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Distribution of Story Shear and Reinforcement in Dual System

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Abstract. Shear wall frame buildings are commonly used in buildings ranging from about 8 to about 30 stories. Shear walls may be simple planar walls, several wall segments commonly are connected to act as a three-dimensional unit, then may enclose spaces in buildings, such as stairs, wells or elevator shaft. In this case, 18 story building with shear wall as planar has been analyzed. The portion of frame is less than 25 % as required in Indonesian standard there are 11.64% in X direction and 12.12 % in Y direction, so the results are compared with the condition if shear wall is released, hence, only boundary elements are placed and taken the maximum value by giving 25 % earthquake load. In the 100 % base shear acting on structure the value of column shear force has greater value at the bottom story of column than if shear wall is released and only 25 % base shear is given. The value of shear force at shear wall in the bottom story is greater in the bottom because there is void in that area. The portion of frame is less than 25 % as greater in the bottom because there is void in that area, so the greater shear force in the story is obtained. As the result, at the lower story the correction of scale factor less than one factor for all story can give the economical design.

1. Introduction

The term shear wall is used to describe a wall that resists lateral wind or earthquake loads acting parallel to the plane of the wall in addition to the gravity loads from floors and roof adjacent to the wall [1]. Shear walls with (h_w/l_w) greater than or equal to 3 are referred to as slender or flexural walls [2]. Although shear walls may be simple planar walls, several wall segments commonly are connected to act as a three-dimensional unit. Such wall assemblies have regular or irregular C, T, L, or H shaped cross sections with webs and flanges then may enclose spaces in buildings, such as stairs, wells or elevator shaft.

Due to the high demand of living place, more medium to high-rise buildings are built recently. The dual system is suitable for the construction of the buildings. A dual system is a structural system in which an essentially complete frame provides support for gravity loads, and resistance to lateral loads that provided by a specially detailed moments resisting frame and shear walls. The system provides good redundancy where perimeter frames are used in conjunction with central shear wall core [3]. However, the standard requirement of the system must acquire the capability of the moments resisting to resist at list 25 % of the base shear [4]. However, some statement was mentioned that the moment frame must be designed to resist at least 25% of design seismic force for the dual system [5]. Therefore, this paper aims to obtain the impact of the 25% of design seismic force designed to the structural elements.



2. Literature Study

A dual system is a structural system in which an essentially complete frame provides support for gravity loads, and resistance to lateral loads is provided by a specially detailed moments resisting frame and shear walls or braced frame. The moments resisting frame must be capable of resisting at list 25 % of the base shear, and the two systems must be designed to resist the total lateral load in portion to their relative rigidity [4]. The system, which provides good redundancy, is suitable for medium and high-rise buildings where perimeter frames are used in conjunction with central shear wall core. A shear wall is a vertical structural element that resist lateral forces in the plane of the wall through shear and bending. Such a wall act as a beam cantilever out of the foundation, and just as with a beam, part of its strength derives from its depth.

