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CRITICAL REVIEW OF COMPUTER-AIDED ANALYSIS AND DESIGN FOR STEEL INDUSTRIAL STRUCTURES

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ABSTRACT

This paper aims to discuss the industrial buildings' Analytical, Numerical, and Experimental results. Before starting the experimental part, the industrial facility with Howe truss configuration of size 18m X 60m was Analyzed and Designed using SAP software and then scaled to a model of length 1.8m X 1m for which load-deflection behavior has been computed. The results of the model from the CIVIL FEM Software are also added.

KEYWORDS: Howe truss, SAP Software, CIVIL FEM Software.

The SAP name has been synonymous with state-of-the-art analytical methods since its introduction over 30 years ago. SAP2000 follows the same tradition, featuring a sophisticated, intuitive, and versatile user interface powered by an unmatched analysis engine and design tools for engineers working on transportation, industrial, public works, sports, and other facilities.

From its 3D object-based graphical modeling environment to the wide variety of analysis and design options completely integrated across one powerful user interface, SAP2000 is proven to be the most integrated, productive, and general-purpose structural program on the market. This intuitive interface allows you to create structural models rapidly and intuitively without long learning curve delays. Now, you can harness the power of SAP2000 for all your analysis and design tasks, including minor day-to-day problems. Objective

Civil FEM is one of the most advanced, comprehensive, and reputable finite element analysis and design software available for the Civil Engineering Projects. The system combines the state-of-the-art general-purpose structural analysis features of ANSYS (ISO-9001) with high-end, civil engineering-specific structural analysis capabilities of Civil FEM, making it a unique and powerful tool for a wide range of civil engineering projects (such as power plants, bridges, tunnels, singular buildings, offshore structures, etc.). Civil FEM Multidiscipline includes all the specialized modules developed for Civil FEM (INTRO, Geotechnical, Bridges, Civil Non-linearity, and Advanced Prestressed Reinforced Concrete Modules), providing users with a complete solution that will suit all their civil engineering needs. Any of these solutions work as an "add-on" with any unlimited ANSYS product: Professional NLT and NLS, Structural, Mechanical, and Multiphysics.

OBJECTIVE:

The objective of the thesis is to find the following:
Analysis and Design of Howe roof truss Industrial building of size 18m x 60m with each bay of span 5m by using SAP software and then to Scale down $1/10^{th}$ of the above Industrial building to prototype of size 1.8m x 1m with each bay of span 0.5m.
To discuss the Analytical, Theoretical, and Experimental Investigation of the Howe roof truss Prototype of size 1.8m x 1m each of span 0.5m.

DESIGN AND ANALYSIS - SAP

In this topic, I am going to discuss the analysis and design of the industrial building of size 18m X 60m with bays of span each 5m and the model of length 1.8m X 1m with bays of span each 0.5m by using the SAP software and CIVIL FEM software.

