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Evaluation of the effect of shear wall distribution in seismic response of precast framed structure

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Abstract—***In this research an attempt has been made to evaluate response of frame structure, subjected to lateral loads such as earthquake with different arrangement of Reinforced Concrete (RC) shear wall in structural plan. For this purpose a ten stories precast building skeletal frame of typical JKR (Public Work Department of Malaysia) quarters is considered and its behavior with different shear wall location under earthquake excitation is studied and comparison of performance has been made. Placement of shear wall did helps a lot in restraint the lateral displacement at tip node. Skeletal frame with original shear wall based on JKR quarters showed the best performance among all although there is only little different in term of shear forces and bending moments in beams.***

Keywords— ***Precast concrete, Lateral load, shear wall, earthquake, time history analysis.***

I. Introduction

The common basis structural forms for IBS can broadly grouped into the following three categories which are skeletal frame system, load bearing wall system and modular cell system. Skeletal frame can easily built by connecting precast columns and beams together with precast flooring or roofing elements supported by the beams. Solid, sandwich or perforated precast concrete panels can be arranged in several different ways so the panels efficiently carry the vertical loads as well the horizontal load for the load bearing wall system. Modular cell system employs three-dimensional modules (or boxes) for fabrication of habitable units that capable of withstanding load from various directions due to their internal stability [1]. Shear wall which constructed either precast concrete components or cast in-situ is one of the most effective bracing systems in IBS structures. Generally, shear walls can either located externally or internally and is always located symmetrically to prevent the torsion due to the applied lateral load.

It is essential to know the products being used for precast concrete construction with its increasingly demand particularly in providing sufficient earthquake resistance. Several researches, studies, experiments and explorations which had being carried out throughout the years in order to recognize the seismic behaviors and performances of precast concrete frame systems and it contributed to the improvement of new design guidelines for the precast jointing systems [2].

The design of precast structure should consider the loadings during the stages of construction and at the serviceability states during the life of the structure with ensure that it can performs satisfactory in the service load range, and has a reasonable margin of safety before the ultimate load is reached and would not fail [3].

According to [4], strength provided by the shear wall against lateral load is very large in compare with the bending capacity of columns.

Even through the investigation which has been done on the hollow block wall system indicated that while the stiffness of this systems is not more considerable but the walls showed good performance as shear wall to resist against lateral load and severe ground vibration [5].

Thus, it is not necessary to position the shear wall everywhere in the structure. The shear wall should position strategically to maximize its effect, for example near to the ends of the structure or in a central core area. Shear wall must be sufficiently strong to ensure the deflections are within the acceptable limit as to function effectively.

Kenneth M.Leet and Chia-Ming Uang [6] stated that shear walls is often inserted at appropriate locations within the building as to limit lateral displacements.

Also variation of stiffness in height of structures (in each story level) is noticeably effected on seismic response of structures during earthquake excitation [7].

Shear walls act in plane as deep cantilever beam-columns with large bending stiffness of higher magnitude several orders of those combine of all columns. Those shear walls are assumed to carry all transverse loads which include earthquake to the foundation due to this stiffness.

Ideally, shear walls should be placed symmetrically around the outermost walls or near the end of buildings or located as core around the staircase or lift shafts. Non-symmetric shear walls will create uneven loadings and cause possible undesirable torsion effects.

In the year 2004 and 2005, tremors from the Sumatran earthquakes had brought safety concerns to the public, government authorities, engineers and researchers especially when no earthquake design had been taken into practices in Malaysia [8].

Shear wall which constructed either as precast concrete components or cast in-situ is one of the most effective bracing systems. As economic factor is one of the main concerns during all of the constructions, placement of shear wall in precast building skeletal frame should be strategic enough to minimize the placement of shear wall without compromise its performance. There is lack of study on effect of different shear wall location on the typical JKR 10 stories quarters. Therefore, in this study, a ten stories precast building skeletal frame of typical JKR quarters under lateral loading is studied with the reduction of original proposed shear wall and performance comparison is made.

For this purpose, an attempt has been made to evaluate the response of precast building skeletal frame with and without shear walls under severe earthquake time history analysis, and investigate the behavior of it with various shear wall positions. Finally, the performance of structure with different shear wall location under lateral loading is compared.

