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Analysis, Design and Optimization of ESP Steel Structure By Using STAAD. Pro

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Abstract - *India is one of the largest country having dense population and parallels among most polluted country in the globe. And air pollution is leading into the list. To overcome on this we are building up in the direction of up gradation. With the help of science & technology we are improving our techniques better and better. Electrostatic Precipitator is one of those technologies which can reduce the air pollution on large scale. In this dissertation we are looking forward to improvise the structure of ESP. In this significant progress process, the computer technology play a very important role, for example, Fluent used in CFD to model gas distribution, SCILAB using in emulation ESP. STAAD is professional steel structure design software, it is very specific, and easy to use, it built-in several countries steel structure specifications. This paper introduces the application of STAAD in ESP structure design. It can be conclude very precise stress of every parts in any loading condition, it's very useful to optimize, decrease the steel consumption and increase security, meanwhile in the condition of "whole type" model, STAAD can conclude the cycle of self-oscillation, analysis the affection and force transmit of every part, also it can analysis the affection of loading distribution. Here by Analysis, design and optimizing the existing structure of Electrostatic Precipitator structure we got overcome local capacity problem and Economy.*

***Key Words*: Electrostatic precipitator, steel structure, Support structure, IS code, American standard code, STAAD.Pro**

1. INTRODUCTION

Electrostatic precipitator (ESP) is a device commonly used in processing industry and energy industry to remove particles or liquid droplets from flue gas. The particle separation is achieved using electrostatic force. In many industrial plants, particulate matter created in the manufacturing process is released as dust in the hot exhaust gases. If released into the atmosphere, the particulates reduce visibility, can contribute to climate change, and lead to serious health problems in humans, including lung damage and bronchitis. Fine particles that are smaller than 2.5 microns (0.0001 inch) in diameter can be especially dangerous because they are drawn deep into the lungs and can trigger inflammatory reactions.

Fig -1: Electrostatic Precipitator

1.1 Mechanism of electrostatic precipitators

An ESP collects and removes particles in flue gas by electrically charging particles. An intense electric field is maintained between high-voltage discharge electrodes, typically wires, rigid electrodes, or rigid frames, and the grounded collecting electrodes, typically plates. A corona discharge from the discharge electrodes ionizes the flue gas passing through the precipitator, and gas ions subsequently ionize fly ash or other particles. The negatively charged particles are then attracted and collected on grounded collecting electrodes (collection plates). Some designs also incorporate high voltage collection surfaces that collect oppositely charged particles. Because precipitators act only on the particulate to be removed, and only minimally hinder flue gas flow, they have very low-pressure drops, and thus low energy requirements and operating costs. The collecting electrodes in dry precipitators are rapped periodically or continuously to dislodge collected particulate, which falls into hoppers for removal. In wet precipitators, a water spray removes the particulate from the collecting plates and discharge electrodes.

1.2 About STAAD Software

STAAD.Pro is a structural analysis and design software which is widely used to analyse and design structures for bridges, towers, buildings, transportation, industrial and utility structures. STAAD.Pro allows structural engineers to analyse and design virtually any type of structure through its flexible modelling environment, advanced features and fluent data collaboration. STAAD is professional steel structure design software, it is very specific, and easy to use, it built-in several countries steel structure specifications, and was favourite by engineers. This article introduces the application of STAAD in ESP structure design. STAAD Structural Analysis and Design is a patent program which shared by Research Engineers International in California America. STAAD features a state-of-the-art user interface, visualization tools, powerful analysis and design engines with advanced finite element and dynamic analysis capabilities.

1.3 STAAD's user Interface in industry standard

Structural Steel is a common building material used throughout the construction industry. Its primary purpose is to form a skeleton for the structure, essentially the part of the structure that holds everything up and together. Complex models can be quickly and easily generated through powerful graphics, text and spread-sheet interfaces that provide true interactive model generation, editing, and analysis. STAAD easily generates comprehensive custom reports for management, architects, owners, etc. The STAAD Structure Wizard contains a library of trusses and frames. Use Structure Wizard to quickly generate models by specifying height, width, breadth and number of bays in each direction. Reports contain only the information you want, where you want it.

1.4 Objectives of the study

- The ESP shall be functional and structurally sound by the proper consideration of all applicable loads.
- To overcome local capacity problem & optimization in order to get an overall economy.
- The basis of design shall be uniform throughout industry.

