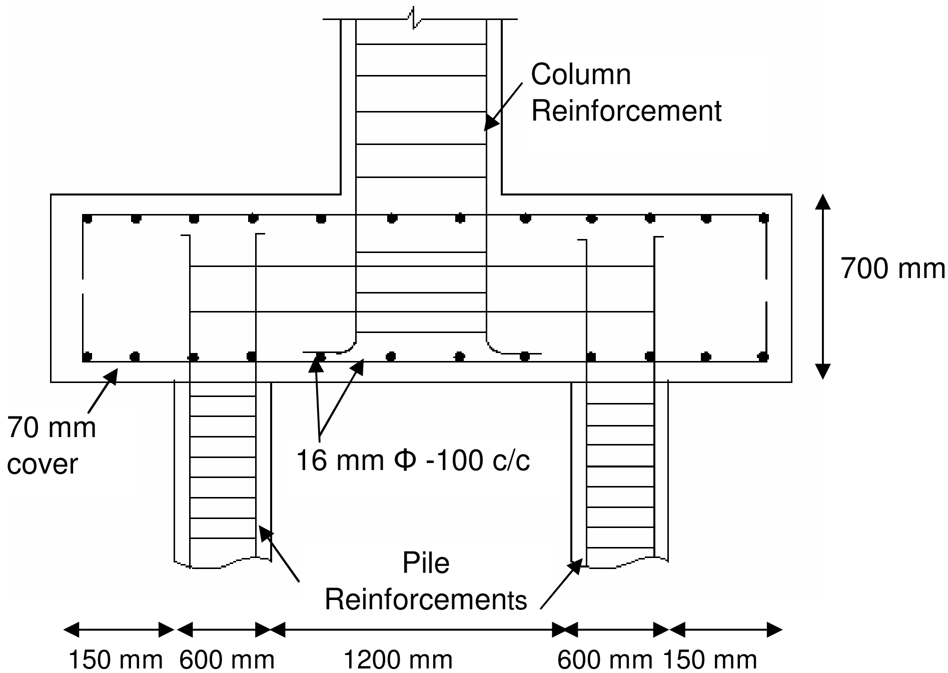
Here Tv > Tc, So Increase the depth of pile cap

SHEAR TWO WAY ACTION

The critical section lies at d/2 around the pedestal of the column

Shear force	Vu	1776	kN
Nominal shear stress	bo	1630	mm
	Tv	0.432369	N/mm2
	Tc	1.25	N/mm2

Here Tc > Tv, SO O.K.


Column
Reinforcement
700 mm
70 mm
cover
16 mm Φ -100 c/c
Pile
Reinforcements
150 mm
600 mm
1200 mm
600 mm
150 mm

CIRCULAR PILE DESIGN

Load =	**P**	**789**	**kN**
pile dia =	**D**	**0.6**	**m**
pile length =	**L**	**21**	**m**
no. of piles provided =	**n**	**4**	
	fck	**20**	**N/mm2**

MAIN REINFORCEMENT:-

Ultimate load | Pu = 1183.5 kN

Effective length | Le | 14 m (assumed)
(Le = (2/3) * L)

Le/D = 23.33333
Le/D > 12 so act as Long Column

min eccentricity | emin | 62 mm > 20 mm
emin = (L/500) + (D/30)

Ultimate moment | Mu | 193.305 kNm
(Mu(add) = Pu/2000xbx(Le/D)2)

Refering to interaction diagram corresponding to d'/D = **0.1**

Pu/(fckbD2) = 0.164375
Mu/(fckbD3) = 0.04474653

p/fck = **0.02**
(Referring chart 56, page-141, SP-16)
p = 0.4
Asc (req) = 1440 mm2

The min. reinf for l/d = 35 is 0.8%
Asc (min.) = 2260.8 mm2

Provide

bars no.	**10**	**nos**
bar dia	**25**	**mm**
area provided =	**4906.25**	**mm2**
provide clear cover of	**40**	**mm**

LATERAL TIES:-

Min. Volume of lateral reinf. Per metre length of pile = 0.2%
((0.2/100)*(π/4)*D^2*1000) 565200 mm2

Vol. of a tie of d1 mm Ø | Vol. = 94652.16 mm3
((π/4) * (d12)*π*D)

d1 = 8 mm

No. of ties/metre of pile = 5.97133758

Spacing for lateral reinf. **167.466667 mm c/c**

< 600 mm =	600	**O.K**
< 48*d1 =	384	**O.K**
<16* bar dia =	400	**O.K**

Max permissible pitch = 300 mm

Provide	**dia (mm)**	**spacing (mm)**
	8	300

For **bottom** length 3xD = 1800 mm, 0.6% volume of ties are required.