II. Modeling

Structural Analysis Program (SAP) is used for modeling and analysis of a ten stories precast building skeletal frame of typical JKR quarters. To obtain the purpose of this study, four different pattern of shear wall distribution defined as bellow. "SW0" which is the RC frame without any type of lateral resistance system. "SW1" consider shear wall around the two lifts, just in one axis. "SW2" defined the shear wall in one perpendicular axis, and the "SW3" proposed some axis in both directions. Figure2 reveals the four mentioned patterns.

A. *Loading*

Dead loads of wall which act on beam have to be calculated and thus assigned for analysis based on BS6399 part one.

Dead load of brick wall (Internal) = 3.36 KN/m^2

Dead load of brick wall (External) = 5.86 KN/m^2

Brick wall is allowed 30% for opening of door and windows. Therefore, dead load of brick wall calculated multiply by 0.7 before assigned on beam of the skeletal frame.

Live load used for analysis is extracted from BS6399 based on function and general use of slab. Live load for residential use of 2.0 KN/m^2 is used for analysis.

B. *Material Properties and Analysis Parameters*

The bellows are the details for the used material in modeling.
Concrete self weight = 24 KN/m^2

Characteristic strength of concrete, f_{cu} =30 N/mm^2

Beam Size of 250 x 500mm

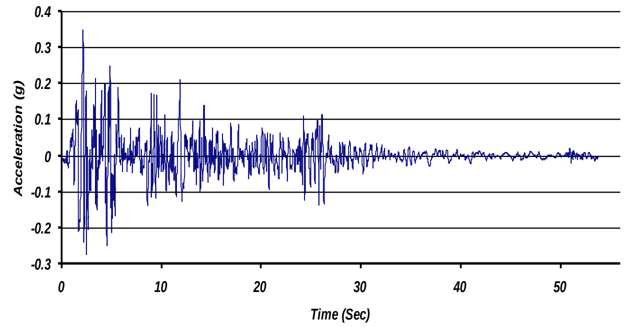
Column Size of 300 x 300mm

Connection Type of rigid beam to column, column to column and column to base

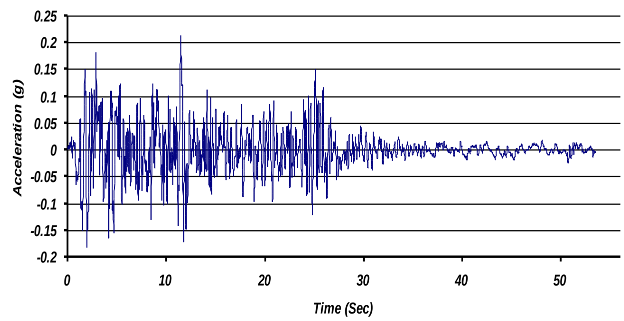
Slab thickness = 150mm

Wall height = 3.5m

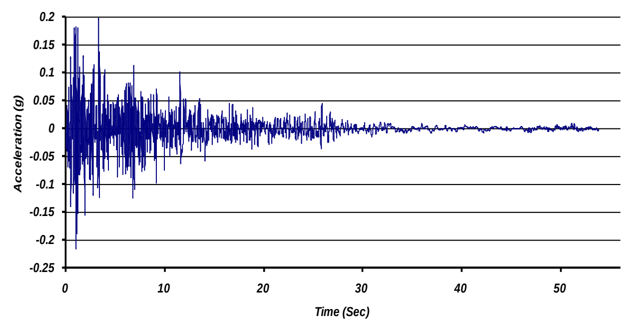
Bs 8110-85 is used for load combination. El-Centro earthquake data record, used in time history analysis. In this case East-West data used in X direction, North-South and Up-Down used in Y and Z directions respectively. The El-Centro earthquake data is shown in Figure**Error! Reference source not found.**.



