International Journal of Research Publication and Reviews, Vol 5, no 8, pp 1017-1024 August 2024

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Analysis and Design of Steel Frame Structure for a Treatment Plant

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ABSTRACT—

The effluent treatment plant is designed to treat the effluent coming from different areas of the plant. The treatment of different effluents varies with the type of effluent. Water is recycled from effluent coming from textile & chemical industries using series of operations. Thus the design of such effluent plant is quite essential in nowadays. The majority of the subsidiary industries, such as locomotive, ship-building, automobiles, machine-tools, engineering, etc., are diametrically associated with steel industry. The quality and quantity of the steel industry of a country significantly inspire the nature and type of the industrial development. This scheme of work looks forward for the analysis and design of a portion of treatment plant in Arulpuram, Tirupur, Tamilnadu and its typical frame, designed with a combination of fink and howe type truss. The analysis is carried out in STAAD.Pro software. For the duration of analysis, dead loads, live loads and wind loads were calculated using IS: 875 (Part 1) - 1987, IS: 875 (Part 2) - 1987 and IS: 875 (Part 3) - 1987 codes respectively and their combinations were smeared on the frame as per IS: 800 – 2007 code. The structural portions of the treatment plant were designed based on IS: 456-2000 code. The load combinations were applied in use to acquire the maximum design loads, moments and shear force.

I. INTRODUCTION

Industrialization is an inevitable feature of economic intensification in a developing country. In the way of employment-intensive industrialization, textile industries are playing an utmost important role offering tremendous opportunities for the economy of India. But, hasty and unplanned clustered growth of industries leads to adverse environmental consequence in an alarming way. Large quantity of water associated with the production of a number of dyeing and textile industries, releases toxic wastewater rich in dye and chemicals to the environment that result in severe water-body pollution. These un-treated industrial effluents not only deteriorate surface water quality, ground water, soil, vegetation, but also cause many water borne diseases that are threatening to public health. Therefore, treatment facility for such wastewater is strictly recommended within the industry.

1.2 Treatment Plant

The concept of CETP was adopted to achieve end-of-the-pipe treatment of combined wastewater to avail the benefit of scale of operation. In addition, the CETP also facilitates in reduction of number of discharge points in an industrial estate for better enforcement and also to make the skilled man power available for proper treatment of effluent. A total of 130 CETPs have come-up in the country, either established or in the process of establishment, to cater to the needs of the industrial clusters/group of industries of which, 91 CETPs are in operation. The status of zone-wise CETPs in the country is given below:

Zone-wise Status of CETPs in India

Northern Zone (UP – 3, Haryana – 1, Punjab –2, Delhi – 10 complete, 2under construction, 3

kept in abeyance) total 16

Western Zone (Gujarat – 19, Maharashtra – 12) total 31 Eastern Zone (WB-1) total 1

Central Zone (Rajasthan – 5, MP- 1) total 6

South Zone (T.N – 33, AP – 2, Karnataka – 2) total 37

1.3 Advantages of CETP

Facilitates ‘economy of scale’ in waste treatment, thereby reducing the cost of pollution abatement for individual SMEs addresses the ‘lack of space’ issue – CETP can be planned in advance to ensure that adequate space is available including plans for expansion in future homogenization of wastewater relatively better hydraulic stability professional control over treatment can be affordable facilitates small scale units, which often cannot internalize the externalities due to control of pollution eliminates multiple discharges in the area, provides opportunity for better enforcement i.e., proper treatment and disposal provides opportunity to improve the recycling and reuse possibilities facilitates better organization of treated effluent and sludge disposal etc.

1.4 Factors

- Categories of effluent generating member industries
- Qualitative/quantitative fluctuations of effluent (equalization/ homogenization / modules)
- Pre-treatment requirements
- Segregation of effluent streams at individual member industry
- Collection and monitoring mechanism
- Treatability choice of technology and degradability, interferences
- Mode of disposal; and
- Charging system

1.5 Truss

In Architecture and Structural Engineering, a truss is a structure comprising one or more triangular units constructed with straight slender members whose ends are connected at joints referred to as nodes. External forces and reactions to those forces are considered to act only at the nodes and result in forces in the members which are either tensile or compressive forces. Moments (torsional forces) are explicitly excluded because, and only because, all the joints in a truss are treated as revolute.

