

# Retrofitting of Truss under Increased Permeability Conditions

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**ABSTRACT:** In design of roof trusses, A-type geometry with different sections (Angle sections, Tube sections etc.) is widely used. Although the A-type geometry is structurally stable, the vertical clearance is limited up to tie member level. In present work, triangular arch truss of span 25m has been analysed for different tube sections (circular and square) to get desired vertical clearance and significant reduction in weight of truss system. Roof trusses are mostly affected by wind pressure. Internal wind pressure in a building depends upon the degree of permeability of cladding to the flow of air. The present paper discuss the behaviour of truss under different permeability conditions as per IS: 875 (part 3)-1987. This study further discusses the methods of retrofitting to be done in order to make the structure to withstand additional wind suction caused due to increased percentage of openings. The analysis and design is performed using SAP2000 programme.

**KEYWORDS:** Permeability conditions, Truss, Axial force, Moment, Retrofitting

## I. INTRODUCTION

Steel trusses are the most popular system for supporting long span roofs in commercial buildings, such as warehouses and aircraft hangars. The normal system used for roof trusses is A-type truss as it is structurally stable. Though it is structurally safe, from the operational point of view, due to the tie member, operations are restricted up to tie member level which is the main concern for present warehouses. Parallel chord truss and Self supporting truss system are the most adopted roof systems in ware houses, storage sheds, industries for large storage space near ports. The characteristics of such units are long span storage area, column free space for uninterrupted view and movement of vehicular traffic for loading and unloading of materials and goods.

Windstorms are one of the major causes for severe damage to roof trusses. Therefore to make sure the structure can withstand from this load, the structure analysis must be conducted carefully by considering the real effect of wind load in the analysis. The total pressure on the walls or roof of an industrial building will depend on the external wind pressure and also on internal wind pressure. Internal wind pressure in a building depends upon the degree of permeability of cladding to the flow of air. In the case of buildings with normal permeability, the internal pressure can be  $\pm 0.2p$ . Here '+' indicates pressure and '-' suction, 'p' is the basic wind pressure. If a building has openings between 5 to 20% of wall area, the internal air pressure will be  $\pm 0.7 p$  and if openings larger than 20% of the wall area, the internal air pressure will be  $\pm 0.7 p$ .

As the percentage of openings increases, additional wind suction will be acted on roof truss. As a result, the axial forces and moments will be increased in truss system. The truss cannot withstand these additional forces which cause failure of some of the members in truss system. If any truss system is constructed for normal permeability condition and if there is need to further increase the percentage of openings due to any operational issues, in order to avoid the demolition of structure which causes a huge project cost, retrofitting technique is adopted as an alternative to overcome the additional forces without disturbing the structure, which results in bring down the forces and moments in the truss system and avoiding the failure of members.

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## II. LITERATURE REVIEW

Dubey et al. (2013) analysed A-type steel roof truss of 12 m span using tubular sections under the normal permeability condition of wind according to Indian Standard Code IS: 875(Part 3)-1987 and compared the results so obtained with the calculations made in SP-38(S&T):1987. This paper concluded that analysis made in SP38:1987 cannot be followed without considering various conditions of class of structures, risk coefficient, terrain conditions, topography factor, and permeability conditions.

Kalyanshetti and Mirajkar (2012) analysed modified Howe truss of span 24m for different types of sections. This study reveals that tubular sections are more economical compared to conventional sections. Total saving of almost 50 % to 60 % in cost is achieved. This study further concluded that square and rectangular shapes are good to adopted compared to circular tube section due to connection difficulties of circular tube sections.

Upendra Pathak and Vivek Garg analysed roof truss of span 16m for different geometries and sections to get the desired optimum truss design. The design is further optimized for varying slopes of truss. The study concluded that A-type truss has lesser weight compared to other truss geometries and truss consists of tube/square hollow section is having much lesser weight compared to angle section. The truss with rigid connection between members is found heavier than the truss with pin connection. Similarly truss supported on fixed base/purlins resting on truss members causes bending moment in top chord of the truss members.