Using

dia (mm)	**spacing req. (mm)**
8	55.82222222

Provide	**dia (mm)**	**spacing req. (mm)**
	8	**55**

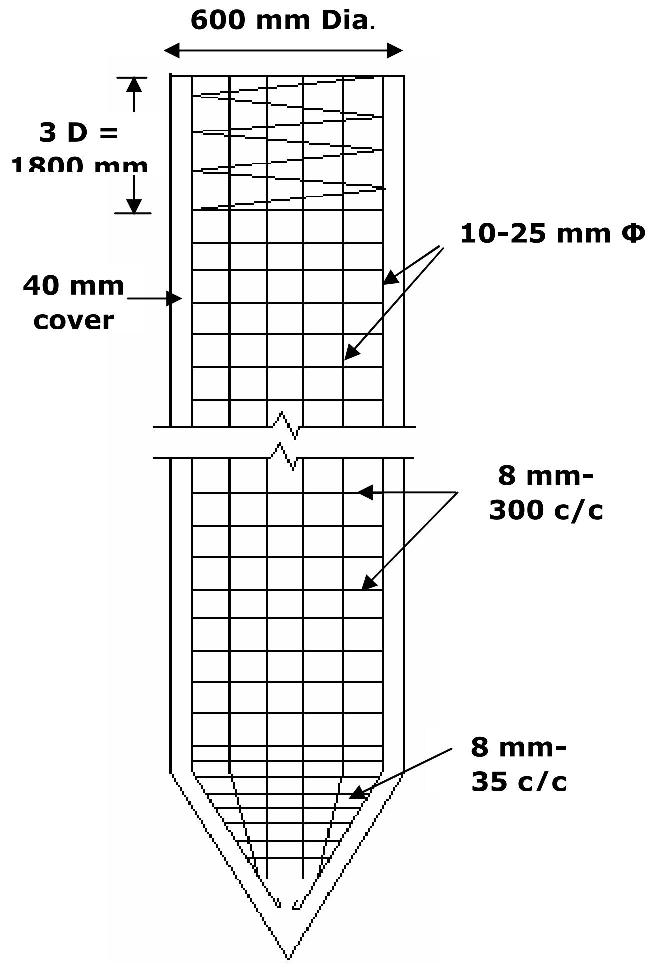
For **top** length 3xD = 1800 mm,
spiral reinforcement shall be provided of 0.6% of gross volume
i.e. = 2160000 mm3/m length

volume of spiral = $(\pi/4) * (d1^2)*\pi*D$
= 80769.8432 mm3

No. of spiral = 26.7426544

spacing = 37.3934459 mm

provide	**dia (mm)**	**spacing (mm)**
	8	**35**



600 mm Dia.
3 D =
1800 mm
10-25 mm Φ
40 mm
cover
8 mm-
300 c/c
8 mm-
35 c/c

WELDED MOMENT RESISTING CONNECTION

End reaction R	**80**	kN
Bending moment M	**360**	kNm
fy	**250**	N/mm2
Allowable shear stress	**108**	N/mm2
Alllowable bending compressive stress	165	N/mm2
Permissible bearingstress 0.75fy	187.5	N/mm2
bending stress in compression	185	N/mm2

Column - B = 900 mm x 900 mm

Flange 600 mm x 28 mm

Web 844 mm x 16 mm

Beam - B4

Flange 500 mm x 32 mm

Web 636 mm x 16 mm

The relevant properties of the section are:

	Beam	Column
Properties	**B4**	**B**
D (Depth of section)	**700**	**900**
B (Width of flange)	**500**	**600**
T (Thickness of flange)	**32**	**28**
t (Thickness of web)	**16**	**16**
h2	**50**	

Provide a plate at the top of the beam flange

Force in top plate 514.2857143 kN

(Force = B.M / lever arm)

Cross sectional area of the plate 3116.88 mm2

(c/s area = force/ allow.bwnding comp. stress)

Provide width of plate **500** mm

(provide more then width of beam flange) **Plate width is OK**

Thickness of the top plate round up 7 mm

(thickness = c/s area / width of plate)

Provide a plate 500 mm

Tapered at the end **450** mm

Provide weld size (assumed) **10** mm

Strength of the weld/mm 756 N

(strength = 0.7 x weld size x all. Shear stress)

