Comparative Analysis on Different Industrial Trusses with Change in Material

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Abstract — In present study, three different industrial trusses, namely, Howe truss, Pratt truss and Warren truss are designed, and performance of the trusses has been evaluated on the basis of the parameters like maximum compressive force, maximum tensile force, maximum, shear, maximum bending moment under compression and node displacement for each alternative under two different materials, i.e., hot rolled steel and cold forged steel. On the basis of the results, ranking of trusses has been done by a well-known statistical technique, coefficient of variance. Results of the research work show the suitability of hot rolled steel for truss making applications. Results also show that hot rolled steel Warren truss shows the best performance out of the available alternatives while the second-best truss design is CFS-Howe truss.

Keywords: Trusses, Hot Rolled Steel, Cold Forged Steel, Howe Truss, Pratt Truss, Warren Truss

I. INTRODUCTION

A truss is one among the main forms of engineering structures that provides a sensible and economical answer for several engineering constructions, particularly within the style of bridges and buildings that demand giant spans. They comprise straight members i.e. bars, connected at their extremities through joints. So no member is continuous through a joint. All the members lie on a plane, whereas the masses carried by the truss, are solely focused forces that act on the joints and lie on identical plane. Once a focused load is to be applied between 2 joints or a distributed load is to be supported by the truss - as within the case of a bridge truss - a floor system should be provided, so as to transmit the load to the joints. Though the members are literally joined along by suggests that of the present of locked or welded connections, it's assumed that they're stapled along.

Therefore, the forces working at every finish of a member are solely axial while not the existence of bending moments or shear forces.

Although the trusses include triangles, there are a super variety of geometrical styles. In many times a particular design characteristic has been named after the authentic designer. Several of the more commonplace truss patterns utilized in truss patterns are: Howe truss, Pratt truss, warren truss, Quadrangular warren truss, Baltimore truss, camelback truss and K truss which are shown in figure 1.2. Among these truss patterns, the three great regarded are the warren, Howe and Pratt truss, which are prominent by the route of the diagonal individuals in each panel

II. SCOPE OF THE STUDY

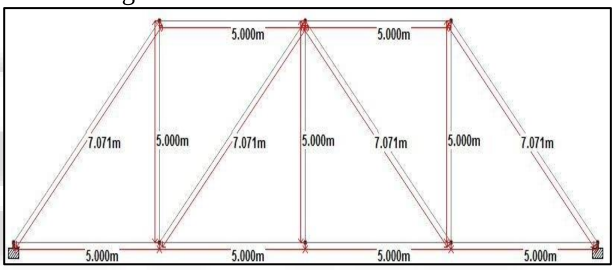
The review of literature reveals that:
1) There is very limited research which compares different industrial trusses; and
2) There is also less research available which analyses the effects of material changes on the performance of trusses.

III. OBJECTIVE OF STUDY

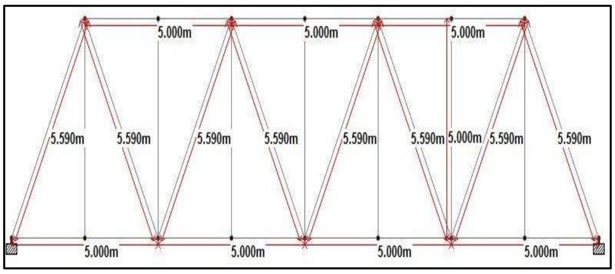
Main objectives of the thesis are to:
1) Analyze the results of material changes on the performance of various industrial trusses; and
2) Ranking of various combinations of materials and trusses.

