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# Analysis & Design of Modular Technological Structure

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***Abstract :*** The Project considers methods of using modular units in construction. The advanced world experience in the construction of modular technological structure is analyzed. It is emphasized that modular construction has the potential to shorten project design and engineering time, reduce costs and improve construction productivity. The installation of modular technological structure is cost-efficient, safe and eco-friendly. A modular technological structure is a prefabricated building that consists of repeated sections called modules. Modularity involves constructing sections away from the structure site, then delivering them to the intended site. Installation of the prefabricated sections is completed on site. Prefabricated sections are sometimes placed using a crane. The modules can be placed side-by-side, end-to-end, or stacked, allowing for a variety of configurations and styles. After placement, the modules are joined together using inter-module connections, also known as inter-connections. The inter-connections tie the individual modules together to form the overall technological structure. For this purpose, a reference project of USA location is taken and modelling in STAAD Pro. software to Analysis & Design of Structure.

***IndexTerms*** **- Modular, Technological Structure, Prefabricate.**

## I. Introduction

A technological structure is a multi-tier steel structure with moment resisting frames (OMRF or SMRF) in one direction and with braced frames in the other. This structure generally supports piping and other equipment such as boilers, condensers, exchangers, vessels, Pump, tank, Air Blower, Turbo Washer etc. on one or more levels. For the design and engineering time, reduce costs and improve construction productivity. To use modular concept in this structure.

A modular building is a prefabricated building that consists of repeated sections called modules. Modularity involves constructing sections away from the building site, then delivering them to the intended site. Installation of the prefabricated sections is completed on site. The structure and various elements are designed for the force and the moment's results under the effect of intended loads. In the structural design, dead load of structure, Equipment load, impact load, live load, wind loads, Wind load on Equipment, Friction load on structure due to Equipment & Piping, Earthquake load etc., are consider for Erection Condition.

### 1. Components of Technological Structure:

The elements of Technological Structure are listed below.

**1) Column and Column Base.**

A column is a structural member which is straight to two equal and opposite compressive forces applied at the ends. Stability plays an important role in the design of compression member because in columns buckling is involved. The problem of determining the column load distribution in an industrial building column is statically indeterminate. To simplify the analysis the column is isolated from the space frame and is analyzed as a column subjected to axial load An industrial building column is subjected to following loads in addition to its self-weight.

Dead load, Live load, Crane load, Wind Load, Seismic Load, Temperature Load.

**2) Main Beam**

A beam is a structural element that primarily resists loads applied laterally to the beam's axis (an element designed to carry primarily axial load would be a strut or column). Its mode of deflection is primarily by bending. The loads applied to the beam result in reaction forces at the beam's support points. For main periphery of Structure, the main beam is design.

**3) Secondary Beam**

To carry the Supports equipment lug, Mezzanine Floors etc. to transfer the load on main beam.

**4) Mezzanine Floors**

In industrial applications, mezzanine floor systems are semi-permanent floor systems typically installed within buildings, built between two permanent original stories. These structures are usually free standing and, in most cases, can be dismantled and relocated. Commercially sold mezzanine structures are generally constructed of three main materials; steel, aluminum, and fiberglass. The decking or flooring of a mezzanine will vary by application but is generally composed of b-deck underlayment and wood product finished floor or a heavy-duty steel, aluminum or fiberglass grating.

**5) Roof Trusses**

Roof trusses are elements of the structure. The members are subjected to direct stresses. Truss members are subjected to direct tension and direct compression.

**6) Staircase Tower**

Stair tower means a structure twelve feet or taller in height, typically consisting of one or more flights of stairs, usually with landings to pass from one level to another.

**7) Crane**

Crane boom deflection is another phenomenon that happens to all cranes. It occurs when a crane is lifting a load and its boom appears to be bending. All booms have this ability to flex so they can absorb the loading forces that come from lifting a heavy weight.

