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Design and analysis of steel structure

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Abstract:

Building be using steel material has become a major trend in all over the world because of many advantages that steel provide. Steel material has many properties that made him better than using concrete in building. Such like easy of formation as it is a very ductile material; also it is lighter than concrete and it also save time and in cost.

The process of design using steel material is similar to other processes, it begins with study the design problem in all its dimensions, structurally, environmentally, costly and its usefulness. Then the process of design begins by settling models and does calculations and feedback. Then finally get to the appropriate design by trials.

Indoor sports are great physical activities that are able to be played year-round and enjoyed regardless of the weather conditions. Indoor sport venues are usually well ventilated, cool and usually accessible. Indoor sports venues also cater for traditional sports such as swimming, basketball and even football, etc.

1. Introduction:

Modern sports complex should be provided spacious and high-quality dressing rooms and other facilities to ensure that players and match officials can carry out their activities in comfort and safety. A sports complex should be covered to protect visitors and players from the rain and from the glare of strong sunlight. In those parts of the world where relatively constant sunshine is normal, as for roof and facade envelope of proposed indoor sports complex, colourful steel plate and aluminium plate structure will be adopted. The shape and type of complex varies according to the community. Modern sports complex should be designed so that all visitors are safe, comfortable and have easy access to toilets and refreshment facilities. Access and exit to and from the play area, both in normal and emergency situations are carefully planned in this complex. In this project the sports court dimensions are taken as per the standard values.

The complex is divided into three sheds, each of same dimensions. The designing of structure includes designing of the structural elements such as principal rafter or roof truss, column and column base, purlins, sag rods, tie rods, gantry girder, bracings, etc. In this structure the walls can be formed of steel columns with cladding which may be profiled or plain sheet, precast or masonry. The wall must be adequately strong to resist the lateral force due to wind or earthquake. The structural performance of this complex is well understood and, for the most part, adequate code provisions are currently in place to ensure satisfactory behaviour in high winds. Steel structures also have much better strength-to-weight ratios than RCC and they also can be easily dismantled.

Fig: Interior of Indoor Sports Complex

Our project involves design and analysis of steel structure by Manual approach as well as TEKLA software. Apart from manual approach we have chosen well known software mainly AutoCAD, TEKLA Structural Designer, TEKLA Structures and STAAD Pro Based on the purpose and requirement at specific instances this software are used respectively.

2. Literature Survey

Navya P1, Dr.Y.M Manjunatp: "Structural Behavior of Industrial Structure Subjected to Lateral Loads"

Industrial structures are low rise steel structures housing workshops or industries and characterized by their comparatively low height and absence of interior walls and partition with or without gantry girders. Since gantry girders contribute to heavy loads a typical hangar building is considered for the analysis. In the current paper, the structural behavior of hangar subjected to lateral loads i.e., both wind load and seismic loads is analyzed by equivalent static analysis using standard FEM software package ETABS. The study encloses behavior of different truss configuration and different frame sections. The member forces are considered as the main parameter.

Arvind Bora, Mrs. Sangeeta Dhyani: "Comparative Study of Tubular Steel Truss Profiles for Roofing Varying Span"

The main objective of this study is to determine the optimized truss profile and its effect to the design of plane truss by using tubular sections with the aid of STAAD Pro v8i 2007. Minimum mass is chosen as the objective function. The study is focused to achieve the following objectives.

To determine the most effective truss profiles in term of its mass among the 23 candidate fixed geometry of profiles, in the design of trusses using steel tubular section for certain spans and rise to save the time of design by avoiding the efforts of trial and error. To determine whether under which conditions the same optimum profile of truss can be applied considering the different spans, rise and span over rise ratios of trusses. To determine the best possible truss profile to be applied in normal practice.

ASHAYERI and L.F. GELDERS:"Warehouse design optimization"

The structural engineers come across analysis and design of various structures whose aim at designing safe, serviceable, durable and economical structures. This dissertation work of Analysis and design of warehouse is a unique concept in structural engineering. The Major part of the thesis include analysis and design of warehouse in software STAAD Pro and further designing manually and calculations are shown in detail for additional understanding. Thesis starts with introduction and design process which explains about importance of warehouse. In methodology we understand the concepts of structural planning involve field work & estimation details. Structural design steps also explained. Modeled structure is showed, analysis and design is done in software and results are shown in tabular forms and specifically by taking a reference of one project details manually design calculations are done starting from load calculations, design of deck slab, base plate, anchor bolt, truss connections and footing, finally we need to understand the advantages and disadvantages of designing in software and manually and difficulties which are explained in conclusions clearly.