INDUSTRIAL BUILDING - HOWE TRUSS

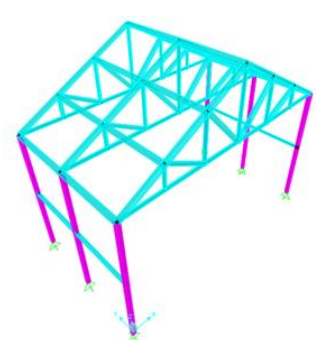

Fig 3.1 Prototype – 3D View

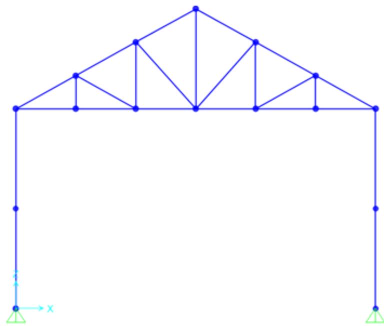

Fig 3.11 Prototype – Front view

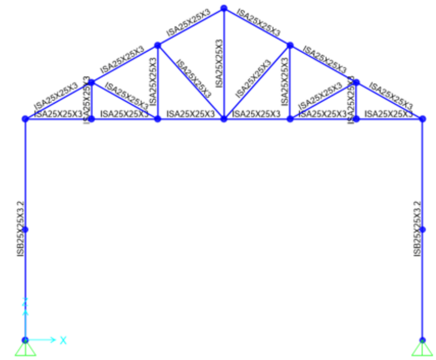

Fig 3.15 Prototype – Front view - Section

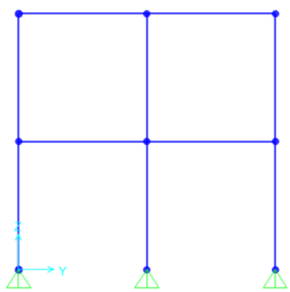

Fig 3.12 Prototype – Side view

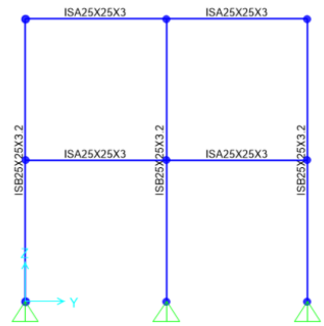

Fig 3.16 Prototype – Side face view – Section

GRAPHICAL OUTPUT

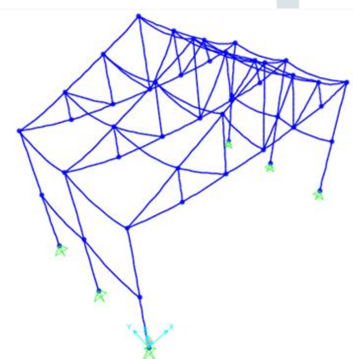

Fig 3.13 Prototype – Deflection profile

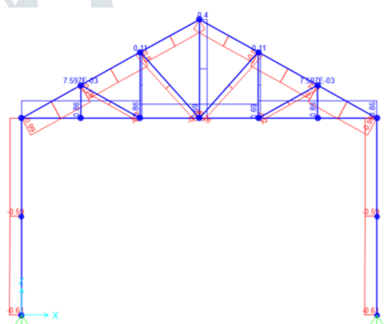

Fig 3.17 Prototype – Axial force

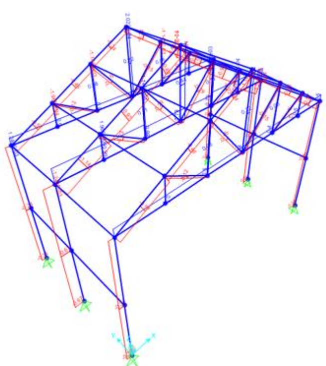

Fig 3.14 Prototype – Axial force

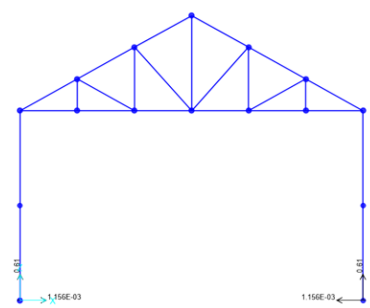

Fig 3.18 Prototype – Base reaction

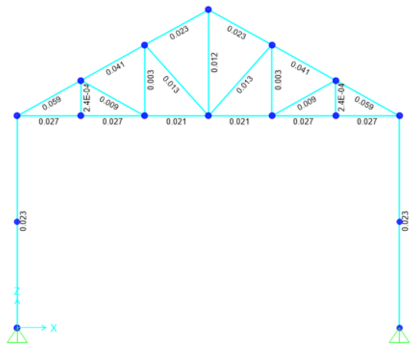

Fig 3.19 Prototype – Load carrying capacity ratio (Effective area)