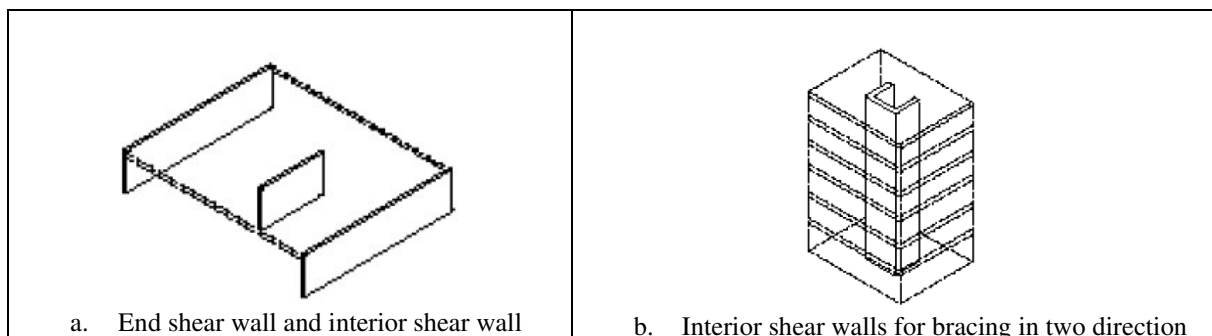


Figure 1. *Shear Wall in Building*

Figure 1 shows two examples of a shear wall, one in a simple one-story building and another in a multi-story building. In Figure 1 (a), the shear wall are oriented in one direction, so only lateral force the shear walls are oriented in one direction, so only lateral forces in this direction can be resisted. The roof serves as the horizontal diaphragm and must also be designed to resist the lateral loads and transfer them to the shear walls. Figure 1(a) also shows an important aspect of shear walls and vertical elements in general. This is the aspect of symmetry that has a bearing on whether torsional effects will be produced. The shear walls in Figure 1 (a) show the shear walls symmetrical in the plane of loading. Figure 1 (b) illustrates a common use of shear walls at the interior of a multistory building. Because walls enclosing stairways, elevator shafts, and mechanical shafts are mostly solid and run the entire height of the building, they are often used for shear walls. Although not as efficient from a strictly structural point of view, interior shear walls do leave the exterior of the building open for windows.

Notice that in Figure 1 (b) there are shear walls in both directions, which is a more realistic situation because both wind and earthquake forces need to be resisted in both directions. In this diagram, the two shear walls are symmetrical in one direction, but the single shear wall produces a nonsymmetrical condition in the other since it is off center. Shear walls do not need to be symmetrical in a building, but symmetry is preferred to avoid torsional effects. Shear walls, when used alone, are suitable for medium rise buildings up to 20 stories high. Shear walls may have openings in them, but the calculations are more difficult and their ability to resist lateral loads is reduced depending on the percentage of open area.

The following requirement for structural analysis under Earthquake Load, mode period requirement, modal analysis requirement, dynamic lateral force must be larger than 85% Static lateral Force ($V_d \leq 85\%V_s$) in dynamic analysis (SNI 1726:2012 Section 7.9.4.1), minimum 90% building mass participation (SNI 1726:2012 Section 7.9.1) , and story shear in frame at each level must carry over 25 % of total story shear at that level in dual system (SNI 1726:2012 Section 7.2.5.1) [4, 6, 7].

3. Analytical Model

The building model in this study is 18 story reinforced concrete building that adopt dual system with special moment resisting frame system. Building model has functional as apartment. The building model

structure is performed Jambi City ($SS=0.25g$, $S1=0.2g$) with site class D [4]. Material property of concrete is $f'_c = 27$ MPa and steel reinforcement is $f_y = 400$ MPa for beam and column elements. Building is a dual structural system in which an essentially complete frame provides support for gravity loads and resistance to lateral loads is provided by a specially detailed moments resisting frame and shear walls. Drawing plans are given in the Figure 2. It can be seen from Figure 2 (c) that wide void can give the effect of the long column.

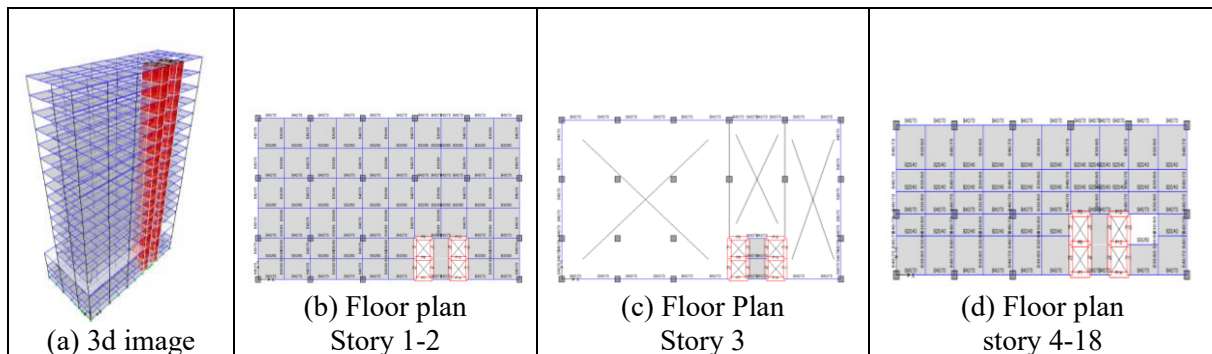


Figure 2. Building Model

4. Results and discussion

Maximum participation mass from each direction is determined as time period and the result are mode 1 and mode 2 are translation and mode 3 is rotation are as required as shown in Figure 3. The mass participation ratio in have meet requirement ($\geq 90\%$) with 100% mass participation in X, Y, and Z direction. The value of dynamic shear force is compared with 85% static shear force of each story and get scale factor which much used for earthquake forces as required in code. The first analysis, shown in Figure 4, the dynamic shear force are not meet requirement 85% static shear force (Figure 4). After correction with updated scale factor then the result is meet requirement shown in Figure 5. Because only one scale factor can be used in structural analysis software, ETABS [8], so give the value of base shear in the lower story greater than its needed. Therefore, an in-economic reinforcement design can be found which is shown in Figure 8.