The main objectives of present study are as follows

- Effect of permeability conditions on roof truss
- Further retrofitting of truss for medium and large permeability conditions
- Optimization of truss for different tubular sections(circular and square)

## III. MODELLING

Truss with square and circular tube sections is modelled in SAP 2000. The spacing of trusses adopted in this study is 5m centre to centre. Truss top chord slope is 1 in 3 and corresponding top chord angle is 18.4°. The parallel distance between the chords is 1.5m. Rise of the truss is 2.5m. Truss is supported on built-up column of 6.5m height. The truss elements between joints are treated as rigid and capable of transferring moment and shear in addition to membrane force.

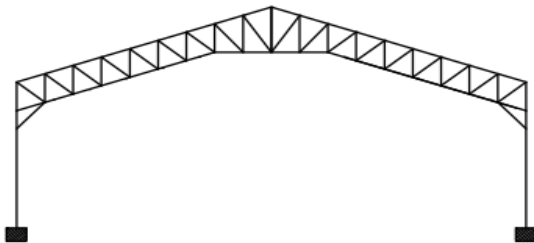


Fig. 1 Truss geometry

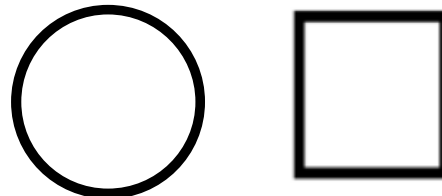


Fig. 2 Type of tube sections

Fig. 1 Indicates the geometry of the truss and Fig. 2 Indicates the type of tube sections (circular and square) used for analysis of truss

Table 1: Parameters for truss design

S.No.	Particulars	Data
1	Span of truss	25m
2	Spacing of trusses	5m
3	Location	Visakhapatnam
4	Roofing	Asbestos sheets (dead weight 171N/m <sup>2</sup> )
5	Dead load	210N/m <sup>2</sup>
6	Live load	582N/m <sup>2</sup>
7	Basic wind speed	55m/s
8	Probability factor or risk coefficient (k1)	1(for 50 years)
9	Terrain, height and structure size factor (k2)	0.98(for terrain category 2, Class B structure and building height 8.5m)
10	Topography factor (k3)	1(for plain land)
11	Design Wind pressure(Pz)	1.743kN/m <sup>2</sup>

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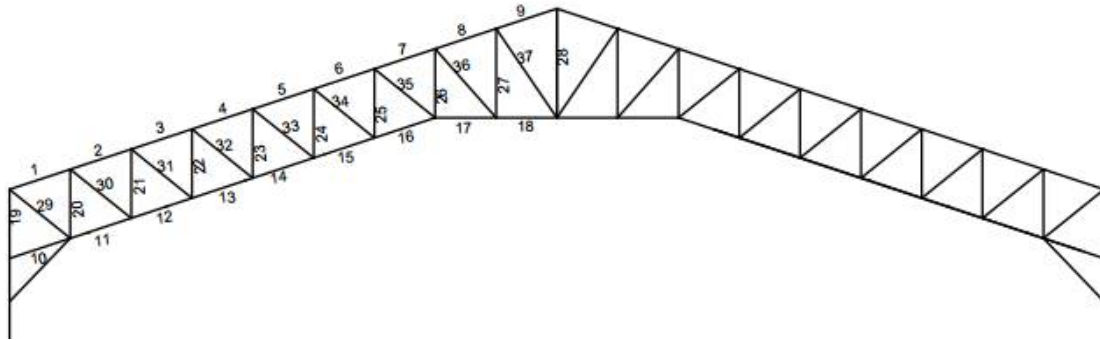


Fig. 3 Member numbering

Fig.3 and Indicates the numbering given to top, bottom, vertical and diagonal chords of truss

Table 2: Nomenclature of truss members

S.No	Element	Member No.
1	Top chord	1 To 9
2	Bottom Chord	10 To 18
3	Vertical members	19 To 28
4	Diagonal members	29 To 37

Table-3: Sectional properties

Members	Circular section	Square section
Top chord	ISNB100M	ISB 113.5x113.5x4.8
Bottom chord	ISNB100M	ISB 113.5x113.5x4.8
Verticals	ISNB65M, ISNB100M	ISB 72x72x3.2, ISB 113.5x113.5x4.8
Diagonals	ISNB65M	ISB 72x72x3.2

Table-2 describes the member numbering of truss chord members adopted for study.