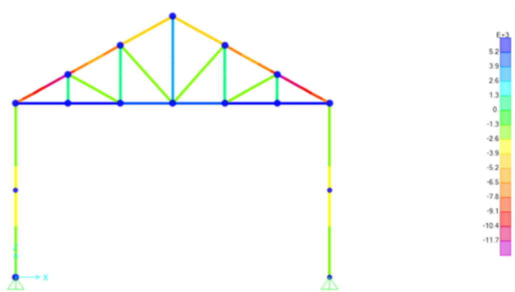

Fig 3.20 Prototype – Stress Diagram – End truss

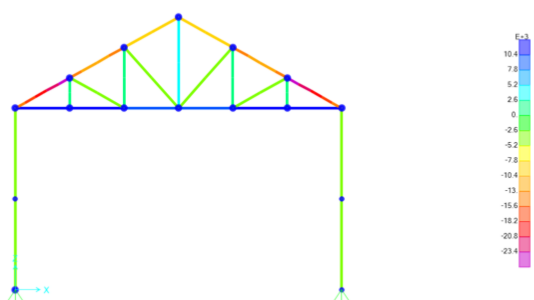

Fig 3.21 Prototype – Stress Diagram – Intermediate truss

NUMERICAL OUTPUT

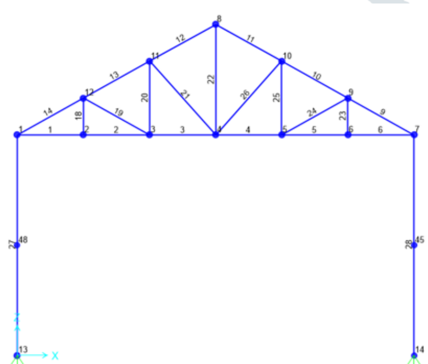

Fig 3.22 Prototype – Beam and Node numbers

DESIGN AND ANALYSIS - CIVIL FEM

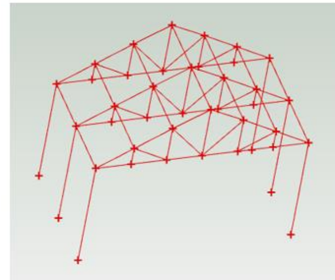

Fig 3.31 Model – 3D View – CIVIL FEM

Fig 3.32 Model – After mesh generation

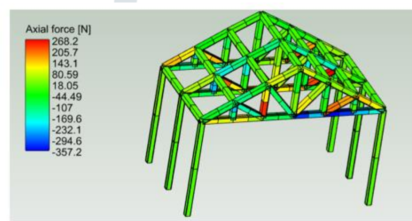

Fig 3.33 Model – Axial Force – CIVIL FEM

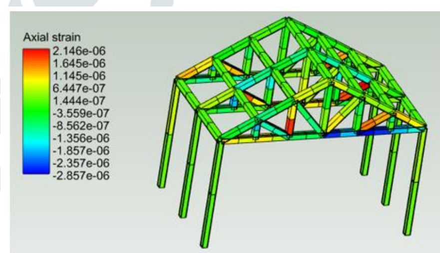

Fig 3.34 Model – Axial Strain – CIVIL FEM

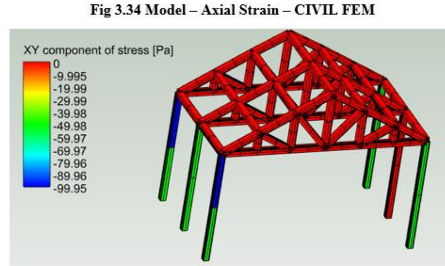

Fig 3.35 Model – Components of stress in XY plane – CIVIL FEM

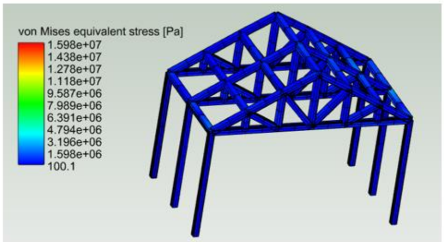

Fig 3.36 Model – Von Mises equivalent stress – CIVIL FEM

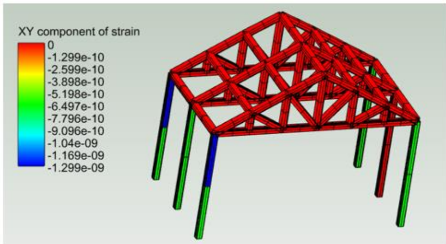

Fig 3.37 Model – Components of strain in XY plane – CIVIL FEM

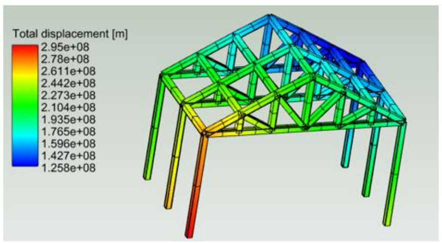

Fig 3.38 Model – Total displacement – CIVIL FEM

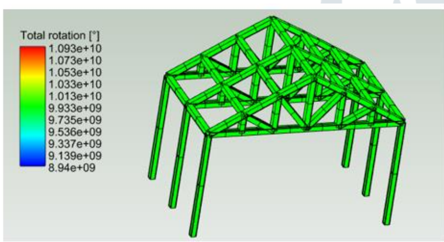

Fig 3.39 Model – Total rotation – CIVIL FEM

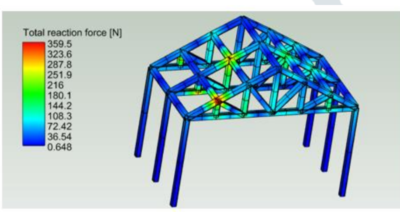

Fig 3.40 Model – Total reaction force – CIVIL FEM

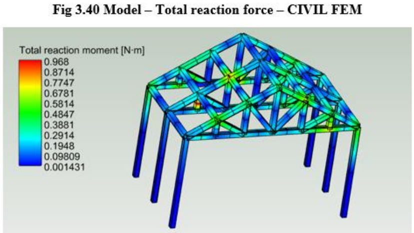