**8) Bracing**

A bracing is structural member commonly used in structures subject to lateral loads such as wind and seismic forces. The bracing member is generally made of structural steel which can work effectively in tension and compression. Bracing transfer the lateral forces axially and reduce sway of structure and structure will be economical. It is observed that lateral movement decreases up to 80% due to the incorporation of the bracing system. By (Nayanmoni Chetia, 2016). The beam and columns that form a frame carry vertical loads and bracing system carries lateral loads.

## 2. Load Consider on Technological Structure:

**1) Earthquake Load (EQ)**

Following Seismic site parameter are considered in the calculations.
Ss = 0.103, S1 = 0.055, TL = 12 Sec. Importance factor (I) = 1, Response Modification Factor (R) = 4, Site Class = D, Fa = 1.6 & Fv = 2.4 Seismic analysis has been done by using Response Spectrum Method (SRSS) in STAAD.

**2) Dead Loads (DL)**

Self-Weight of Structure = 1.10 x Total weight of Structural member

**3) Cable Tray + Cable Load (CTC)**

Dead loads for cable trays on pipe racks shall be estimated as follows, unless actual load information is available and requires otherwise, A uniformly distributed dead load of 1.0 kPa for a single level of cable trays and 1.9 kPa for a double level of cable trays.

**9) Platform Dead Load (PDL)**

Dead load of walking platform, Handrails etc.

**10) Fire Proofing Load (FP)**

Fire protection refers to measures taken to prevent fire from becoming destructive, reduce the impact of an uncontrolled fire, and save lives and property.

**11) Live Load (L)**

Live loads are gravity loads produced by the use and occupancy of the building or structure. These include the weight of all movable loads, such as personnel, tools, miscellaneous equipment, movable partitions, wheel loads, parts of dismantled equipment, stored material, etc.

**12) Snow Load (S)**

Snow load is the downward force on a building's roof by the weight of accumulated snow and ice. The roof or the entire structure can fail if the snow load exceeds the weight the building was designed to shoulder. Or if the building was poorly designed or constructed. It doesn't take a blizzard to cause problems.

**13) Pipe Empty Load (PE)**

For checking uplift and components controlled by minimum loading, 60% of the estimated piping operating loads shall be used if combined with wind or earthquake unless the actual conditions require a different percentage.

**14) Pipe Operating Load (PO)**

Pipe content load is the weight of contents (fluid load) minus the empty weight of process equipment, vessels, tanks, piping, and cable trays maximum during normal operation.

**15)Pipe Test Load (PT)**

Test dead load (DT) is the empty weight of the pipe plus the weight of test medium contained in a set of simultaneously tested piping systems. The test medium shall be as specified in the contract documents or as specified by the owner. Unless otherwise specified, a minimum specific gravity of 1.0 shall be used for the test medium.

**16)Equipment Empty Load (EE)**

for process equipment and vessels is the empty weight of the equipment or vessels, including all attachments, trays, internals, insulation, fireproofing, agitators, piping, ladders, platforms, etc. Empty dead load also includes weight of machinery (e.g., pumps, compressors, turbines, and packaged units).

**17)Equipment Operating Load (EO)**

for process equipment and vessels is the empty dead load (EE) plus the maximum weight of contents (including packing/catalyst) during normal operation.

**18)Equipment Test Load (ET)**

for process equipment and vessels is the empty dead load (De) plus the weight of test medium contained in the system. The test medium shall be as specified in the contract documents or as specified by the owner. Unless otherwise specified, a minimum specific gravity of 1.0 shall be used for the test medium. Equipment and pipes that may be simultaneously tested shall be included. Cleaning load shall be used for test dead load if the cleaning fluid is heavier than the test medium.

**19)Pipe Friction Load (PF)**

Friction forces caused by thermal expansion or contraction shall be determined using the appropriate static coefficient of friction. Coefficients of friction shall be in accordance with below Fig 5.

| | |
|---|---|
| Steel to Steel | 0.4 |
| Steel to Concrete | 0.6 |
| Proprietary Sliding Surfaces or Coatings (e.g., "Teflon") | According to Manufacturer's Instructions |