2. METHODOLOGY

The data provided by 'CNSES Global', which is Structural Engineering Solution Company. The guidance of dissertation is done under Mr. Atul Sonavane who is the Design manager of the company. First and foremost thing has to carried out is to study and well understanding of vendor drawing that given by company.

2.1 Modelling the structure

The modelling of supporting structure of electrostatic precipitator is been designed and analysed by STAAD.Pro Software. Two different models are developed as follows,

Model 1: ESP structure with Indian Design

Model 2: ESP structure with American Design

Modelling of designs are same as per requirement of vendor drawing of ESP.

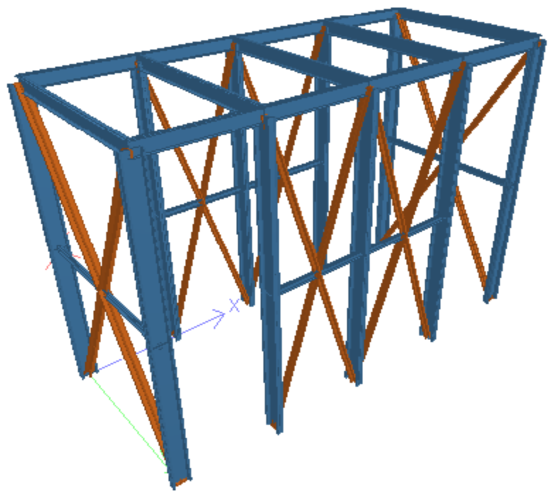

Fig -2: 3D Rendered view of Model

2.2 Type of bracing system

In the modelling of ESP's supporting structure, Cross bracing (X-shaped) is used for both Indian and American design. The region behind is, cross bracing increases the Structural capability to withstand seismic activity. It is utilizing to reinforcing Structure in which diagonal support intersect placed in X shaped manner, these supports compression and tension forces. With different forces, one brace will be under tension while other is being compressed.

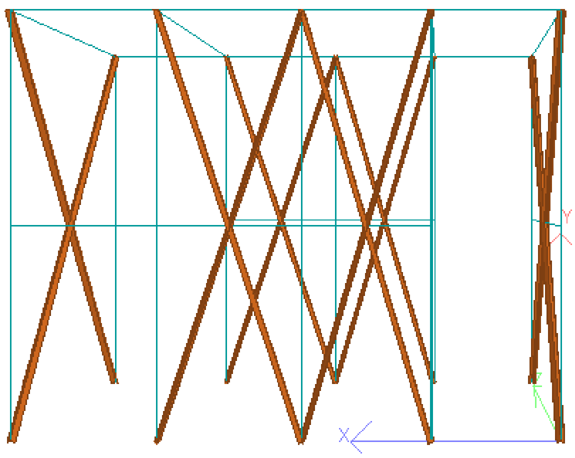

Fig -3: Cross bracings

In other hand disadvantage of Chevron bracing Unless the beams are designed to carry this net vertical load together with the axial loads that develop from the chevron braces, a plastic hinge eventually forms at mid-span of the beams before the tension braces reach their yield tensile capacity.

2.3 Applying various types of loads

All loads listed here in to be act as load combinations, whichever produce the most unfavourable effect in either the support system of electrostatic precipitator or structural system as a whole or structural member is being considered. The most unfavourable effect may occur when one or more of the contributing loads are not acting.

2.4 Primary load combinations are considered

Both models are designed by serviceability which deals with durability of structure and by collapse which deals with safety of structure. In Indian design total numbers of load combinations are 46 and in American design total number of load combinations are 73.

2.5 Design parameter

Both models (Indian & American) are designed by serviceability which deals with durability of structure and by collapse which deals with safety of structure. For Indian model 'IS800 2007 LSD' code is used. For American model 'AISC 360-10' code is used.