Fig 3.41 Model – Total reaction moment – CIVIL FEM

EXPERIMENTAL STUDY

In this chapter, I will discuss the experimental study of the model and the fabrication details.

MODEL DESCRIPTIONS

Table 5.1 Model – Details

DESCRIPTION	VALUE	UNITS
SPAN LENGTH	1.8	m
NO OF BAYS	2	
BAY LENGTH	0.5	m
TOP CHORD MEMBER SECTION	ANGLE SECTION 25X25X3	mm
BOTTOM CHORD MEMBER SECTION		
TIE MEMBER SECTION		
PURLIN SECTION		
COLUMN	BOX SECTION25X25X3.2	mm
GUSSETED PLATE THICKNESS	3	mm
BOUNDARY CONDITIONS	PINNED SUPPORT	
TYPE OF CONNECTION	WELD	

MODEL FABRICATION

In this topic, I am going to discuss the step-by-step fabrication procedure.

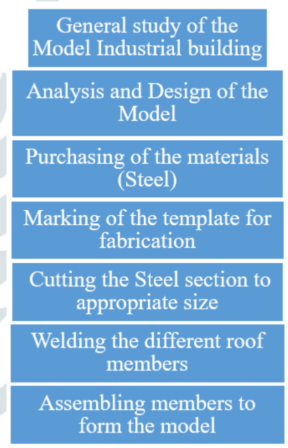

Fig 5.1 Cutting of the Section

Fig 5.2 Assembling the members

Fig 5.3 Assembling the purlins

Fig 5.4 Fabricated Truss

Fig 5.5 Fabricated Model

EXPERIMENTAL SETUP

In this topic, I will discuss the experimental setup consisting of LVDT setup and dial gauge. LVDT setup consists of one Reading indicator and two deflection needles, which are used to measure the end truss deflection at two points at the mid-span, as shown in Fig. 5.5. A dial gauge is also used to measure the deflection at the mid-span of the intermediate truss, as shown in Fig. 5.5. Total deflection is taken at four points.

