

ANALYSIS OF SQUAT SHEAR WALL WITH DIFFERENT DIMENSIONS AND
POSITIONS OF OPENING UNDER DIFFERENT TYPE OF STATIC LOAD

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ABSTRACT

Shear walls are usually used in high-rise building or building on high frequency of wind area as the structural element to restrain lateral forces. Openings are created on the shear wall for the architecture, ventilation or mechanical and electrical purposes. With the existence of the opening, the strength of the wall is reduced by the reduction in concrete area and the discontinuity of the reinforcement due to opening which may lead to structural failure. The main objective is to study the effect of size and position of the opening towards the structural behavior of the shear wall under different type of static loads. The analysis is done using the software ANSYS12.0. The samples are SW1, SW2, SW3, SW4, SW5, SW6, SW7 and SW8 where SW1 is solid shear wall while SW2, SW3, SW4, SW5, SW6, SW7 and SW8 are shear walls with different size and position of opening. They are analyzed by using 2 different types of loads which are uniformly distributed axial load and uniformly lateral load. From the same magnitude of loads applied towards the shear walls, they are compared by the cracking pattern and the stress distribution. Under both axial and lateral loads, it shows a significance results that the shear wall with greater opening size shows less efficiency. The position of opening further from the support shows a more significance effect towards the strength of the wall from axial load but opposite from the lateral load. Besides, the closer the position of the shear wall to the load, the less efficient it is. As a conclusion from the results, the most suitable position of the opening on the shear wall is further from the support and the loads and it shows that there is a significance effect even from a smallest opening.

ABSTRAK

Dinding ricih biasanya digunakan di dalam bangunan tinggi atau bangunan pada frekuensi tinggi di kawasan angin sebagai elemen struktur untuk menahan daya sisi. Bukaannya yang dibuat pada dinding ricih bagi seni bina, pengudaraan atau tujuan mekanikal dan elektrik. Dengan adanya pembukaan, kekuatan dinding dikurangkan dengan pengurangan kawasan konkrit dan ketakselajaran tetulang akibat pembukaan yang boleh membawa kepada kegagalan struktur. Objektif utama adalah untuk mengkaji kesan saiz dan kedudukan pembukaan terhadap kelakuan struktur dinding ricih di bawah pelbagai jenis beban statik. Analisis ini dilakukan dengan menggunakan ANSYS12.0 perisian. Sampel adalah SW1, SW2, SW3, SW4, SW5, SW6, SW7 dan SW8 mana SW1 adalah dinding ricih pepejal manakala SW2, SW3, SW4, SW5, SW6, SW7 dan SW8 adalah dinding ricih dengan saiz dan kedudukan pembukaan berbeza. Mereka dianalisis dengan menggunakan 2 jenis beban yang teragih seragam beban paksi dan beban seragam sisi. Dari magnitud yang sama beban yang dikenakan terhadap dinding ricih, mereka berbanding dengan corak keretakan dan agihan tegasan. Di bawah kedua-dua beban paksi dan sisi, ia menunjukkan kepentingan yang menyebabkan dinding ricih dengan saiz bukaan yang lebih besar menunjukkan kecekapan kurang. Kedudukan pembukaan lanjut daripada sokongan menunjukkan kesan signifikan yang lebih kepada kekuatan dinding dari beban paksi tetapi bertentangan dari beban sisi. Selain itu, lebih dekat dengan kedudukan dinding ricih kepada beban, yang kurang berkesan ia. Sebagai kesimpulan dari hasil, kedudukan yang paling sesuai pembukaan pada dinding ricih yang lebih jauh daripada sokongan dan beban dan ia menunjukkan bahawa terdapat kesan yang signifikan walaupun dari pembukaan yang paling kecil.

TABLE OF CONTENTS

		Page
SUPERVISOR’S DECLARATION		ii
STUDENT’S DECLARATION		iii
ACKNOWLEDGEMENTS		v
ABSTRACT		vi
ABSTRAK		vii
TABLE OF CONTENTS		viii
LIST OF TABLES		xi
LIST OF FIGURES		xi
LIST OF SYMBOLS		xv
CHAPTER 1 INTRODUCTION		
1.1	General	1
1.2	Problem Statement	1
1.3	Objective of Study	2
1.4	Scope of Study	2
CHAPTER 2 LITERATURE REVIEW		
2.1	General	8
2.2	Squat Shear wall	8
2.3	Design of Shear wall	9
2.4	Effect of Opening	9
2.5	Static Load	10
2.6	ANSYS Modeling	10
	2.6.1 Element	10
	2.6.2 Modeling	11
	2.6.3 Steel Reinforcement	12
	2.6.4 Meshing	13
	2.6.5 Non-Linear Analysis	13
2.7	Cracking	14

