STUDY OF VARIATION OF STRESS CONCENTRATION IN COMPOUND SHEAR WALL

A DISSERTATION

Submitted in the partial fulfilment of the
requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
EARTHQUAKE ENGINEERING
(With Specialization in Structural Dynamics)

By

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CANDIDATE'S DECLARATION

I hereby, declare that the work which is being presented in this dissertation entitled, "**STUDY OF VARIATION OF STRESS CONCENTRATION IN COMPOUND SHEAR WALL**", being submitted in the partial fulfilment of the requirements for the award of the degree of Master of Technology in Earthquake Engineering with specialization in Structural Dynamics, to the Department of Earthquake Engineering, Indian Institute of Technology Roorkee, Roorkee, under the supervision of Dr. R.N. Dubey, Associate Professor, Department of Earthquake Engineering, Indian Institute of Technology Roorkee, Roorkee, is an authentic record of my own work carried out during the period of June 2018 to June 2019.

I declare that I have not submitted the material embodied in this dissertation for the award of any other degree or diploma, to any other university or institute.

Place: Roorkee
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CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief.

Place: Roorkee
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ABSTRACT

It has been established in past that the location of stress concentration in any structure is often the point where failure occurs or it serves as site for start of propagation leading to failure. This phenomenon when tested on non-planar shear wall (T-shape, L-shape etc.) has been found correct. In an experiment done by Inada, 2008 [10]when load was applied on L- shape shear walls with help of jacks in laboratory and dynamic loading conditions were established, it was found that wall failed at the junction point where stress concentration is expected to occur.

There is no clause present in Indian codes which deals with design and detailing recommendations for compound shear wall (except for boundary zone). The Uniform Building Code (UBC 1997) offers only limited guidance for the design and detailing of shear walls of compound configurations in plan. The present study has been done keeping this in mind so that few practical suggestions can be put forward regarding design of compound shear wall.

Study of compound shear wall has been done with objective of studying the effect of shear concentration at re-entrant corners. Models are prepared in the software SAP2000 and the analysis has been done to obtain the values of stress at corner point. Length of flange, thickness of wall and height of building is varied and variation of shear stress at corner point is studied. Values of stress has been plotted against ratio of length of wall to thickness of wall keeping the height of building constant and it has been observed that they follow a particular pattern.

It can be said that the length to thickness ratio of shear walls should be such that stress at the re-entrant corner is minimal to avoid failure of the structure.

ACKNOWLEDGEMENTS

It is my great pleasure to express my most sincere gratitude and thankfulness to Dr. R.N. Dubey, Associate Professor, Department of Earthquake Engineering, Indian Institute of Technology Roorkee, Roorkee for his dedicated guidance, generous help and the precious time he gave in supervising this dissertation work.

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Place: Roorkee **Sumit Jain**
Dated:

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Chapter 1 : INTRODUCTION

1.1 Background

Shear walls are found effective for load transfer due to dynamic loads. Shear wall is a vertical member that can resist lateral forces directed along its orientation. Concrete shear walls are widespread in many earthquake prone countries. It has been in practice since 1960's and has been used in buildings ranging from medium to high-rise.

Demand for proper housing and residential facility is gaining pace over a decade now in India and for this purpose use of high rise building is inevitable, so is use of shear walls.

Shear walls are major part of construction in earthquake prone areas. Architectural and functional requirement promote use of non-planar shear walls or otherwise called as compound shear walls.

A comprehensive study has been made on planar shear walls till date but understanding behaviour of compound shear wall requires more study. Behaviour of these flanged walls is different from planar walls during earthquake. This topic has been chosen in the present study to understand the behaviour of compound shear wall and efforts have been made to put forward few practical recommendations for design.

1.2 Objectives

The primary objective of this dissertation is to study variation of stress concentration on compound shear wall by changing dimensional parameters of wall. The specific objectives of present study are:

- Objective of this thesis is to analyse the buildings having shear walls with non-planar sections and study the impact of loading on such configurations. It has been highlighted from previous studies that such shapes compound shear walls result in stress concentration which may prove detrimental in case of earthquake loading.
- To compare the result of various models by changing configuration of shear wall, plan, vertical and horizontal dimensions, flange width of shear walls under same loading combinations.

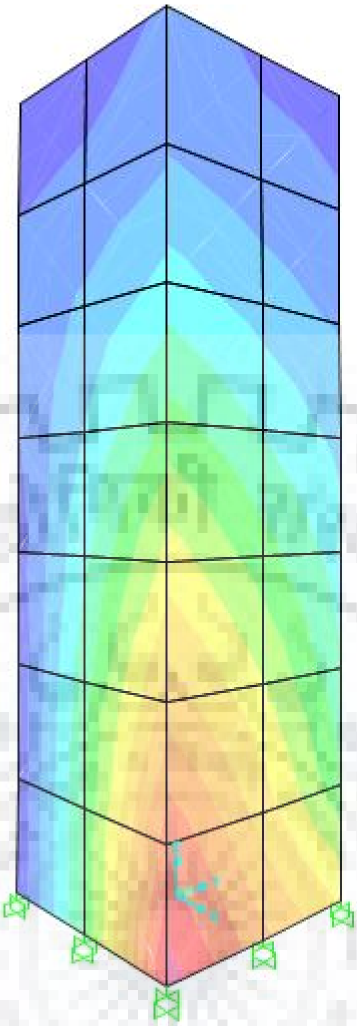

Figure 1.1 Stress concentration at corner region in L-shape shear wall

- Indian codes and standards have covered specifications and detailing of planar shear wall in great depth but lacks in proper provisions for compound shear walls, so this thesis also emphasizes on need for introduction of such provisions in Indian Standards.
- Aim of thesis is to understand change in stress in wall when dimensions of non-planar walls are varied and based on this study some basic recommendations have been made which may help in safe designing of non-planar shear walls.

1.3 Need for Study

When any structure or specimen, which has re-entrant corners or discontinuity, is subjected to loading it has been observed that the stress lines are concentrated near that corner or discontinuity and this phenomenon is called stress concentration. Same effect can be observed in structural walls with non-planar shape (L-,H-,T- etc) which is shown in figure 1.1. Site of this stress concentration can become point of initiation of failure of structure. In past studies have been conducted to verify this effect and it has been found at few earthquake sites that failure in buildings did initiate due to stress concentration which has been discussed in detail in chapter 2. Therefore proper study is required for understanding the behaviour for these configurations of shear walls.

1.4 Limitations

Although many models are prepared and analysed but still all possible configuration and shapes are not studied herein and more further study is required for this purpose. Experimental study should also be taken up in the future for better understanding.

1.5 Disposition

Chapter 1	Gives introduction of subject and problem statement. It also highlights the limitations which have been made.
Chapter 2	This chapter presents the facts gathered from various research publications and other literature as well as history of high rise building in relation with shear walls.
Chapter 3	This chapter gives various codal provisions given in standards of different countries regarding designing and detailing of compound shear wall.
Chapter 4	Method adopted for studying numerical variation of shear stress on different dimensions of wall is discussed in this chapter.
Chapter 5	This chapter shows result from analyses made and some discussion on it.
Chapter 6	Contains conclusions from study made.

Chapter 2 : LITERATURE REVIEW

This chapter gives the brief history of high rise buildings and shear walls. It also aims to summarize the past work which has been looked into during period of this study relevant to achieve the objective. This chapter also clarifies importance of this study.

2.1 High Rise Building

Due to high urban densities in countries like India use of high rise building is necessary. At end of 19th century modern high rise building came into existence and since then there has been gradual improvement in height of buildings. High rate of urbanization and industrial revolution has been contributing factors for steady increase in height of building.

Following figure represents evolution of high rise building with respect to height:

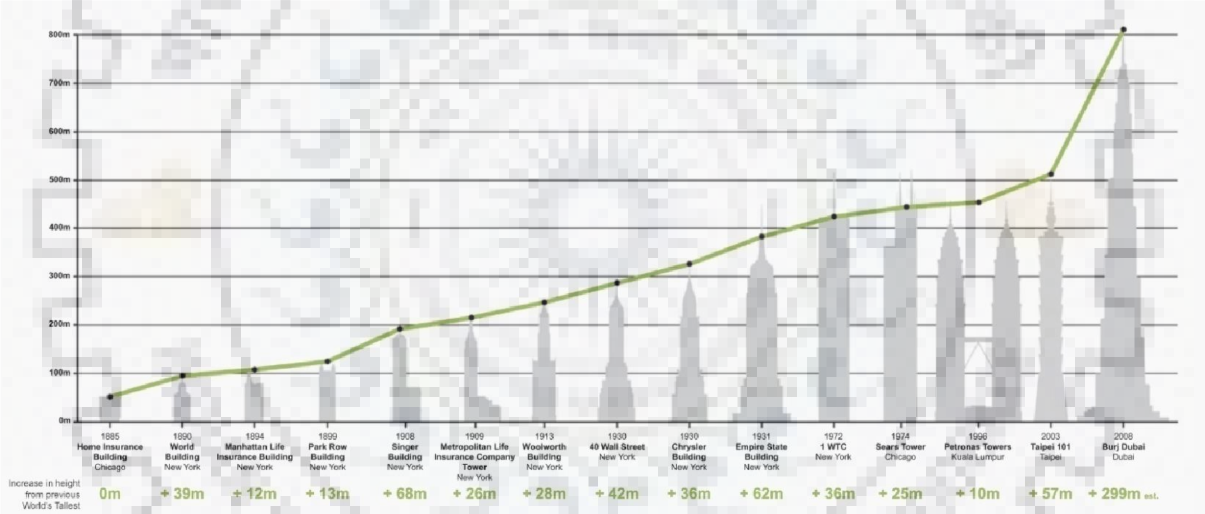

Figure 2.1 Buildings which once held title of world tallest building [9]

Properly detailed and designed buildings with shear walls have performed satisfactorily in past earthquakes.

2.2 Problems in seismic design and detailing of compound shear wall plan configuration

Sarkasian (2003) in his article mainly focused on need for coming up with rational approach in selecting effective flange width and boundary zone length while designing shear walls with shape other than rectangle. In this article author tried to explain the problems regarding design of compound shear wall by taking example of design of St. Reigs Museum which is a 40 storey tower [15].

In this paper author concluded that current provision in various codes and standards very efficiently discusses design approach to planar shear wall but fails to throw light on detailing and designing of compound shear wall which still holds true till date although this issue has been addressed in European codes up to some extent but not much has been done regarding this context in India.

2.3 Past Studies

Chaouch et al. (2014) performed in his research deals with study and understanding behaviour of L-shaped RC shear wall. A parametric study was performed with more than 200 models created and analysed. Main results of numerical analysis on shear stress variation in an L-shaped reinforced concrete wall were presented and it was found stress concentration at corners in shear wall can be reduced by selecting proper aspect ratios. Analysis was performed on a building by changing number of stories, shear wall length and its thickness. Reinforced concrete structures with L shape walls offers advantages of open space and flexible architecture modelling [8].

In many cases, these complex members show completely different behaviours than rectangular walls, and special consideration is needed when these shapes are used in structures. The stiffness, strength, and ductility of such walls can be completely different in opposite directions.