**Fig.1: Coefficients of Friction**

**20)Pipe Guide Load (PGL)**

The pipe containing fluid is mostly have high temperature around 110°C to 120°C. because of this high temperature pipe tends to expand in both longitudinal and transverse direction. To restrict the movement of pipe in transverse direction guide support is provided. As the stiffness of pipe is minimum in transverse direction guide support are provided at short interval in one stretch of Piperack It resists the forces,

Transverse Pipe Friction load – PFT

Transverse Pipe Anchor load – PAT

**21) Pipe Anchor Load (PAL)**

When both guide and axial stop support are provided at same point then it is called as anchor support and the frame bay in which anchor bay lies it's a anchor bay. At anchor bay longitudinal and transverse forces are very high, so both side of bracing are provided at anchor bay mostly. It resists the forces,

Transverse Pipe Friction load – PFT

Transverse Pipe Anchor load – PAT

Longitudinal Pipe Friction load – PFT

Longitudinal Pipe Anchor load – PAT

**22)Wind Load (WL)**

Wind Load Calculation - As per ASCE 7-10

| | |
|---|---|
| Basic wind speed at site (V) in mph | = 115 mph. |
| Eave's height of the structure (h) in ft. | = 60 ft. |
| Exposure category | = C |
| Building Type | = Enclosed |

## 3. Load Combination for Technological Structure:

PIP STC 01015 is the standard which gives guidelines for load combination of industrial structure.

Load combinations are provided in PIP for specific types of structures in both allowable stress design (ASD) and strength design format.

| ASCE 7-10, IBC 2012 or IBC 2015 Comb. No. | General Load Combination | PIP STC01015 Comb. No. | Buildings and Open Frame Structures Specific Load Combination | Description |
|---|---|---|---|---|
| 1 | D | 4-1.1 | $D_s + D_o + T_s$ | Operating Weight + Sustained Thermal (Sustained Load Case for Deflection or Settlement) |
| | | 4-1.2 | $D_s + D_o + T_s + T_t$ | Operating Weight + Sustained Thermal + Temporary Thermal |
| | | 4-1.3 | $D_s + D_t^a + T_s^b + T_t^c$ | Test Weight[a] + Sustained Thermal[b] + Temporary Thermal[c] |
| 2 | D + L | 4-2.1 | $D_s + D_o + T_s + L$ | Operating Weight + Sustained Thermal + Live |
| | | 4-2.2 | $D_s + D_t^a + T_s^b + L$ | Test Weight[a] + Sustained Thermal[b] + Live |