(a) North – south component



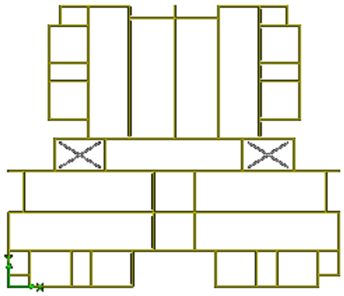
(b)- East – West component



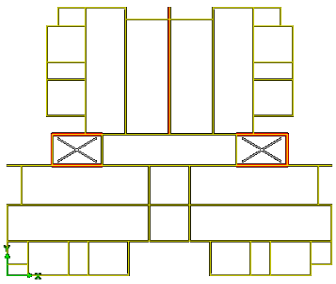
(c) Up – down component

Figure1. Earthquake record components of El-Centro (Imperial Valley Irrigation District, USA-1940)

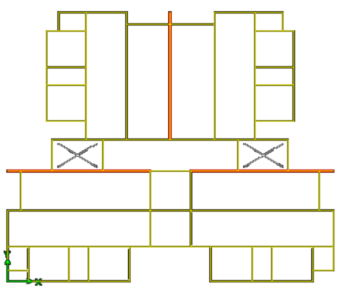
Figure 2 shown the plan of modeled structure with different shear wall distribution patterns.



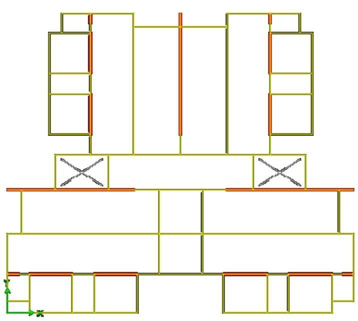
SW0



SW1



SW2



SW3

Figure 2. Structure plan without shear wall shown with "SW0", and shear wall distribution pattern 1 to 3 illustrated by "SW1" to "SW3" respectively

III. *Result and discussion*

The Figure3 compare the diaphragm displacement between the RC frame structure, and equipped structure with shear wall pattern "SW1". As it can be seen the maximum displacement from 489 mm in "SW0" slightly reduced to 474 mm by using pattern no "SW1". The comparison of "SW2" and "SW0" is illustrated on Figure 4. The results indicate a dramatic reduction from 489mm on "SW0" to 208mm on "SW2".
The last comparison of diaphragm displacement between "SW3" and "SW0" reveals on Figure5. The comparison graph clearly shown enormous decline from 489mm to 138mm.In another word it can be said that "SW1", "SW2", and "SW3" reduced for 3.06%, 57.46, and 71.78%, respectively.

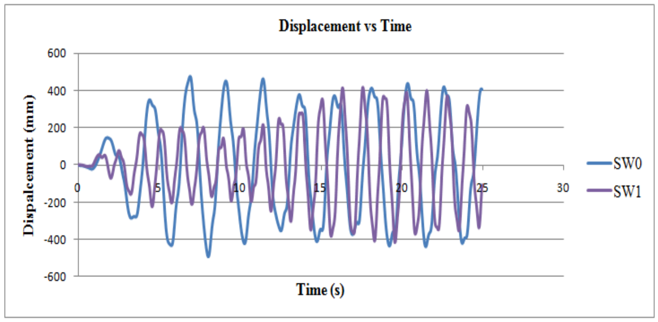


Figure3. Comparing the displacement of the structure with shear wall pattern no SW1 with SW0

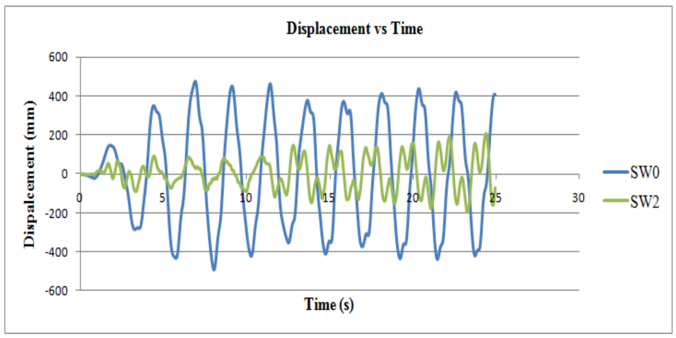


Figure4. Comparing the displacement of the structure with shear wall pattern no SW2 with SW0