Aminnia and Hosseini in 2015 studied the effects of placement and cross-section shape of shear walls in multi-story RC buildings with plan irregularity on their seismic behaviour by using nonlinear time history analyses.

Many studies have been conducted in the context of analysis and design of shear walls; however, few studies have been performed changing both location and shape of shear walls in multi-story buildings, especially those with irregular plan so this paper deals with one such study showing that shape of wall cross section is also an effective factor [14].

Based on the numerical results obtained with eight different shear walls placement-shape patterns, it was found that drift and base shear varies in wide range of value from one pattern to other [14].

Experimental study performed by Wei Lee(2010) Seismic performance of L-shaped RC shear wall subjected to cyclic loading produces some results which can be taken up to further investigation. Although results of this study are unrelated to topic of interest of this work but observations reported by authors during this study can be used for further understanding. In the above mentioned study six walls with L-shape were taken with different slenderness ratio and web length and are subjected to loading under different axial stress. During study failure pattern was observed and it was found every specimen failed in same way with main crack occurring at web root. This failure pattern rises question why web root is subjected to failure although proper reinforcement has been provided [13].

2.4 Gap Area in Research

This section discusses why it is important to study stress concentration in compound shear wall. For underlining the importance of study required this section presents the summary of a case study done by team of researchers after Chile 2010 earthquake and an experimental study done by Inada in 2008.

Wallace et al. (2012) in his paper Damage and implications for seismic design of RC structural wall buildings deals with study of earthquake which hit Chile on 27 October 2010. Earthquake which occurred had M_w 8.8.

Details of damage which occurred during EQ and their possible reasons are listed and discussed in this paper.

Observed damage: Large damage was noted in shear walls and few important points are highlighted below:

Crushing and spalling of concrete and buckling of vertical reinforcement were observed, often over the entire wall length. Typically, the damage was concentrated over a short height equal to one to three times the wall thickness, this may be because buckling of vertical bars.

Lateral instability (buckling), primarily at web boundaries of T- or L-shaped wall cross sections, was observed. This mode of failure has not been studied efficiently yet.

In majority of cases location of damage was at place of sudden change in cross section or discontinuity, this was likely due to stress concentration as suggested by author [17].

Figure 2.2 Damage at wall discontinuity [17]

Severe damage was observed in tall building but a 15 storey RC building collapsed constructed in 2007. Researches commented based on observed wall damage in a large number of buildings, as well as the wall configuration for the Alto Río building, it appears quite likely that flexural compression failure (concrete crushing, rebar buckling) occurred at the location where the transverse wall lengths were reduced on the side of the building with parking.

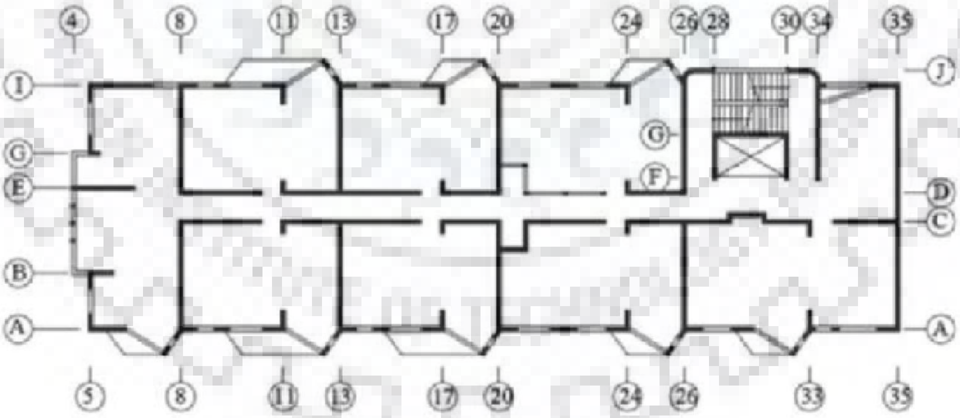

Figure 2.3 Alto Rio typical floor plan [17]

Figure 2.3 shows typical plan of Alto Rio building and in his work he mentioned that initiation of damage may have started at axes 8, 13 and 20 (with T-walls). Alternatively, axes 11, 17 or 24 with L-shape walls could also be points of initiation of failure. High shear stresses most likely leads to failure of these transverse walls and once these walls fail redistribution of axial load will make other elements more prone to failure. Following figure shows complete collapse of Alto Rio building.

Figure 2.4 Overall view of collapsed building in Alto Rio [17]

Wall lateral instability failures were observed in building with high axial stress suggesting minimum wall thickness criteria should be readdressed.

Role of wall configuration was also discussed in paper suggesting T- and L- shaped walls behave differently in earthquake and need to be carefully reviewed.

Inada (2008) performed an experimental study on 3 different L shaped shear walls. Load-drift relationship and strain distribution was studied. All three walls were of same height but flange section lengths were changed and also direction of loading. Failure started at location of re-entrant corner in all three walls and then continued depending on loading direction [10].

Following figure shows the failure in one of the specimen during experiment.

Figure 2.5 Specimen after loading [10]

Chapter 3 : CODAL PROVISIONS

This chapter deals with various codal provisions given in various American and European codes regarding compound shear wall .This chapter mainly assembles all the provisions and suggestions given in Indian Standards which can be useful in designing flanged walls in earthquake prone areas. It is important to know all these provisions so that proper models can be prepared satisfying all these clauses and further study can be carried out.

This chapter also shows lack of guidelines given in Indian standards for design flange shear walls.

3.1 Universal Building Code 1997

The Uniform Building Code (UBC) 1997 Edition, provide the guidance for the design and detailing of compound shear walls. Main points to be considered during designing and detailing of compound shear wall are:

Effective flange width
Overall detailing
Boundary zone design

3.1.1 Effective flange width

UBC 1997 Section 1921.6.6.2 states that the effective flange widths to be used in the design of I-, L-, C-, or T-shaped sections shall not be assumed to extend further from the face of the web than:

(i) One-half the distance to an adjacent shear wall web
(ii) 15 percent of the total wall height for the flange in compression or 30 percent of the total wall height for the flange in tension, not to exceed the total projection of the flange [11].

3.1.2 Boundary zone design

Boundary zone is end region where compressive strain induced is more than 0.003 due to earthquake [11].

Section 1921.6.6.4 of UBC 1997 states that shear walls and portions of shear walls not meeting the requirements of section 1921.6.6.4 Items 1 and 2, or 3 and having $P_u < 0.35\ P_o$ shall have boundary zones at each end a distance varying linearly from 0.25 l_w to 0.15 l_w for

P_u varying from 0.35 Po to 0.15 Po. The boundary zone shall have minimum length of 0.15 l_w and shall be detailed in accordance with section 1921.6.6.6 [11].

Also, Section 1921.6.6.6 item 1.3 states that boundary zones shall have a minimum length of 18 inches at each end of the wall or portion of wall. Item 1.4 also says that in I-, L-, C-, or T-shaped sections, the boundary zone at each end shall include the effective flange width and shall extend at least 12 inches into the web [11].

3.2 SEAOC Blue Book: Seismic Design Recommendations

SEAOC Blue Book states that Connected or intersecting wall sections shall be considered as integral units. The strength of flanges, boundary members, and webs shall be evaluated on the basis of compatible interaction between these elements. The effect of wall openings shall also be considered [16].

3.3 ACI-318R-14

In this code term shear wall and structural wall is used synonymously.

Section 18.10.1.1of ACI 318 applies to special structural walls and all special structural walls components including wall piers and coupling beams which can be considered as part of seismic-force-resisting system.

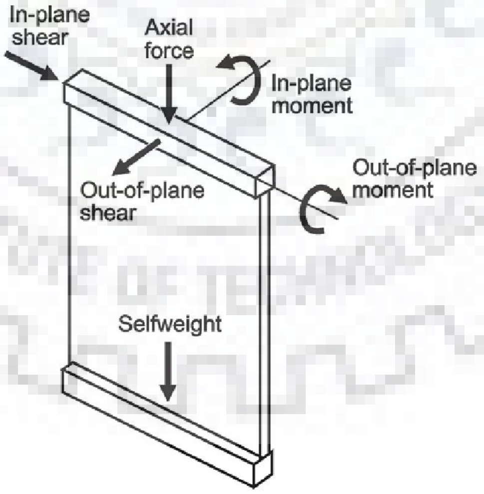

Figure 3.1 Different action of forces in shear wall [1]

3.3.1 Minimum reinforcement

Section 18.10.2.1 of code states that The distributed web reinforcement ratios, ρ_ℓ and ρ_t, for structural walls shall be at least 0.0025, except that if Vu does not exceed $A_{cv\lambda}\,'\,f_c$, ρ_ℓ and ρ_t shall not exceed values given in code [1].

3.3.2 Boundary element design

18.10.6.2Walls or wall piers with $h_w/\ell_w \geq 2.0$that are effectively continuous from the base of structure to top of wall and are designed to have a single critical section for flexure and axial loads shall satisfy (a) and (b) or shall be designed by 18.10.6.3:

(a) Compression zones shall be reinforced with special boundary elements where

$$c \geq \frac{lw}{600(\frac{1.5\delta u}{hw})}$$

and corresponds to the largest neutral axis depth calculated for the factored axial force and nominal moment strength consistent with the direction of the design displacement δu. Ratio δu/hw shall not be taken less than 0.005.

(b) Where special boundary elements are required by (a), the special boundary element transverse reinforcement shall extend vertically above and below the critical section at least the greater of ℓ_w and $M_u/4V_u$ [1].

3.4 Eurocode-08:2004

Structural element supporting other elements and having an elongated cross-section with a length to thickness ratio l_w/b_w of greater than 4.Different clauses which are relevant for designing and detailing of compound shear wall are listed below:

Clause 5.4.1.2.3 of code states that minimum web thickness should be greater of 150 mm or clear storey height divided by 20.

Section 5.4.3.4.1 of EU-08 states composite or compound wall sections as intersecting or connecting rectangular segments such as L-,T-,C- etc should be taken as one integral unit. Composite wall section consists of webs (or web) and flange.

It states for the calculation of flexural resistance, the effective flange width on each side of a web should be taken to extend from the face of the web by the minimum of:

a) the actual flange width;
b) one-half of the distance to an adjacent web of the wall; and
c) 25% of the total height of the wall above the level considered [2].

3.5 IS 13920:2016

Different clauses which are relevant to designing of compound shear wall are listed below.

i. Minimum thickness of shear wall should be 150 mm and it must conform fire resistance as per IS 456(2000).
ii. Value of minimum ratio of length to thickness of wall should be 4.
iii. Length of flange considered in design of flanged section wall is given by minimum of:
    a. actual available width
    b. one-tenth of wall height
    c. half the distance between adjacent structural wall
iv. As per IS 13920:2016 boundary element should be provided when extreme compressive stress in wall exceeds $0.2f_{ck}$and this boundary zone will continue upto compressive stress of $0.15f_{ck}$.[4]

3.6 IS 16700:2017

Various relevant clauses which are important for modelling of structure in this work are listed below.

a) Plan geometry should be regular. It should be rectangular or elliptical.
b) Aspect ratio should be less than 5.
c) Maximum inter storey elastic drift ratio should be h/250.
d) Minimum concrete grade used should be M-30.
e) Maximum concrete grade should be M-70. If higher grade is used it should be ensured that compressive strain remains within 0.002.
f) Code limits damping ratio to 2% for critical concrete building.
g) Vertical and horizontal both seismic effects should be considered for seismic zone V.