Table -1: Design parameter for Indian design

Sr.no	Parameter 1 (Serviceability)	
1	Maximum allowable local deflection	240
2	Ratio of actual load to section capacity	0.9
3	Print design output at detail level	2
	Parameter 2 (Collapse)	
1	End connection type factor	0.8
2	Beam parameter	1
3	Cm value in local Y-axis	0.9
4	Cm value in local Y-axis	0.9
5	Ratio of the moment at the end of laterally unsupported length of beam & column	1
6	Ratio of the moment at the end of laterally unsupported length of bracing & girt	0.8
7	Permissible ratio of actual allowable stress	0.95
8	Ultimate tensile strength of steel in KN/m^2	420000
9	Yield strength of steel in KN/m^2	250000
10	K value in minor axis	1.2
11	K value in major axis	1.2
12	Length in local Z axis for slenderness value	13 m
13	Length in local Y axis for slenderness value	6.5 m
14	Length in local X axis for slenderness value	6.5 m
15	Net section factor for tension member	0.9
16	Slenderness limit for Beam (compression)	250
17	Slenderness limit for Column (compression)	180

Table -2: Design parameter for American design

Sr.no	Parameter 1 (Serviceability)	
1	Maximum allowable local deflection	400
2	Permissible ratio of actual load to section capacity	0.9
3	Print design output at detail level	2
	Parameter 2 (Collapse)	
1	Beam parameter	1
2	Ratio of the moment at the end of laterally unsupported length of beam & column	1
3	Ratio of the moment at the end of laterally unsupported length of bracing & girt	0.8
4	Permissible ratio of actual allowable stress	0.95
5	Ultimate tensile strength of steel	420000 KN/m^2
6	Yield strength of steel	250000 KN/m^2
7	K value in minor axis	1.2
8	K value in major axis	1.2
9	Length in local Z axis for slenderness value	13 m
10	Length in local Y axis for slenderness value	6.5 m
11	Length in local X axis for slenderness value	6.5 m
12	Net section factor for tension member	0.9
13	Slenderness limit for compression member	180

3 RESULT AND DISCUSSION

3.1 Stabilized structure by considering all applicable loads

In both modeling, after optimization of structure is capable of withstanding with the each and every load. Both models are designed by serviceability which deals with durability of structure and by collapse which deals with safety of structure. In Indian design total numbers of load combinations are 46 and in American design total number of load combinations are 73. That much variety of load combinations together with load factors for each load type in order to ensure the safety of structure under different maximum expected loading scenario. In American design (Model-2), load combinations for structure are created on the basis of load combinations of pipe rack design format from PIP (Process industry practices).Load combination created for structure of both allowable stress design (ASD) and strength design format. Load combinations is as follows,

Table -3: Load combinations by serviceability

LOAD COMBINATIONS- ASD (SERVICEABILITY) (Based on PIP STC01015 Table no.7)			
Load Comb. No.	**Loading Combination**	**Allowable Stress Multiplier**	**Allowable Stress**
1	DL + EE + WL	1.00	Empty Weight + Wind load (Wind Uplift Case)
2	0.9(DL + EE) + 0.7SL	1.00	Empty Weight + Earthquake (Earthquake Uplift Case)
3	DL + EO + TL + ET	1.00	Operating Weight +Thermal Expansion of Structure & ESP
4	DL + EO + ET + (WL or 0.7SL)	1.00	Operating Weight +Thermal Expansion of ESP + (Wind or Earthquake)
5	0.9(DL) + 0.6 (EO) + ET + 0.7SL	1.00	Operating Weight +Thermal Expansion of ESP + Earthquake (Earthquake Uplift Case)
6	DL + DT + WL	1.20	Test Weight + Wind Load

Table -4: Load combinations by collapse

LOAD COMBINATIONS- STRENGTH DESIGN (COLLAPSE) (Based on PIP STC01015 Table no.8)		
Load Comb. No.	**Loading Combination**	**Allowable Stress**
1	0.9(DL + EE) + 1.6 WL	Empty Weight + Wind load (Wind Uplift Case)
2	0.9(DL + EE) + 1.0 SL	Empty Weight + Earthquake (Earthquake Uplift Case)
3	1.4(DL + EO + TL + ET)	Operating Weight +Thermal Expansion of Structure & ESP
4	1.2(DL + EO + ET) + (WL or 0.7SL)	Operating Weight +Thermal Expansion of ESP + (Wind or Earthquake)
5	0.9(DL + EO) + 1.2 ET + 1.0 SL	Operating Weight +Thermal Expansion of ESP + Earthquake (Earthquake Uplift Case)
6	1.4(DL + DT)	Test Weight
7	1.2(DL + DT) + 1.6 WL	Test Weight + Wind Load

3.2 Standardization of design

As per literature Revive studied till now for this dissertation work (Supporting system of ESP), no specific standardized design had work as per Indian standard and American standard by CAE method. After this thesis work satisfactorily design is available in Indian standard and American standard.