Length of weld required	680.27	mm
Length = force / strength of weld		
Provide side fillet weld	90.135	mm
provide side fillet weld round up	**120**	mm
	Provided side fillet weld is O.K	
Total length of the weld	690	mm
(total = 2 x side fillet weld + tapered length)		
	Provided weld length is O.K.	
The length of the unwelded portion of the plate		
Should be equal to the width of plate	500	mm
Length of the top plate	620	mm

Design of seat angle

Bearing lendth b = (b > 1/2 x R / (σp t))	13.33	mm
Bearing lendth b = (b = R / (σp t)-(√3 h2))	-59.94	mm
Provide bearing length (max of both value)	13.33	mm
Provide a clearance	**20**	mm
Minimum angle leg	33.33	mm
(min angle leg = bearing length + clearance)		

Select I.S.A. 200 x 200 x 12 mm

length	**200**	mm
bredth	**200**	mm
thickness	**12**	mm
value of R	**13.5**	see steel table

e1 = clearance + b/2 - thickness - R	1.165	mm
t = (6 M e / B σbs)^1/2	2.24	
	Provided angle is OK	
Provide angle section		
length	**200**	
bredth	**200**	
thickness	**12**	
Vertical shear/mm Tvf1 =	200	N/mm
(Tvf1 = end reaction / 2 x length of angle)		

Horizontal shear/mm Tvf2 =	6.99 N/mm
(Tvf2 = (end reaction x e1) / (2 x length2 x 1/6))	

Resultant Shear/mm = Strength of weld/mm
(√ (Tvf1)2 + (Tvf2)2) = 0.7 x s x allow. Shear stress

S =	2.65 mm
Round up S =	3 mm
Provide fillet weld length	**6** mm

Force in the two stiffeners = M/D 514.2857143 kN

Pull in stiffeners should be equal to the strength of the weld…

Assume the size of the weld	**10** mm
L = force / (0.7 x s x allow. Shear stress)	680.27 mm

Provide stiffener plates for the half the depth of the column section…

Max col. flange length available for connection 278 mm

Let us provide a stiffner plate

width	**200** mm
thickness	**10** mm

Total length of the weld that can be accomodated to connect
the stiffener with the column flange 744 mm

< 1112 mm

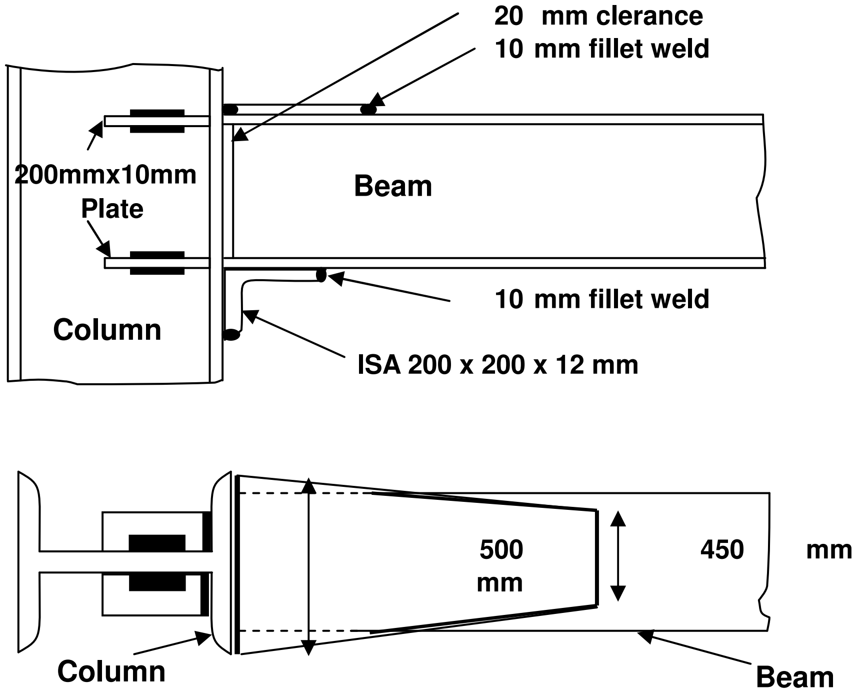
The remaining length of the weld can be adjusted on the stiffener plate
connecting the web of column.
Let us provide weld length on each side = **40** mm

Let us provide weld length on each side of
the stiffener plate joining it with column web

Total length of web provided 904 mm

> 680.27

Provided length is OK



Detailing of Connection

APPENDIX – C

DRAWING SHEETS

1. General Arrangement (G.A) Drawing.

2. Double conveyor transfer tower structure
   - Structural Drawings

3. Parallel conveyor transfer tower structure
   - Structural Drawings