1. **Structure Geometry Drawing**

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1. **General Description**
   1. **Introduction**

The following report presents the structural analysis & design of the “Farabi Yanbu Petrochemicals, Gatehouse 1, Job Id 18 068 1A”. The design is according to ASCE STANDARD ASCE-SEI 7-10, as executed in the STAAD.Pro V8i-SS6 Structural Analysis and Design software package.

* 1. **Description of the Structure**

The Space frame represents a rectangular double layer structure, supported by four short steel columns. The Geometric line sketch illustrates the over-all geometry of the structure. Covering is to consist of sandwich panels supported over purlins connected to purlin stools at each top chord joint.

* 1. **Design Philosophy**

The space frame structure itself is made up of pipes (members) joined to each other using the propriety Multi-Flange™ connecting concept, that is unique to the ME-SSP® Space frame system. This concept allows certain favorable partial fixity to members’ ends, but the design shall be based on the basis of pinned-pinned three-dimensional truss as stipulated in the STAAD.Pro v8i software package. Design of the space frame structure is prepared and made in compliance with the AISC design requirements and scope of other project approved standards.

* 1. **Technical References**
* ASCE/ SEI 7-10: Minimum design loads for buildings and other structures.
* IBC: International building code of international code council (ICC).
* SBC 301: Saudi building code requirements; loading and forces.
* ANSI/AISC 360-05: Specification for Structural Steel Buildings.
* AISC 2005: Steel construction manual.
* ACI-318/318M-08: Building code requirements for structural concrete.
* ASTM A36/A36M: Standard specification for carbon structural steel.
* ASTM A53/A53M: Standard specification for pipe (welded and seamless).
* SAES-A-112: Saudi Aramco Engineering Standard (metrological Data)
* RCSC-04: Specification for structural joints using ASTM A325 or A490 Bolts.
  1. **Design Load Criteria**

The space frame structure is designed considering project specifications and relevant code provision for the following loading conditions:

* + 1. **Dead Loads**

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| --- | --- | --- |
| **Reference** | **Calculation** | **Output** |
|  | The self-weight is automatically generated during the design analysis iterations | ***Sw*** |
| Client provided Dwgs & Specs | Roof Dead Loads (Sandwich Panels roofing and purlins) [Zone:801] | ***Rl*** = 0.15 kN/m2 |
| Services [Zone:802] | ***Ds*** = 0.05 kN/m2 |

* + 1. **Roof Live Loads**

|  |  |  |
| --- | --- | --- |
| **Reference** | **Calculation** | **Output** |
| Client provided specs. | Ordinary flat, pitched, and curved roofs [Zone:803] | ***Lo*** = 2.00 kN/m2 |

* + 1. **Wind Loads**

|  |  |  |
| --- | --- | --- |
| **Reference** | **Calculation** | **Output** |
| ASCE 7-10  Table 1.5-1 | Risk Category III |  |
| SAES A-112 | Basic wind speed, 3-sec gust at 10m above ground level,  Wind speed ***V*** = 152 km/hr (For Yanbu as per client specs) | ***V*** = 152 km/hr  = 42.22m/s |
| ASCE 7-10  Sec 26.1.1  Table 26.6-1 | Buildings – Main Wind Force Resisting System  Directionality Factor **Kd** = 0.85 | ***Kd*** = 0.85 |
| Sec. 26.7.2  Sec. 26.7.3 | Structure is in unobstructed area. | Exposure Category C |
| Sec. 26.8.2  Table 26.8-1 | No hills, ridges or escarpments exist in the area | Topographic Factor  ***Kzt*** = 1.00 |
| ASCE 7-10  Sec. 26.9.1 | Structure is low rise | Gust Effect Factor  ***G*** = 0.85 |
| ASCE 7-10  Sec. 26.10 | Structure considered Open | Enclosure Specification is Open |
| ASCE 7-10  Table 26.11-1  pg. 258 | Internal Pressure Coefficients for Enclosed Buildings | **(*GCpi*)** = ±0.00 |
| ASCE 7-10  Table 27.3-1 | Height above ground 8.9m | Velocity Pressure Coefficient,  ***Kz*** = 0.97 |

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| **Reference** | **Calculation** | **Output** |
| As per Client Specs | ***qh*** *=**0.613****Kz Kzt Kd V2***  = 0.613 x 0.97 x 1.00 x 0.85 x (42.22)2  = 905.35 N/m2 | ***qh***=0.9054 kN/m2 |