Stephen D., Roberts Ruddell Reed, Jr. "Optimal Warehouse Bay Configurations"

This paper deals with the determination of warehouse bay configurations which minimize the costs of handling and construction under the assumption of random storage locations. Two specific bay configuration schemes are developed. Under the unrestricted case, adjacent bays are not required to use common columns at bay corners. The restricted case, however, requires the use of common corners. Solution methodologies are developed to evolve optimal configurations for each case and example computational results are presented. The developments presented serve as analytical aids for storage or warehouse design in that they may be used for direct solution or as “benchmarks” for alternative design evaluation.

3. STEEL DESIGN

Method of steel design:
All parts of the steel framework of a structure should be capable of sustaining the most adverse combination of the dead loads, superimposed load and floor loads, wind loads, seismic forces where applicable and any other forces or loads to which the building may be reasonably subjected without exceeding the permissible stresses. Steel structures may be proportioned based on simple design, semi-rigid design, fully rigid design ad plastic design or plastic theory.

•Simple design:

This method applies to structures in which the end connections between members are such that the structure will not develop restraint moments adversely affecting the members of the structure as a whole, and in consequence the structure for the purpose of design be assumed to be pin-jointed.

• Semi-rigid design:

This method permits a reduction in the maximum bending moment in beams suitably connected their supports, so as to provide a degree of direction fixity, in the case of triangulated frames, it permits account being taken of the rigidity of the connections and the moment of inter-section of members.

• Fully Rigid design:

This method as compared to the methods of simple and semi-rigid designs, gives the greatest rigidity and economy in the weight of steel used when applied in appropriate cases. The end connections of members of the frame should have sufficient rigidity to hold the original angles between such members and the members they connect virtually unchanged. The design is virtually based on theoretical methods of elastic analysis and the calculated stress should confirm to the provisions of the relevant code.

5.2 Component Parts:

Modern steel truss members are manufactured in a wide variety of shapes and sizes. A few common examples are shown on the following page. The model truss we will be building uses both solid bars and hollow tubes.

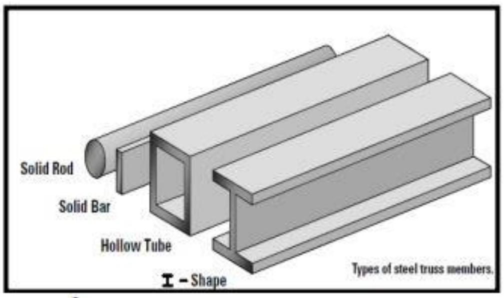
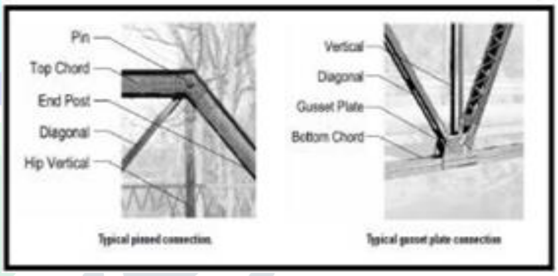


Fig: Type of steel truss members.

There are two common types of structural connections used in trusses-pinned connections and gusset plate connections.



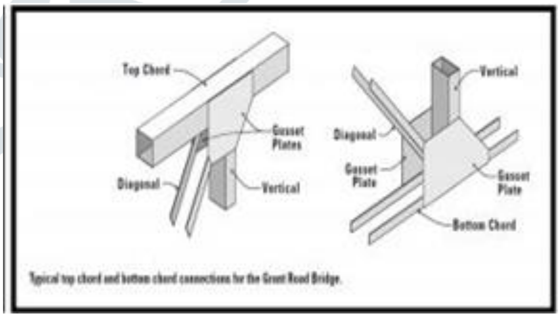
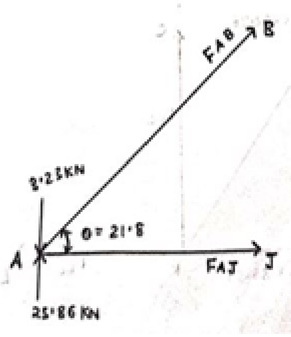