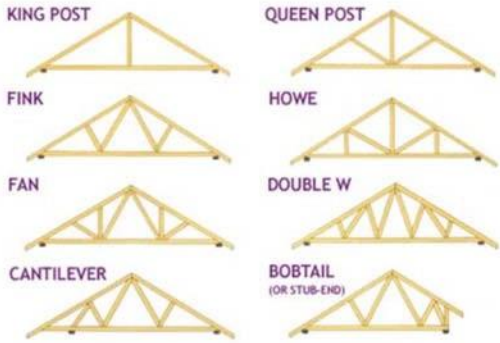


Figure 1.2: Types of Truss

2. REVIEW OF LITERATURES

Tara Sen, H. N. Jagannatha Reddy. Among the various natural fibers such as, sisal fibers, bamboo fibers, coir fibers and jute fibers are of particular interest as these composites have high impact strength besides having moderate tensile and flexural properties compared to other lignocellulosic fibers. Also by considering the case of waste disposal, an attempt is made to study the possibilities of reusing the above natural fibres which not only has various applications but also helps to solve the problem of waste disposal atleast to a small extent.

STRUCTURAL USES OF STAINLESS STEEL — BUILDINGS AND CIVILENGINEERING', **GRAHAM GEDGE (2008)**

This paper briefly discusses the important properties and commercial aspects of stainless steel alloys and alloys relevant to structural designers. The paper also describes about the contemporary progresses in the use of these alloys and discusses about the obstacles faced while using stainless steel in structural engineering that are related to both supply chain costs and efficiency of design. The paper communicates the use of hot rolled, cold formed and fabricated products, the preventing factors of use of steel including actual cost and fluctuating costs, a clear idea on the importance of balance between initial cost and whole life cost, maintenance factors and the requirement of sustainable structures. This paper helped to understand the relevance of using stainless steel as a construction material for the structural elements of the structure.

STEEL FRAME CONNECTION TECHNOLOGY OF THE NEW MILLENNIUM: SATISFYING HEIGHTENED PERFORMANCE EXPECTATIONS WITH SIMPLICITY AND RELIABILITY AT LOW COST', DAVID L HOUGHTON (2000)

This paper explains that the side plate connection system is a breakthrough technology because of its proven performance and reliability, durability, versatility, and cost efficiency. It eliminates recognized technical uncertainties of T-joint complete penetration groove weld to connect beam flanges directly to a column flange, and to connect a heavy bracing member's flanges to either a column flange or beam flange. Connection ductility and robustness are achieved by using redundant clearly defined load paths that can be determined by simple statics, giving due design consideration to the direction of applied load on each weld. The unique trademark geometry, simple design configuration, increased connection stiffness, and proven construction methods that collectively characterize the attributes of the side plate connection system are ideally suited to satisfy a wide variety and technically diverse set of design environments and construction applications for steel frame structures. This paper reveals the diverse benefits of side plate connection.

COLD FORMED STEEL JOINTS AND STRUCTURES -A REVIEW', BAYAN A. (2011)

This mentions the structural use of cold formed steel in construction continually growing rapidly across the world exceeded that for hot rolled steel structural members. The use of thinner sections and high strength steels leads to design problems for structural engineers, which may not normally be encountered in routine structural steel design. This paper has concentrated on structural design consideration of cold formed steel sections and research developments on joints and structures, which have come into view in the principal journals in this area in

purpose of increasing the usage of cold formed steel members. It was concluded from the review that studying connections and portal frame among single cold formed steel sections in both experimental and numerical approach becomes a new area of study.