3.3 Solution on local capacity problem

Before designing ESP's supporting structure, Chevron (inverted-V) bracing is been used. Arrangement of bracing system is set as vertical bracing. This bracing created an angle of 15 to 20 degree from bottom of column. In modelling of structure chevron bracing is replaced by Cross bracing (X-shaped). Cross bracing increases the Structural capability to withstand seismic activity. It is utilize to reinforce Structure in which diagonal support intersect placed in X shaped manner, these supports compression and tension forces. With different forces, one brace will be under tension while other is being compressed. In the X bracing axial stiffness of the beam does not occur. On the other hands, under severe earthquake ground motions, the braces are expected to buckle and lose their compressive strength. The beams are then pulled downward due to the combined action of the gravity loading and the tension acting braces. Unless the beams are designed to carry this net vertical load together with the axial loads that develop from the braces, a plastic hinge eventually forms at mid-span of the beams before the tension braces reach their yield tensile capacity. One more disadvantage is it costly compared to Cross-brace, due to larger material consumption and fabrication.

3.4 Steel consumption

The analysis has been carried out in order to study the steel consumption of ESP's supporting structure using two different codes, having two different locations i.e. Model 1 (Indian design) and model 2 (American design) is carried out using STAAD.Pro software. As per data provided by CNSES Global Company the total tonnage of structure is 58.488. After optimizing the structure by CAE analysis the results is as follows,

3.4.1 Steel consumption by Indian design

Table -5: Steel consumption by Indian design

Profile	Length (m)	Weight (kN)
ISMB 600 TB	130.00	278.624
ISMB 400 ST	67.98	40.99
ISMB 200 ST	30.49	7.21
ISA 150X150X12 LD	123.20	65.86
ISA 180X180X15 LD	76.42	61.17

As per above table,

ISMB 600 is used for column,

ISMB 400 is used for beams,

ISMB 200 is used for girt,

ISA 150X150X12 & ISA 180X180X15 is used for bracings.

As we know, 1kN = 0.1tons

Overall steel consumption for column section is 13.0 tons.

Overall steel consumption for beam section is 6.798 tons.

Overall steel consumption for bracing is 19.962 tons.

Overall steel consumption for girt is 3.049 tons.

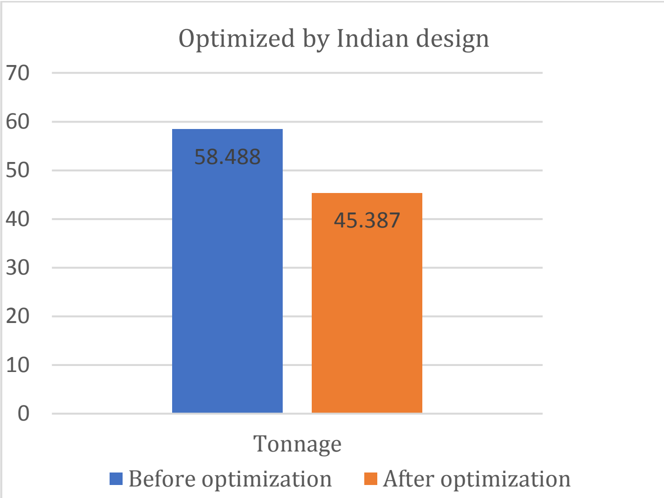

Fig -4: Steel optimization by Indian design

Overall steel consumption for Whole structure is 45.387 tons.

Near about 22.39% is saved by Indian Design.

3.4.1 Steel consumption by American design

Table -6: Steel consumption by Indian American design

Profile	Length (m)	Weight (kN)
W 30X148 ST	78.00	168.547
W 30X90 ST	52.00	67.779
W 24X103 ST	67.98	102.085
L 80X80X8 LD	199.62	155.124
W 12X50 ST	30.49	22.062

As per above table,

W 30X148 & W30X90 is used for column,

W 24X103 is used for beams,

W 12X50 is used for girt,

L 80X80X8 is used for bracings.