Fig:Typical Truss connections

4. Analysis of Truss by Method of Joints

JOINT A:



$\sum V = 0$

$-3.28 + 25.86 + F_{AB} \sin\theta = 0$

$F_{AB} = \frac{-25.86+3.23}{\sin\theta}$

$F_{AB} = \frac{-22.63}{\sin 21.80}$

$F_{AB} = -60.93$ KN (Compression)

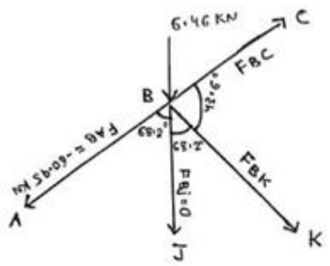
$\sum H = 0$

$F_{AJ} + F_{AB} \cos\theta = 0$

$F_{AJ} = - F_{AB} \cos(21.8) = -(-60.93) \cos(21.8)$

$F_{AJ} = 56.57$ KN (Tension)

JOINT B:



$\sum V = 0$

$-6.46 - F_{AB} \cos\theta - F_{BK} \sin\beta + F_{BK} \sin\alpha = 0$

$-6.46 - (-60.93) \left(\frac{4}{10.77}\right) - F_{BK} \left(\frac{1}{2.69}\right) + F_{BK} \left(\frac{4}{10.77}\right) = 0$

$- F_{BK} \left(\frac{1}{2.69}\right) + F_{BK} \left(\frac{4}{10.77}\right) = 16.66$ - (1)

$\sum H = 0$

$F_{BC} \cos\alpha + F_{Bk} \cos\beta - F_{BA} \sin\theta = 0$

$F_{BC} \left(\frac{10}{10.77}\right) + F_{BK}\left(\frac{2.5}{2.69}\right) - (-60.93) \times \left(\frac{10}{10.77}\right)$

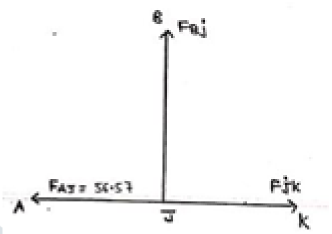
$\left(\frac{10}{10.77}\right) F_{BC} + \left(\frac{2.5}{2.69}\right) F_{BK} = -56.57$ – (2)

From equation (1) & (2)

$F_{BC} = -8.80$ KN (Compression)

$F_{BK} = -52.26$ KN (Compression)

JOINT J:



$\sum V = 0$

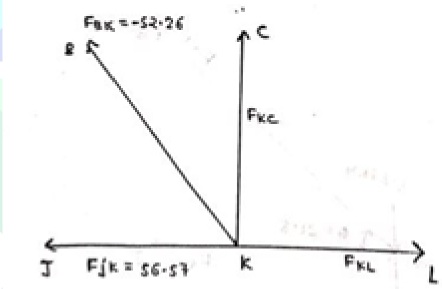
$F_{BJ} = 0$

$\sum H = 0$

$-F_{AJ} + F_{JK} = 0$

$F_{JK} = 56.57$ KN

JOINT K:



$\sum V = 0$

$F_{Bk} \sin\beta + F_{Ck} = 0$

$(-52.26) \left(\frac{1}{2.69}\right) + F_{Ck} = 0$

$F_{CK} = -19.42$ KN (Compression)

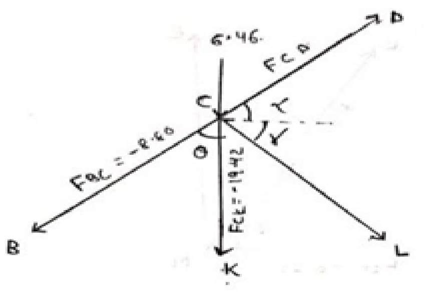
$\sum H = 0$

$-F_{Bk} \cos\beta - F_{JK} + F_{KL}$

$- (-52.26) \left(\frac{2.5}{2.69}\right) - 56.57 + F_{Ck} = 0$

$F_{KL} = 8$KN

JOINT C:



$\sum V = 0$

$-6.46 + F_{CD}\,Sin\alpha - F_{CL}\,Sin\,\gamma - F_{Ck} - F_{CB}\,Cos\theta = 0$