Table-3 Indicates the type of circular and square tube sections assigned to truss members in this study.

Table 4: Permeability conditions identification

Condition	Description
Normal permeability	Openings <5% of wall area
Medium permeability	Openings between 5-20% of wall area
Large permeability	Openings >20% of wall area

Table 5: Model identification

Model identification	Description
NPCT	Normal permeability circular tube
MPCT	Medium permeability circular tube
LPCT	Large permeability circular tube
NPST	Normal permeability square tube
MPST	Medium permeability square tube
LPST	Large permeability square tube

Table-4 indicates the permeability conditions based on percentage of openings from IS 875-part3

Table-5 indicates the description of model identification for representing the results

## IV. RESULTS AND DISCUSSIONS

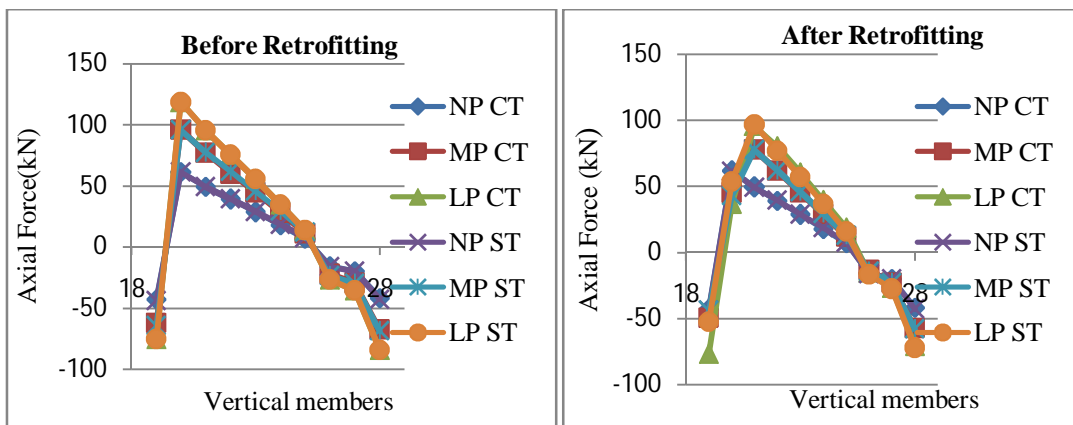
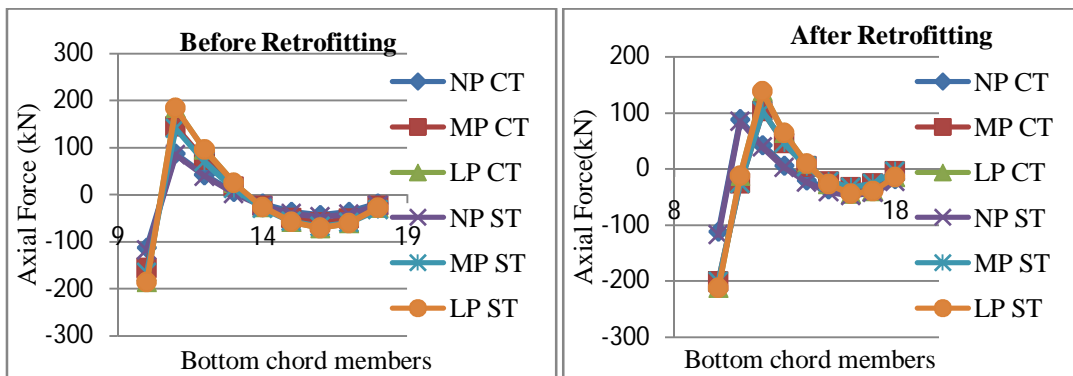
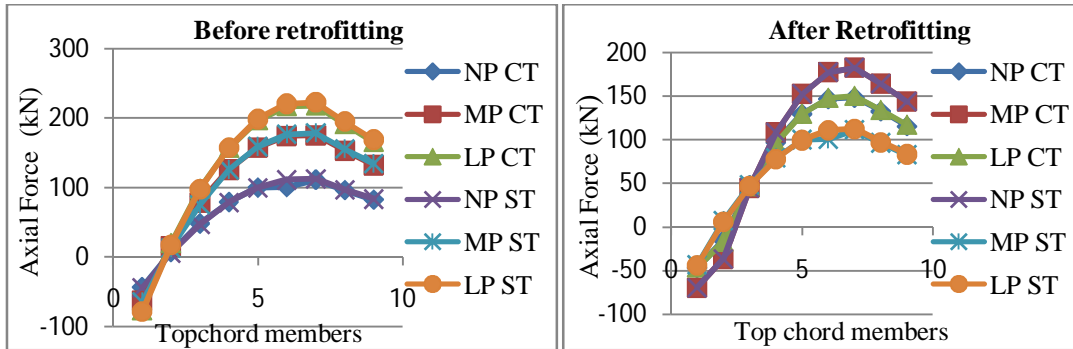
The various analyses have been performed in sap 2000 for different load combinations and results are compared to understand the behaviour of truss for different permeability conditions