Fig 5.6 Experimental Setup

Fig 5.7 Load Setup

TESTING PROCEDURE

The testing is done by loading the weight at the model's top. Five beams each weigh 50 Kg, and one sheet weight 50 Kg in total 350 Kg is taken as the dead load on the model. Now, the load is given at the top in a ratio of 40 Kg. Then, five cubes weighing 8 Kg are loaded to take the deflection at the four points, and five cubes are again loaded to the deflection. Then again, five cubes are loaded to take the deflection. Then again, five cubes are packed to take the deflection, and then a weight of 40 Kg is loaded to take the deflection, and then again, a weight of 40 Kg is loaded to take the deflection, and then again, a consequence of 40 Kg is loaded, to take the deflection.

EXPERIMENTAL INVESTIGATION

Table 5.2 Load vs Deflection

REFERENCE	LOAD			DEFLECTION									
				1		2		3			4		
	Kg	N	KN	mm	mm	mm	mm	div	div	mm	div	div	mm
5 BEAM + 1 SHEET (DEAD WIEGHT 350 KG)	0	0	0	-5.42	0	-11.325	0	58	0	0	22	0	0
5 BEAM + 1 SHEET + 5 CUBE	40	400	0.4	-5.39	0.03	-11.3	0.02	51	3	0.03	25	4	0.04
5 BEAM + 1 SHEET + 10 CUBE	80	800	0.8	-5.32	0.1	-11.23	0.09	55	8	0.08	30	8	0.08
5 BEAM + 1 SHEET + 15 CUBE	120	1200	1.2	-5.27	0.15	-11.17	0.15	71	13	0.13	35	13	0.13
5 BEAM + 1 SHEET + 20 CUBE	150	1500	1.5	-5.21	0.21	-11.12	0.21	75	17	0.17	40	18	0.18
5 BEAM + 1 SHEET + 20 CUBE + 40 KG WEIGHT	200	2000	2	-5.15	0.25	-11.07	0.25	80	22	0.22	44	22	0.22
5 BEAM + 1 SHEET + 20 CUBE + 80 KG WEIGHT	240	2400	2.4	-5.11	0.31	-10.98	0.34	84	25	0.25	48	25	0.25
5 BEAM + 1 SHEET + 20 CUBE + 120 KG WEIGHT	280	2800	2.8	-4.98	0.44	-10.89	0.43	89	31	0.31	54	32	0.32

NUMERICAL INVESTIGATION

Using the Method of joints, the truss shown in Fig 5.4 is solved, and the following member force Values are obtained.

MEMBER FORCE – END TRUSS

Table 5.1 Member forces – End truss

MEMBER NAME	TYPE OF THE MEMBER	MEMBER FORCE (KN)	BEHAVIOUR OF THE MEMBER
AC,CA,GB,BG	TOP CHORD	0.55	COMPRESSION
CD,DC,GF,FG	TOP CHORD	0.44	COMPRESSION
DE,ED,EF,FE	TOP CHORD	0.18	COMPRESSION
AH,HA,BL,LB	BOTTOM CHORD	0.47	TENSION
HI,IH,KL,LK	BOTTOM CHORD	0.47	TENSION
IJ,JI,JK,KJ	BOTTOM CHORD	0.374	TENSION
HC,CH,GL,LG	TIE MEMBER	0	ZERO FORCE MEMBER
ID,DI,KF,FK	TIE MEMBER	0.055	TENSION
CI,IC,KG,GK	TIE MEMBER	0.11	COMPRESSION
DJ,JD,JF,FJ	TIE MEMBER	0.07	COMPRESSION
EJ,JE	TIE MEMBER	0.07	TENSION

