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Shape Optimization of Roof Truss

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Abstract— **The aim of this thesis is to concentrate on the impacts of various truss shapes in the design of plane truss by utilizing angle section. The need of this study emerges where in some cases it is difficult or requiring much investment to pick a successful and optimum truss shape during the design period. In researching the adequacy of different truss shapes, an aggregate of 20 truss shapes (Pitched Pratt Roof Truss, Pitched Howe Roof Truss, Fan Roof Truss, Pratt Roof Truss, Howe Roof Truss, Warren Roof Truss, Fink Roof Truss, Diamond Roof Truss, Low Profile Roof Truss, vault Roof Truss, Mono Roof Truss, Studio vault Roof Truss, Polynesian Roof Truss, Flat Roof Truss, Parallel Chord Scissor Roof Truss, Sloping Flat Roof Truss, Barrel Vault Roof Truss, Room-In-Attic Roof Truss, Half Scissor Roof Truss) with pin and roller support are chosen. The design loads are circulated to the joints so that there is no moment to be opposed by the members. The different spans and depth of 20 shape trusses were selected and designed with the guide of STAADPro. The span of 8m, 9m, 10m, 12m, 14m and depth is 1/4th and 1/5th of span is selected. This research shows the comparison of all trusses between different spans and heights. Optimum trusses from every arrangement of trusses are find out if the effective shapes are the same for various spans and heights. The self weights acquired from the STAADPro are in the unit of KN which is utilized as a part of find out the cost of materials. This study demonstrates that there is no conviction in deciding the best shapes neither with same span nor height. The best truss shape is really particular for each truss span and height. The feature has been attributed to the alignment of the compression chords and tension chords in a symmetric manner, which allows the truss to distribute the load in most effective way. Also it is noted that more the angle made by the compression and tension chords more effectively the load is distributed. In any case, close results may be gotten where it helps to give guidelines in choosing a truss that does not waste much material. Along these lines, this strategy to decide the effective trusses is worthy and can be advanced for future inquires about.**

Keywords—Optimization;Span;Depth;Leastweight

I. INTRODUCTION

A truss is made out of members joined together at joints. The members from a truss are normally straight it is. All the joints are supposed to be pinned through a few or all the joints might be fixed rather than pinned. For the most part, the configuration of truss framework incorporates, selecting part sizes, joint areas and the number of members. A truss demonstrates like a deep beam. A beam gets to be stronger and stiffer when it is deeper. Be that as it may, when the span is long and just conveys a light load, it might waste a lot of material simply holding itself. This is on account of the bending moment capacity is most proficiently represented by the depth of section. In the event that single section is utilized, a substantial part of the web is unused. Moreover, a Single big section will be very costly furthermore infeasible in erection and manufacture. Though a truss is valuable when there is a lot of depth and intermediate light loading, it can look very complicated, however it can be the simple case in calculation when contrasted with a beam particularly when all the joints are considered pinned. Before steel was turned into a economically valuable material, trusses were made of wood or iron. These days, trusses are quite often made of steel, however some concrete trusses also exist, and some little examples do utilize timber. The members utilized as a part of steel truss framework are normally angles, double angles, C-channels, double C-channels, square hollow section, circle hollow section, cold-formed steel and so on. The truss structures are required to be designed in a manner that they have enough quality and rigidity to fulfill the strength and serviceability limitation. It is not hard to consider that there are a significant number of structures with various shapes which meet the necessity. Yet, among them it is the most practical one that interests the Structure Engineer the most. Until the approach of structural optimization, the standard path to follow in the provision of this problem was to make utilization of the experience and intuition of the engineers. The subject of optimization is a good topic in verging on each control. The extraordinary research in computational abilities in the most recent 40 years have cultivated amazing improvements in design optimization schemes in all order of engineering, so as in structural engineering. The development of structural optimization algorithms has helped engineers, all things considered, in finding the most suitable structural shape for a specific loading system. There has been a significant extensive number of research works which the shape of the structure was treated as a design variable.