| 3 | D + ($L_r$ or S or R) | 4-3.1 | $D_s + D_o + T_s + (L_r^d \text{ or } S \text{ or } R^d)$ | Operating Weight + Sustained Thermal + (Roof Live[d] or Snow or Rain[d]) |
| | | 4-3.2 | $D_s + D_t^a + T_s^b + (L_r^d \text{ or } S \text{ or } R^d)^e$ | Test Weight[a] + Sustained Thermal[b] + (Roof Live[d] or Snow or Rain[d])[e] |
| 4 | D + 0.75 L + 0.75 ($L_r$ or S or R) | 4-4.1 | $D_s + D_o + T_s + 0.75\ T_t + 0.75\ L + 0.75\ (L_r^d \text{ or } S \text{ or } R^d)$ | Operating Weight + Sustained Thermal + Temporary Thermal + Live + (Roof Live[d] or Snow or Rain[d]) |
| | | 4-4.2 | $D_s + D_t^a + T_s^b + 0.75\ T_t^c + 0.75\ L + 0.75\ (L_r^d \text{ or } S \text{ or } R^d)^e$ | Test Weight[a] + Sustained Thermal[b] + Temporary Thermal[c] + Live + (Roof Live[d] or Snow or Rain[d])[e] |
| 5 | D + (0.6 W or 0.7 E) | 4-5.1 | $D_s + D_o + T_s + 0.6\ W$ | Operating Weight + Sustained Thermal + Wind |
| | | 4-5.2 | $D_s + D_o + T_s + 0.7\ E_o$ | Operating Weight + Sustained Thermal + Earthquake |
| | | 4-5.3 | $D_s + D_t^a + T_s^b + 0.6\ W_p$ | Test Weight[a] + Sustained Thermal[b] + Partial Wind |
| 6a | D + 0.75 L + 0.75 (0.6 W) + 0.75 ($L_r$ or S or R) | 4-6a.1 | $D_s + D_o + T_s + 0.75\ L + 0.75\ (0.6\ W) + 0.75\ (L_r^d \text{ or } S \text{ or } R^d)$ | Operating Weight + Sustained Thermal + Live + Wind + (Roof Live[d] or Snow or Rain[d]) |
| | | 4-6a.2 | $D_s + D_t^a + T_s^b + 0.75\ L + 0.75\ (0.6\ W_p) + 0.75\ (L_r^d \text{ or } S \text{ or } R^d)^e$ | Test Weight[a] + Sustained Thermal[b] + Live + Partial Wind + (Roof Live[d] or Snow or Rain[d])[e] |
| 6b | D + 0.75 L + 0.75 (0.7 E) + 0.75 S | 4-6b | $D_s + D_o + T_s + 0.75\ L + 0.75\ (0.7\ E_o) + 0.75\ S$ | Operating Weight + Sustained Thermal + Live + Earthquake + Snow |
| 7 | 0.6 D + 0.6 W | 4-7.1 | $0.6\ (D_s + D_e) + T_s^{f,g} + 0.6\ W$ | Empty Weight + Sustained Thermal[f,g] + Wind (Wind Uplift Case) |
| | | 4-7.2 | $0.6\ (D_s + D_o) + T_s^g + 0.6\ W$ | Operating Weight + Sustained Thermal[g] + Wind (Sustained Thermal and Wind Uplift Case) |
| 8 | 0.6 D + 0.7 E | 4-8.1 | $0.6\ (D_s + D_e) + T_s^{f,g} + 0.7\ E_e$ | Empty Weight + Sustained Thermal[f,g] + Earthquake (Earthquake Uplift Case) |
| | | 4-8.2 | $0.6\ (D_s + D_o) + T_s^g + 0.7\ E_o^h$ | Operating Weight + Sustained Thermal[g] + Earthquake[h] (Sustained Thermal and Earthquake Uplift Case) |