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| --- | --- | --- |
| Fig. 27.4-4  pg. 267 | Open Building; h = 8.9 m; θ = 0˚    Wind along +X direction  Distance from the windward edge (≤0.5L)  Case A: CNW = [Zone:]  Case B: CNL = [Zone:]  Distance from the windward edge (>0.5L, ≤L)  Case A: CNW = [Zone:]  Case B: CNL = [Zone:] Wind along -X direction  Distance from the windward edge (≤0.5L)  Case A: CNW = [Zone:]  Case B: CNL = [Zone:]  Distance from the windward edge (≤0.5L)  Case A: CNW = [Zone:]  Case B: CNL = [Zone:]  Wind along +X direction  Distance from the windward edge (≤0.5L)  Case A: CNW = 1.2 [Zone:804]  Case B: CNL = -1.1 [Zone:805]  Distance from the windward edge (>0.5L, ≤L)  Case A: CNW = 0.3 [Zone:806]  Case B: CNL = -0.1 [Zone:807]  Wind along -X direction  Distance from the leeward edge (≤0.5L)  Case A: CNW = 1.2 [Zone:808]  Case B: CNL = -1.1 [Zone:809]  Distance from the leeward edge (>0.5L, ≤L)  Case A: CNW = 0.3 [Zone:810]  Case B: CNL = -0.1 [Zone:811]    Wind along +Y direction  Distance from the windward edge (≤h)  Case A: CN = -0.8 [Zone:804]  Case B: CN = 0.8 [Zone:805]  Distance from the windward edge (>h,< 2h)  Case A: CN = -0.6 [Zone:806]  Case B: CN = 0.5 [Zone:807]  Distance from the windward edge (> 2h)  Case A: CN = -0.3 [Zone:808]  Case B: CN = 0.3 [Zone:809]  Wind along -Y direction  Distance from the windward edge (≤h)  Case A: CN = -0.8 [Zone:810]  Case B: CN = 0.8 [Zone:811]  Distance from the windward edge (>h,< 2h)  Case A: CN = -0.6 [Zone:812]  Case B: CN = 0.5 [Zone:813]  Distance from the windward edge (> 2h)  Case A: CN = -0.3 [Zone:814]  Case B: CN = 0.3 [Zone:815] |  |
| **Reference** | **Calculation** | **Output** |
| Eqn. 6-18A  pg. 69 | Open Building; Clear wind flow h = 7.10m;  Wind along +X direction  Distance from the windward edge (≤0.5L)  Case A: p= 1.1163 kN/sq.m [Zone:804]  Case B: p= -1.0233 kN/sq.m [Zone:805]  Distance from the windward edge (>0.5L, ≤L)  Case A: p = 0.2791kN/sq.m [Zone:806]  Case B: p= -0.0930 kN/sq.m [Zone:807]  Wind along -X direction  Distance from the windward edge (≤0.5L)  Case A: p= 1.1163 kN/sq.m [Zone:808]  Case B: p= -1.0233 kN/sq.m [Zone:809]  Distance from the windward edge (>0.5L, ≤L)  Case A: p = 0.2791kN/sq.m [Zone:810]  Case B: p= -0.0930 kN/sq.m [Zone:811]  Wind along +Y direction  Distance from the windward edge (≤0.5L)  Case A: p= -0.7442 kN/sq.m [Zone:812]  Case B: p= 0.7442 kN/sq.m [Zone:813]  Distance from the windward edge (>0.5L, ≤L)  Case A: p = -0.5581 kN/sq.m [Zone:814]  Case B: p= -0.4651 kN/sq.m [Zone:815]  Distance from the windward edge (>0.5L, ≤L)  Case A: p = -0.2791kN/sq.m [Zone:816]  Case B: p= 0.2791 kN/sq.m [Zone:817]  Wind along -Y direction  Distance from the windward edge (≤0.5L)  Case A: p= -0.7442 kN/sq.m [Zone:818]  Case B: p= 0.7442 kN/sq.m [Zone:819]  Distance from the windward edge (>0.5L, ≤L)  Case A: p = -0.5581 kN/sq.m [Zone:820]  Case B: p= -0.4651 kN/sq.m [Zone:821]  Distance from the windward edge (>0.5L, ≤L)  Case A: p = -0.2791 kN/sq.m [Zone:822]  Case B: p= 0.2791 kN/sq.m [Zone:823] |  |



* + 1. **Temperature Loading**

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| --- | --- | --- |
| **Reference** | **Calculation** | **Output** |
| As per client Specs | The temperature loading is obtained as the difference between the highest and lowest one-day mean. For Yanbu, as per client specs | ΔT = ± 30ºC |

* 1. **Description of the Primary Load Cases**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| LC1 | ***Sw*** | Self-Weight |  | LC2 | ***Rl*** | Roof Dead Loads = 0.15 kN/m2 |
| LC3 | ***Ds*** | Services = 0.05 kN/m2 |  | LC4 | ***Lr*** | Roof Live Load = 2.00 kN/m2 |
| LC5 | *W+x* | Wind along +X Direction (A) |  | LC6 | *W-x* | Wind along +X Direction (B) |
| LC7 | *W+y* | Wind along -X Direction (A) |  | LC8 | *W-y* | Wind along -X Direction (B) |
| LC9 | *W+y* | Wind along +Y Direction(A) |  | LC10 | *W+y* | Wind along +Y Direction (B) |
| LC11 | *W+y* | Wind along -Y Direction(A) |  | LC12 | *W+y* | Wind along -Y Direction (B) |
| LC13 | *T* | Temperature Loading ±30 ˚C |  |  |  |  |