II. LITERATURE REVIEW

There is lot of research of engineers required in the trusses optimization field with the goal of getting optimum truss weights. Among them Andrew B. Templeman (1983) [1] in his entitled paper “Optimization Method in Structural Design” explained the major reason of his practice why only little research output in structural optimization has been applied to design practice is that very little of it satisfies the specific needs of its potential users. William Prager (1976) [18] talked about the optimum design of a truss which comprises of bars interfacing the loaded joint to settled joints on a flat roof where just a solitary load and two choices loads were considered. The talk is on plastic and flexible design in his paper. Samuel L. Lipson and Krishna M.Aggarwal (1974) [15] studied on Weight optimization of Plane Trusses. In the paper, general technique for weight optimization utilizing the unpredictable strategy has been introduced. S. Rajasekaran [16] research on Computer Aided Optimum Design of industrial Roof (1983) where the design procedure on the optimal design of industrial roof is carried out. M. P. Saka (1991) [12] has carried out a lot of studies about the optimization on structure of trusses where for an optimum geometry design of roof trusses by optimality criteria method. M Ohsaki (1994) [12] has carried out a study to find optimal topologies of trusses with stress and displacement constraints under multiple static loading conditions using genetic algorithm. Lluis Gil and Antoni Andreu (2001) [11] exhibits a technique for the recognizable proof of the optimum shape and cross sections of a plane truss under stress and geometrical requirements. Weniyarti Bt. Yunus in 2005 [19], studied on the theme to examine the impacts of Various Truss Shapes on Design was completed by alum. Upendra Pathak and Dr. Vivek Garg did research in august 2015 [17] carried out the study about Optimization and Rationalization of Truss Design. In design of steel trusses different types of geometries and sections are widely used. Er. Sanjeev kumar, Brahmjeet Singh and Er. Bhupinder Singh (March 2016) [7] studied about Optimization of Roof Truss Using STAAD PRO V8i.The purpose of their job is to study the effect of different spacing, span, and pitches, in order to find out the most economical truss by using angle section.

III. METHODOLOGY

To accomplish the task a total of 20 shapes of various types of trusses were selected. Their Load calculation, analysis and design

The loading subjected to a truss system could be dead loads, live loads, and wind load. For roof truss system, the dead loads may be consisting of cladding, insulation, self weight of trusses and purlins, services etc. For live load, according to IS: 800-2007 and IS: 875 (part-I, II, III) 0.75 kN/m^2 may be used where the entrance to the roof is available only for service purpose. Otherwise, 1.5 kN/m^2 may be used if the purpose is more than that. In local practice, especially for buildings up to three storeys, no additional wind load is considered on the roof. Therefore, the loadings used in this research include dead load of 0.40 kN/mm^2 (includes roof sheet, purlin and other finishes) and live load of 0.75 kN/mm^2 both on plan whereas wind load is not considered in this study.
The example of detailed loading calculation is as below (for Truss 1 with span = 12m):

Data:
Spacing of truss = 6m
Height of truss = 2.5m
Dead Load (on plan) = 0.40 kN/m^2
Imposed Load (on plan) = 0.75 kN/m^2

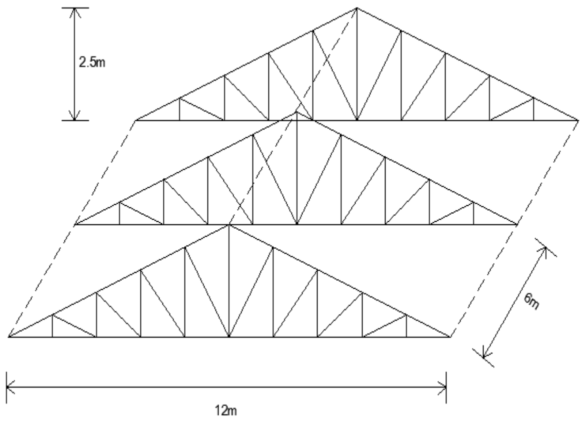

FIGURE 3.1: Typical layout of trusses with labels

Calculation for distance between nodes (purlins):
Length of top chords (half span) = 6 / cos(tan^{-1} 2/5) = 6.46m
Distance between purlins = 6.46m/6 = 1.07m
Calculation for point load on nodes:
Dead Load (on slope) = 0.40 kN/m^2 x (6m/6.46m) = 0.37 kN/m^2
Total Dead Load (G_k) = 0.37 kN/m^2 x 1.07m x 6m = 2.38 kN
Imposed Load (on slope) = 0.75 kN/m^2 x (6m/6.46m) = 0.69 kN/m^2
Total Imposed load (Q_k) = 0.69 kN/m^2 x 10.7m x 6m = 4.47 kN
Total point load = 1.4 G_k + 1.6Q_k
= 1.4(2.38kN) + 1.6(4.47kN)
= 10.48 kN

Similarly the load calculation of all the 20 types of Roof Truss is calculated.