CHAPTER 3 RESEARCH METHODOLOGY

3.1	General	15
3.2	Flow chart of methodology	16
3.3	Preprocessor	17
	3.3.1 Element	17
	3.3.2 Material Properties	18
	3.3.3 Real Constant	18
	3.3.4 Cross-Section	19
	3.3.5 Modeling	20
	3.3.5.1 Nodes	20
	3.3.5.2 Volume	21
	3.3.5.3 Key Points	22
	3.3.5.4 Lines	23
	3.3.5.5 Area	23
	3.3.5.6 Elements	24
	3.3.5.7 Booleans	25
	3.3.6 Meshing	26
	3.3.7 Merge Items	27
3.4	Solutions	28
	3.4.1 Boundaries Conditions and Loads	28
	3.4.1.1 Displacement	28
	3.4.1.2 Pressure	29
	3.4.2 Solution and Controls	30
	3.4.3 Nonlinear Diagnostics	32
3.5	Post-Processor	33
	3.5.1 Deformed Shape	33
	3.5.2 Contour Plot	33
	3.5.2.1 Displacement for vector sum	34
	3.5.2.2 X/Y-Component of Stress	34
	3.5.3 Crack/Crush	35

CHAPTER 4 RESULTS AND DISCUSSIONS

4.1	General	36
4.2	Displacement of vector sum	36
	4.2.1 Displacement for different size of opening	37
	4.2.2 Displacement for different position of opening	38
4.3	Cracking Pattern	48
	4.3.1 Cracking pattern for different position of opening	48
	4.3.2 Cracking pattern for different position of opening	49

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1	General	58
5.2	Conclusion	58
5.3	Recommendation	59
REFERENCES		60

LIST OF TABLES

Table No.	Title	Pages
1.1	Material properties of concrete	3
1.2	Material properties of steel	3
1.3	Detail dimension of shear wall models	3
4.1	Maximum nodal displacement with different size of opening	38
4.2	Maximum nodal displacement with different position of opening	39

LIST OF FIGURES

Figure No.	Title	Pages
1.1	Dimension of shear wall	4
1.2	Model of shear walls	4
1.3	Main reinforcement arrangement	6
1.4	Opening reinforcement	7
1.5	Different types of static load	7
2.1	SOLID65 3-D reinforced concrete solid	11
2.2	LINK8 3-D Spar	11
2.3	Models for reinforcement	12
3.1	Flow chart of methodology	16
3.2	Element	17
3.3	Material properties	18
3.4	Real Constant	19
3.5	Beam tool	20
3.6	Nodes for SW2	21
3.7	Block by dimensions	21
3.8	Volume of SW1	22
3.9	Key point for SW2	22
3.10	Lines of SW2	23
3.11	Area of SW2	24
3.12	Element of SW2	24
3.13	Volume of SW2 after subtract	25
3.14	Volume of SW2 after divide	26

3.15	Global Element size	26
3.16	Type of Mesh	27
3.17	Volume of SW2 after meshing	27
3.18	Merge coincident	28
3.19	Displacement fixed	29
3.20	Pressure	30
3.21	Basic tab of solution control	31
3.22	Nonlinear tab of Solution control	31
3.23	Nonlinear convergence criteria	32
3.24	Nonlinear Diagnostics	32
3.25	Deformed shape	33
3.26	Contour nodal solution data	34
3.27	Contour element solution data	35
3.28	Cracking and crushing locations in concrete elements	35
4.1	Displacement of vector sum of SW1 under axial load	40
4.2	Displacement of vector sum of SW1 under lateral load	40
4.3	Displacement of vector sum of SW2 under axial load	41
4.4	Displacement of vector sum of SW2 under lateral load	41
4.5	Displacement of vector sum of SW3 under axial load	42
4.6	Displacement of vector sum of SW3 under lateral load	42
4.7	Displacement of vector sum of SW4 under axial load	43
4.8	Displacement of vector sum of SW4 under lateral load	43
4.9	Displacement of vector sum of SW5 under axial load	44
4.10	Displacement of vector sum of SW5 under lateral load	44

4.11	Displacement of vector sum of SW6 under axial load	45
4.12	Displacement of vector sum of SW6 under lateral load	45
4.13	Displacement of vector sum of SW7 under axial load	46
4.14	Displacement of vector sum of SW7 under lateral load	46
4.15	Displacement of vector sum of SW8 under axial load	47
4.16	Displacement of vector sum of SW8 under lateral load	47
4.17	Cracking Pattern of SW1 under axial load	50
4.18	Cracking Pattern of SW1 under lateral load	50
4.19	Cracking Pattern of SW2 under axial load	51
4.20	Cracking Pattern of SW2 under lateral load	51
4.21	Cracking Pattern of SW3 under axial load	52
4.22	Cracking Pattern of SW3 under lateral load	52
4.23	Cracking Pattern of SW4 under axial load	53
4.24	Cracking Pattern of SW4 under lateral load	53
4.25	Cracking Pattern of SW5 under axial load	54
4.26	Cracking Pattern of SW5 under lateral load	54
4.27	Cracking Pattern of SW6 under axial load	55
4.28	Cracking Pattern of SW6 under lateral load	55
4.29	Cracking Pattern of SW7 under axial load	56
4.30	Cracking Pattern of SW7 under lateral load	56
4.31	Cracking Pattern of SW8 under axial load	57
4.32	Cracking Pattern of SW8 under lateral load	57