Various provisions are given in section 7 of this code for modelling and computer analysis, relevant provisions with respect to topic are listed below:

a) Fixed support should be given for seismic effect calculations.
b) For building h>150m staged constructions should be considered.
c) Thickness of structural wall >maximum of 160mm or h/20.
d) Nominal design shear should be limited to 0.5 times maximum allowed shear.
e) For zone 4 and 5 thickness of wall should not be less than 200mm.
f) In case of flat slab system column should not be included in lateral load resisting system and shear wall should be assumed to carry all loads [7].

Chapter 4 : MODELLING

This chapter consist of process adopted for carrying out numerical study for variation of shear stress on RC shear wall building.

Building with same plan and different height is considered and analysed for earthquake loading as per IS 1893(Part-1):2016 with help of SAP2000. For each building height, length and thickness of shear wall are changed to study effect of this change on maximum shear stress anywhere in the wall. Taking into account the variation of these three parameters, models were prepared and analysed. Detailed process is explained below.

Firstly, a building with selected plan is taken and modelled. Then keeping its height and thickness of wall constant, length of shear wall is changed several times and model is analysed for stress at corner region. This stress is then plotted against ratio of length of wall to thickness of wall (L/t) and value of L/t at which peak stress occurs is found out.

Now building with same plan and different heights are taken and above process is repeated. The same graph i.e. between L/t and shear stress is plotted for every height. All these graphs are then drawn on same plot for comparison and result obtained are shown in next section.

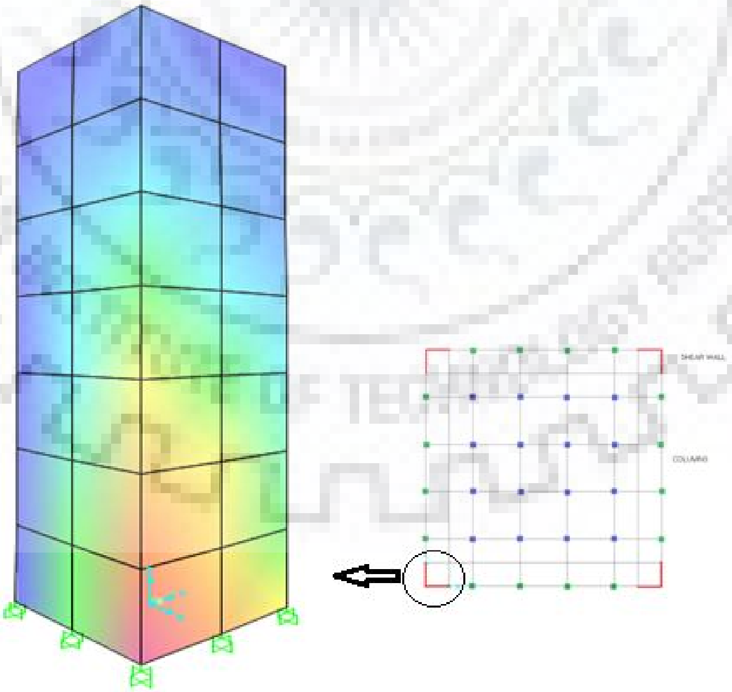

Figure 4.1 Stress concentration at corner

4.1 Plans considered

4.1.1 Plan-1

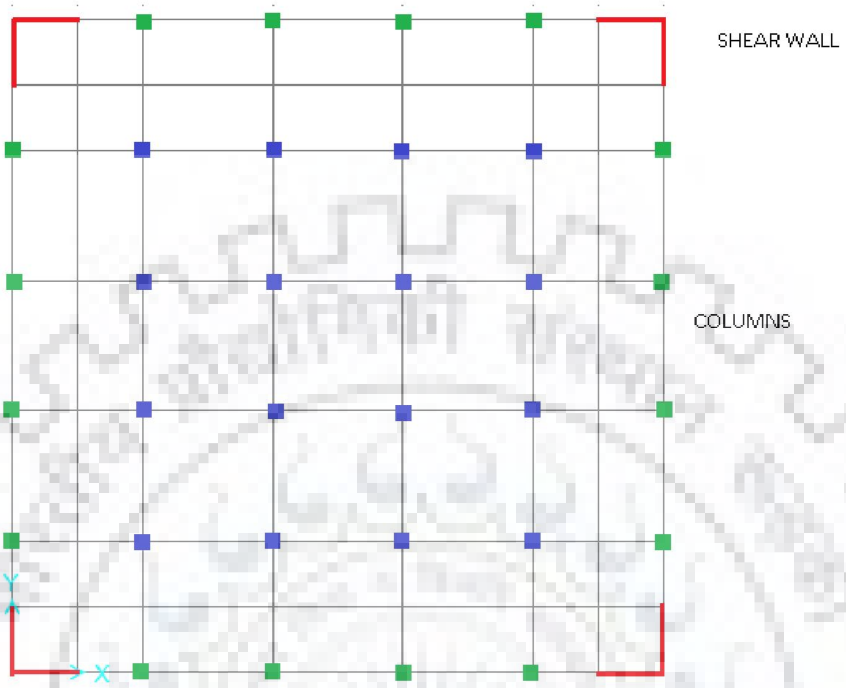

Figure 4.2 Basic Plan-1 of building considered

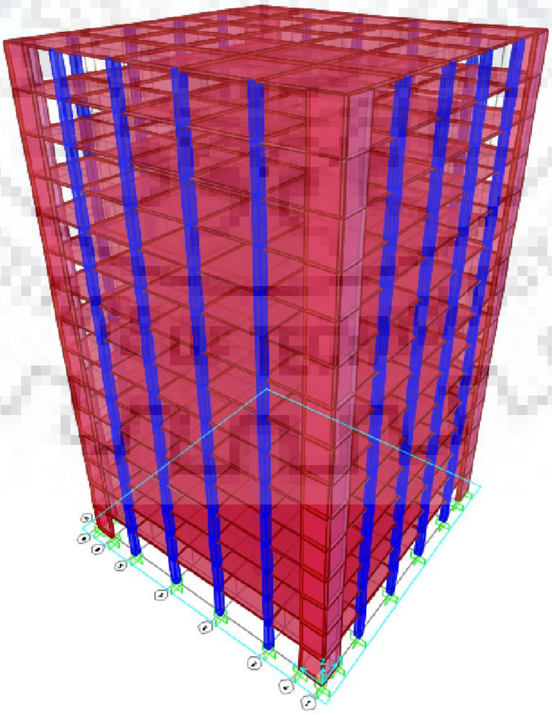

Figure 4.3 Elevation of model of plan-1

Table 4.1 Dimensions of building withPlan-1

Height of each storey	2.8 m
Slab thickness	0.150 m
Grid spacing	5 m
Dimension of peripheral columns	0.6mx0.6m
Dimension of inner columns	0.5mx0.5m
Concrete	M-35

Table 4.2 Loads applied on building with Plan-1

Floor finish	0.92 kN/m^2
Roof finish	4.45 kN/m^2
Load due to partition wall	1.5 kN/m^2
Live Load	2 kN/m^2
Zone	V
Importance Factor	1
Response Reduction Factor	5
Soil Type	II

Three heights of this model were taken for analysis and they are 19.6 m, 30.8 m and 42 m and length of wall taken is taken from 1m to 5m at interval of 1m each. Three thickness considered are 200mm, 250mm and 300mm.

4.1.2 Plan-2

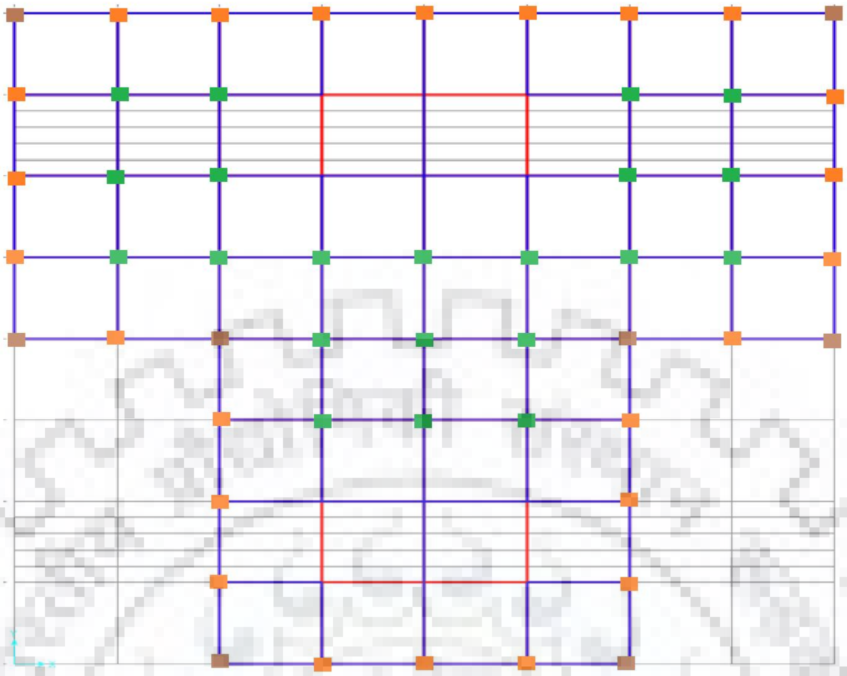

Figure 4.4 Basic plan-2 of building considered

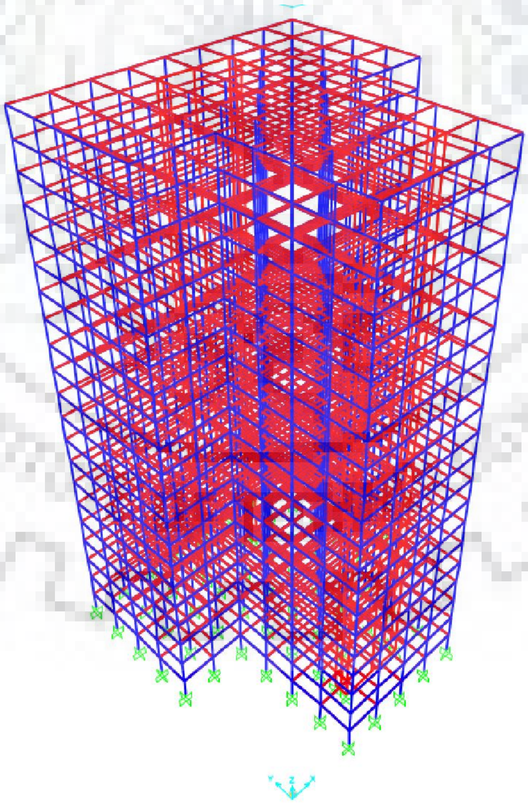

Figure 4.5 Elevation of model of plan-2

Table 4.3 Dimensions of building with plan-2

Slab thickness	0.150 m
Grid spacing	5 m
Dimension of peripheral columns	1.0mx1.0m
Dimension of inner columns	0.8mx0.8m
Dimension of beams	0.4mx0.6m
Concrete	M-40

Table 4.4 Loads applied on building with plan-2

Imposed load	1.5 kN/m^2
Live load	4.0 kN/m^2
Importance factor	1
Zone factor	V
Response reduction factor	5
Soil type	II

Three heights of this model were taken for analysis and they are 49.8 m, 75 m, and 100.2 m respectively and length of wall taken is taken from 1m to 5m at interval of 1m each. Three thickness considered are 200mm, 250mm and 300mm.