IV. RESULT AND DISCUSSION

Here a total of 20 different truss structure analyzed and designed for 8m to 14m span. Each truss designed for this span and the depth of truss is varying with .025 and 0.2 for each fix span up to where gets the least weight of truss. In designing, each type of truss getting a minimum self-weight at different depth due to different geometry of truss for a given span has been analyzed. There are three chords in each and every truss, top chord usually sloped and parallel to bottom chord, middle chord for vertically and inclined members. For these chords we use different single angle section.
It is observed from the study that the design is optimum for MONO ROOF TRUSS at the considered spans and pitches.
The detailed summary after the optimization procedure has been shown in following tables and graphs.

S.No	Span 8m and Pitch (0.25 and 0.2)		
	Type of Truss	*Pitch*	*Steel Take off (kN)*
1	Pitched Pratt Roof Truss	0.2	1.82
2	Pitched Howe Roof Truss	0.25	3.02
3	Fan Roof Truss	0.25	2.44
4	K Roof Truss	0.2	2.55
5	Pratt Roof Truss	0.2	2.11
6	Howe Roof Truss	0.2	2.16
7	Warren Roof Truss	0.2	1.78
8	Fink Roof Truss	0.25	2.05
9	Diamond Roof Truss	0.2	2.24
10	Low Profile Roof Truss	0.25	2.70
11	vault Roof Truss	0.25	1.79
12	Mono Roof Truss	0.2	1.10
13	Studio vault Roof Truss	0.2	2.96
14	Polynesian Roof Truss	0.2	2.59
15	Flat Roof Truss	0.2	2.18
16	Parallel Chord Scissor Truss	0.2	2.11
17	Sloping Flat Roof Truss	0.2	2.93
18	Barrel Vault Roof Truss	0.2	2.82
19	Room-In-Attic Roof Truss	0.2	3.05
20	Half Scissor Roof Truss	0.2	1.77

TABLE 4.1: Optimum weight of 20 type of Roof Truss with 8m span and various pitch (0.25 and 0.2)

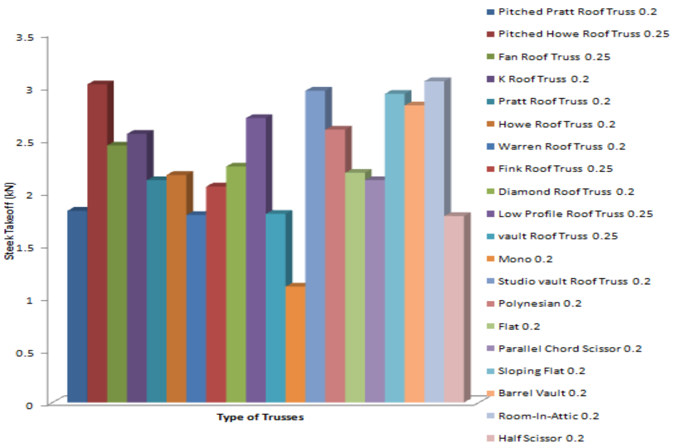

FIGURE 4.1: Optimum weight of 20 type of Roof Truss with 8m span and various pitch (0.25 and 0.2)

S. No	Span 9m and Pitch (0.25 and 0.2)		
	Type of Truss	*Pitch*	*Steel Take off (kN)*
1	Pitched Pratt Roof Truss	0.25	2.19
2	Pitched Howe Roof Truss	0.25	3.67
3	Fan Roof Truss	0.25	3.18
4	K Roof Truss	0.25	3.22
5	Pratt Roof Truss	0.2	2.62
6	Howe Roof Truss	0.2	2.68
7	Warren Roof Truss	0.2	2.39
8	Fink Roof Truss	0.25	2.69
9	Diamond Roof Truss	0.25	2.96
10	Low Profile Roof Truss	0.2	3.05
11	vault Roof Truss	0.2	1.64
12	Mono Roof Truss	0.25	1.54
13	Studio vault Roof Truss	0.25	3.21
14	Polynesian Roof Truss	0.2	3.08
15	Flat Roof Truss	0.25	1.73
16	Parallel Chord Scissor Truss	0.25	1.97
17	Sloping Flat Roof Truss	0.25	3.11
18	Barrel Vault Roof Truss	0.2	3.16
19	Room-In-Attic Roof Truss	0.25	3.75
20	Half Scissor Roof Truss	0.25	2.00