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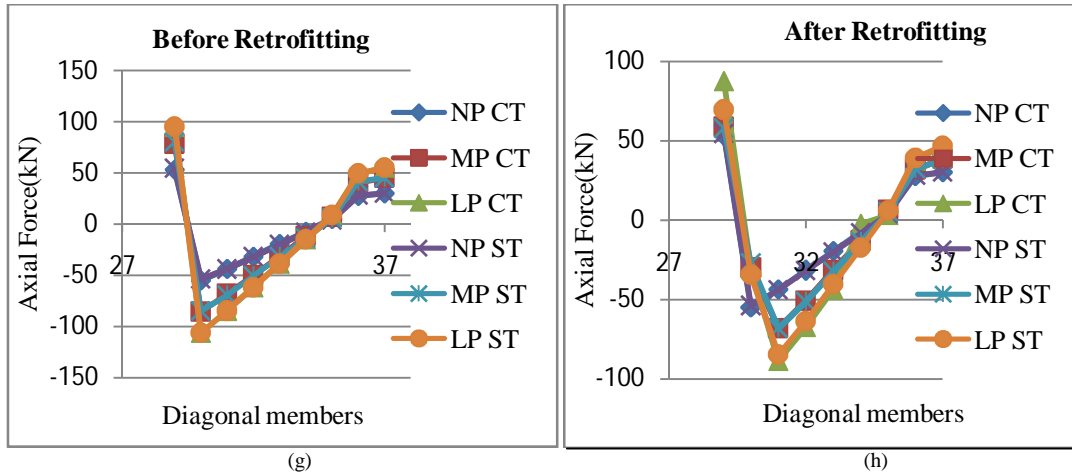
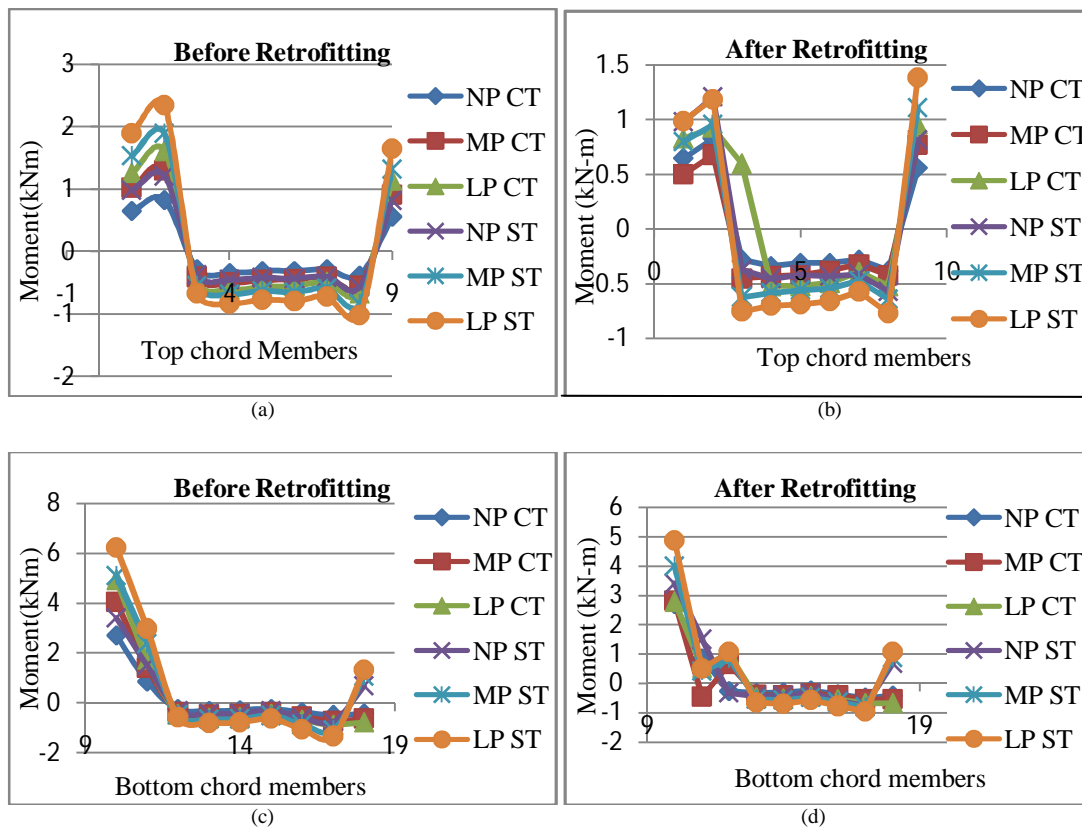