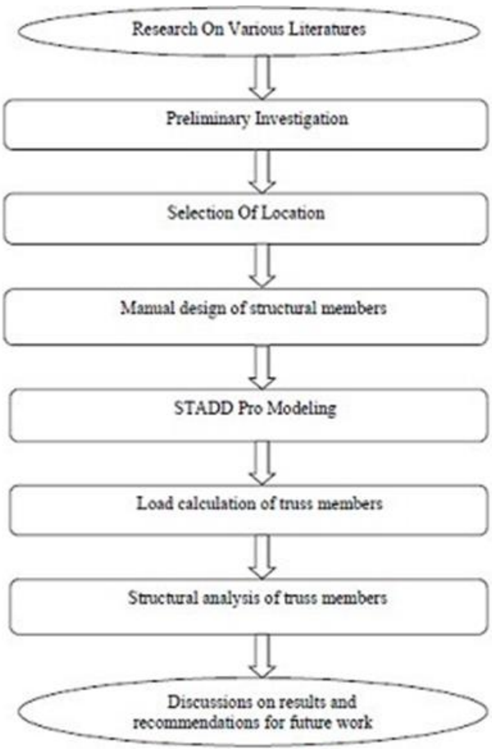
STUDY, TEST AND DESIGNING OF COLD FORMED SECTION AS PER AISI CODE', SUNIL M. HARDWANI (2012)

This explains use of hot rolled steel member in structures as a well-known practice in construction industry. But, in case of light and moderate loaded structures, the usage of hot rolled steel section leads to overweight and is uneconomical. To overcome this deficiency, a new form steel known as cold formed steel has come into practice. Cold Formed steel product such as Z-purlin has been commonly used in metal building industry more than 40 years in unites state due to their wide range of application, economy, ease of fabrication and high strength-to-weight ratios. Z- purlins are predominantly used in light load and medium span situations such as roof systems. The paper describes the review of the literature on local buckling, torsional bucking, Distortional buckling, Channel section with Stiffened Lip and Channel section with un-stiffened lip formed members. For tensile test a test specimen of Z section fabricated according to the IS: 1608 - 2005.The design of cold formed section is also explained with numerical example is provided in the paper.

NUMERICAL ANALYSIS OF COLD-FORMED STEEL PURLIN-SHEETING SYSTEMS, L.C.M. VIEIRA JR. (2008)

This paper explains the structural behavior of a cold-formed steel purlin-sheeting system as complex. According to him, to adequately model the response using computational methods, the numerical analysis must consider material and geometrical nonlinearity, and in addition the influence of contact between the purlin, sheeting, and connection should also be considered. In the study, models proposed in the literature were analyzed and compared with a finite element model that was developed considering the essential nonlinearities including contact. With the success of the model a parametric study is conducted to better understand the impact of the purlin, sheeting, and connection variables on the purlin demands in wind uplift. Empirical design expressions are generated using the parametric study to provide engineers a more convenient means to predict the bending demands on the purlin as a function of the displacement due to wind uplif

3. METHODOLOGY



4. EXPRIMENTAL INVESTICATION

4.1Geotechnical Investigations

The geotechnical investigation includes mobilization of boring rings with all necessary equipment and personnel, boring of five boreholes of 150 mm diameter with rotary drilling equipment through soil profile such as, sand, silt, clay and gravel to a maximum depth of 18.5 m, penetration of standard penetration testing machine to the bore holes and then collected the disturbed samples, further proceeded for various laboratory tests. The objective of investigation was to ascertain the nature and characteristics of sub-soil below the ground level at the proposed site. The study is carried out for the identification of suitable foundation system for the proposed structure and assessment of safe bearing capacity. Safe bearing capacity of 300KN/m2 can be used in lateritic gravelly silty sand. The site for a proposed plant is pre-selected before design. It is better to give due consideration to the factors governing site selection which is related to the design of the plant. The factors to be considered are as follows: ease of access to arterial road, local availability of raw materials, accessibility of facilities like water supply, electricity, telephone, etc., topography and water drainage, soil condition, space for storage of raw materials and finished products, accessibility, transportation facilities to deliver raw materials and finished products, waste disposal facilities, etc.

4.2 Location of Site

Tiruppur is located at 11.1075°N 77.3398°E. It has an average elevation of 295 metres (967 feet). Tiruppur is situated on the banks of the Noyyal River. The southern part of the city enjoys more rainfall. The mean maximum and minimum temperatures for Tiruppur city during summer and winter vary between 35 to 22 °C (95 to 72 °F). Arulpuram is a Locality in Tiruppur City in Tamil Nadu State. Arulpuram effluent treatment plant was selected as study area. In which a portion of the treatment plant was designed along with the roofing structure undertaken by TWIC (Tamilnadu Water Investment Company).