MEMBER FORCE – INTERMEDIATE TRUSS

Table 5.2 Member forces – Intermediate truss

MEMBER NAME	TYPE OF THE MEMBER	MEMBER FORCE (KN)	BEHAVIOUR OF THE MEMBER
MO,OM,NS,SN	TOP CHORD	1.15	COMPRESSION
OP,PO,SR,RS	TOP CHORD	0.92	COMPRESSION
PQ,QP,RQ,QR	TOP CHORD	0.574	COMPRESSION
MT,TM,NX,XN	BOTTOM CHORD	0.99	TENSION
TU,UT,XW,WX	BOTTOM CHORD	0.99	TENSION
UV,VU,VW,WV	BOTTOM CHORD	0.79	TENSION
TO.OT,XS,SX	TIE MEMBER	0	ZERO FORCE MEMBER
UP,PU,WR,RW	TIE MEMBER	0.115	TENSION
OU,UO,WS,SW	TIE MEMBER	0.23	COMPRESSION
PV,VP,VR,RV	TIE MEMBER	0.344	COMPRESSION
QV,VQ	TIE MEMBER	0.344	TENSION

PROTOTYPE – WELD DESIGN

In this topic, I will discuss the member section, weld size, weld length, and the gusseted plate size used to connect each member about the IS code Standards.

Table 5.3 Weld Design

DESCRIPTION	VALUES	UNITS
Section	25x25x3	mm
Size of Weld	3	mm
Ultimate stress of the material	410	N/mm2
Yield stress of the material	250	N/mm2
Partial safety factor	1.25	
Member load	0.334	KN
Effective throat thickness	0.7x3=2.1	
Centroid axis of the section	1.32	mm
Gusseted plate thickness	3	mm
Strength of weld	(2.1 x 410)/(1.732x1.25) = 397.69	N/mm
Force resisted by the weld at centre (P2)	397.69x25/1000 = 9.94	KN
Force resisted by the weld at top (P1)	(0.334x1000x1.32)/25 - (9.94/2) = 4.95	KN
Force resisted by the weld at bottom (P3)	4.65	KN
Length of weld at top (Lw1)	4.95x1000/397.69 = 13	mm
Length of weld at centre (Lw2)	9.94x1000/397.69 = 25	mm
Length of weld at bottom (Lw3)	4.65x1000/397.69=12	mm

CONCLUSION

This thesis has been carried out to study the behavior of the real-time Industrial building to the model fabricated with the same properties with a scale ratio of 1/10th. Also, to check the real-time building analysis and design, which is almost like the model manufactured and tested in the laboratory for the experimental study.

INDUSTRIAL BUILDING

From the chapter 3, the Analysis and Design of the industrial building has been done by using the SAP software and CIVIL FEM software. From the results obtained from the software, a 1/10th ratio model has scaled down the Industrial building, and the optimized steel quantity has arrived.

MODEL

The scaled ratio of the model is analyzed by the method of joints, and then the member force is computed to design the weld connection by providing a gusseted plate.

The experimental study has been carried out in which a model has been fabricated and then tested in the laboratory to compute the Load deflection behavior of the model. Then, the graph has been plotted for load and deflection to find the stiffness value.

From the experimental study, it has been clearly understood from the load-deflection curve that the stiffness for the intermediate truss is higher compared to the end truss.

Table 6.2 Model - Steel Quantity

SL.NO	MEMBER	SECTION	LENGTH	WIEGHT	
			mtr	KN	Kg
1	Top Chord	ANGLE 25X25X3	6	0.066	6.6
2	Bottom Chord		5.4	0.0594	5.94
3	Tie Members		4.3	0.0463	4.63
4	Purlins		8	0.088	8.8
5	Column	BOX 25X25X3.2	6	0.1188	11.88
			TOTAL	0.3695	36.95

Table 6.3 Model – Design details

DESCRIPTION	VALUES	UNITS
Section	25x25x3	mm
Length of weld at top (Lw1)	13	mm
Length of weld at centre (Lw2)	25	mm
Length of weld at bottom (Lw3)	12	mm
Gusseted plate thickness	3	mm

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