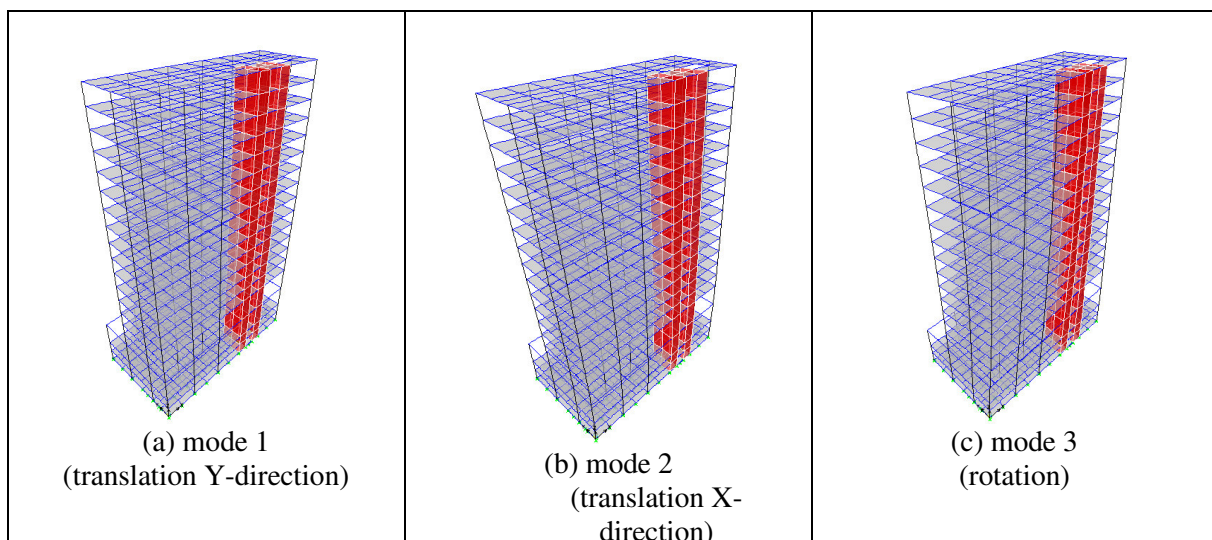
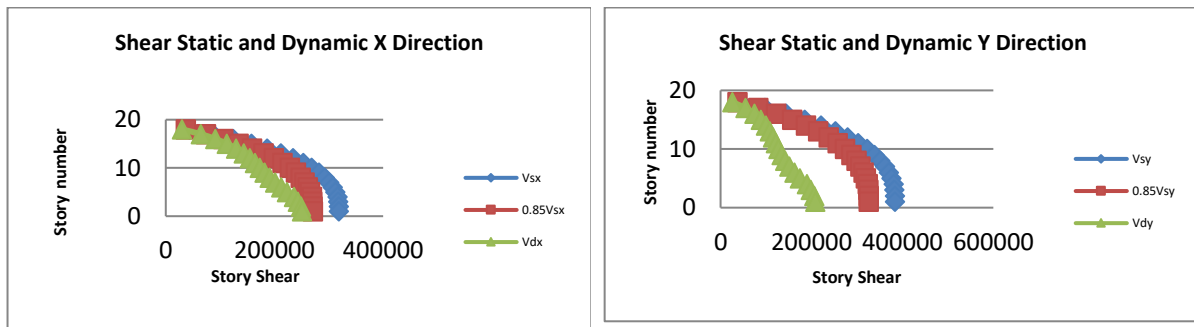
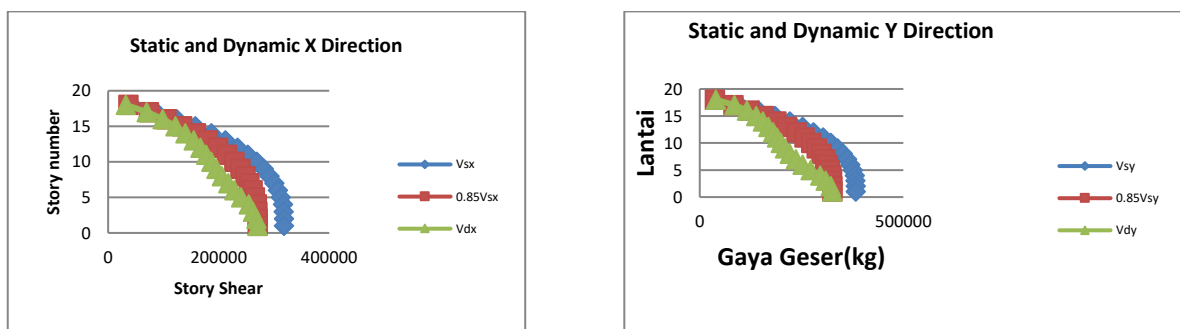