TABLE 4.2: Optimum weight of 20 type of Roof Truss with 9m span and various pitch (0.25 and 0.2)

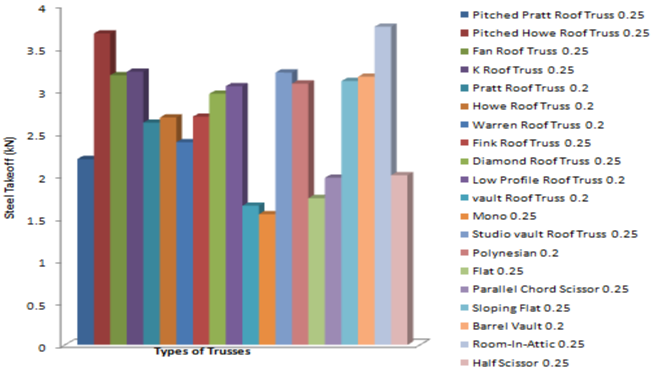

FIGURE 4.2: Optimum weight of 20 type of Roof Truss with 9m span and various pitch (0.25 and 0.2)

S. No	Span 10m and Pitch (0.25 and 0.2)		
	Type of Truss	*Pitch*	*Steel Take off (kN)*
1	Pitched Pratt Roof Truss	0.2	3.41
2	Pitched Howe Roof Truss	0.25	4.36
3	Fan Roof Truss	0.25	3.81
4	K Roof Truss	0.2	4.00
5	Pratt Roof Truss	0.2	3.67
6	Howe Roof Truss	0.2	3.68
7	Warren Roof Truss	0.2	2.85
8	Fink Roof Truss	0.25	3.29
9	Diamond Roof Truss	0.2	3.68
10	Low Profile Roof Truss	0.25	3.32
11	vault Roof Truss	0.25	2.10
12	Mono Roof Truss	0.25	1.81
13	Studio vault Roof Truss	0.25	4.27
14	Polynesian Roof Truss	0.25	2.22
15	Flat Roof Truss	0.2	3.42
16	Parallel Chord Scissor Truss	0.2	2.36
17	Sloping Flat Roof Truss	0.2	3.64
18	Barrel Vault Roof Truss	0.2	3.63
19	Room-In-Attic Roof Truss	0.25	4.31
20	Half Scissor Roof Truss	0.2	3.10

TABLE 4.3: Optimum weight of 20 type of Roof Truss with 10m span and various pitch (0.25 and 0.2)

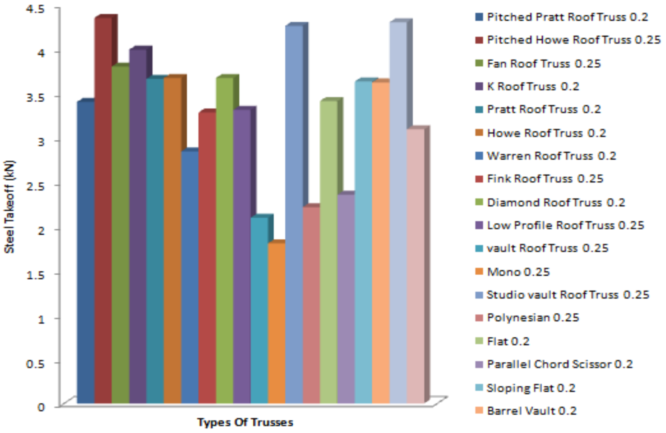

FIGURE 4.3: Optimum weight of 20 type of Roof Truss with 10m span and various pitch (0.25 and 0.2)