4.2 Comparison of Result with Previous Studies

Not many in past have attempted similar kind of study. Chouch (2014) in his paper Numerical Study on Shear Stress Variation of RC Wall with L Shaped Section has attempted similar kind of study with L-shaped shear wall and presented result of investigation in his paper. He did his work based on Algerian seismic regulation RPA99/V2003 (RPA, 2003) and one such graph of shear stress variation is presented here so as to validate the result obtained in this work.

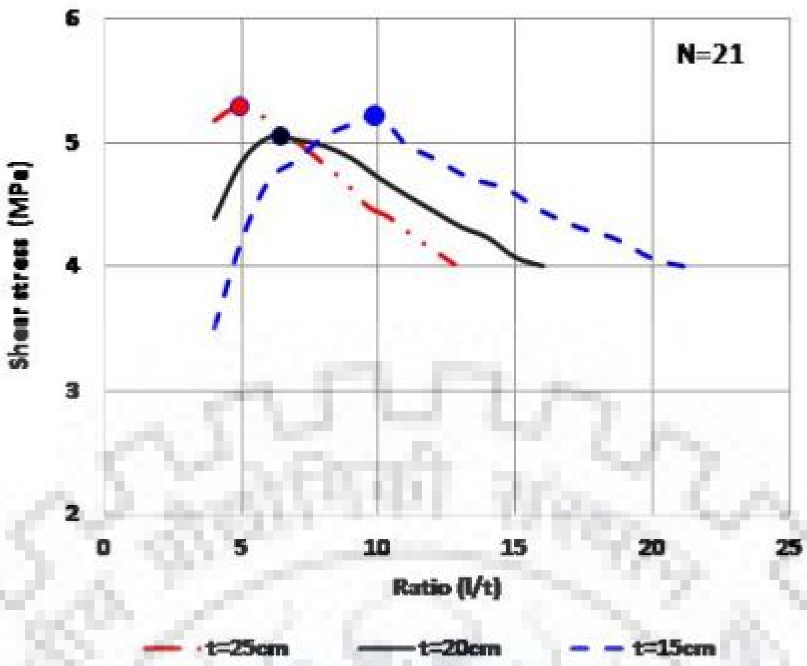

Figure 4.6 Maximum shear stress distribution for 21 story building [8]

From above figure it is clear that for a particular thickness shear stress first increases then decreases after peak value which is in agreement with results found in this work.

Chapter 5 : RESULTS AND DISCUSSIONS

After analysis of all the models values of maximum shear stress were noted in all cases. It was found maximum shear stress in all cases occurred at point of stress concentration i.e. corner points. When values of these maximum shear were plotted against ratio of length of flange to thickness of wall (L/t) it was found that for particular thickness L/t at which shear stress is maximum remains same in all cases. This can be verified from figures below.

Following graphs are corresponding to values for building having **plan-1**

For this case value of length of flange of wall varies from 1m to 4m at interval of 0.5m.

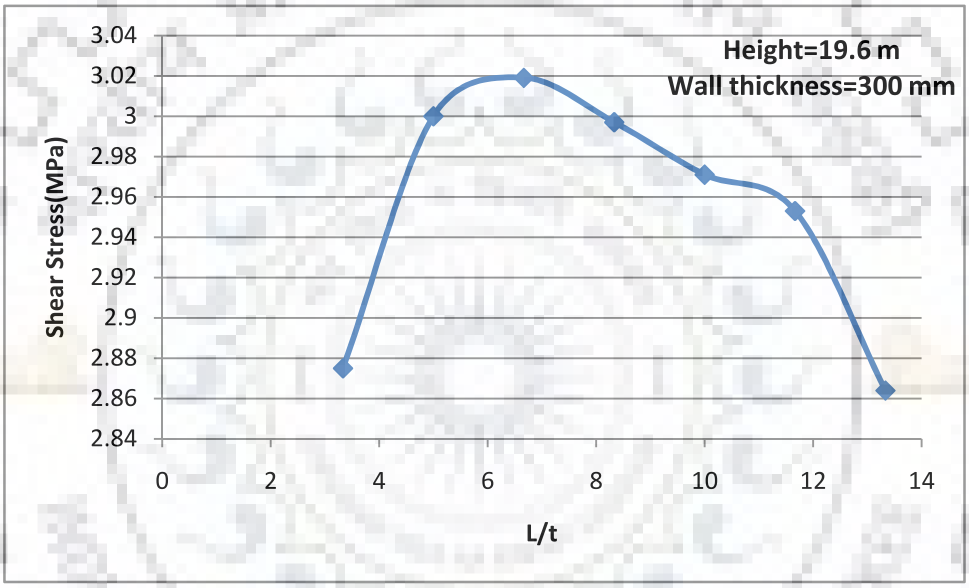

Figure 5.1 Shear stress vs L/t graph for building with height 19.6 m and wall thickness 300mm

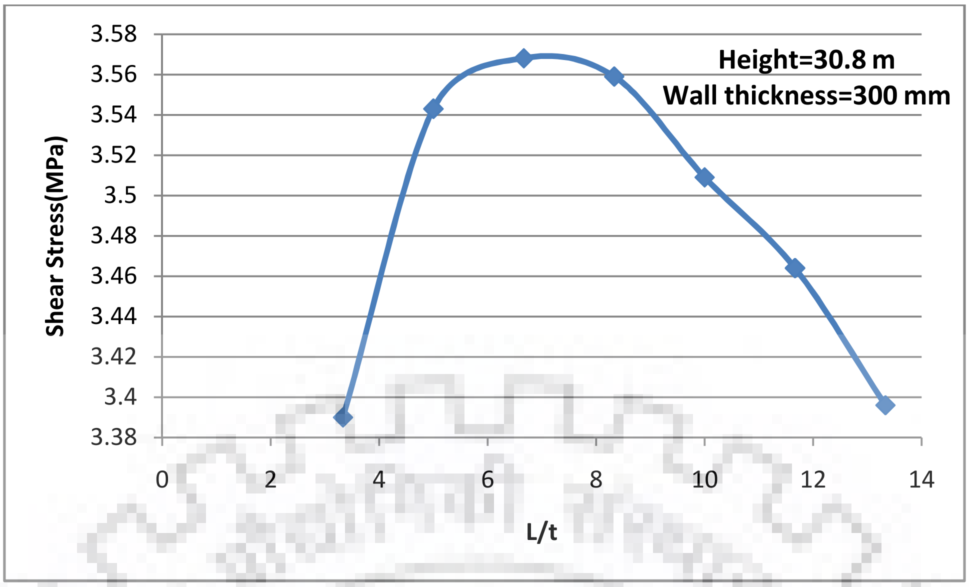

Figure 5.2 Shear stress vs L/t graph for building with height 30.8 m and wall thickness 300mm

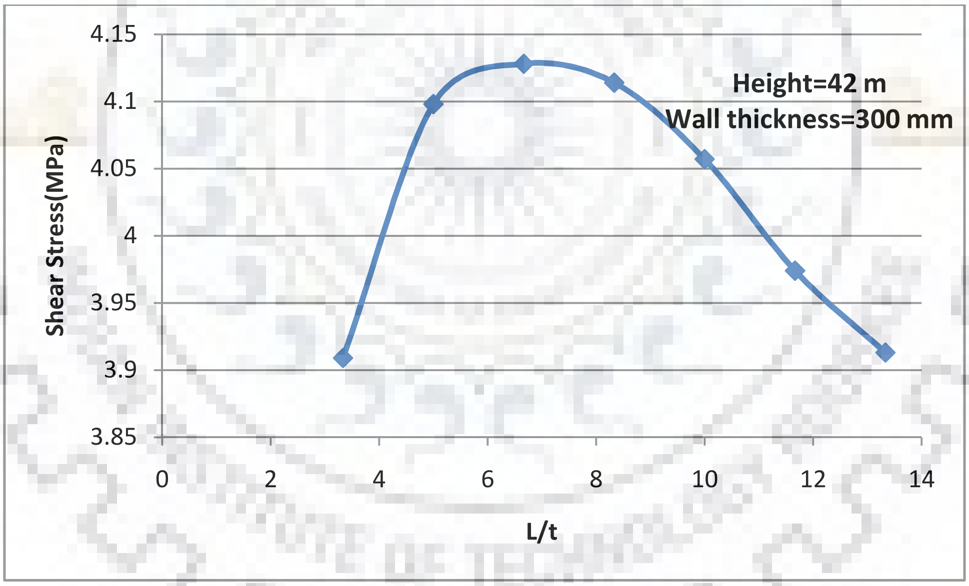

Figure 5.3 Shear stress vs L/t graph for building with height 19.6 m and wall thickness 300mm

Plotting above three graphs on one single graph for comparison we obtain following plot.

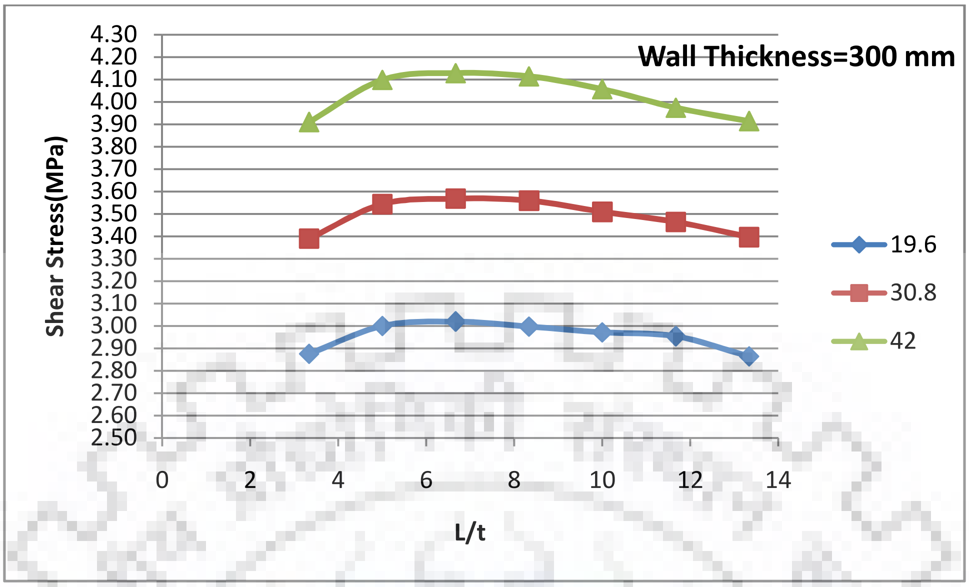

Figure 5.4 Graph showing variation of maximum shear stress with L/t ratio for different height of building for wall thickness 300mm

From Figure 5.4 it is clear that for all heights value of shear is maximum for L/t = 6.67 for wall thickness of 300 mm.