Fig. 4: Variation of Axial force in truss members for different permeability conditions for different sections  
 (a) Axial force in Top chord members before retrofitting (b) after retrofitting  
 (c) Axial force in Bottom chord members before retrofitting (d) after retrofitting  
 (e) Axial force in Vertical members before retrofitting (f) after retrofitting  
 (g) Axial force in Diagonal members before retrofitting (h) after retrofitting

From the Fig.4, it can be observed that for both sections, as the percentage of openings increase, the axial force and is found to be increased and after retrofitting, the axial force is found to be reduced to some extent.



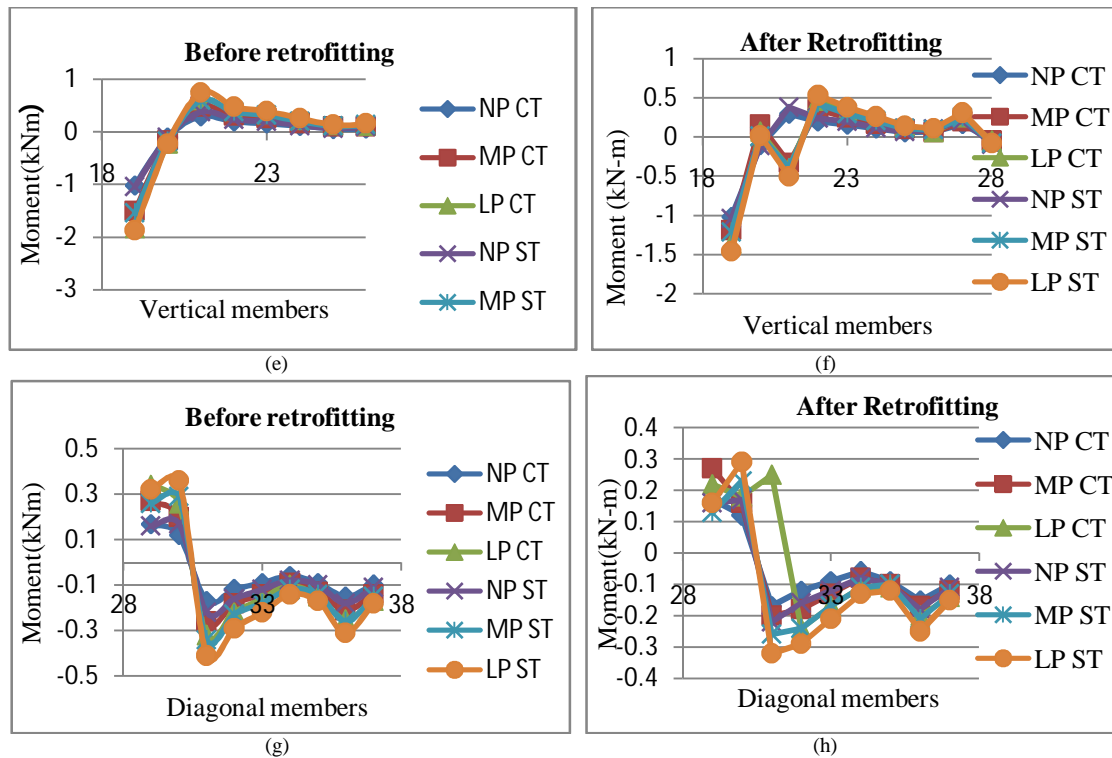


Fig. 5: Variation of moment in truss members for different permeability conditions for different sections  
 (b) Moment in Top chord members before retrofitting (b) after retrofitting  
 (d) Moment in Bottom chord members before retrofitting (d) after retrofitting  
 (f) Moment in Vertical members before retrofitting (f) after retrofitting  
 (h) Moment in Diagonal members before retrofitting (h) after retrofitting

From the Fig.5, it can be observed that for both sections, as the percentage of openings increase, moment is found to be increased and after retrofitting, moment is found to be reduced to some extent.