S.No	Span 12m and Pitch (0.25 and 0.2)		
	Type of Truss	*Pitch*	*Steel Take off (kN)*
1	Pitched Pratt Roof Truss	0.25	3.30
2	Pitched Howe Roof Truss	0.25	4.54
3	Fan Roof Truss	0.25	4.15
4	K Roof Truss	0.2	4.43
5	Pratt Roof Truss	0.2	4.19
6	Howe Roof Truss	0.2	3.81
7	Warren Roof Truss	0.2	3.41
8	Fink Roof Truss	0.25	3.48
9	Diamond Roof Truss	0.2	4.47
10	Low Profile Roof Truss	0.2	4.01
11	vault Roof Truss	0.2	3.26
12	Mono Roof Truss	0.2	2.04
13	Studio vault Roof Truss	0.2	5.91
14	Polynesian Roof Truss	0.2	3.82
15	Flat Roof Truss	0.2	2.7
16	Parallel Chord Scissor Truss	0.2	3.58
17	Sloping Flat Roof Truss	0.2	4.00
18	Barrel Vault Roof Truss	0.2	3.68
19	Room-In-Attic Roof Truss	0.25	4.55
20	Half Scissor Roof Truss	0.2	4.01

TABLE 4.4: Optimum weight of 20 type of Roof Truss with 12m span and various pitch (0.25 and 0.2)

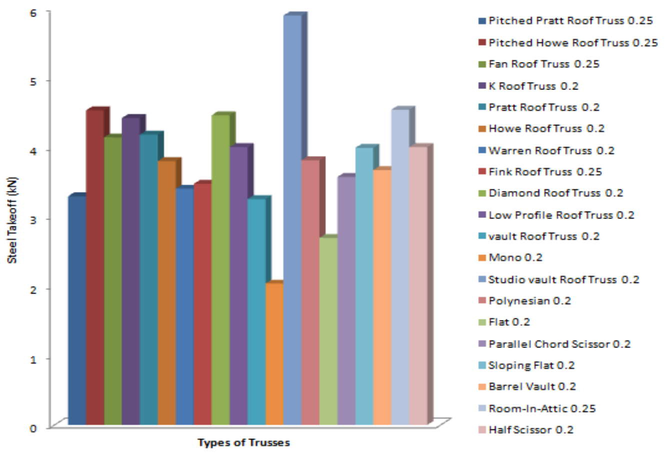

FIGURE 4.4: Optimum weight of 20 type of Roof Truss with 12m span and various pitch (0.25 and 0.2)

S.No	Span 14m and Pitch (0.25 and 0.2)		
	Type of Truss	*Pitch*	*Steel Take off (kN)*
1	Pitched Pratt Roof Truss	0.2	4.65
2	Pitched Howe Roof Truss	0.25	5.65
3	Fan Roof Truss	0.25	5.16
4	K Roof Truss	0.2	5.51
5	Pratt Roof Truss	0.25	6.43
6	Howe Roof Truss	0.2	4.95
7	Warren Roof Truss	0.25	5.31
8	Fink Roof Truss	0.25	4.58
9	Diamond Roof Truss	0.2	5.44
10	Low Profile Roof Truss	0.2	5.40
11	vault Roof Truss	0.2	3.70
12	Mono Roof Truss	0.2	2.44
13	Studio vault Roof Truss	0.2	9.12
14	Polynesian Roof Truss	0.2	4.00
15	Flat Roof Truss	0.25	4.19
16	Parallel Chord Scissor Truss	0.2	4.89
17	Sloping Flat Roof Truss	0.2	4.02
18	Barrel Vault Roof Truss	0.2	3.79
19	Room-In-Attic Roof Truss	0.2	7.80
20	Half Scissor Roof Truss	0.2	4.95

TABLE 4.5: Optimum weight of 20 type of Roof Truss with 14m span and various pitch (0.25 and 0.2)

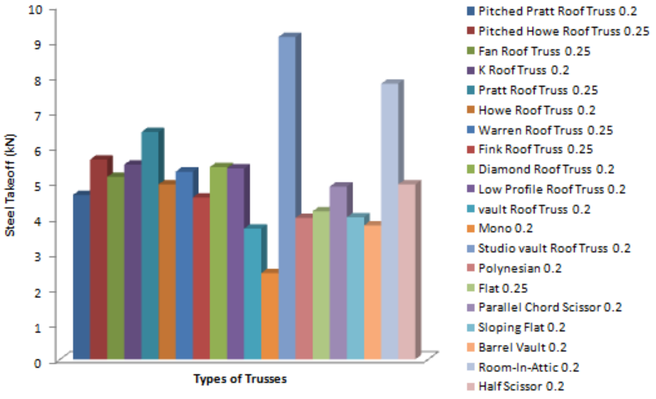

FIGURE 4.5: Optimum weight of 20 type of Roof Truss with 14m span and various pitch (0.25 and 0.2)