Figure 3. Building mode shape



(a) X-direction (b) Y-direction
Figure 4. Building static dan dynamic story shear (before correction)



(a) X direction (b) Y-direction
Figure 5. Building static dan dynamic story shear (after correction)

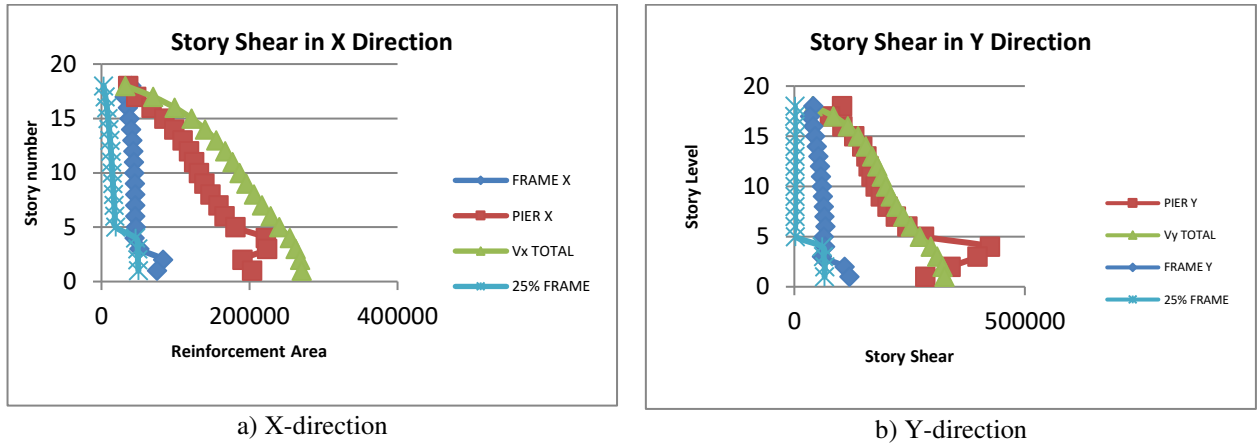
Discussing the material from Table 1 are portion that received by frame is identified from base shear in frame and base shear from pier shear wall about 11.64 % in X direction (lower than 25 %) and 12.12 % in Y direction (lower than 25 %), are not accepted code. The results are the distribution that received by frame are about 11.64 % in X direction (lower than 25 %) and 12.12 % in Y direction (lower than 25 %). The destination of this statement is for second defense mechanism [9, 10] is to prevent 25 % base shear if shear wall collapse. To prove this by giving 25 % earthquake load that is present by 25 % base shear acting in structure without shear wall only boundary condition is placed. By giving 25 % earthquake load in the shear wall less from structure except boundary elements, shown in Figure 8, the result of column reinforcement based on without shear wall model, with 25% base shear force from full model (frame + shear wall).

Table 1. Frame base shear ratio

Direction	Location	Base Shear (kN)	Frame-Base Shear Percentage (%)
X	Frame	798.32	11.64%
	Building (Frame + Shear wall)	6859.9	
Y	Frame	1148	12.12%
	Building (Frame + Shear wall)	9470.62	

In Figure 6 in the 100 % base shear acting on structure the value of column shear force have greater value at the bottom story of column than if shear wall is released and only 25 % base shear is given. The value of shear story by adding the column shear force and shear wall force greater than by shear force total. The value of shear force at shear wall in the bottom story is greater in the bottom because