Initially both circular tube and square tube sections are analysed and designed for particular sizes. As the permeability increases, some of these members are found to be failed. As replacement of the truss is not an economical option, retrofitting need to be an alternative to strengthen the roof truss in order to withstand the wind suction.

#### Retrofitting techniques adopted

**For truss with circular tube section**, to withstand the suction due to medium permeability, an additional knee bracing system need to be provided (Fig.7(a))and further welding of plate of thickness 20mm up to length of 29.28% span from supports bring down the forces and moments and make the structure to withstand suction due to large permeability to with stand suction due to large permeability(Fig.8(a)).

**For truss with square tube section**, providing of additional knee bracing bring down the forces and moments and make the structure to withstand suction due to both medium permeability and large permeability (Fig.7(b) and Fig.8(b)).

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Table 6: weights of truss system for different tube sections before and after retrofitting

Permeability condition	condition	Total Weight of single truss(kN)	
		Circular pipe	Square pipe
Normal permeability		29.299	31.536
Medium permeability	After retrofitting	30.283	32.591
Large Permeability	After retrofitting	68.372	32.591

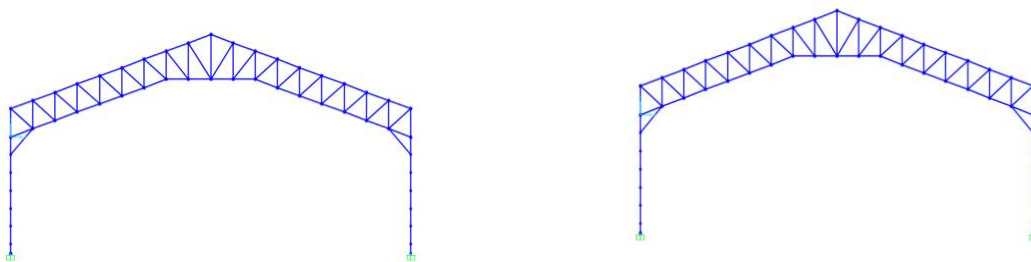


Fig. 6 Model of truss before retrofitting for (a) Circular tube and (b) Square tube