Overall steel consumption for column section is 23.632 tons.

Overall steel consumption for beam section is 10.208 tons.

Overall steel consumption for bracing is tons 15.512 tons.

Overall steel consumption for girt is tons 2.206 tons.

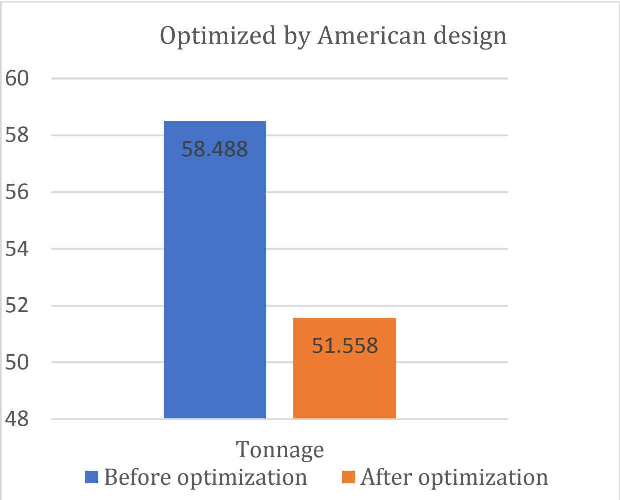

Fig -5: Steel optimization by American design

Overall steel consumption for Whole structure is 51.55 tons.

Near about 11.94% is saved by American Design.

4. CONCLUSIONS

- After optimization more reasonable structural design parameter were obtained.
- The modeling of supporting structure of ESP including top beam, column, and bracings were finished in this study.
- At last optimization of structure is been obtained by result interpretation carried out & by comparing the tonnage of the structure before and after the dissertation work. The optimized, stable, structure which is the aim of 'CNSES Global' has achieved.
- Nearly 22.39% of tonnage saved by Indian design and 11.94% by American design.

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REFERENCES

[1] The Institute of Clean Air Companies, Structural design criteria for ESP casings, ICAC 1993

[2] Xuewen Wang, Bo Li, and Zhaojian Yang,Finite Element Analysis and Lightweight Optimization Design, Hindawi,6 Nov. 2017

[3] Main Frame Structure of Large Electrostatic Precipitator, 8 January 2018.

[4] Petri sjoholm, Heikki torvela, "Gas cleaning technology", Industrial ventilation design guide book, 2001

[5] Gallimberti, Recent advancement in the physical modelling of electrostatic precipitators, Elsevier, 9 Jan. 1998

[6] M. Karunakaran, P. Sivakumar, N. Chira, Electrostatic precipitator in ash removal system, International journal of innovative technology and exploring engineering, February 2019

[7] R. S. Adhav, A. Samad, and F. Kenyery, "Optimal design of an Electrostatic precipitator to handle upto 10% GVF", International Journal of Oil Gas and Coal Technology, vol.13, no.4, 2016

[8] K. P. Shah, "Construction, Working, Operation and Maintenance of Electrostatic Precipitators", January 2017

[9] The Institute of Clean Air Companies, Terminology for Electrostatic precipitators, ICAC, November 2000

[10] F.J. Gutiérrez Ortiz , B. Navarrete, L. Canadas,"Dimensional analysis for assessing the performance of electrostatic precipitators", Elsevier, 20 July 2010

[11] XIE Hongwei, PENG Renhong, GAO Xing, Application of STAAD in ESP Structure Design, Wuhan kaidi sky science and technology, 2009

[12] G. S. Mill and W. O. Milligan, "Electrostatic precipitator", Access Science' McGraw-hill Education, 2014

[13] IS 800:2007 – General construction in steel-code of practice

[14] IS 875 (part 1):1987 – Code of practice for design loads other than earthquake for buildings and structures-Dead loads

[15] IS 875 (part 2):1987 - Code of practice for design loads other than earthquake for buildings and structures-Imposed loads

[16] IS 875 (part 3):2015 - Code of practice for design loads other than earthquake for buildings and structures-Wind loads

[17] IS 1893 (part 4):2015 - Criteria for earthquake resistant design of structures-Industrial structures

[18] PIP STC01015 Structural design criteria

[19] ASCE 7-05 - Minimum Design Loads for buildings and other Structure

[20] AISC 360-16 – Specification for structural steel building