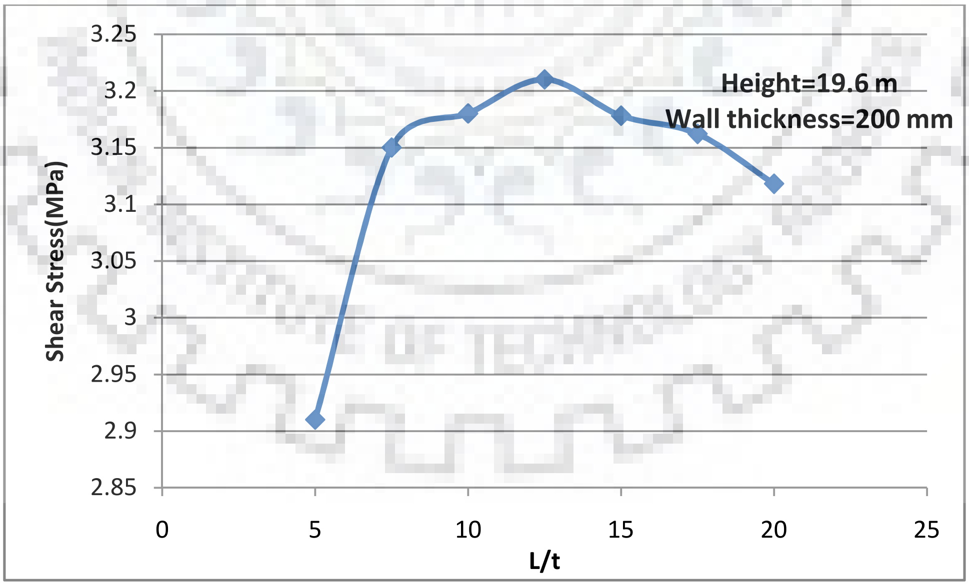

Figure 5.5 Shear stress vs L/t graph for building with height 19.6 m and wall thickness of 200mm

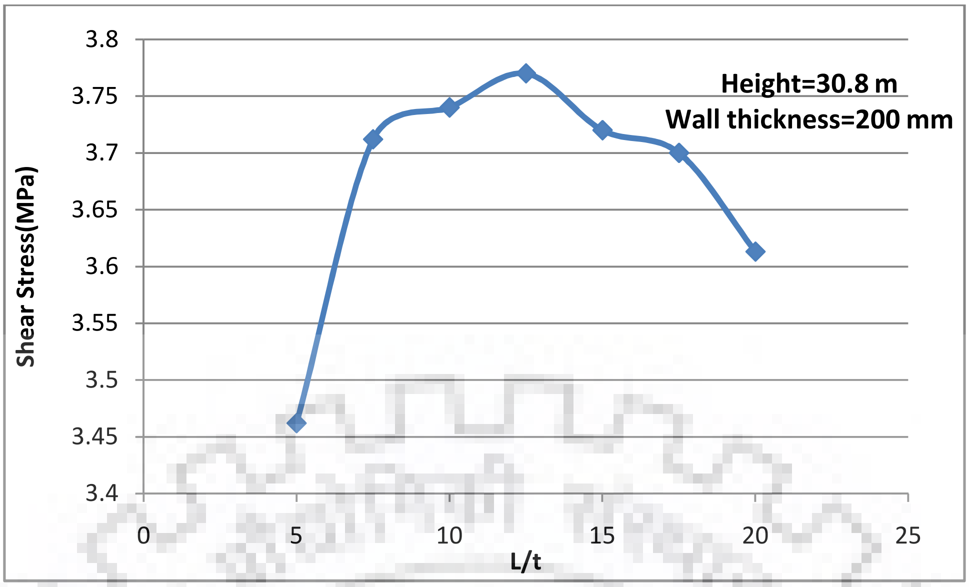

Figure 5.6 Shear stress vs L/t graph for building with height 30.8 m and wall thickness 200 mm

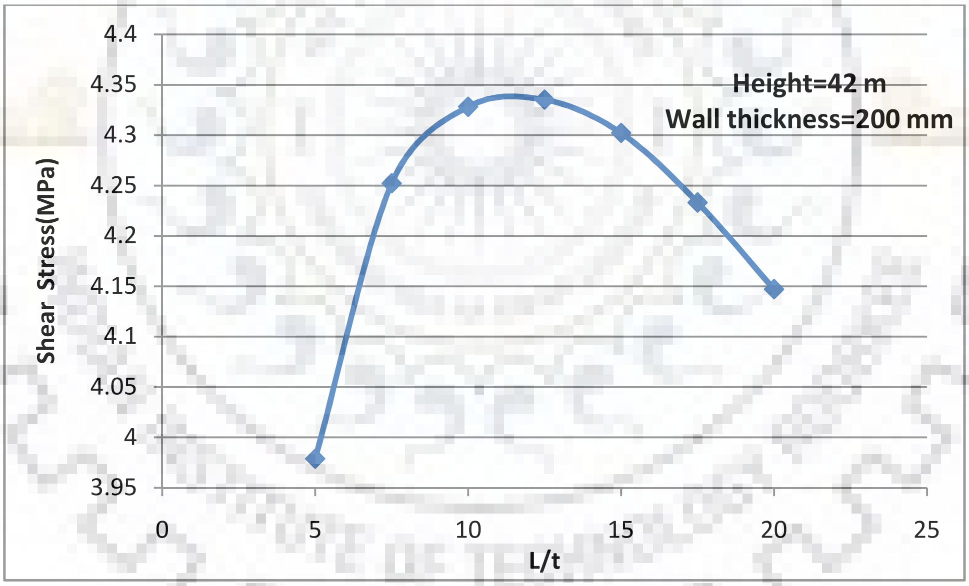

Figure 5.7 Shear stress vs L/t graph for building with height 42 m and wall thickness 200 mm

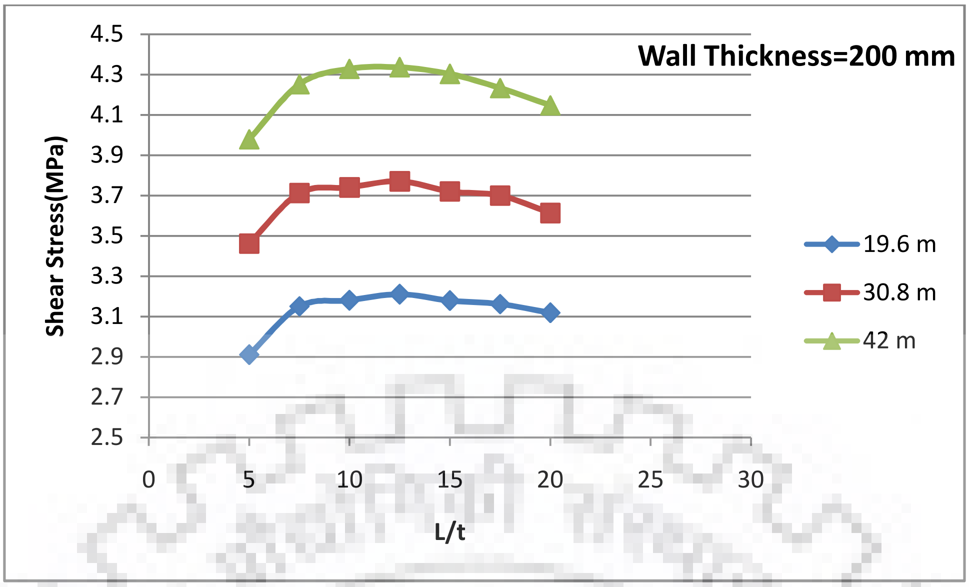

Figure 5.8 Graph showing variation of maximum shear stress with L/t ratio for different height of building for wall thickness 200mm

From Figure 5.8 it is clear that for all heights value of shear is maximum for L/t = 12.5 for wall thickness of 200 mm.

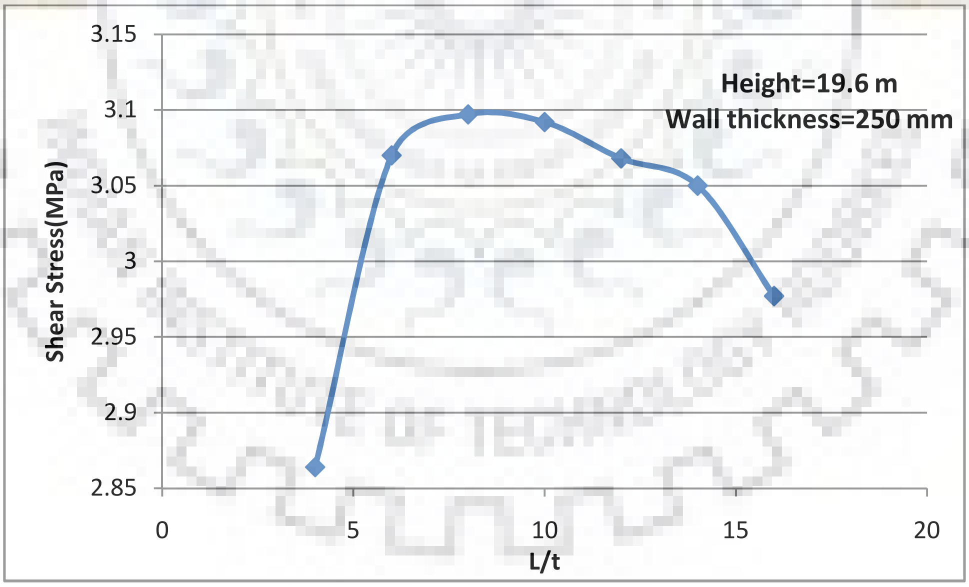

Figure 5.9 Shear stress vs L/t graph for building with height 19.6 m and wall thickness 250 mm

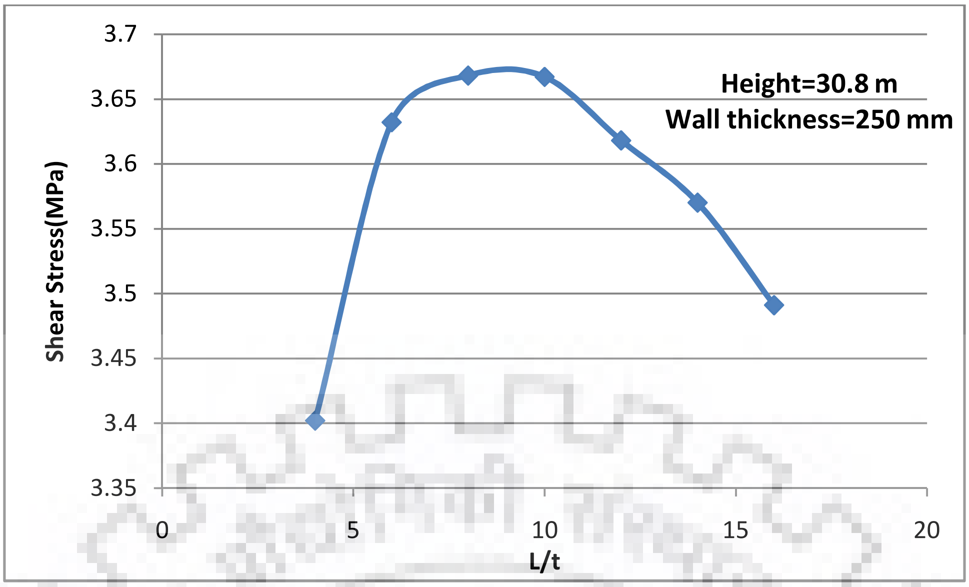

Figure 5.10 Shear stress vs L/t graph for building with height 30.8 m and wall thickness 250 mm