5. STAAD.PRO ANALYSIS OF TREATMENT PLANT

5.1 Chemical Storage Godown

Figure 6.1: Chemical Storage Godown

Figure 6.2: Beam Stress Distribution

Figure 6.3: Combination of Loads

Figure 6.4: Shear & Displacement

6. STRUCTURAL ASPECTS

The structural analysis of the steel frame structure mainly involves the analysis of its roof truss or bent. The design of the members can be done only after the roof truss is analyzed. To calculate the different loads on the truss, the roof coverings and purlins are designed first. A structure is subjected to various types of loadings such as permanent, semi-permanent, movable, moving and occasional. The permanent loads are due to self-weight of structure, semi-permanent ones are due to fixtures, which are rarely removed, movable loads are due to machines, stationary, etc. and moving loads are mostly moving on the structure. The occasional loads are due to wind, earthquake or floods. For design purpose the analysis if carried out for loads described, designed for and checked for occasional loads by permitting increase in permissible stresses and strains. All the truss elements were considered as plain frames because the length of the structure is large compared to its breadth. While analyzing a truss, it is assumed that bending takes place only in one direction, that is a three dimensional analysis is avoided. The most critical load on industrial building is wind load. The structure is analyzed for wind as per IS: 875 (Part3) - 1987.

7.2 IS Code Recommendations on Loads on Buildings

The reference for the basic loads for the building is referred in accordance with IS: 875 – 1987. The basic loads coming on the structure are dead loads, live loads, snow loads, dynamic imposed loads, erection loads, accidental loads, wind loads and earthquake loads.

7.2.1 Dead Loads

The dead loads may be calculated on the basis of unit weights of materials given in IS: 875 (Part 1) – 1987. The dead loads on the buildings comprises of the weight of walls, partitions, floors, beams, slabs and roofs and shall include weight of all other permanent construction in the building. The dead load on the roof truss of industrial buildings includes the dead load of roofing, purlins, trusses, bracing systems, etc. The weight of bracing may be assumed to be 12 to 15 *N/m2* of the plan area. An empirical formula for estimating the dead weight of truss is given by {((Span//3) +5) x 10}

7.2.2 Live Loads

Live loads are assumed to be produced by the intended use of occupancy of a building, comprising the weight of movable partitions, distributed and concentrated loads, loads due to impact and vibration and dust load but excluding snow, seismic, wind and other loads due to creep, shrinkage, differential settlement and temperature changes etc. The live loads of various occupancies were obtained from IS: 875 (Part 2) – 1987.The code specifies the following live loads to be assumed in the analysis of an industrial building.

Table 7.1 – Live Loads

Roof slope	**Access**	**Live load**
≤10o	Provided	1.5 kN/m2of plan area
	Not provided	0.75 kN/m2 of plan area
≥10o		Less 0.02 kN/m2 for every degree increase in slope over 10 but not less than 400 N/m2

8. LOAD CALCULATION OF STEEL FRAME STRUCTURE

The analysis and design of steel frame structure correspond to the treatment plant sections mentioned above is detailed at this juncture.

8.1 General Details

Client : TWIC

Project : Structural design of plant Location : Arulpuram, Tiruppur

Type of building : Effluent treatment plant

Area of building : 22979 m2 (247343.900 *sq.ft.*)

8.2 Building Details

Eave height: 12.00 m Ridge height: 16.00 m Number of spans: 4 Nos Single span width: 30.00 m Total span width: 120.00 m Number of bays: 16 Nos Single bay length: 12.00 m Total bay length: 192.00 m Roof angle: 15o

8.3 Load Calculation

8.3.1. Data Required

Roof truss type : Combination of fink and howe type truss Slope of truss, $\propto = 15^o$

Half span of truss, *l* = 15.00 *m*

Slanting half span, *ls* = l/cos = 15/ cos15 = 15.50 m Single bay length, lb = 12 m

8.3.2 Dead Load Calculation

Weight of purlins, w1 = 100 N/m Weight of GI sheets, w2 = 150 N/m2 Weight of bracing, w3 = 12 N/m2