IV. PROBLEM STATEMENT & METHODOLOGY

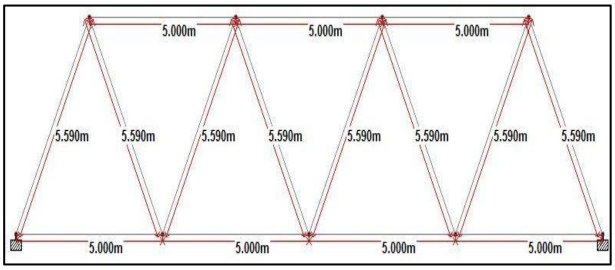
In order to solve any problem, the first step need is a systematically designed problem. Problem formulation is defined as a first step of a solution. The research problem was the comparison of Howe, Pratt and Warren trusses using different materials. Basic structures of trusses were designed. The following models were obtained.



Howe Truss



Pratt Truss



Warren Truss

S.N.	Property	Unit	Hot Rolled Steel	Cold Rolled Steel
1	Young's Modulus	GPA	190	190
2	Poisson's Ratio		0.29	0.29

3	Density	gm/cm^3	8	7.8
4	Thermal Coefficient	/^{0}C	1.20E-05	1.20E-05
5	Critical Damping coefficient		0.03	0.03
6	Shear Modulus	GPA	73	73

Table 4.1 Properties of the materials used

A. *Types of loads:*

1) Live load
2) Dead Load
3) Wind Load

B. *Load Combinations:*

1) 1.5 (DL + LL)
2) 1.2 (DL +LL +WL)
3) 1.2 DL + 1.2 LL + (-1.2 WL)
4) 1.2 (DL + LL)
5) 1.5 (DL + WL)
6) 1.5 DL + (-1.5 WL)
7) 1.5 DL
8) 0.9 DL

S.No	Type of Load	Factor	Magnitude	Position
1.	Self-weight	1.5	--	Member load
2.	UDL	--	1 kN/m	Member load
3.	Live load	--	10 kN/m	Load on bottom chord

Table 4.2: Details of Loads

V. RESULTS AND DISCUSSION

Load Case	Beam	Node	Axial Fx (kN)	Shear Fy (kN)	Shear Fz (kN)	Torsion Mx (kNm)	Bending My (kNm)	Bending Mz (kNm)
Max Fx	10	1	224.103	4.847	0.000	0.000	0.000	6.584
Min Fx	7	3	-143.092	-0.030	-0.000	-0.000	-0.000	0.000
Max Fy	3	3	-26.711	39.004	0.000	0.000	0.000	31.905
Min Fy	3	3	-26.711	-39.004	0.000	-0.000	-0.000	31.905
Max Fz	11	1	65.970	4.797	16.271	0.000	0.000	0.679
Min Fz	11	2	65.970	4.797	-16.271	0.000	-0.000	0.679
Max Mx	10	1	8.092	0.587	1.121	0.29	0.471	0.619
Min Mx	4	4	-8.098	1.244	-7.461	-0.29	-0.647	0.619
Max My	5	1	65.970	4.797	0.000	0.000	83.45	0.000
Min My	1	1	65.970	4.797	0.000	-0.000	-83.45	0.000
Max Mz	1	1	65.970	4.797	0.000	0.000	0.000	34.056
Min Mz	2	2	-8.098	0.196	4.431	0.037	0.333	-1.780

Table 5.1: Summary of Forces for CFS-Howe Truss

Load Case	Beam	Node	Axial Fx (kN)	Shear Fy (kN)	Shear Fz (kN)	Torsion Mx (kNm)	Bending My (kNm)	Bending Mz (kNm)
Max Fx	11	12	226.15	3.313	0.000	0.000	0.000	1.194
Min Fx	16	10	-183.589	1.973	0.000	0.000	0.000	1.531
Max Fy	1	1	64.694	26.05	0.000	0.000	0.000	17.481
Min Fy	8	9	64.694	-26.05	0.000	0.000	0.000	17.481
Max Fz	15	1	107.369	2.170	22.869	0.000	-115.06	2.273
Min Fz	15	9	107.369	-2.170	-22.869	0.000	-115.06	2.273
Max Mx	1	1	27.246	3.836	-20.150	0.597	-78.833	0.60
Min Mx	1	1	27.246	3.836	-20.150	-0.597	-78.833	0.60
Max My	15	1	107.369	2.170	22.869	-0.000	-115.06	2.273
Min My	16	9	107.369	-2.170	-22.869	0.000	-115.06	2.273
Max Mz	8	1	64.694	26.05	0.000	0.000	0.000	17.481
Min Mz	14	15	190.976	3.360	0.000	0.000	0.000	-1.708