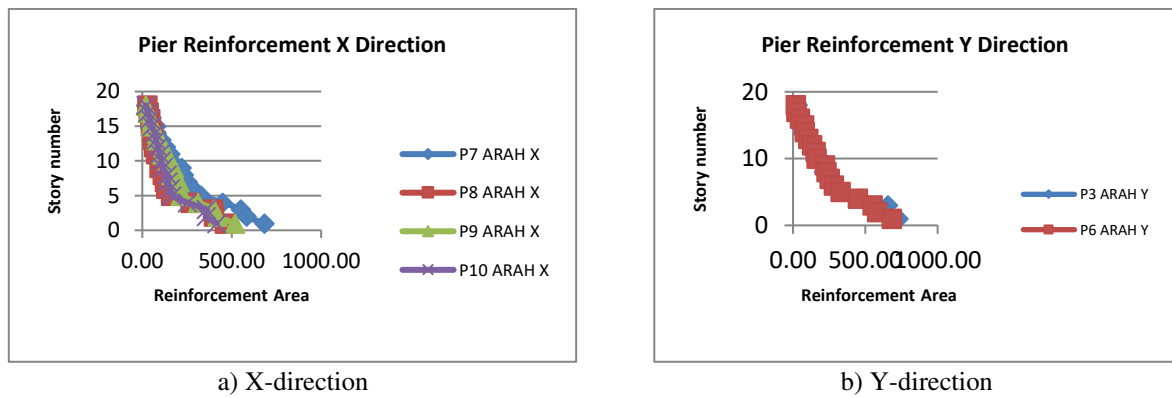
there is void in that area. The portion of frame is less than 25 % as greater in the bottom because there is void in that area, so will give the greater shear force in the story.



a) X-direction b) Y-direction

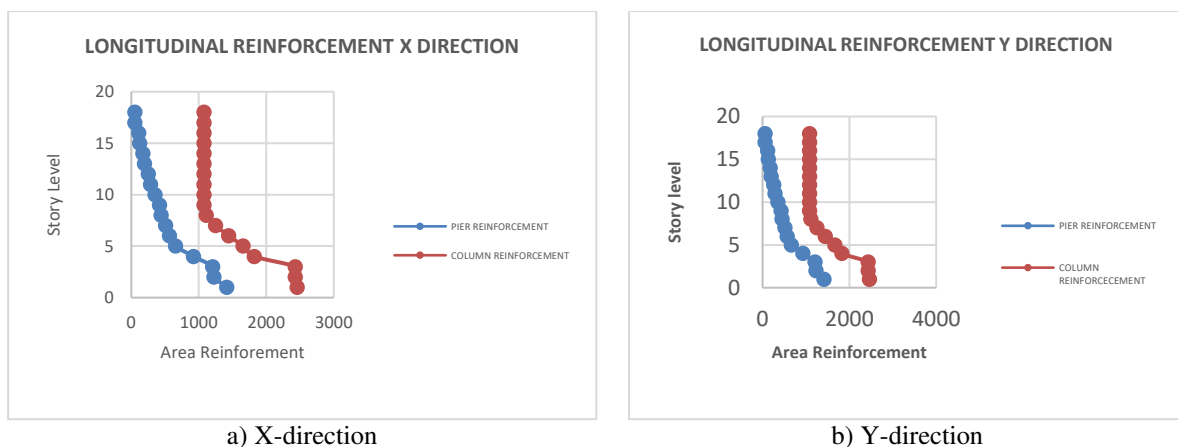
Figure 6. Distribution of story shear in dual system

It can be seen that at Figure 78, the area of longitudinal pier reinforcement is bigger in the bottom story and decreases in upper story. It can be seen that at Figure 8, the area of longitudinal column reinforcement is bigger than the area of longitudinal pier reinforcement in X and Y direction.



a) X-direction b) Y-direction

Figure 7. Pier reinforcement



a) X-direction b) Y-direction

Figure 8. Column and pier longitudinal reinforcement

5. Conclusion

The conclusion is that portion that received by frame are about 11,64 % in X direction (lower than 25 %) and 12,12 % in Y direction (lower than 25 %). The condition if shear wall is released only boundary element are placed and giving 25 % earthquake load given 18,57 % in X direction frame (lower than 25 %) and 21,52 % in Y direction frame (lower than 25 %), so earthquake which acting to the structures less than 25 % capacity of frame resisted earthquake load. In the 100 % base shear acting on structure the value of column shear force has greater value at the bottom story of column than if shear wall is released and only 25 % base shear is given. The portion of frame is less than 25 % as greater in the bottom because there is void in that area, hence, the greater story shear is obtained. The area of longitudinal pier reinforcement is bigger in the bottom story and decreases in upper story. The area of longitudinal column reinforcement is bigger than the area of longitudinal pier reinforcement in X and Y direction

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