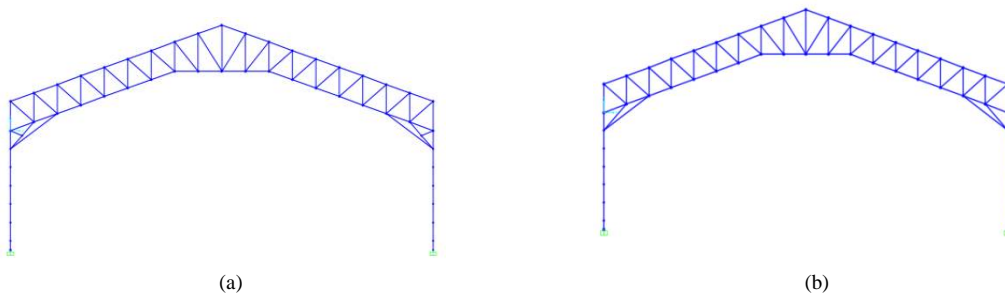


Fig.7 Model of truss after retrofitting for (a) circular tube and (b) square tube for medium permeability

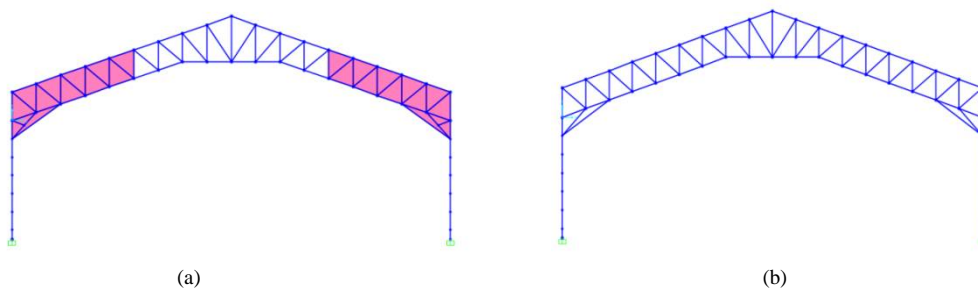


Fig.8 Model of truss after retrofitting for (a) circular tube and (b) square tube for large permeability

## DISCUSSIONS

### Before retrofitting

- The overall axial force in the system is increased by 58% for medium permeability and 96% for large permeability for circular tube section.
- The overall axial force in the system is increased by 63% for medium permeability and 105% for large permeability square tube section.

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- The overall moment in the system is increased by 51% for medium permeability and 85% for large permeability for circular tube section and square tube section.

## After retrofitting

- The overall axial force in the system is increased by 35% for medium permeability and 70% for large permeability for circular tube section.
- The overall axial force in the system is increased by 41% for medium permeability and 82% for large permeability square tube section.
- The overall moment in the system is increased by 16% for medium permeability and 43% for large permeability for circular tube section.
- The overall moment in the system is increased by 19% for medium permeability and 48% for large permeability for square tube section.

## Comparison of tube sections

- After retrofitting for medium permeability condition, the overall weight of truss system is increased by 3% for circular tube section and square tube section
- After retrofitting for medium permeability condition, the overall weight of truss system is increased by 103% for circular tube section and it is 3% for square tube section.

## V. CONCLUSIONS

- As the percentage of openings is increasing, the axial force and moment in the truss system is increasing drastically which leads to failure of truss members.
- After retrofitting for medium permeability, the axial force and moment in the truss system is reduced by 23% and 35% for circular tube section and 22% and 32% for square tube section.
- After retrofitting for large permeability, the axial force and moment in the truss system is reduced by 26% and 42% for circular tube section and 23% and 37% for square tube section.
- Square tube section is good to be adopted compared to circular tube, due to less weight of the section after retrofitting.

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