LIST OF SYMBOLS

%	Percentage
mm	Millimeter
m	Meter
kPa	Kilo Pascal
MPa	Mega Pascal
GPa	Giga Pascal
N	Newton

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Shear wall is a vertical structural element that provides strength to restrain the building from axial load and lateral force such as wind, earthquakes or blast. Shear walls are more preferable in high rise building such as apartment, condominium, office tower or wall of lift and so on. The best position of shear wall were structurally is in the center of each half of the building. However, it is rarely practical. Therefore, the shear walls were usually positioned at the ends Shear walls are usually perforated for architectural purpose like windows. However, the openings of the shear wall has create disturbance against the stress distribution.

Therefore, the shear wall is analyzed by using the finite element analysis with non-linear static analysis to study the changes of the behavior of the shear wall such as stress distribution, cracking position and so on. The finite element analysis is conducted by using ANSYS 12.0 software. With the aids of the software, the structure can be design in a virtual experiment and the materials can be tested. The engineers can analyze the safety, strength, comfort and therefore the result is cost-effective.

1.2 PROBLEM STATEMENT

Squat shear wall is used as structural element to restrain axial load and lateral loads. Unlike slender shear wall, squat shear wall usually failed by shear before by drift effect from lateral forces. These failures are not preferable as it always occurs after elastic

deformation and may fail the whole building structure. The stress distribution of shear wall is same as a column when resisting axial load and beam when resisting lateral load. However, with the presence of opening on the shear wall, it has caused disturbance towards the stress distribution. Therefore, the size and positioning of the shear wall shall be considered and analyzed during design phases.

1.3 OBJECTIVE OF STUDY

The main objectives are to study:

- i. The effect of different opening size of shear wall to stress distribution and crack pattern under different types of static load.
- ii. The effect of different location of opening on the shear wall to stress distribution and crack pattern under different types of static load.

1.4 SCOPE OF STUDY

In this study, the dimensions of all shear walls model are 3.1m width x 3.1m height x 0.300m thick. The concrete and steel reinforcement properties are referred to previous study done by (Musmar 2013). The concrete material properties are listed in the Table 1.1. Smeared steel reinforcement is used and the properties are listed in Table 1.2. The steel plate is used when applying the several types of forces. The Elastic modulus and Poisson's ratio of the steel plate is same as the steel reinforcement (Kachlakev et al, 2001; Wolanski, 2004). The element selected in this study is SOLID65 for concrete while LINK8 for reinforcement steel. The real constants are set and the cross section of the concrete and steel are to be defined.

All the models are labeled with SW-n where n is the number of sample. The SW1 is the solid shear wall while the other 7 are the shear wall with opening. SW2, SW5, SW6, SW7 and SW8 have the same size of opening but different on different location of the shear wall. SW2, SW5 and SW6 are increased by 0.3 m in both width and height ascendingly. The Table 1.3 has shown the detail dimensions of the shear walls model while the Figure 1.1 shows the model of the shear wall with the dimension. Positive value of

horizontal distance represent that the direction is to the right and vice versa. Positive value of vertical distance represent the direction is to the up and vice versa. All the models with different type of opening are also shown in Figure 1.2.

Table 1.1: Material properties of concrete

Material Model	Linear Elastic
Modulus of Elasticity, E_s	25743MPa
Poisson's Ratio	0.3
Open Shear transfer Coefficient, β_t	0.2
Closed Shear transfer Coefficient, β_c	0.9
Uniaxial Cracking Stress	3.78 MPa
Uniaxial Crushing Stress f_c	30 MPa

Table 1.2: Material properties of steel

Material model prior to initial yield surface	Linear elastic
Elastic Modulus, E_s	200 GPa
Poisson's Ratio	0.3
Yield's Stress, f_y	412 MPa
Material model beyond initial yield surface and up to failure	Perfect plastic

Source: Musmar (2013)

Table 1.3: Detail dimension of shear walls model

Sample	Opening height, h (m)	Opening width, b (m)	Horizontal distance from the right, x (m)	Vertical distance from the top, y (m)
SW1	-	-	-	-
SW2	0.9	0.9	0	0
SW3	1.2	1.2	0	0
SW4	1.5	1.5	0	0
SW5	0.9	0.9	-0.5	0
SW6	0.9	0.9	0	0.5
SW7	0.9	0.9	0.5	0
SW8	0.9	0.9	0	-0.5