**Fig.2: Building & Open Frame Structure ASD Load Combination**

| ASCE 7-10, IBC 2012 or IBC 2015 Comb. No. | General Load Combination | PIP STC01015 Comb. No. | Buildings and Open Frame Structures Specific Load Combination | Description |
|---|---|---|---|---|
| 1 | 1.4 D | 5-1.1 | $1.4\ (D_s + D_o) + 1.2\ T_s$ | Operating Weight + Sustained Thermal |
| | | 5-1.2 | $1.4\ (D_s + D_t^a) + 1.2\ T_s^b$ | Test Weight[a] + Sustained Thermal[b] |
| 2 | 1.2 D + 1.6 L + 0.5 ($L_r$ or S or R) | 5-2.1 | $1.2\ (D_s + D_o) + 1.2\ T_s + 1.0\ T_t + 1.6\ L + 0.5\ (L_r^c \text{ or } S \text{ or } R^c)$ | Operating Weight + Sustained Thermal + Temporary Thermal + Live + (Roof Live[c] or Snow or Rain[c]) |
| | | 5-2.2 | $1.2\ (D_s + D_t^a) + 1.2\ T_s^b + 1.0\ T_t^d + 1.6\ L + 0.5\ (L_r^c \text{ or } S \text{ or } R^c)^e$ | Test Weight[a] + Sustained Thermal[b] + Temporary Thermal[d] + Live + (Roof Live[c] or Snow or Rain[c])[e] |
| 3 | 1.2 D + 1.6 ($L_r$ or S or R) + (L or 0.5 W) | 5-3.1 | $1.2\ (D_s + D_o) + 1.2\ T_s + 1.0\ T_t + 1.6\ (L_r^c \text{ or } S \text{ or } R^c) + 0.5\ L^f$ | Operating Weight + Sustained Thermal + Temporary Thermal + (Roof Live[c] or Snow or Rain[c]) + Live[f] |
| | | 5-3.2 | $1.2\ (D_s + D_o) + 1.2\ T_s + 1.6\ (L_r^c \text{ or } S \text{ or } R^c) + 0.5\ W$ | Operating Weight + Sustained Thermal + (Roof Live[c] or Snow or Rain[c]) + Wind |
| | | 5-3.3 | $1.2\ (D_s + D_t^a) + 1.2\ T_s^b + 1.0\ T_t^d + 1.6\ (L_r^c \text{ or } S \text{ or } R^c)^e + 0.5\ L^f$ | Test Weight[a] + Sustained Thermal[b] + Temporary Thermal[d] + (Roof Live[c] or Snow or Rain[c])[e] + Live[f] |
| | | 5-3.4 | $1.2\ (D_s + D_t^a) + 1.2\ T_s^b + 1.6\ (L_r^c \text{ or } S \text{ or } R^c)^e + 0.5\ W$ | Test Weight[a] + Sustained Thermal[b] + (Roof Live[c] or Snow or Rain[c])[e] + Wind |
| 4 | 1.2 D + 1.0 W + L + 0.5 ($L_r$ or S or R) | 5-4.1 | $1.2\ (D_s + D_o) + 1.2\ T_s + 1.0\ W + 0.5\ L^f + 0.5\ (L_r^c \text{ or } S \text{ or } R^c)$ | Operating Weight + Sustained Thermal + Wind + Live[f] + (Roof Live Load[c] or Snow or Rain[c]) |
| | | 5-4.2 | $1.2\ (D_s + D_t^a) + 1.2\ T_s^b + 1.0\ W_p + 0.5\ L^f + 0.5\ (L_r^c \text{ or } S \text{ or } R^c)^e$ | Test Weight[a] + Sustained Thermal[b] + Partial Wind + Live[f] + (Roof Live[c] or Snow or Rain[c])[e] |
| 5 | 1.2 D + 1.0 E + L + 0.2 S | 5-5 | $1.2\ (D_s + D_o) + 1.2\ T_s + 1.0\ E_o + 0.5\ L^f + 0.2\ S$ | Operating Weight + Sustained Thermal + Earthquake + Live[f] + Snow |
| 6 | 0.9 D + 1.0 W | 5-6.1 | $0.9\ (D_s + D_e) + 1.2\ T_s^{g,h} + 1.0\ W$ | Empty Weight + Sustained Thermal[g,h] + Wind (Wind Uplift Case) |
| | | 5-6.2 | $0.9\ (D_s + D_o) + 1.2\ T_s^h + 1.0\ W$ | Operating Weight + Sustained Thermal[h] + Wind (Wind Uplift Case) |
| 7 | 0.9 D + 1.0 E | 5-7.1 | $0.9\ (D_s + D_e) + 1.2\ T_s^{g,h} + 1.0\ E_e$ | Empty Weight + Sustained Thermal[g,h] + Earthquake (Earthquake Uplift Case) |
| | | 5-7.2 | $0.9\ (D_s + D_o) + 1.2\ T_s^h + 1.0\ E_o^i$ | Operating Weight + Sustained Thermal[h] + Earthquake[i] (Earthquake Uplift Case) |
| N/A[j] | N/A[j] | 5-8.1 | $1.2\ (D_s + D_o) + 1.2\ T_s + 1.2\ T_t + 0.5\ L + 0.5\ (L_r^c \text{ or } S \text{ or } R^c)$ | Operating Weight + Sustained Thermal + Temporary Thermal + Live + (Roof Live[c] or Snow or Rain[c]) |
| | | 5-8.2 | $1.2\ (D_s + D_t^a) + 1.2\ T_s^b + 1.2\ T_t^d + 0.5\ L + 0.5\ (L_r^c \text{ or } S \text{ or } R^c)^e$ | Test Weight[a] + Sustained Thermal[b] + Temporary Thermal[d] + Live + (Roof Live[c] or Snow or Rain[c])[e] |

**Fig.3: Building & Open Frame Structure LRFD Load Combination**

## 4. AIM:

- To design heavy equipment supporting technological structure for operating condition.
- To check the behavior of structure for storey drift & deflection.