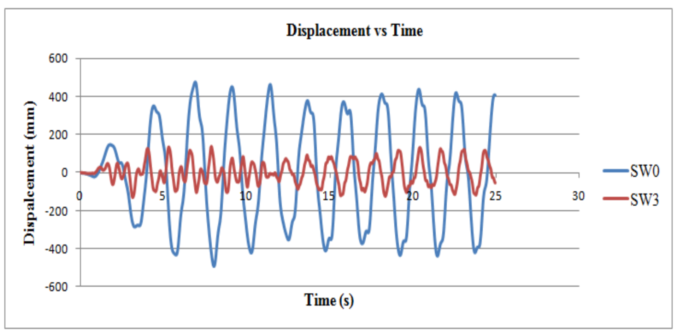


Figure5. Comparing the displacement of the structure with shear wall pattern no SW1 with SW0

Figure 6 demonstrate the summarized result of displacement among the patterns “SW0” to “SW3”.

The graph clearly shows the consequent reduction from pattern “SW0” to “SW3”.

Based on the code of practice the allowable lateral displacement for structure is limited to H/200 where H is height of structure so in this case by consider of height of structure which is equal to 32 meters the allowable lateral displacement is considered as 160mm.

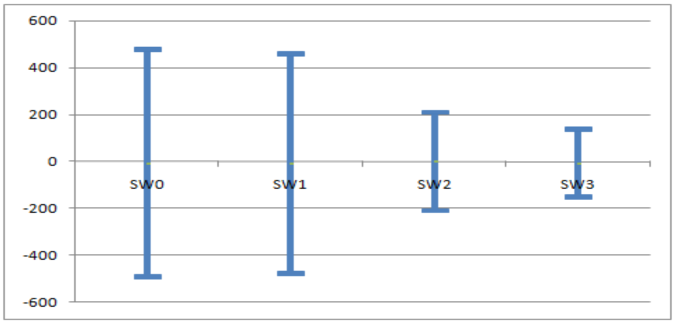


Figure 6. Summarizing the displacement amplitude among the three different patterns of distribution and RC frame building

Figure 7 and Table I illustrate the summarized result of the different shear wall distribution pattern in the structure.

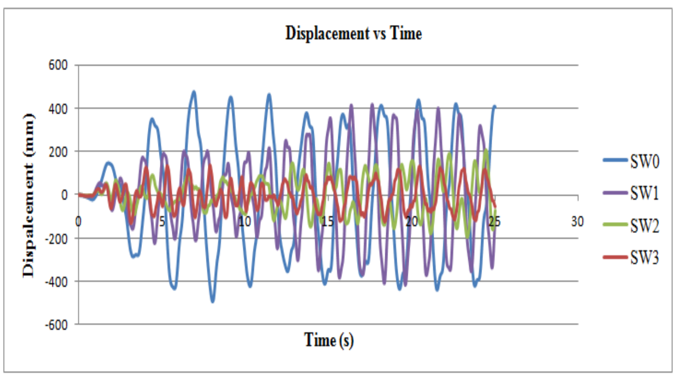


Figure 7. Time history displacement of top story under earthquake excitation

Note: dots mark on graph represent the maximum displacement for each case in the first 25 second

Table I. Maximum amplitude displacement for each case in the first 25 second in East-West Direction

	Maximum (positive)	Maximum (negative)	Maximum (amplitude)	Reduction percentage
SW0	477.56	-489.69	967.34	--
SW1	459.34	-474.00	933.34	3.51
SW2	210.67	-208.54	419.22	56.66
SW3	138.28	-149.24	287.53	70.27

IV. Conclusion

In this study, the behavior of precast building skeletal frame with different shear wall location under lateral loading studied and comparison of performance is made. So, a ten stories precast building skeletal frame of typical JKR quarters is modeled and analyzed by SAP software. Four different distribution patterns are defined for this investigation.

Based on the result, the different shear wall distributed modeled patterns shown 3.51%, 56.66%, and 70.27% reduction for “SW1”, “SW2”, and “SW3”, respectively. Pattern “SW3” is the only model which could satisfy the limitation of the code of practice with 138mm diaphragm displacement.

At last, the investigated result shown that, not only distribution of the shear wall is important, but also number of wall enormously effect of the reduction of displacement on the structure.

V. *References*

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