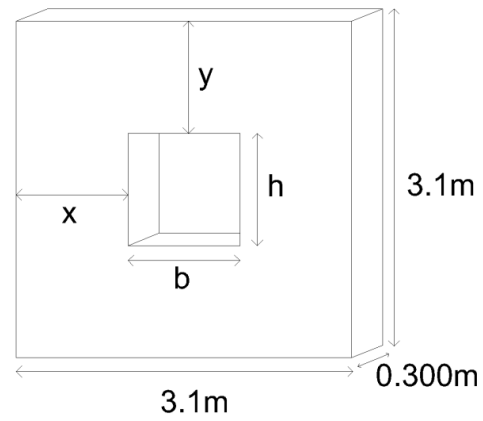


Figure 1.1: Dimension of shear wall

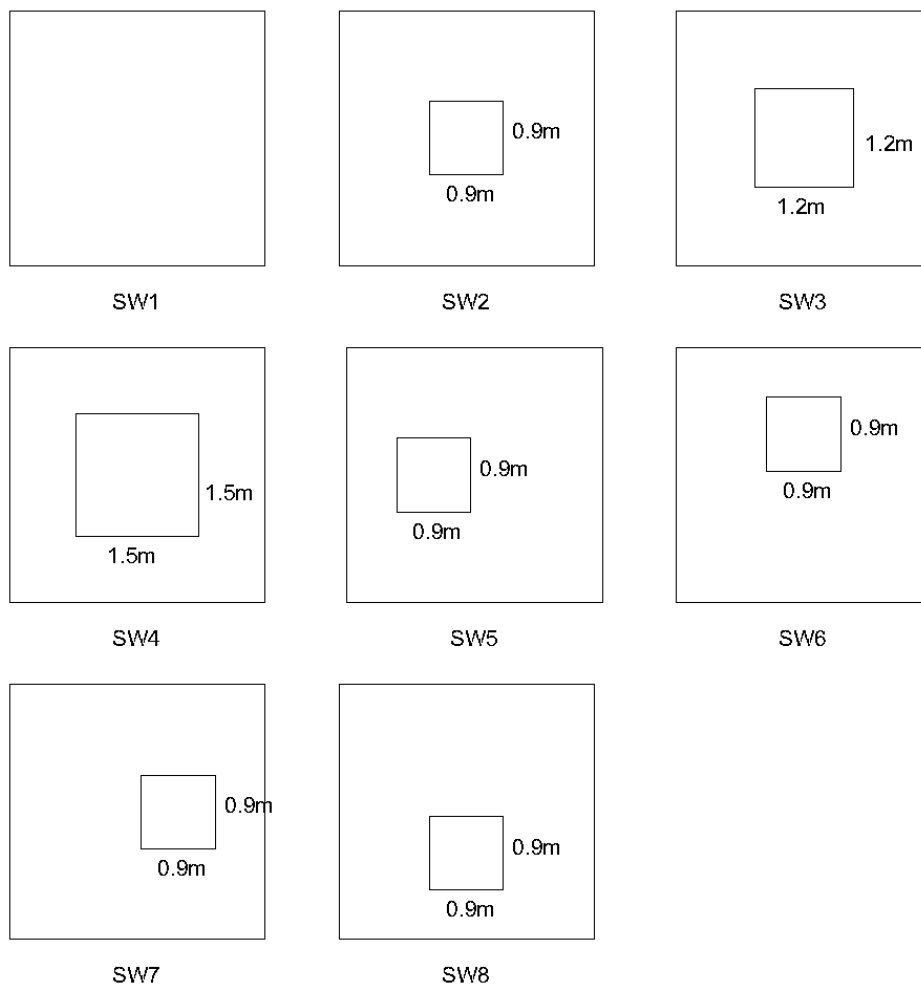


Figure 1.2: Model of Shear Wall

The diameter of the reinforcement steel bar in this study is 12mm for both vertical and horizontal. Both the spacing of the vertical and horizontal reinforcements is 200mm. The main reinforcement arrangement as well as the cross sections of the SW1 as the solid shear wall is shown in Figure 1.3.

The International Residential code specified that extra reinforcement shall be added to the side of opening if the width of the opening exceeds 2 feet which is 0.6m approximately. Since all the samples with opening in this study already exceed 2feet, therefore, extra reinforcement shall be added. The opening reinforcement arrangement is shown in below Figure 1.4. There is 1 reinforcement bar at each side of the opening while 1more extra at top with minimum of 1 inch above the top reinforcement to create lintel for resist the axial force towards the opening. In this case, the unit used in the model is in SI unit; therefore, the distance between the 2 top reinforcement is 0.1m. All the diameter and material properties of the side reinforcements are same as the vertical and horizontal of main reinforcement.

The analysis done in this study is 3-Dimensional finite element analysis. The solid shear wall SW1 was used as the reference for the other remaining models with openings. In this study, SOLID65 provided by ANSYS software is used as the element for concrete while LINK8 is used as the element for reinforcement steel. The material properties of the concrete and steel are referred to the previous study done by (Musmar 2013). The elastic and plastic deformations in concrete and reinforcement can be simulated.