### 5. PROBLEM STATEMENT:

We need to Analysis & Design of 14’5”x 14’5” x 66’ module of 180’5” x 197’ x 66’ Technological structure with heavy equipment’s like boilers, condensers, exchangers, vessels, Pump, tank, Air Blower, Turbo Washer etc. for operating condition after the structure is safe for Deflection, Story Drift, Utility Ratio.

### 6. OBJECTIVE:

In the present study, Following Objectives were set:

- Design & Analysis of modular Technological Structure for Heavy Equipment for operating in STAAD Pro.
- To analyze the structure by square root of sum of squares (SRSS) method for seismic analysis.
- To study the different loads and their behaviour on structure.
- To reduce the effect of horizontal loads on structure.
- To calculate the Displacement, and storey drift.
- To calculate the tonnage of the structure.

### 7. STRUCTURAL DETAILS: -

| Type of building: | Technological Structure |
|---|---|
| Building dimension | 180’5” x 197’ |
| Height of the column | 66’ |
| Area of the Structure | 35560 Sq.ft |
| Type of roofing | GI sheet |
| Location of the Structure | West Virginia |
| Bay spacing | 14’5” |
| Wind speed | 115mph |

**Table No.1: Structural Details**

### 8. BASIC LOADS ON TECHNOLOGICAL STRUCTURE: -

- EARTHQUAKE LOAD (EQX)
- EARTHQUAKE LOAD (EQY)
- EARTHQUAKE LOAD (EQZ)
- DEAD LOAD (DS)
- CABLE TRAY + CABLE LOAD (CTC)
- PLATFORM DEAD LOAD (PDL)
- FIRE PROOFING LOAD (FP)
- LIVE LOAD (L)
- SNOW LOAD (S)
- PIPE EMPTY LOAD (PE)
- PIPE OPERATING LOAD (PO)
- PIPE TEST LOAD (PT)
- EQUIPMENT EMPTY LOAD (EE)
- EQUIPMENT OPERATING LOAD (EO)
- EQUIPMENT TEST LOAD (ET)
- PIPE FRICTION LOAD X (PFX)
- PIPE FRICTION LOAD Z (PFZ)
- PIPE GUIDE LOAD (PGL)
- PIPE ANCHOR LOAD (PAL)
- PIPE CONTINGENCY LOAD (PCL)
- BUNDLE PULL LOAD (BP)
- HANDLING DEVICE LOAD (HDL)
- VIBRATION LOAD (VL)
- CRANE LOAD (CL)
- OTHER LOAD (OL)
- TEMPERATURE RISE LOAD (TRL)
- TEMPERATURE FALL LOAD (TFL)
- WIND LOAD X (WLX-EP+IP)
- WIND LOAD X (WLX-EP+IS)
- WIND LOAD -X (WL-X-EP+IP)
- WIND LOAD -X (WL-X-EP+IS)
- WIND LOAD Z (WLZ-EP+IP)
- WIND LOAD Z (WLZ-EP+IS)
- WIND LOAD -Z (WL-Z-EP+IP)
- WIND LOAD -Z (WL-Z-EP+IS)