Table 5.2: Summary of Forces for CFS-Pratt Truss

Load Case	Beam	Node	Axial Fx (kN)	Shear Fy (kN)	Shear Fz (kN)	Torsion Mx (kNm)	Bending My (kNm)	Bending Mz (kNm)
Max Fx	10	1	224.101	4.847	0.000	0.000	0.000	6.584
Min Fx	7	6	-143.092	-0.303	0.000	-0.000	-0.000	0.29
Max Fy	3	3	-26.711	39.004	0.000	0.000	0.000	31.995
Min Fy	2	3	-26.711	-39.004	0.000	-0.000	0.000	31.995
Max Fz	10	1	65.970	4.797	16.271	0.000	-83.451	6.025

Min Fz	11	5	65.970	4.797	-16.271	0.000	83.451	6.025
Max Mx	1	1	8.098	0.517	0.000	0.288	-1.175	2.463
Min Mx	4	4	8.098	1.244	-0.000	-0.288	5.504	2.463
Max My	11	1	65.970	4.797	16.271	0.000	-83.451	6.025
Min My	10	5	65.970	4.797	-16.271	0.000	83.451	6.025
Max Mz	1	1	26.711	3.843	0.000	0.000	8.321	34.705
Min Mz	2	2	-8.098	0.196	4.431	0.037	8.321	-1.780

Table 5.3: Summary of Forces for CFS-Warren Truss

Load Case	Beam	Node	Axial Fx (kN)	Shear Fy (kN)	Shear Fz (kN)	Torsion Mx (kNm)	Bending My (kNm)	Bending Mz (kNm)
Max Fx	10	1	227.25	4.993	0.000	0.000	0.000	6.713
Min Fx	7	6	-144.015	-0.075	-0.000	-0.000	-0.000	0.701
Max Fy	3	3	-26.722	39.10	0.000	0.000	0.000	31.870
Min Fy	2	3	-26.722	-39.10	0.000	-0.000	0.000	31.870
Max Fz	10	1	68.818	5.035	16.536	0.129	-83.031	6.410
Min Fz	11	5	68.818	5.035	-16.536	0.129	83.031	6.410
Max Mx	1	1	8.290	0.517	0.000	0.690	-9.368	0.157
Min Mx	4	4	8.290	1.552	-0.000	-0.690	5.687	5.857
Max My	11	1	68.818	5.035	16.536	-0.129	-83.031	6.410
Min My	10	5	68.818	5.035	-16.536	-0.129	83.031	6.410
Max Mz	1	1	26.722	3.797	0.000	0.000	9.907	35.370
Min Mz	2	2	-8.290	0.392	4.309	0.157	9.907	-1.892

Table 5.4: Summary of Forces for HRS-Howe Truss

Load Case	Beam	Node	Axial Fx (kN)	Shear Fy (kN)	Shear Fz (kN)	Torsion Mx (kNm)	Bending My (kNm)	Bending Mz (kNm)
Max Fx	11	12	259.351	3.588	0.000	0.000	0.000	0.890
Min Fx	16	10	-185.503	2.086	0.000	0.000	0.000	1.861
Max Fy	1	4	65.053	26.15	0.000	0.000	0.000	18.434
Min Fy	8	9	65.053	-26.15	-0.000	0.000	0.000	18.434
Max Fz	15	1	111.188	2.185	23.495	0.650	-113.251	0.000
Min Fz	15	1	111.188	2.185	-23.495	0.650	113.251	0.000
Max Mx	1	4	27.841	3.919	19.525	1.911	5.517	4.454
Min Mx	1	4	27.841	3.919	19.525	-1.911	80.517	4.454
Max My	15	1	111.188	2.185	23.495	0.650	-113.251	2.193
Min My	15	1	111.188	2.185	23.495	0.650	-113.251	2.193
Max Mz	1	4	65.053	26.15	-0.000	-0.000	0.000	18.434
Min Mz	14	15	193.278	0.080	0.000	0.000	0.000	-2.230