* 1. **Load Combination Factors**

To achieve basic combination employed in designing the space frame structure, table of load combination factors is generated using the load cases described above and in accordance with “combining nominal loads using Allowable Stress Design” required by ASCE 7-10 as follows:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No. | Description | Combination |  | No. | Description | Combination |
| 101 | ***Sw*** + ***Rl*** + ***Ds*** | D |  | 217 | ***Sw*** + ***Rl*** + ***Ds*** + 0.75 ***Lr*** +0.45*W+x* (**A**) | D + 0.75Lr + 0.45W |
| 102 | ***Sw*** + ***Rl*** + ***Ds*** +*T* | D + T |  | 218 | ***Sw*** + ***Rl*** + ***Ds*** + 0.75 ***Lr*** + 0.45 *W+x* (**B**) |
| 103 | ***Sw*** + ***Rl*** + ***Ds*** –*T* | D – T |  | 219 | ***Sw*** + ***Rl*** + ***Ds*** + 0.75 ***Lr*** +0.45 *W-x* (**A**) |
| 104 | ***Sw*** + ***Rl*** + ***Ds*** + ***Lr*** | D + Lr |  | 220 | ***Sw*** + ***Rl*** + ***Ds*** + 0.75 ***Lr*** +0.45 *W-x* (**A**) |
| 105 | ***Sw*** + ***Rl*** + ***Ds*** + 0.75 ***Lr*** +*T* | D + 0.75Lr + T |  | 221 | ***Sw*** + ***Rl*** + ***Ds*** + 0.75 ***Lr*** +0.45 *W+y* (**A**) |
| 106 | ***Sw*** + ***Rl*** + ***Ds*** + 0.75 ***Lr*** –*T* | D + 0.75Lr – T |  | 222 | ***Sw*** + ***Rl*** + ***Ds***+ 0.75 ***Lr*** + 0.45 *W+y* (**B**) |
| 201 | ***Sw*** + ***Rl*** + ***Ds*** +0.6 *W+x* (**A**) | D + 0.6W |  | 223 | ***Sw*** + ***Rl*** + ***Ds*** + 0.75 ***Lr*** +0.45 *W-y* (**A**) |
| 202 | ***Sw*** + ***Rl*** + ***Ds*** + 0.6 *W+x* (**B**) |  | 224 | ***Sw*** + ***Rl*** + ***Ds*** + 0.75 ***Lr*** +0.45*W-y* (**B**) |
| 203 | ***Sw*** + ***Rl*** + ***Ds*** +0.6 *W-x* (**A**) |  |  |  |  |
| 204 | ***Sw*** + ***Rl*** + ***Ds*** +0.6 *W-x* (**B**) |  |  |  |  |
| 205 | ***Sw*** + ***Rl*** + ***Ds*** +0.6 *W+y* (**A**) |  |  |  |  |
| 206 | ***Sw*** + ***Rl*** + ***Ds*** + 0.6 *W+y* (**B**) |  |  |  |  |
| 207 | ***Sw*** + ***Rl*** + ***Ds*** +0.6 *W-y* (**A**) |  |  |  |  |
| 208 | ***Sw*** + ***Rl*** + ***Ds*** +0.6 *W-y* (**B**) |  |  |  |  |
| 209 | ***Sw*** +0.6(***Rl*** + ***Ds***) +0.6 *W+x (***A**) | 0.6D + 0.6W |  |  |  |  |
| 210 | ***Sw*** +0.6(***Rl*** + ***Ds***) ***+*** 0.6 *W+x (***B**) |  |  |  |  |
| 211 | ***Sw*** + ***0.6***(***Rl*** + ***Ds***) +0.6 *W-x* (**A**) |  |  |  |  |
| 212 | ***Sw*** +0.6(***Rl*** + ***Ds***) ***+*** 0.6 *W-x* (**B**) |  |  |  |  |
| 213 | ***Sw*** +0.6(***Rl*** + ***Ds***) ***+*** 0.6 *W+y* (**A**) |  |  |  |  |
| 214 | ***Sw*** +0.6(***Rl*** + ***Ds***) ***+*** 0.6 *W+y* (**B**) |  |  |  |  |
| 215 | ***Sw*** +0.6(***Rl*** + ***Ds***) +0.6 *W-y* (**A**) |  |  |  |  |
| 216 | ***Sw*** +0.6(***Rl*** + ***Ds***) ***+*** 0.6 *W-y* (**B**) |  |  |  |  |