## 9. TECHNOLOGICAL STRUCTURE

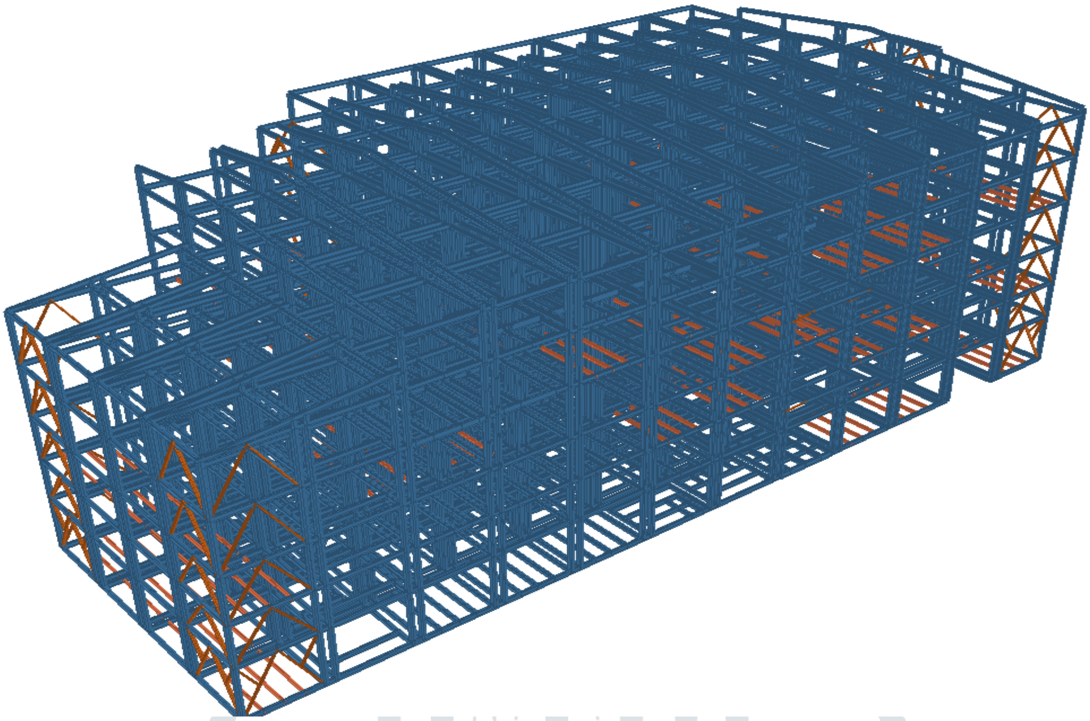


**Fig.4: Staad 3D Model View**

## 10. RESULT AND DISCUSSION

### 1) GENERAL

A design of Equipment Supported Technological Structure is done with Deflection is within a limit, there are no member is failed is strength. Structure is Safe for operating condition & Erection point of view.
The structural analysis & design of the skid the structural steel material of grade ASTM A992 is used. Following are the material characteristic which used for design is mentioned: -
Characteristic Yield Strength of Steel for UB / UC Sections (A992) = 50 $kip/inch^2$
Characteristic Ultimate Strength of Steel for UB/UC Section (A992) = 65 $kip/inch^2$
Characteristic Yield Strength of Steel for Angle/Channel Section (A36) = 36 $kip/inch^2$
Characteristic Ultimate Strength of Steel for Angle/Channel Section (A36) = 58 $kip/inch^2$
Total Structural Steel Tonnage = **1007 Ton.**

### 2) DEFLECTION SUMMARY

Deflection Summary for Technological Structure

| | | | Horizontal | Vertical | Horizontal | Resultant |
|---|---|---|---|---|---|---|
| | Node | L/C | X mm | Y mm | Z mm | mm |
| Max X | 5244 | 2001 DS+CTC | **32.327** | -0.957 | 21.259 | 38.703 |
| Min X | 5265 | 1008 DS+CTC | **-32.713** | -0.533 | -11.939 | 34.827 |
| Max Y | 7106 | 2002 DS+CTC | -3.825 | **1.693** | -11.401 | 12.144 |
| Min Y | 6859 | 1013 DS+CTC | 0.137 | **-14.060** | 0.242 | 14.063 |
| Max Z | 4937 | 1007 DS+CTC | 26.192 | -6.508 | **26.807** | 38.040 |
| Min Z | 4937 | 2002 DS+CTC | -26.247 | -5.261 | **-26.324** | 37.544 |

**Fig.5: Deflection of Technological Structure**

The limiting permissible horizontal deflection for multi-storied steel structure Maximum member is Height/200
Allowable horizontal deflection for Z- Direction = (16.46x1000)/200 = 82.3 mm.
Maximum actual Deflection = 32.713 mm.
Allowable horizontal deflection for X- Direction = (19.512x1000) /200 = 97.5 mm.
Maximum actual Deflection = 14.060 mm.