Table 5.5: Summary of Forces for HRS-Pratt Truss

Load Case	Beam	Node	Axial Fx (kN)	Shear Fy (kN)	Shear Fz (kN)	Torsion Mx (kNm)	Bending My (kNm)	Bending Mz (kNm)
Max Fx	6	7	208.981	4.886	0.000	0.000	0.000	2.805
Min Fx	9	6	-169.632	2.086	0.000	0.000	0.000	1.860
Max Fy	1	4	52.695	40.039	0.000	0.000	0.000	37.088
Min Fy	4	5	52.695	-40.039	-0.000	0.000	0.000	37.088
Max Fz	8	1	62.959	1.900	15.921	-0.298	-78.162	1.518
Min Fz	15	5	62.959	-1.900	-15.921	0.298	78.162	1.518
Max Mx	1	4	15.598	1.517	13.975	0.570	-55.228	2.826
Min Mx	1	9	15.598	1.517	-13.975	-0.570	55.228	2.826
Max My	8	1	62.959	1.900	15.921	0.298	78.162	1.518
Min My	8	1	62.959	1.900	15.921	0.298	-78.162	1.518
Max Mz	1	4	52.695	40.039	0.000	0.000	0.000	37.088
Min Mz	7	8	74.247	-0.287	0.000	0.000	0.000	-0.826

Table 5.6: Summary of Forces for HRS-Warren Truss

S. No	Type of Material	Type of Truss	Forces		Maximum Bending Moment in compression (kN-m)	Maximum Torsion (kN-m)	Node Displacement (mm)
			Maximum Axial Force (kN)	Maximum Shear (kN)			
1.	Cold Formed steel	CFS-Howe	224.10	39.00	83.45	0.29	18.51
2.		CFS-Pratt	226.15	26.05	115.06	0.60	19.10
3.		CFS-Warren	224.10	39.00	83.45	0.29	15.50
4.	Hot Rolled Steel	HRS-Howe	227.25	39.10	83.03	0.70	3.95
5.		HRS-Pratt	259.35	26.15	113.25	1.91	15.80
6.		HRS-Warren	208.98	40.04	78.16	0.57	14.01