The analysis is initiated by applying low loads and is stepwise increased to study the stress distribution. Different types of static loads include lateral and axial loads are applied on the model to obtain different results. The results are compared to study the changes. The different types of the static load are uniformly distributed axial load and uniformly distributed lateral load. The different types of loads are shown in the Figure 1.5. All the results of SW3 to SW8 are compared to SW1 and SW2 to identify the effect of the made by the changes of the parameter.

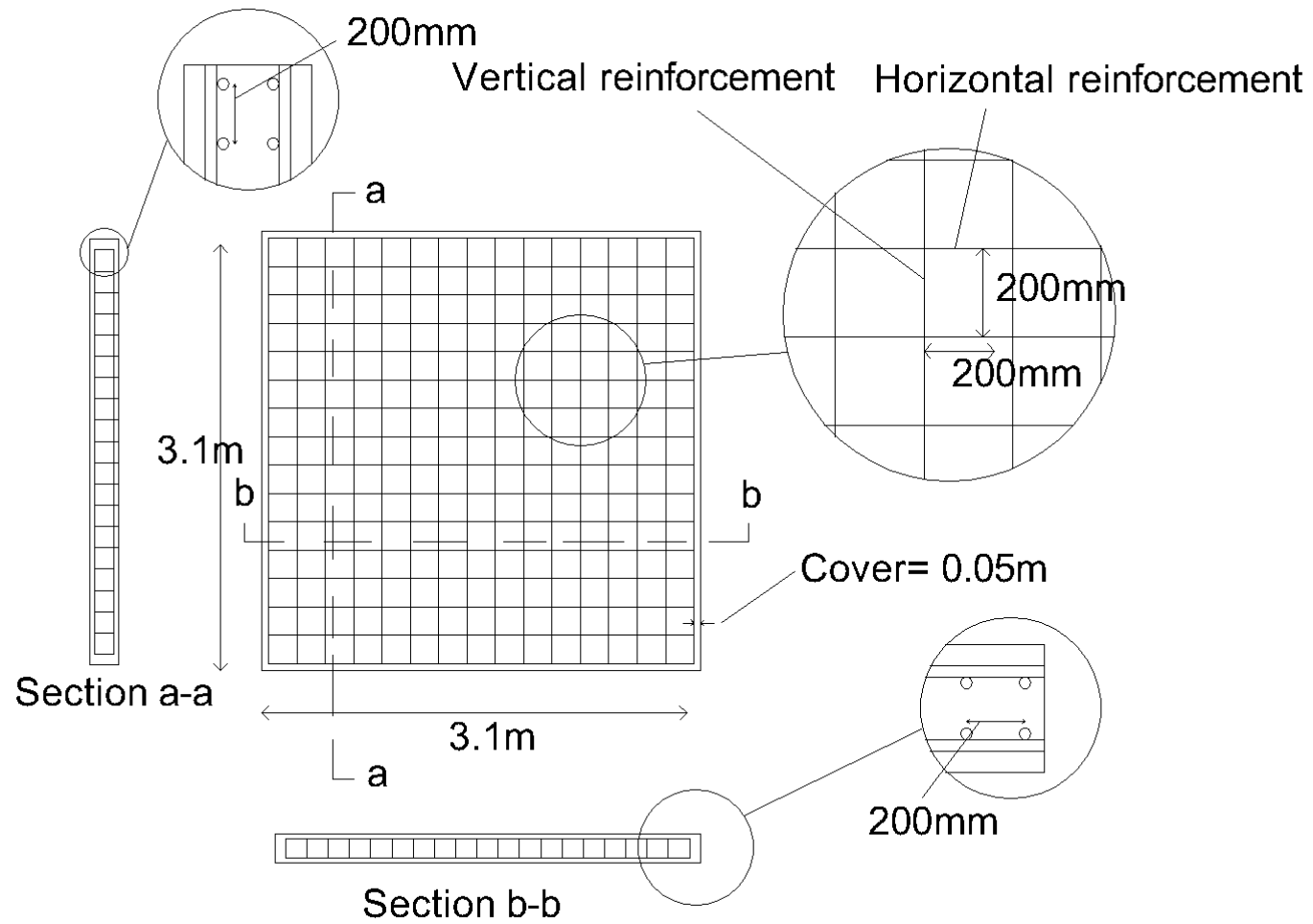


Figure 1.3: Main reinforcement arrangement

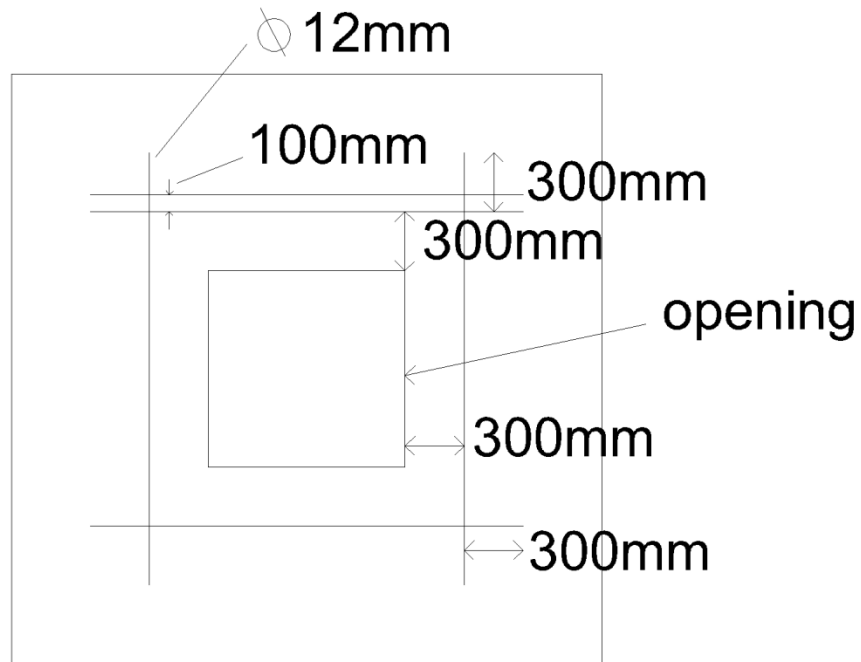


Figure 1.4: Opening Reinforcement

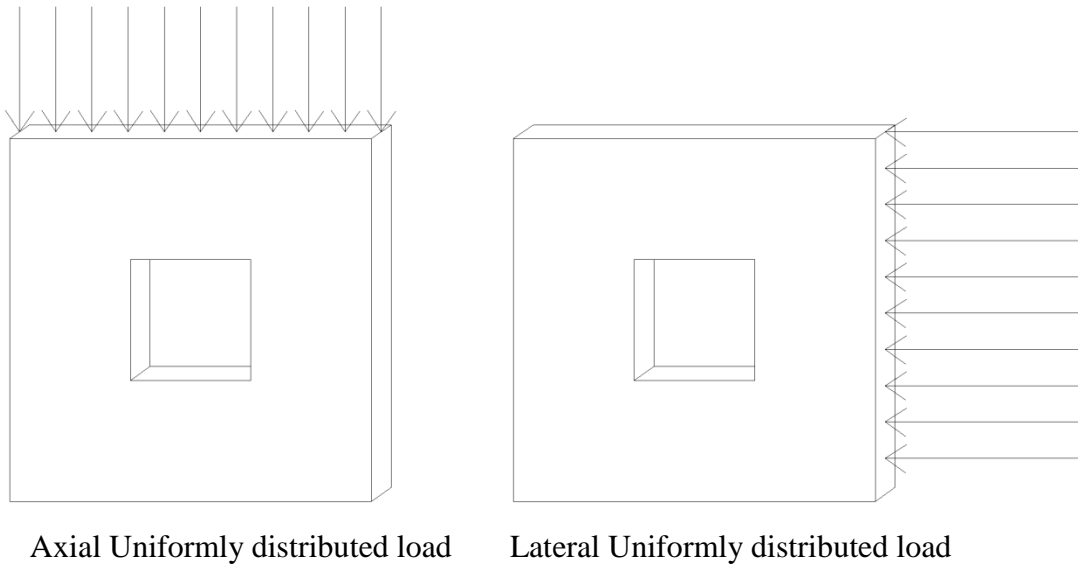


Figure 1.5: Different type of static loads

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Shear wall is the vertical component in a building which helps in resisting both axial force and lateral force. Lateral force is much more mainly resisted as the axial forces are already resisted by beam and column. The efficiency of shear wall is referred to the rigidity or stiffness. The solid shear wall appears to be the most efficient and therefore highly desirable. However, most of the shear walls are come with opening as the needs of architecture design such as windows and door.

2.2 SQUAT SHEAR WALL

The aspect ratio of the wall will determine the behavior of wall dominated by flexure or shear. Aspect ratio of less than 2 is known as squat walls which its behavior is dominate by shear. The shear walls used in this analysis are squat shear wall as its aspect ratio is 1. From a study conducted by Hidalgo et al. (2002), the deformation capacity gets smaller as the aspect ratio decrease and the strength deterioration of wall increased. Therefore, a squat shear wall is preferred in this study for more significance results.

2.3 DESIGN OF SHEAR WALL

Lefas et al. (2010) has done experimental work on 13 structural walls to investigate the cause of failure of shear wall. They found that strength and deformational response of the wall are independent of the uniaxial concrete strength characteristics within a range of 30 to 55 MPa. The reinforcement arrangement of this study is referred to the previous study done by Lefas et al (2010). Besides, the International residential code (R606.12.2.3.3) states that the horizontal joint reinforcement shall be provided at the bottom and top of wall openings and shall be extend not less than 24inches (610mm). The extra reinforcement steel above the top reinforcement is added to create a lintel to support axial force from the top of the opening. Diagonal reinforcement can be added to strengthen the element from cracking at the edges of opening.