V. CONCLUSION

Based on the study carried out, a few outcomes are the truss geometry plays a deciding role in determining the resultant forces in the respective compression and tension members which in turn determines the self-weight of the structure and hence the cost. For same span the among all the nine truss, Warren truss geometry seems to be the most optimum truss configuration with about 10% savings in weight when compared to its closest contenders Pratt truss or Howe truss. It is also observed that the optimum depth of any truss increases linearly with respect to its span as noted from optimality curve. It can be concluded that the geometrical parameters such as depth of truss, span or the topology of truss varies in a piece-wise linear function with no clearly defined pattern. So only a trial and error method coupled with structural engineer's intuition can accomplish an optimum selection of the truss system.

REFERENCES

[1] Andrew B. Templeman. Optimization Methods in Structural Design Practice. *Journal of Structural Engineering*. 1983. Volume 109: 2420-2433..

[2] Andrew B. Templeman. A Dual Approach to Optimum Truss Design. 1976. *J.Struct. Mech*. 4(3): 235-255.

[3] A. J. Morris. *Foundations of Structural Optimization: A Unified Approach*. John Wiley and Sons Ltd. 1982.

[4] British Standards Institution. *Part 1: Code of Practice for Design – Rolled and Welded Sections*. BS 5950-1. 2000.

[5] Daniel L. Schodek. *Structures*. 3rd. ed. USA: Prentice Hall, Inc. 1998.

[6] E. W. Parkes. *Braced frameworks*. 2nd. ed. Great Britain: Pergamon Press Ltd. 1974.

[7] Er. Sanjeev Kumar, Brahmjeet Singh, Er. Bhupinder Singh. *Optimization of Roof Truss using STAAD PRO V8i*. ISSN:2349-7688, Volume -3, Issue 1, March 2016,PP 86-90.

[8] H. Randolph Thomas, JR. and Daniel Brown. Optimum Least-Cost Design of A Truss Roof System. 1977. *Computers and Structures*. Volume 7: 13-22.

[9] Hitesh K. Dhameliya, Jaiprakash B. Sharma, Yogendra Tandel. *Parametric Studies of Standard 2-D roof Truss Configuration*, Volume 11 Number 5 – May 2014

[10] John F. Fleming. *Analysis of Structural Systems*. 3rd. ed. USA: Prentice Hall, Inc.1997.

[11] Lluis Gil and Antoni Andreu. Shape and Cross-Section Optimization of a Truss Structure. *Computers and Structures*. Volume 79: 681-689.

[12] M. P. Saka. *Optimum Geometry Design of Roof Trusses by Optimality Criteria Method.* 1991. *Computers and Structures*. Volume 38, No.1: 83-92.

[13] M. Ohsaki. Genetic Algorithm for Topology Optimization of Trusses. 1995. *Computers and Structures.* Volume 57, No. 2: 219-225.

[14] Raphael T. Haftka and Zafer Gurdal. *Elements of Structural Optimization*. Exp. ed. Netherlands. Kluwer Academic Publishers. 1992.

[15] Samuel L. Lipson and Krishna M. Agrawal. Weight Optimization of Plane Trusses. 1974. *Journal of the Structural Division, ASCE*. Volume 100, ST5, May 1974: 865-879.

[16] S. Rajasekaran. Computer Aided Optimal Design of Industrial Roof. *Journal of Structural Engineering*. 1983. Volume 10, No 2, July 1983: 41-50.

[17] Upendra pathak and Dr.Vivek Garg. *Optimization and Rationalization of Truss Design.* Volume :02, Issue: 05, Aug-2015.

[18] William Prager. Geometric Discussion of the Optimal Design of a Simple Truss. 1976. *J.Struct. Mech*. 4(1): 57-63.

[19] Weniyarti Bt. Yunus. *To Investigate the Effects of Different Truss Shapes on Design*. B.Sc Thesis. Universiti Teknologi Malaysia; 2005.