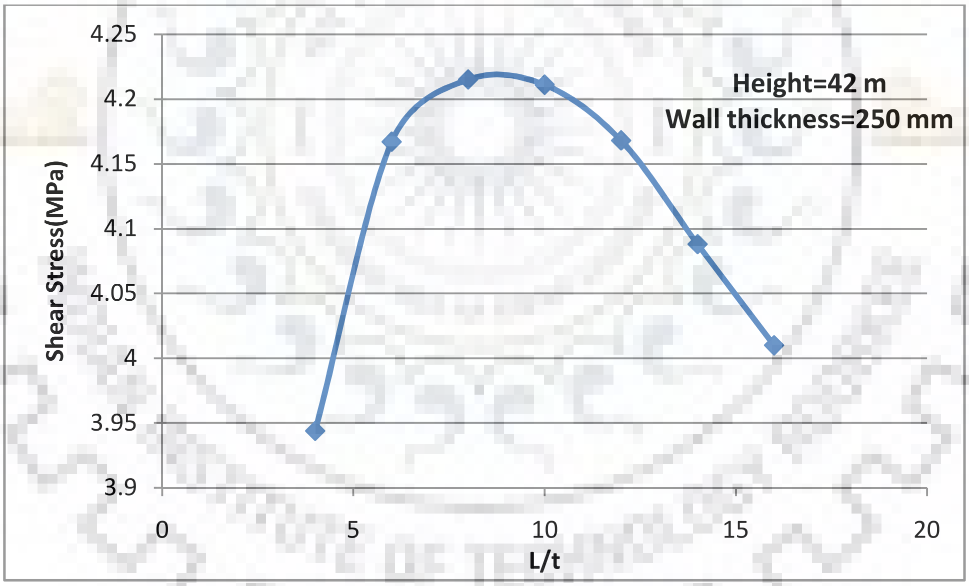

Figure 5.11 Shear stress vs L/t graph for building with height 42 m and wall thickness 250 mm

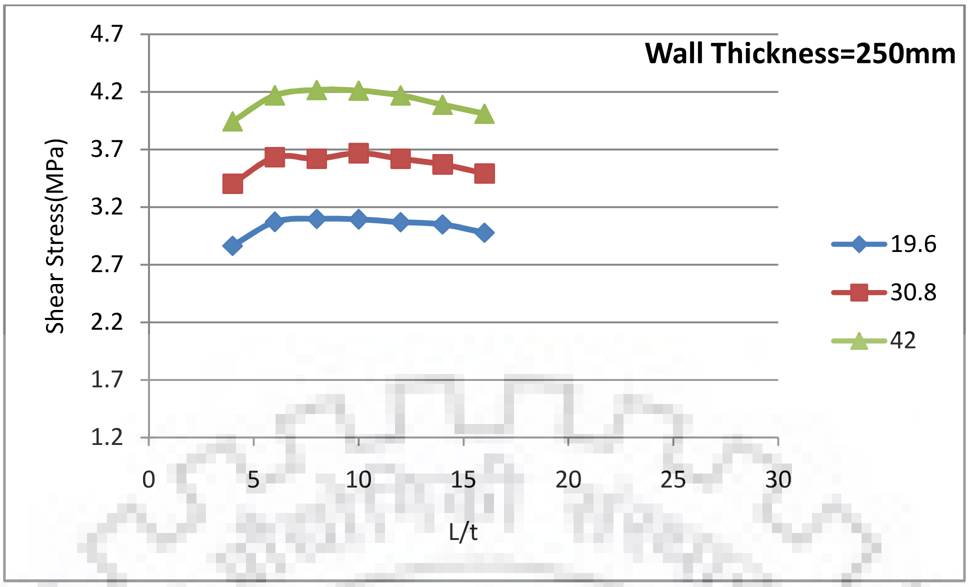

Figure 5.12 Graph showing variation of maximum shear stress with L/t ratio for different height of building for wall thickness 250mm

From Figure 5.12 it is clear that for all heights value of shear is maximum for L/t = 10 for wall thickness of 250 mm.

Above observation shows L/t at which shear stress is maximum is function of thickness also and its variation with thickness is shown below.

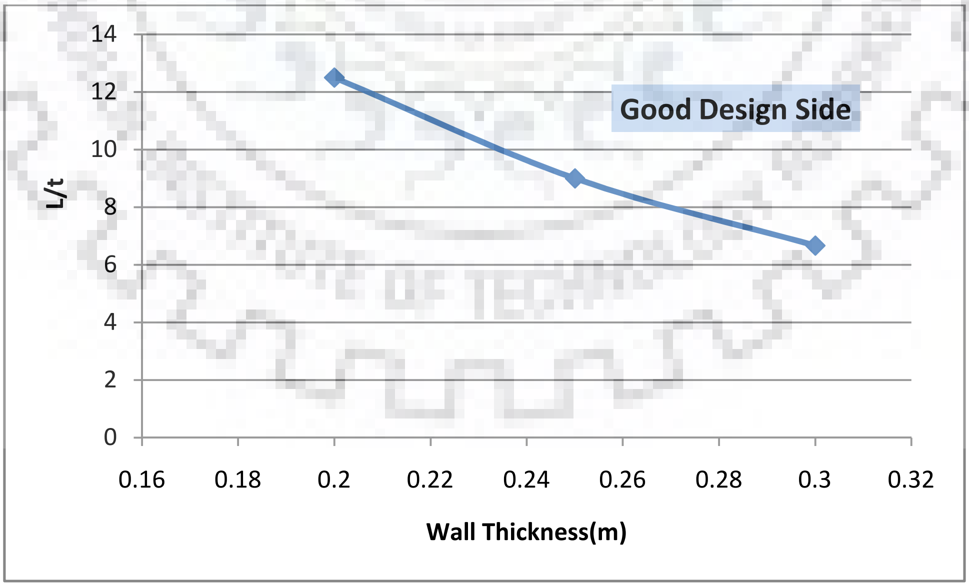

Figure 5.13 L/t vs wall thickness graph for Plan-1

Area to right of curve can be considered as good design side because shear stress on this side is below peak value. One can argue that values on left side of curve also lies below peak value but it was observed models lying on left side of curve attract less overall shear force than ones which lie on right side of curve. Models lying on left side of curve have comparatively smaller length so moment of inertia of these walls is less as compared to walls with more length. Less moment of inertia of walls means their force attracting capacity is comparatively less, so walls on left side of curve have low value of stress because less shear force acts on them. Purpose of shear wall is to attract as much force as it can, so models lying on left side of curve cannot be considered good for design.

Following graphs are corresponding to values for building having **plan-2.**

For this case value of length of wall taken is taken from 1m to 5m at interval of 1m each.

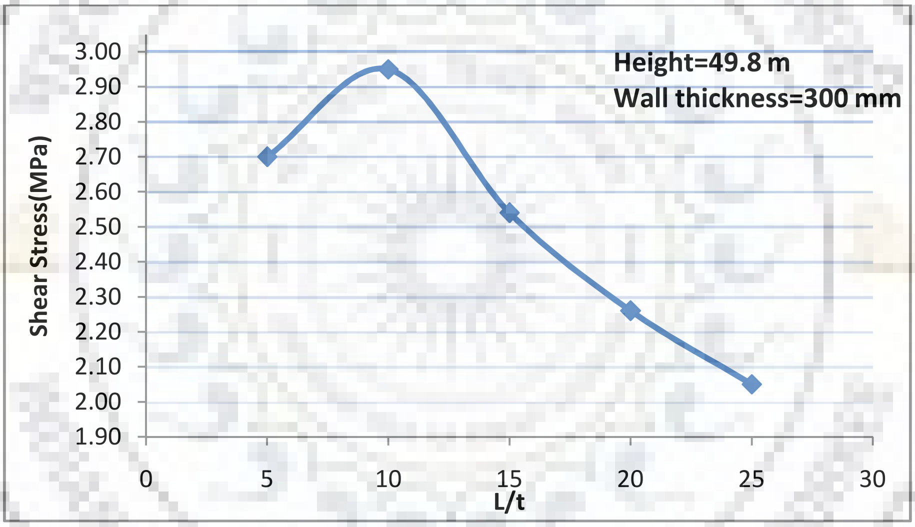

Figure 5.14 Shear stress vs L/t graph for building with height 49.8 and wall thickness 200 mm

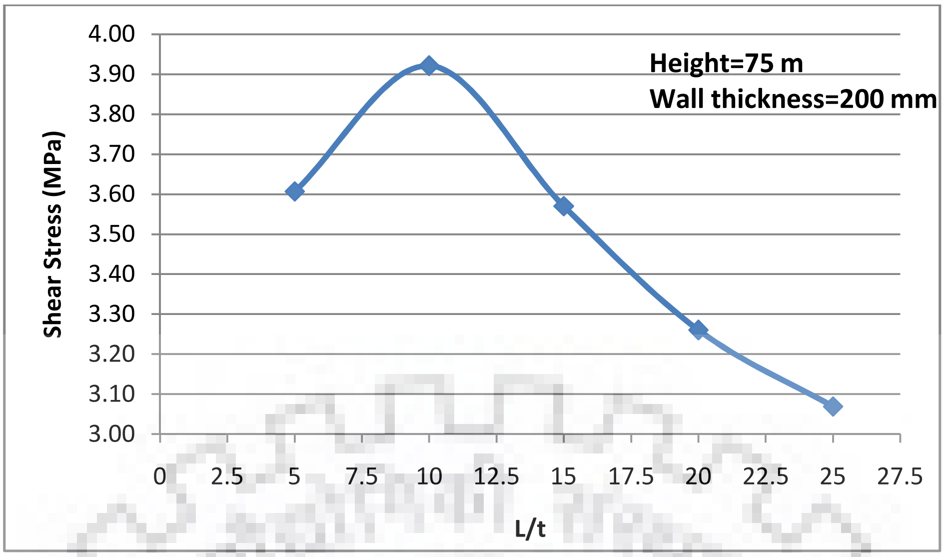

Figure 5.15 Shear stress vs L/t graph for building with height 75 m and wall thickness 200 mm