2.4 EFFECT OF OPENING

The reinforcement around opening is highly affecting the ductility and shear strength of the shear wall with opening. The shear capacity contributed by the diagonal reinforcement reached 40% of its yield strength while the shear capacity contributed by the horizontal and vertical only reach 20% of its yield strength. This has shown that both the depth and width of the opening are affecting the shear capacity of the wall. (Lin & Kuo, 1988).The larger the size of the opening is, the greater is the stress flow disturbance within the shear wall while in case of small opening; the shear wall will behave as coupled shear wall (Musmar, 2013). From the research done by Vecchio and Chan (1990), they have tested several panels with and without extra reinforcement around the opening. The cracking, yielding of reinforcement can lead to a significant reduction in the overall strength and stiffness. With several tests, they concluded that added reinforcement around the opening can be effectively alleviating the detrimental effects caused by the opening.

2.5 STATIC LOAD

The static load is a mechanical force applied slowly to an assembly or object. The engineers usually use static load tests to determine the maximum force an engineering structure can support for safety purposes. Besides maximum allowable loads, the static loads also can help to discover the mechanical properties of materials.

2.6 ANSYS MODELING

The ANSYS finite element software is used in this research to model the reinforced concrete shear walls. There are several properties need to be set before start the modeling which is to define the elements, material properties and cross section of the model.

2.6.1 Element

The solid65 finite element is chosen in this as it is a dedicated three-dimensional eight node isoperimetric elements with three degree of freedom at each node, which is x, y and z directions (Musmar, 2013). The figure 2.1 is the geometry of SOLID65 element. The Figure 2.1 is obtained from Saberi et al. (2013). In ANSYS, SOLID65 is also known as 3-D Reinforced Concrete Solid which is capable in tension and crushing in compression. SOLID65 element is able to model the nonlinear response of concrete material based on a constitutive model for the tri-axial behavior of concrete which is capable of plastic deformation and cracking in three orthogonal directions at each integration point (Musmar, 2013). For reinforcement, LINK8 is chosen as the element in the ANSYS. The element is defined by two nodes, cross-sectional area, initial strain and the material properties. The geometry, node locations and the coordinate system for this element are shown in Figure 2.2. The element is oriented along the length of the element from node I to node J.

Figure 65.1 SOLID65 Geometry

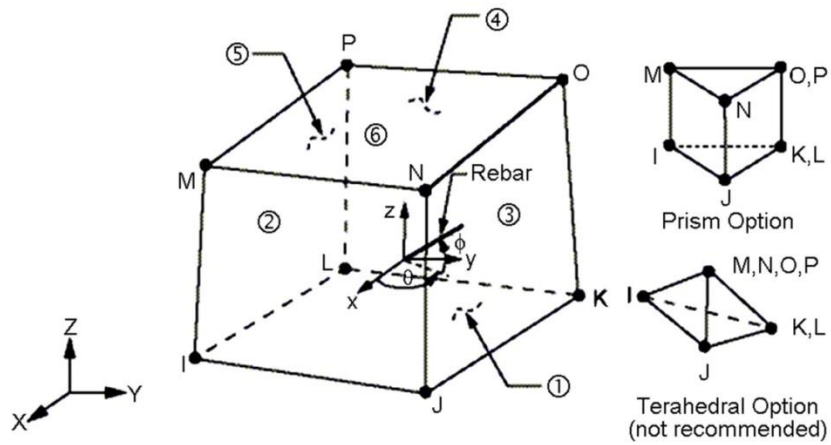


Figure 2.1: SOLID65 3-D Reinforced Concrete Solid

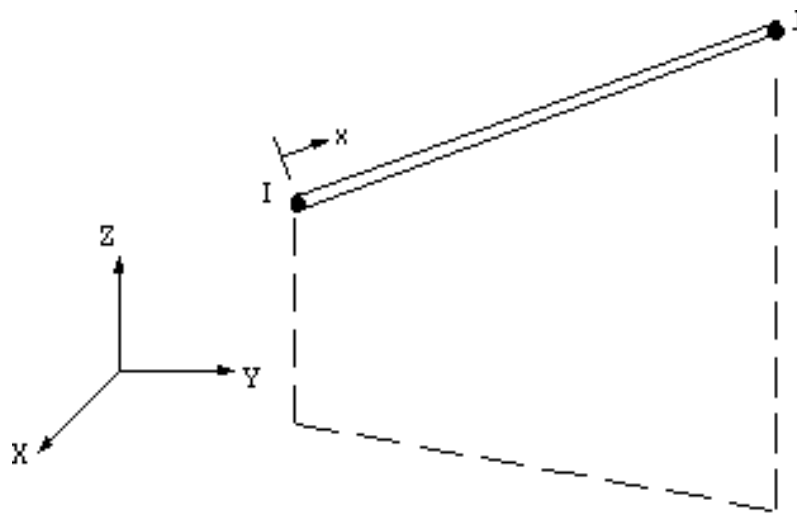


Figure 2.2: LINK8 3-D Spar

2.6.2 Modeling

The key points or nodes are some several of coordinate created to define the body of a structure. They are then connected by lines or element. The properties of element and material are chose before modeling. The real constant of the material can be selected. The size of

element can be selected by using meshing. The rectangular mesh is recommended for element SOLID65 to obtain good result (Raongjant and Jing 2008). The boundaries condition shall be specified by giving the location and information of the boundaries.