Table 5.7: Summary of Results

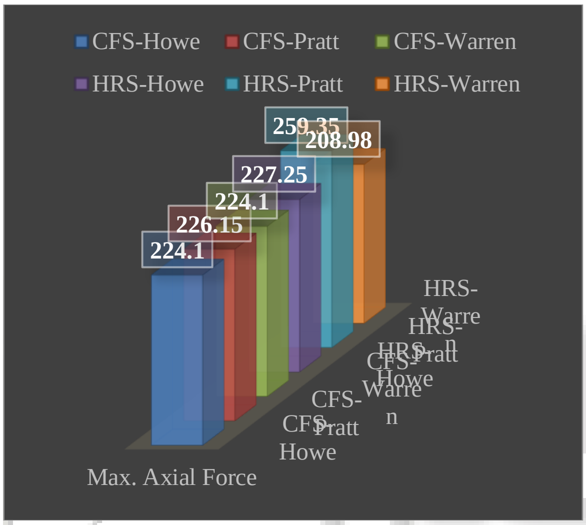


Fig. 5.1: Graphical Representation of Results for Axial Forces

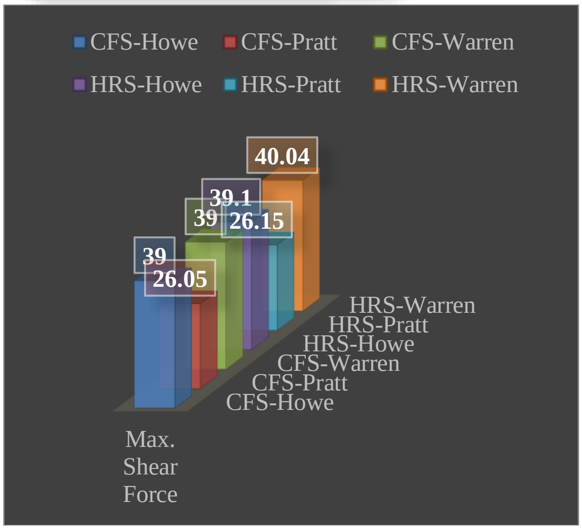


Fig. 5.2: Graphical Representation of Results for Shear Force

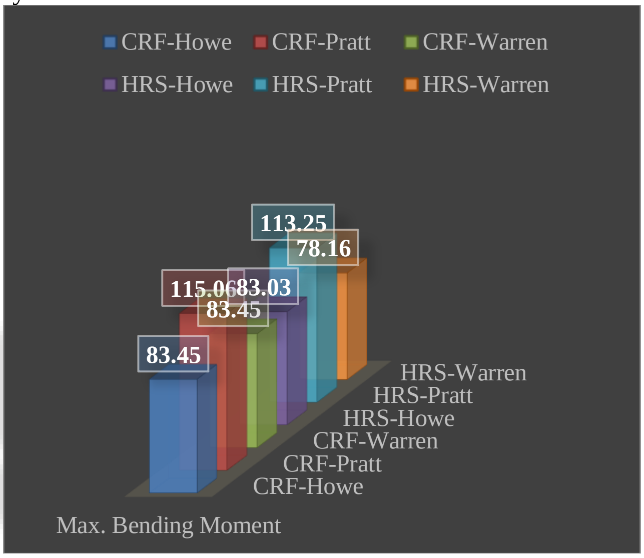


Fig. 5.3: Graphical Representation of Results for Maximum Bending Moments in Compression