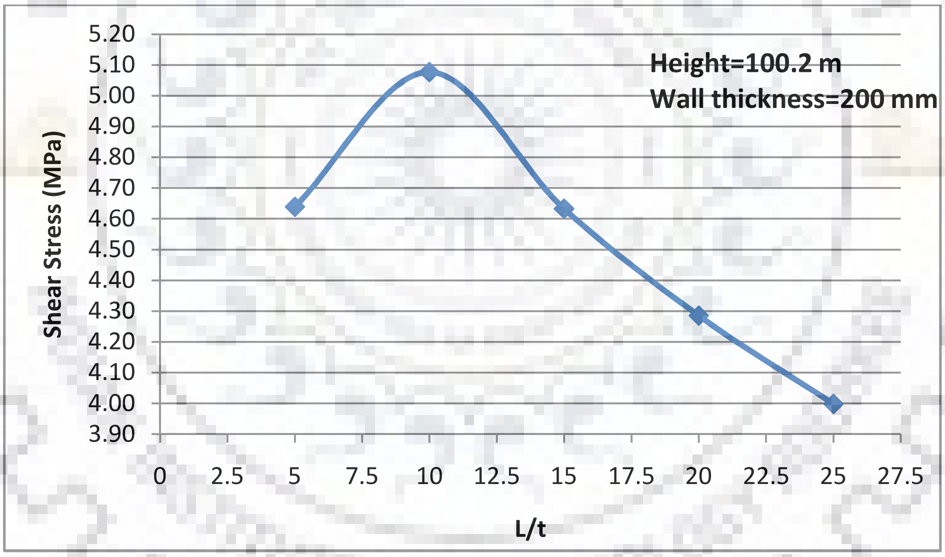

Figure 5.16 Shear stress vs L/t graph for building with height 100.2 m and wall thickness 200 mm

When graphs in Figure 5.14, Figure 5.15 and Figure 5.16 are plotted on same graph then we get following graph.

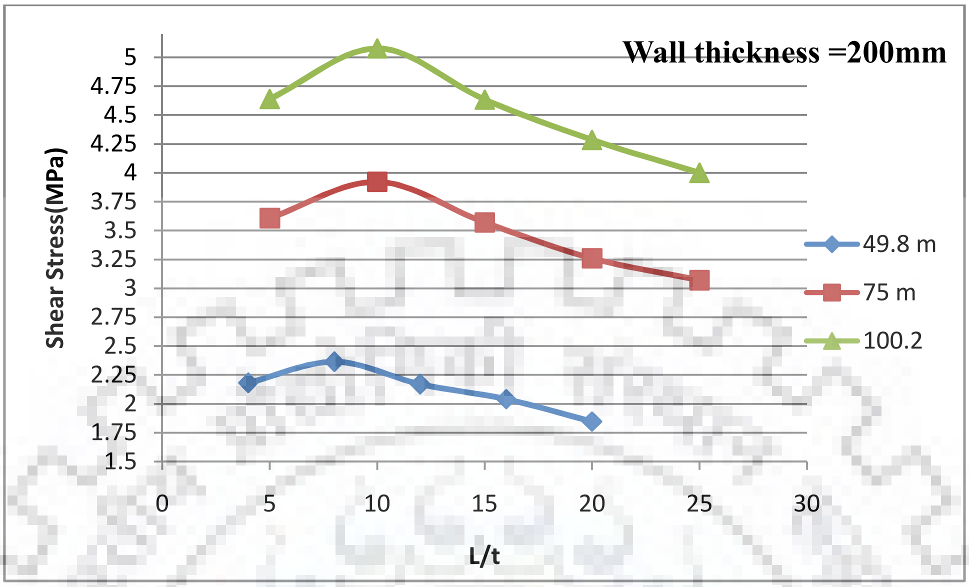

Figure 5.17 Graph showing variation of maximum shear stress with L/t ratio for different height of building for wall thickness 200mm

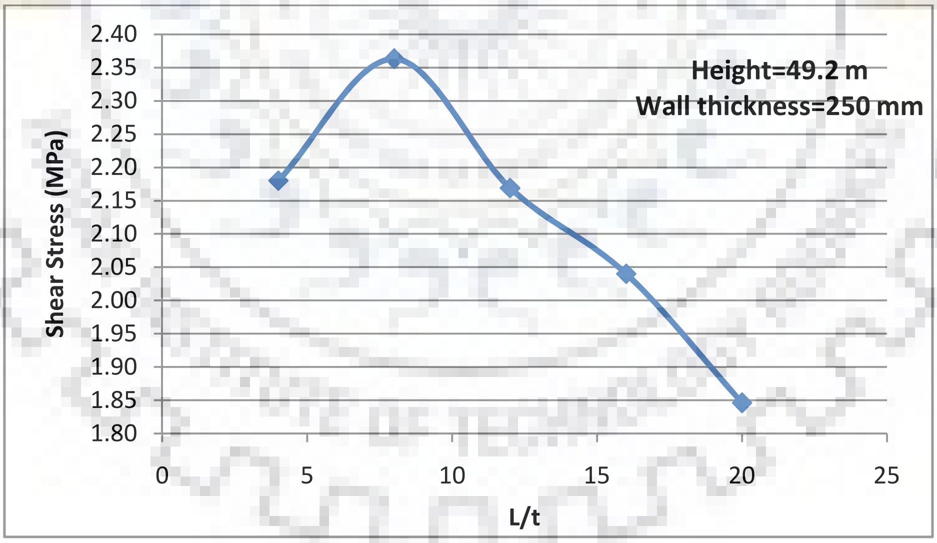

Figure 5.18 Shear stress vs L/t graph for building with height 49.8 m and wall thickness 250 mm

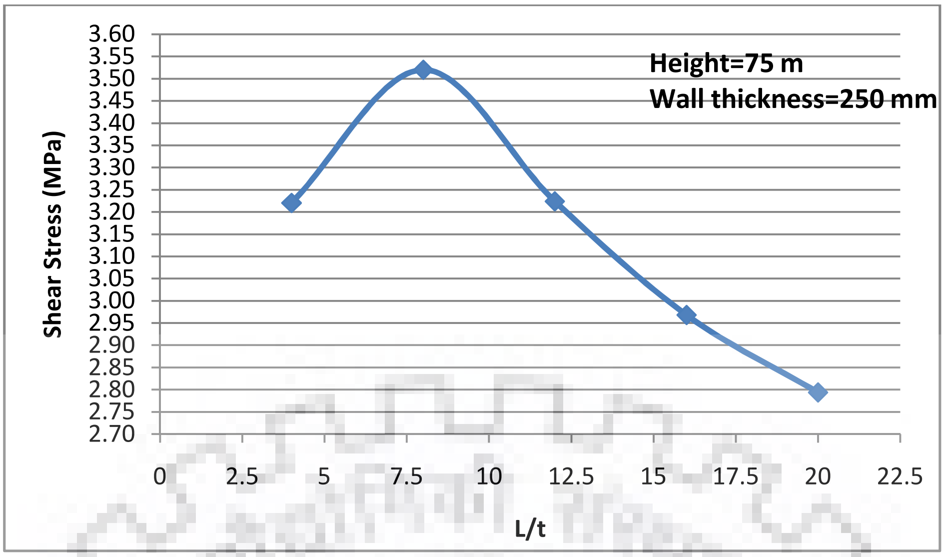

Figure 5.19 Shear stress vs L/t graph for building with height 75 m and wall thickness 250 mm

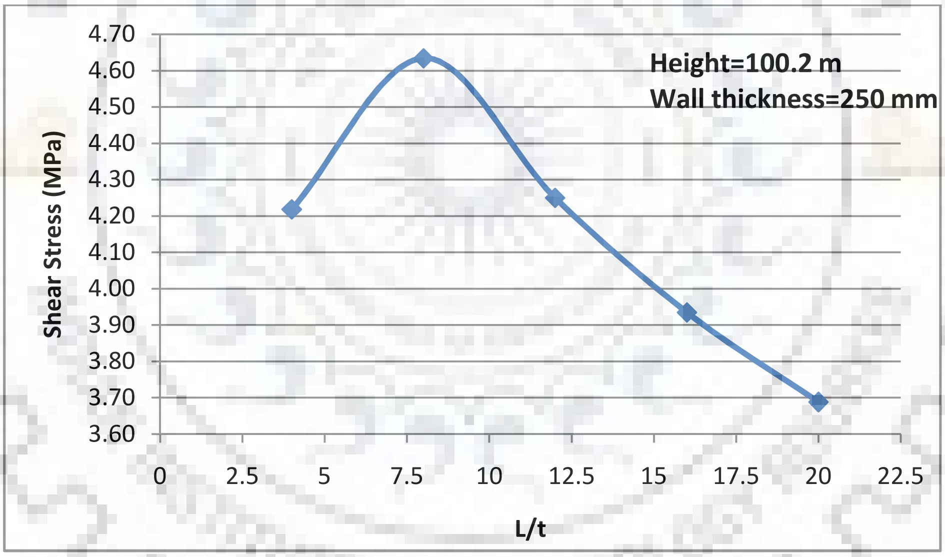

Figure 5.20 Shear stress vs L/t graph for building with height 100.2 m and wall thickness 250 mm

Combining Figure 5.18, Figure 5.19, Figure 5.20 we get following plot.

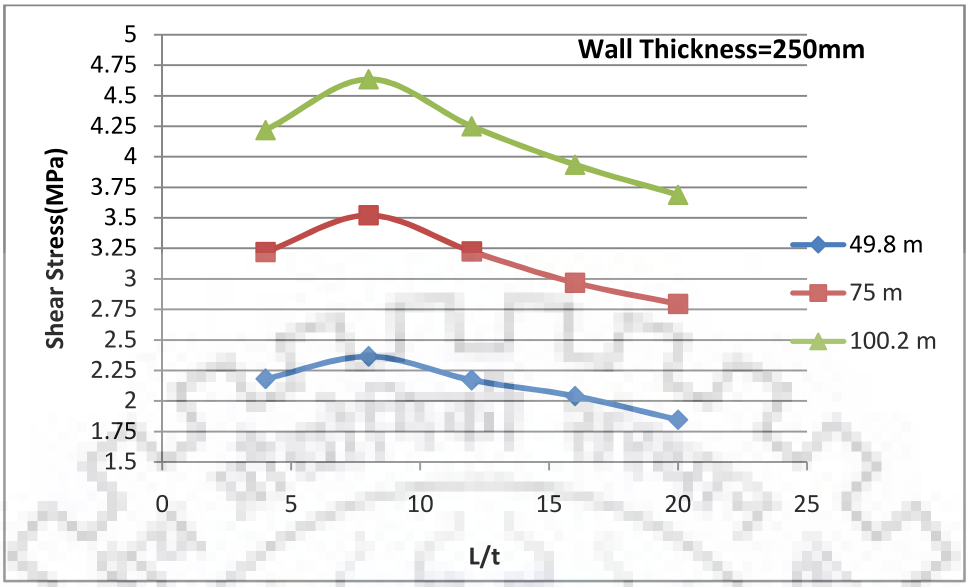

Figure 5.21 Graph showing variation of maximum shear stress with L/t ratio for different height of building for wall thickness 250mm

From Figure 5.21 it is clear that for all heights value of shear is maximum for L/t = 8 for wall thickness of 250 mm.