Self-weight of truss by empirical formula,

w4 = [(span/3) + 5] x 10

= 100 N/m2

Total weight per m2, w5 = w2+w3+ w4

= 150+12+100

= 262 N/m2

Total load on intermediate panel points, g

= w5 x lb x lp + w1 x lb

= 262x12x1.5+100x12

= 4716+1200

= 5916 N

≅ 6 kN

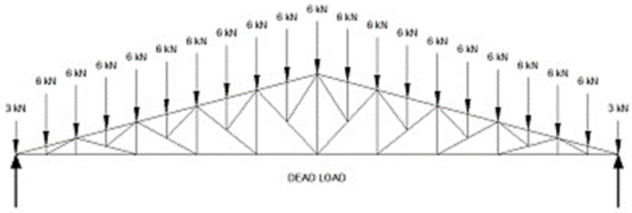


Figure 8.1 Dead loads distribution on roof truss

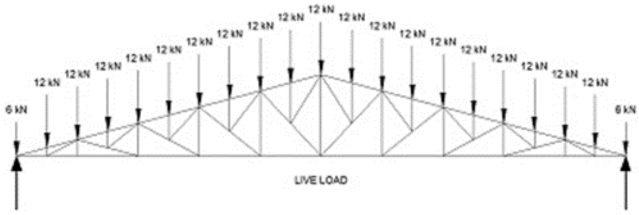


Figure 8.2 Live loads distribution on roof truss

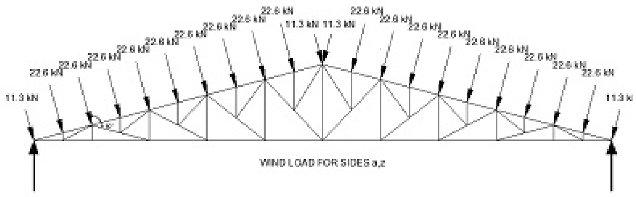


Figure 8.3 Wind loads distribution on roof truss

8. STAAD.PRO ANALYSIS

8.1 Input Data

Staad.Pro analysis was carried out for various trial sections and the section with combination of fink and howe type was found to be economical. The various data relevant to truss was applied in the software. 2ISMC250, 2ISMC100 and ISMC100 were used for the members. Support condition was provided as hinged.

8.2 Analysis Method

Dead loads, Live loads and wind loads as per the calculated values were applied. The structure was analysed for dead load, live load, wind load and combinations loads as the following

- **(i)** 1.5 (Dead Load + Live Load)
- **(ii)** 1.5 (Deal Load + Wind Load)
- **(iii)** 1.2 (Dead Load + Live Load + Wind Load)

8.3 Analysis Results

Table 9.7 - Steel Take-Off

PROFILE	LENGTH (*m*)	WEIGHT (*kN*)
D ISMC250	24.00	14.259
D ISMC100	65.05	11.693
ST ISMC100	79.75	7.168
TOTAL		33.120

Diagrams


Figure 8.1 - Shear force diagram


Figure 8.2 - Bending moment diagram


Figure 8.3 - Bending stress diagram

Figure 8.4 Reactions

9. RESULTS AND DISCUSSION

From the investigation of analysis report, the data required for the further development of the project have been obtained. The member forces required for the design of the members were obtained as shown in the Figure. As the loading and combinations are symmetrical, the values can be mirrored to obtain the forces for the whole structure.

Figure 9.1 - Member forces

The other relevant data obtained from the analysis of the structure can be summarized as follows:

Maximum axial force	1.63 *kN*
Maximum shear force	46.5 *kN*
Maximum bending moment	36.1 *kN*
Support reaction	60.0 *kN*

Table 9.1 – Results from Analysis of Structure

10. CONCLUSION

The comprehensive scrutinizes of the project can be wrapping up by considering the analysis and design of an effluent treatment plant structure located at Arulpuram, Tiruppur. In this project, some portion of the structure was analyzed by incorporating with a combination of fink and howe type truss. The structure was modeled and analyzed using the structural designing software STAAD.ProV8I. The results obtained from the STAAD output have been thoroughly examined.

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