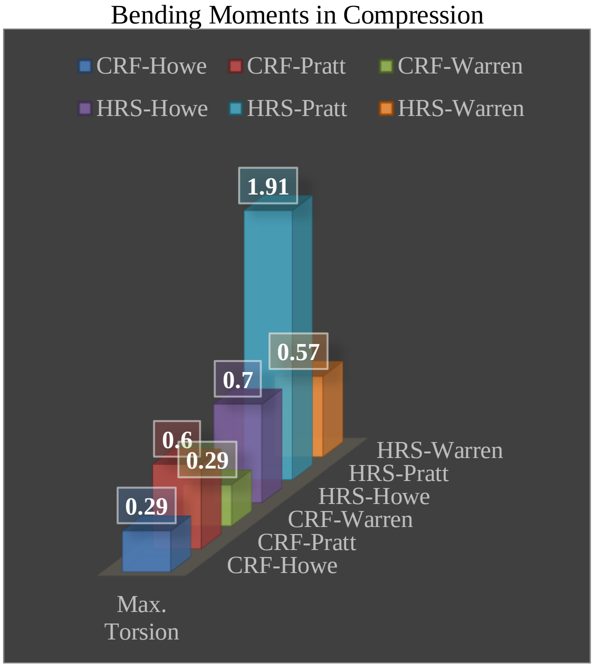


Fig. 5.4: Graphical Representation of Results for Maximum Torsion in Compression

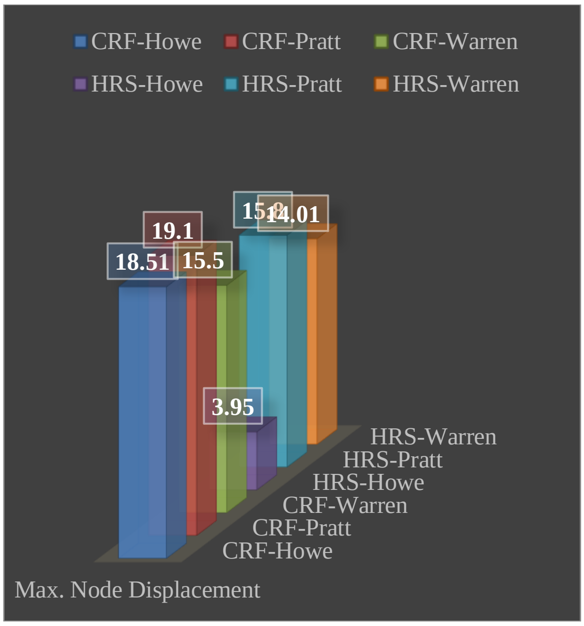


Fig. 5.5: Graphical Representation of Results for Maximum Node Displacement

From results obtained above, rankings to the trusses made of two materials can be assigned, as follows.

S. No	Type of Material	Type of Truss	Maximum Axial Force	Rank	Maximum Shear	Rank	Maximum Bending Moment in compression	Rank	Maximum Torsion	Rank	Node Displacement	Rank
1.	Cold Rolled steel	CFS-Howe	224.10	2	39.00	3	83.45	3	0.29	1	18.51	5
2.		CFS-Pratt	226.15	4	26.05	1	115.06	5	0.60	3	19.10	6
3.		CFS-Warren	224.10	2	39.00	3	83.45	3	0.29	1	15.50	3
4.	Hot Rolled Steel	HRS-Howe	227.25	3	39.10	4	83.03	2	0.70	4	3.95	1
5.		HRS-Pratt	259.35	5	26.15	2	113.25	4	1.91	5	15.80	4
6.		HRS-Warren	208.98	1	40.04	5	78.16	1	0.57	2	14.01	2

Table 5.8: Ranking of Materials

in order to get a common ranking, a statistical tool, coefficient of variance was calculated for different criteria. Coefficient of variance is defined as the ratio of standard deviation to the average for scores in percentage. While dealing with parameter, the ranking procedure for the criteria is selected for which value of coefficient of variance is minimum. Table 5.13 shows the details of coefficient of variance for different criteria.

S.No	Parameter	Maximum Axial Force	Maximum Shear	Maximum Bending Moment in compression	Maximum Torsion	Node Displacement
1.	Standard Deviation	16.60	6.82	16.72	0.60	5.50
2.	Average	228.32	34.89	92.73	0.73	14.48
3.	Coefficient of Variance	0.0727	0.1955	0.1803	0.8309	0.3802
4.	%Coefficientof Variance	7.27	19.55	18.03	83.09	38.02

Table 5.9: Details of Coefficient of Variance for different Criteria

S.No	Truss	Rank
1.	CFS-Howe	2
2.	CFS-Pratt	4
3.	CFS-Warren	2
4.	HRS-Howe	3
5.	HRS-Pratt	5
6.	HRS-Warren	1

Table 5.10: Overall Rankings of Trusses

VI. CONCLUSION

In present research work, comparison of two well-known truss building materials, hot rolled steel and cold formed steel is made for industrial truss applications. For this purpose, three types, namely, Howe truss, Pratt truss, and Warren truss, were designed in STAAD.Pro software and five parameters, maximum axial force, maximum shear, maximum bending moment and maximum node displacement were investigated for all the alternatives made up of hot rolled steel and cold formed steel. Due to unavailability of common rankings, coefficients of variance of alternatives were calculated, which give the rankings of trusses as well as suitability of materials. Following points represent the conclusion drawn from the research work.

Out of the available options, best material for industrial truss application is Hot Rolled steel and out the three alternatives, best truss design is Warren truss and the Second-best truss design is CFS-Howe truss.

HRS-Pratt Truss is least preferable as per the adopted parameters.

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