$-6.46 + (\frac{4}{10.77})\,F_{CD} - F_{CL}(\frac{2}{0.5\sqrt{41}}) - (-19.42) - (-8.80)\,(\frac{4}{10.77}) = 0$

$(\frac{4}{10.77})\,F_{CD} - (\frac{2}{0.5\sqrt{41}})\,F_{CL} = -16.22$ – (3)

$\sum H = 0$

$F_{CD}\,Cos\alpha + F_{CL}\,Cos\,\gamma - F_{Ck} - F_{Bc}Sin\vartheta = 0$

$F_{CD}\,(\frac{10}{10.77}) + F_{CL}\left(\frac{2.5}{0.5\sqrt{41}}\right) - (-8.80)\,(\frac{10}{10.77})$

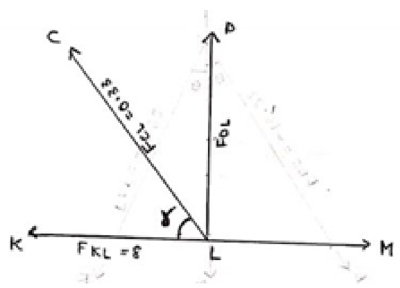
$(\frac{10}{10.77})\,F_{CD} + \left(\frac{2.5}{0.5\sqrt{41}}\right)\,F_{CL} = -8.17$ – (4)

From equation (3) & (4)

$F_{CD} = -20.42$ KN (Compression)

$F_{CL} = 0.33$ KN (Tensile)

JOINT L:



$\sum V = 0$

$F_{CL}\,Sin\,\gamma + F_{DL} = 0$

$0.33\ x(\frac{2}{0.5\sqrt{41}}) + F_{DL} = 0$

$F_{DL} = -0.20$ KN (Compression)

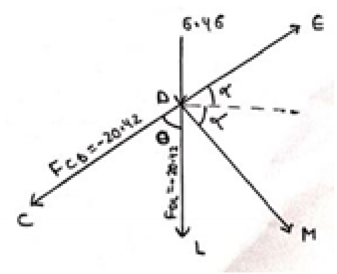
$\sum H = 0$

$-F_{KL} - F_{CL}\,Cos\,\gamma + F_{LM} = 0$

$-8 - 0.33\ x\left(\frac{2.5}{0.5\sqrt{41}}\right) + F_{LM} = 0$

$F_{LM} = 8.25$ KN (Tension)

JOINT D:



$\sum V = 0$

$-6.46 + F_{DE}\,Sin\alpha - F_{DM}\,Sin\gamma - F_{DM} - F_{CD}Cos\theta = 0$

$-6.46 + F_{DE}\left(\frac{4}{10.77}\right) - F_{DM}(\frac{3}{0.5\sqrt{61}}) - (-0.20) - (-20.42)(\frac{4}{10.77})$

$\left(\frac{4}{10.77}\right)\,F_{DE} - (\frac{3}{0.5\sqrt{61}})\,F_{DM} = -1.32$ – (5)

$\sum H = 0$

$-F_{CD}Sin\theta + F_{DE}\,Cos\alpha + F_{DM}\,Cos\gamma = 0$

$-(-20.42)\ x\left(\frac{10}{10.77}\right) + F_{DE}\left(\frac{10}{10.77}\right) + F_{DM}\left(\frac{2.5}{0.5\sqrt{41}}\right) = 0$

$\left(\frac{10}{10.77}\right)\,F_{DE} + \left(\frac{2.5}{0.5\sqrt{41}}\right)\,F_{DM} = -18.96$ – (6)

From equation (5) & (6)

$F_{DM} = -0.100$ KN (Compression)

$F_{DE} = -16.22$ KN (Compression)

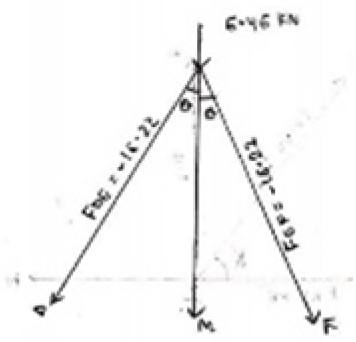
JOINT E:

$\sum H = 0$

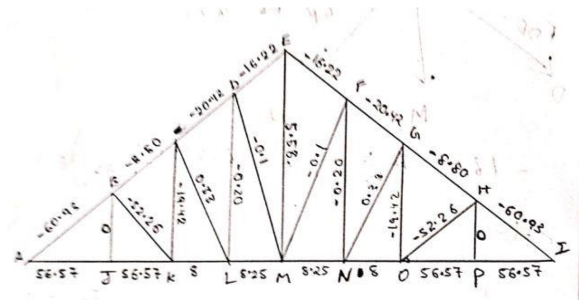
$-6.46 - F_{DE}Cos\theta - F_{EF}Cos\theta - F_{EM} = 0$

$-6.46 - (-16.22)\left(\frac{4}{10.77}\right) - (-16.27)\left(\frac{4}{10.77}\right) = F_{EM}$

$F_{EM} = 5.58$ KN (Tension)



Axial force due to Dead load



5. ACKNOWLEDGEMENT

We would like to thank all the authors of different research papers referred during writing this paper. It was very knowledge gaining and helpful for the further research to be done in future..

6. RESULTS:

Material Listing

Steel Beams Rolled Non-Composite

Section Size	Grade	No.	Total Length [m]	Mass [kg]	Surface Area [m2]	Embodied Carbon Mass [kgCO2e]
RHS 100.0x50.0x3.2	Fe 410 WA	15	90.000	630.67	26.011	0
RHS 145.0x82.0x4.8	Fe 410 WA	12	72.000	1146.06	31.501	0
Total		27	162.000	1776.73	57.512	0

Steel Columns Rolled:

Section Size	Grade	No.	Total Length [m]	Mass [kg]	Surface Area [m2]	Embodied Carbon Mass [kgCO2e]
SC 120	Fe 410 WA	2	9.860	258.78	6.460	0
SC 140	Fe 410 WA	23	115.000	3826.21	88.446	0
SC 150	Fe 410 WA	13	65.000	2402.77	54.629	0
SC 160	Fe 410 WA	6	30.000	1256.57	26.298	0
Total		44	219.860	7744.34	175.834	0

Steel Braces Rolled

Section Size	Grade	No.	Total Length [m]	Mass [kg]	Surface Area [m2]	Embodied Carbon Mass [kgCO2e]
175L	Fe 410 WA	20	233.238	5215.45	141.932	0
200L	Fe 410 WA	20	246.577	6255.11	169.724	0
Total		40	479.815	11470.56	311.656	0

Steel Trusses

Section Size	Grade	No.	Total Length [m]	Mass [kg]	Surface Area [m2]
250H3	Fe 410 WA	2	10.770	1397.12	18.474
SHS 100.0x100.0x4.0	Fe 410 WA	2	1.000	23.99	0.783
SHS 100.0x100.0x4.0	Fe 410 WA	2	2.000	47.99	1.566
SHS 100.0x100.0x4.0	Fe 410 WA	2	2.693	64.61	2.108
SHS 100.0x100.0x4.0	Fe 410 WA	2	3.000	71.98	2.348
SHS 100.0x100.0x4.0	Fe 410 WA	2	3.202	76.82	2.506
SHS 100.0x100.0x4.0	Fe 410 WA	2	3.905	93.70	3.057
SHS 100.0x100.0x4.0	Fe 410 WA	1	4.000	47.99	1.566
SHS 132.0x132.0x4.8	Fe 410 WA	1	20.000	381.69	10.354
Total		16		2205.88	42.762

Pile Caps:

Member Reference	Grade	Mass [kg]	Surface Area [m2]	Volume [m3]	Reinforcement [kg]	Reinforcement [kg/m3]	Embodied Carbon Mass [kgCO2e]
PC 1	M 20	2453.06	8.509	1.0	35.27	37	0
PC 2	M 20	1254.25	4.990	0.5	23.94	49	0
PC 3	M 20	1672.33	5.560	0.7	32.13	49	0
PC 4	M 20	1881.38	5.845	0.7	39.62	54	0
PC 5	M 20	1881.38	5.845	0.7	34.26	46	0
PC 6	M 20	2453.06	8.509	1.0	35.27	37	0
PC 7	M 20	1881.38	5.845	0.7	39.62	54	0
PC 8	M 20	1881.38	5.845	0.7	39.62	54	0
PC 9	M 20	1254.25	4.990	0.5	23.94	49	0
PC 10	M 20	1881.38	5.845	0.7	39.62	54	0
PC 11	M 20	1672.33	5.560	0.7	32.13	49	0
PC 12	M 20	1881.38	5.845	0.7	39.62	54	0
PC 13	M 20	1672.33	5.560	0.7	32.13	49	0
PC 14	M 20	1672.33	5.560	0.7	32.13	49	0
PC 15	M 20	1672.33	5.560	0.7	32.13	49	0
PC 16	M 20	1672.33	5.560	0.7	32.13	49	0
PC 17	M 20	1881.38	5.845	0.7	39.62	54	0
PC 18	M 20	1254.25	4.990	0.5	23.94	49	0
PC 19	M 20	1254.25	4.990	0.5	23.94	49	0
PC 20	M 20	1254.25	4.990	0.5	23.94	49	0
PC 21	M 20	1881.38	5.845	0.7	34.26	46	0
PC 22	M 20	1254.25	4.990	0.5	23.94	49	0
Total		37516.6	127.078	14.7	713.20	48	0

Member Reference	Dimension [mm]	Shape	Installation Type	Installation Length [m]	No.	Total Length [m]
pile	500	Circular	Driven	5.000	46	230.000

Piles;

Pile Caps

Loose bars

Type	Unit Mass [kg/m]	Total Length [m]	Total Mass [kg]
T16	1.580	176.162	278.34
T20	2.470	176.060	434.87
Total			713.20

Trusses by Type

Type	No.	Mass [kg]	Surface Area [m2]
Howe	10	22257.31	427.470
Total	10	22257.31	427.470

Steel

Grade	No.	Mass [kg]	Surface Area [m2]
Fe 410 WA	271	43248.94	972.472
Total	271	43248.94	972.472

Concrete

Grade	Mass [kg]	Surface Area [m2]	Volume [m3]
M 20	37516.64	127.078	14.7
Total	37516.64	127.078	14.7

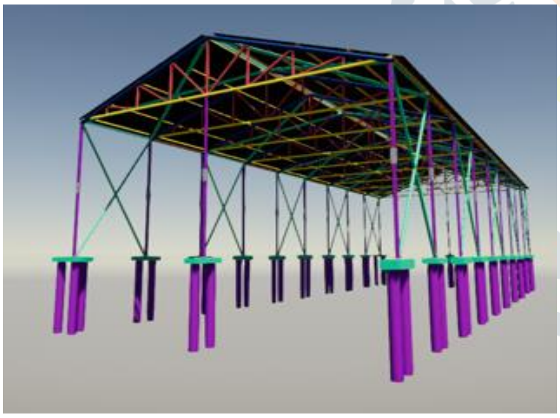
Total :

Material	Mass [kg]	Surface Area [m2]	Volume [m3]
Steel	43248.94	3215.668	5.5
Concrete	37516.64	127.078	14.7
Total	80765.58	3342.746	20.2

Reinforcement

Type	Total Mass [kg]
Pile Caps	713.20
Total + 10.00 % slab detailing allowance	713.20

BUILDING INFORMATION MODELING AND DRAWING



7. CONCLUSION:

This study effectively conveys that steel structure can be easily design by simple design procedure in accordance with country standards in Tekla software. In light of the study it can be conclude that steel structure are more advantageous than RCC structures in terms of cost effectiveness, life span, quality control, speed in construction and simplicity in erection.

Tekla structural designer is modern software can be used as a tool to understand the holistic behaviour of any structure and design steel, RCC and composite building structure and its components.

BIM was carried out by a tool Tekla structure. BIM is promising and more advantageous compared to the traditional process. It provides a better platform to address the technical issues.

The benefits such as increased communication, design integration, lean construction, reduced waste, paperless documentation, clash detection, casting, programming, simulation and modelling are for superior to that of CAD. It enables the most efficient delivery of a sustainable development.

The following are the major observations drawn from the project work.

- The steel structure is analysed for the respected loads acting on the structure as per the codes.
- The steel structure is analysed for the different load combination.
- The material quantity is calculated for the optimized design of the structure.

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7. Steel Table: - For Dimensions and Properties of rolled steel members (equal & unequal angles, I, channels & T sections). STEEL TABLE BY R.AGOR (M.K.S UNITS AND S.I.UNITS) BIRLA PUBLICATIONS (2015 EDITION)