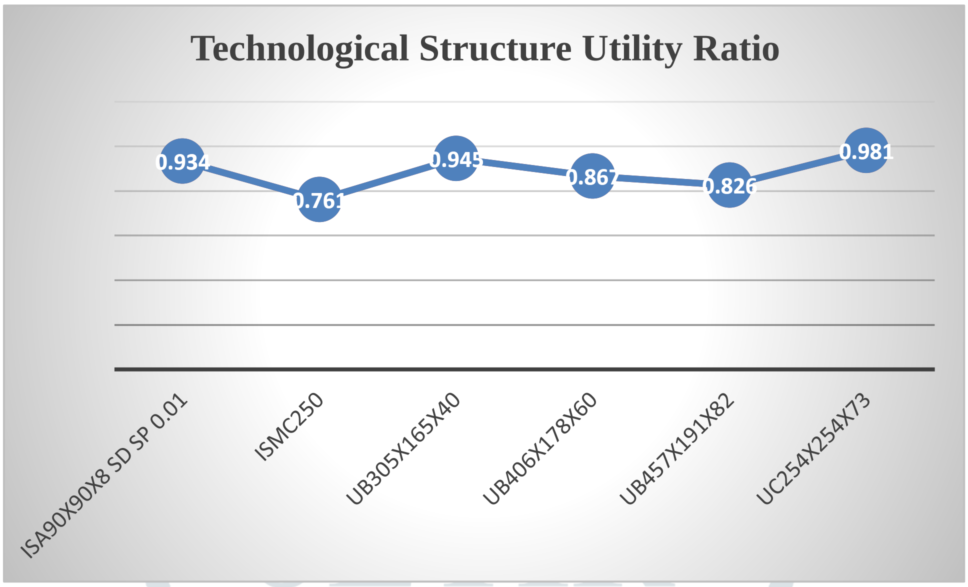
### 3) UTILITY CHECK RATIO

Utility ratio is the ratio of Actual Load on member to the capacity of member, if it exceeds **more than 1** then load on member will be greater than its capacity and member gets collapsed.
Member Unity Ratio of Technological structure for ASD & LRFD load combinations

| | Member Type | Member Size | Utility Ratio |
|---|---|---|---|
| **Technological Structure** | Bracing Member | ISA90X90X8 SD SP 0.01 | 0.934 |
| | Mezzanine Beam | ISMC250 | 0.761 |

| | | | |
|---|---|---|---|
| | Beam | UB305X165X40 | 0.945 |
| | | UB406X178X60 | 0.867 |
| | | UB457X191X82 | 0.826 |
| | Column | UC254X254X73 | 0.981 |

**Table No. 2: Unity Ratio of Technological Structure**




**Graph No. 1: Unity Ratio of Technological Structure**

In Equipment supported technological structure the maximum ratio of **Column is 0.981** for load combination No. 4008 1.2(DS+CTC+PDL+FP+PO+EO+PCL+HDL+CL)-PFX-PFZ-1.2PGL-1.2PAL+1.6L+0.5S, Critical in H1-1a is **Members Subject to Flexure and Compression.**

For **Beam** the maximum unity ratio is up to **0.945** for load combination No. DS+CTC+PDL+FP+PO+EO+PCL +HDL+CL+PGL+PAL+L, Critical in **Deflection.**

For Bracing member maximum unity ratio is 0.934 for load combination No. 4008 1.2(DS+CTC +PDL+FP+PO+EO+PCL+HDL+CL)-PFX-PFZ-1.2PGL-1.2PAL+1.6L+0.5S**,** bracing member are critical in H2-1 **Members Subject to Flexure and Axial Force.**

## 11. Conclusion

- The technological structure is found critical/governing for the following load combination 1.2(DS+CTC+PDL+FP+PO+EO+PCL+HDL+CL)-PFX-PFZ-1.2PGL-1.2PAL+1.6L+0.5S with unity **0.981**.
- Maximum vertical deflection for the structure is found 14.060 mm, and horizontal displacement /storey drift is 32.71mm.
- Total optimized structural Steel Tonnage is 1007 Ton.
  As per construction point of view modular structure is best suited for fast construction instead of having higher steel tonnage in comparison to stick built structure. It has less chances of errors due to shop manufacturing.

## References

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