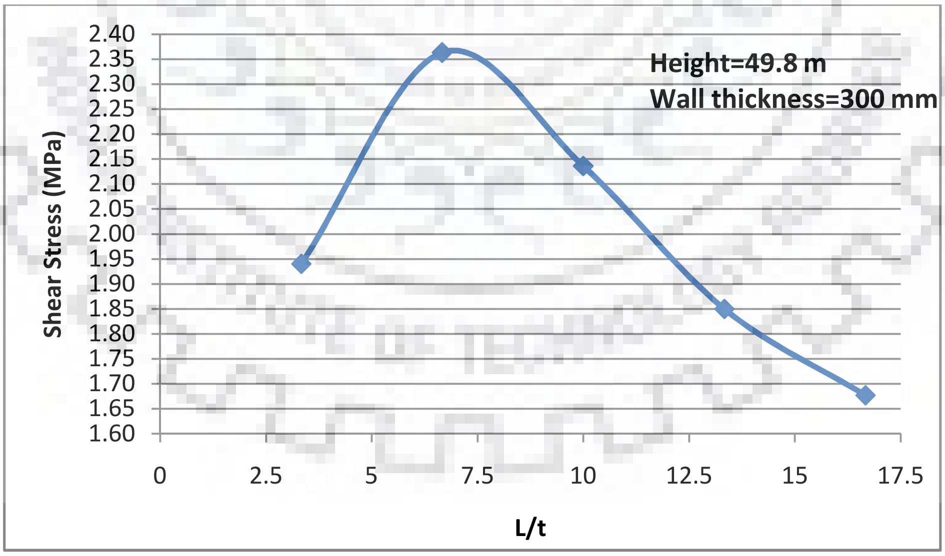

Figure 5.22 Shear stress vs L/t graph for building with height 49.8 and wall thickness 300 mm

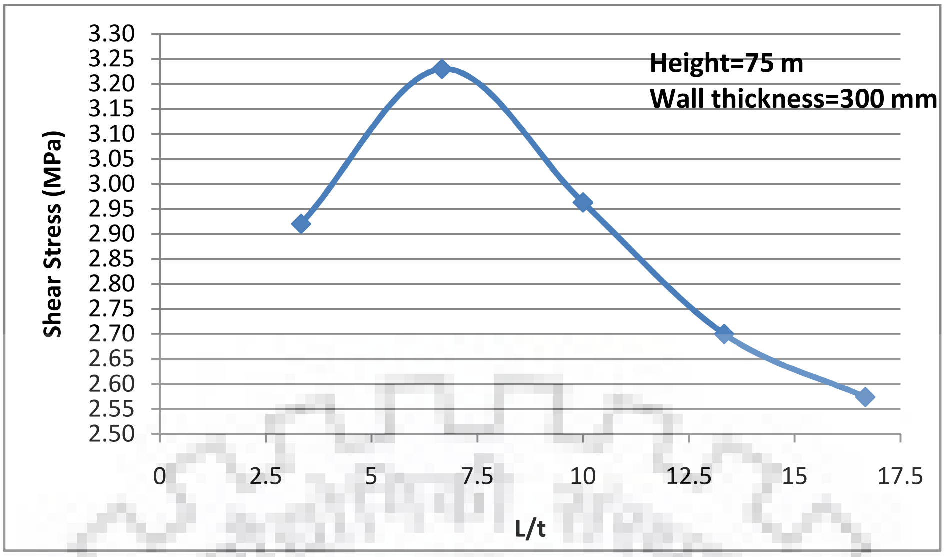

Figure 5.23 Shear stress vs L/t graph for building with height 75 m and wall thickness 300 mm

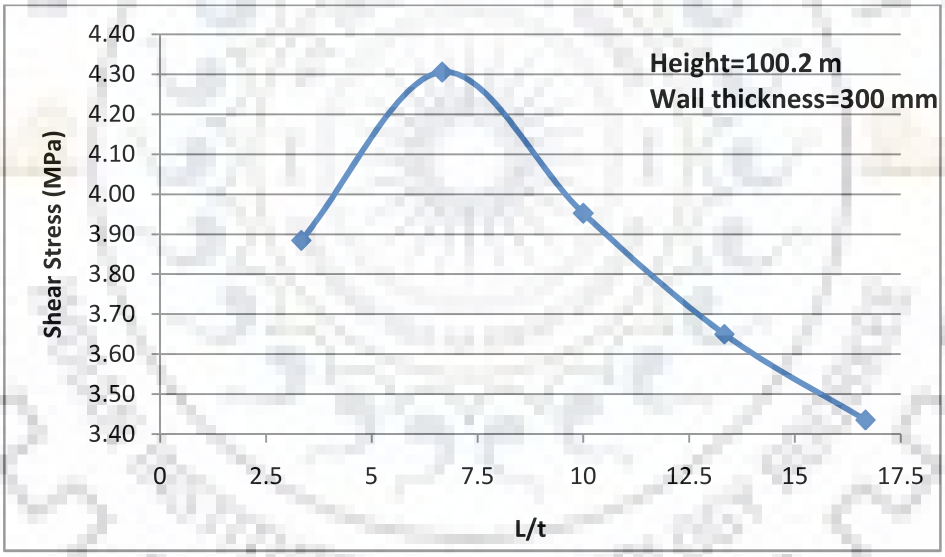

Figure 5.24 Shear stress vs L/t graph for building with height and wall thickness 300 mm

Combining Figure 5.22, Figure 5.23, Figure 5.24 we get following plot

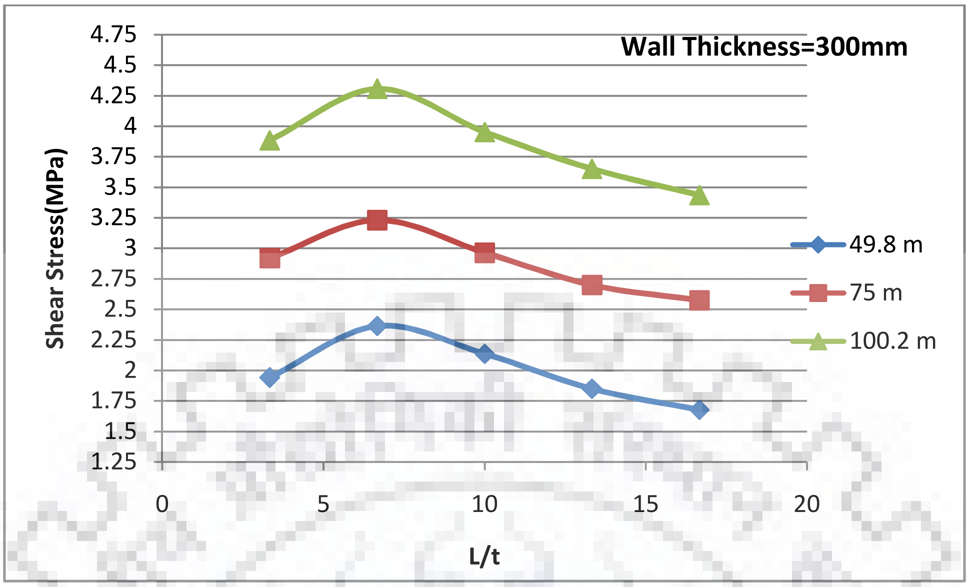

Figure 5.25 Graph showing variation of maximum shear stress with L/t ratio for different height of building for wall thickness 300mm

Above observations shows L/t at which shear stress is maximum is function of thickness also and its variation with thickness is shown below.

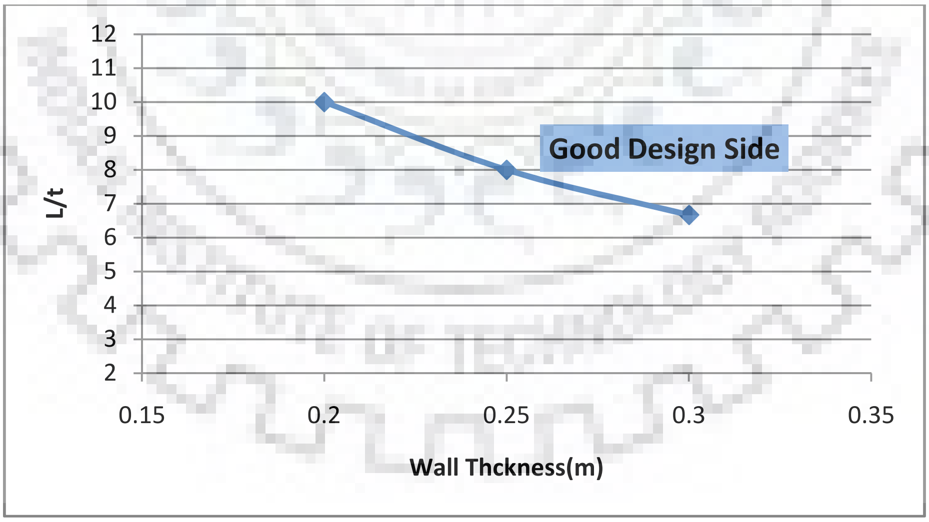

Figure 5.26 L/t vs wall thickness graph (for plan-2)

Area to right hand side is good design side based on similar kind of reasoning given for plan-1 results. Models on left side of curve will have less moment of inertia due to smaller dimensions, so they attract less force and which beats the purpose of shear wall.

Chapter 6 : CONCLUSIONS and FUTURE SCOPE

6.1 Conclusions

Two plans of building are considered one with L-shaped wall and other with C-shaped wall. For each building height, length and thickness of shear wall are changed to study effect of this change on maximum shear stress anywhere in the wall. Taking into account the variation of these three parameters, models were prepared and analysed. Building is analysed for earthquake loading as per IS 1893(Part-1):2016 with help of SAP2000.

Based on the foregoing numerical study following conclusions are drawn;

- During modelling of building it was found that the current code addresses issue of designing rectangular (planar) shear wall very efficiently but not much has been said about compound shear walls. Therefore, more studies need to be undertaken for design of compound shear walls.
- Based on study performed, it can be said that the variation of shear stress follows a particular pattern when seen against ratio of length of wall to thickness of wall. From graphs plotted it can be inferred that shear stress first increases and then starts decreasing after it reaches peak.
- It was seen for particular thickness of wall, L/t ratio at which shear stress value is at its peak remained same irrespective of height of building.
- L/t(at which shear stress is maximum) vs wall thickness graphs were then plotted for both the plans. It was found critical L/t ratio tend to decrease with increase in thickness of wall.
- Clause 10.1.3 of IS 13920: 2016 states that minimum ratio of length of wall to thickness of wall should be 4. Based on results obtained in the present study it can be said that the L/t ratio 4 given in the code above, does not lie on good design side in any of the cases studied and hence it may not hold truefor compound shear wall. So detailed exhaustive studies should be carried out for appropriate value of L/t ratio for compound shear wall.

6.2 Future Scope

- Although many models are prepared and analysed but still all possible configurations of building and shapes of shear wall are not studied.
- For more precise conclusion other configurations at various other heights can be studied.
- Placement of wall can be changed in each configuration and then its behaviour can be studied.
- To verify result of this study experimental study should be taken up in future.

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