2.6.3 Steel reinforcement

There are three techniques that exist to model steel reinforcement in finite element models for reinforced concrete. Figure 2.3 shows the three models which are discrete, embedded and smeared model (Tavarez 2001).

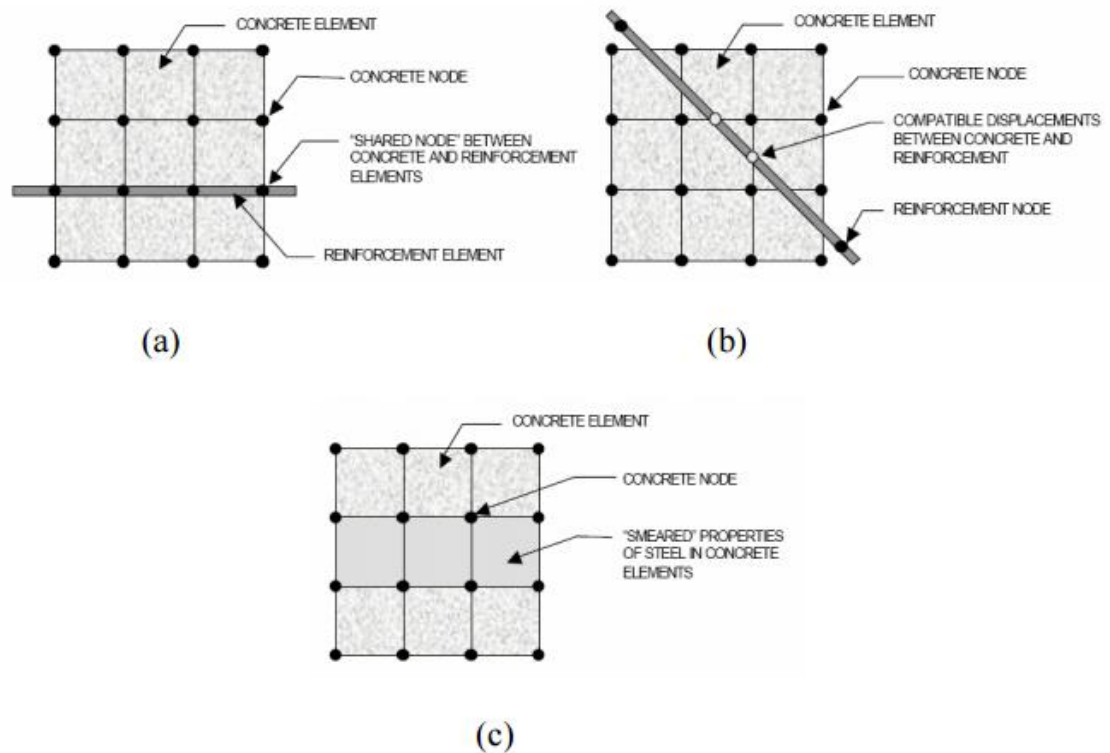


Figure 2.3: Models for reinforcement in Reinforced concrete: (a) discrete; (b) embedded; and (c) smeared

Source: Tavarez 2001

The reinforcement in discrete model as shown in Figure 2.3 (a) uses bar or beam elements that are connected to concrete mesh nodes. Therefore, the concrete and the reinforcement mesh share the same nodes and concrete occupies the same regions occupied by the reinforcement. The embedded model overcomes the concrete mesh restrictions because the stiffness of the reinforcing steel is evaluated separately from the concrete elements. The model is built in a way that keeps reinforcing steel displacement compatible with the surrounding concrete elements. The smeared model assumes that reinforcement is uniformly spread throughout the concrete elements in a defined region in finite element mesh. This approach is used for large- scale models where the reinforcement does not significantly contribute to the overall response of the structure.

Fanning (2001) modeled the response of the reinforcement using the discrete model and the smeared model for reinforced concrete beams. It was found that the best modeling strategy was to use the discrete model when modeling reinforcement.

2.6.4 Meshing

It is necessary to use a fine mesh finite element model for an accurate analysis of a shear wall with openings, but if the entire structure were divided into finer mesh with a large element numbers, it would require significance of computational time and memory. Besides, it is also inconvenient to use inconsistent of grid for the shear wall and frame in modeling the structure

2.6.5 Non-linear analysis

Linear analysis is not preferable as it only able to approximate the real nonlinear behavior of the concrete. Linear assumption sometime differs too much from reality therefore mislead information. The results of linear analysis may lead to over design as the inaccuracy for some materials such as concrete. The linear analysis are using Hooke's law (linear relationship between stress and strain), while other materials properties are constant and deformation are