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Study on the Moment Change at Slab-Column Joints Due to Shear Wall's Length Variations

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Abstract: A ten-storied building with length variations of shear walls, which are perpendicular to the lateral load acting on the building, has been studied here. The finite element based software, ETABS (version 9.6) has been used for determining the moment at different area objects due to the lateral load and Simpson's one-third rule has been used to calculate the line moment from mesh area. Five different shear wall lengths- 4.5ft, 5.5ft, 6.67ft, 7.5ft and 8.5ft, are included here. The study shows that, moment in magnitude has been increased with the increasing of shear wall length but the percentage of total moment passed through the column strip is decreased and vice versa for middle strip. The moment in magnitude at column strip decrease by increasing of shear wall length but the optimum length will be 33% (approximate) of total span. The moment percentage of column strip moment passing through effective (c+3h) strip decreases by increasing of shear wall length.

Keywords: Shear Wall, Length Variation, Lateral Load, Column Strip, Middle Strip

1. Introduction

Flat Plate concrete slabs are not preferred in high rise buildings hotels, motels, hospitals and residential buildings etc-- for vulnerability under lateral loads such as wind and earthquake as flat plate transforms lateral loads to columns without the help of beams, column capitals and drop walls. But, now-a-days, Flat Plate concrete slabs become more popular for their aesthetic view and easy arrangements. However, considering high demand of flat plate, engineers advice to add shear walls to reduce vulnerability under lateral loads. A significant numbers of researches have been done over flat plate slabs stability and shear wall stability, positions and strength etc.

S. D. Bothara et.al discussed about the lateral behavior of a typical flat slab building which is designed according to I. S. 456 -2000 by means of dynamic analysis. The inadequacies of these buildings are discussed by means of comparing the behavior with that of conventional flat slab & Grid slab system selected for this purpose. To study the effect of drop panels on the behavior of flat slab during lateral loads, Zone factor and soil conditions –the other two important parameters which influence the behavior of the structure, are also covered. Software ETABS is used for this purpose. In this study among the number of stories, zone and soil condition is developed [12].

S. Bhat et.al studied about comparison of the difference between the earthquake behavior of buildings with and without shear wall using STAAD. pro [13].

Climent et.al focused on the behavior of corner slab–column connections with structural steel I- or channel-shaped sections (shear heads) as shear punching reinforcement [14].

J. M. Babaso studied about the performance of steel plate shear wall during past earthquakes events and the testing on steel plate and also the different case study of SPSW system [15].

V. R. Harne studied to determine the solution for shear wall location in multistory building. A RCC building of six-storey placed in Nagpur subjected to earthquake loading in zone-II is considered. An earthquake load is calculated by seismic coefficient method using IS 1893 (PART–I):2002. These analyses were performed using STAAD Pro. The study has been carried out to determine the strength of RC shear wall of a multistoried building by changing shear wall location. Three different cases of shear wall position for a 6 storey building have been analyzed. Incorporation of shear wall has become inevitable in multi-storey building to resist lateral forces [16].

S. W. Han et.al told about the effective beam width model (EBWM) used for predicting lateral drifts and slab moments under lateral loads. They also studied on slab stiffness with respect to crack formation. This studies developed equations for calculating slab stiffness reduction factor by conducting nonlinear regression analysis using stiffness reduction factors [17].

U. Gupta et.al studied to compare the behavior of multi-storey buildings having flat slabs with drops to the two way slabs with beams and to study the effect of part shear walls on the performance of these two types of buildings under seismic forces. This work provides a good source of information on the parameters lateral displacement and storey drift [18].

E. S. Finzel et al told about the record of flat-slab subduction in southern Alaska by integrating stratigraphic, provenance, geochronologic, and thermo chronologic data from the region directly above and around the perimeter of ongoing flat-slab subduction [19].

Y. Mirzaei et.al studied that the column failure due to an explosion can propagate in the structure through punching shear failure at the location of the neighboring columns, leading to progressive collapse. An analytical model is developed to be used in a finite element model of flat plate/slab structures to estimate the initiation of punching shear failure as well as post-punching shear response using ABAQUS [20].

M. A. Musmar indicated that openings of small dimensions yield minor effects on the response of shear walls with respect to both normal stresses along the base level of shear walls and maximum drift. Cantilever behavior similar to that of a solid shear wall takes place and analogous to that of coupled shear walls. On the other hand, when openings are large enough, shear walls behave as connected shear walls, exhibiting frame action behavior [21].

S. K. Mohammed et.al studied about a comparison of structural behavior in terms of strength, stiffness and damping characteristics which is done by arranging shear walls at different locations/configurations in the structural framing system. The elastic (response spectrum analysis) as well as in-elastic (nonlinear static pushover analysis) analyses are carried out for the evaluation of seismic performance. The results of the study indicate that the provision of shear walls symmetrically in the outermost moment resisting frames of the building and preferably interconnected in mutually perpendicular directions forming a core will lead to better seismic performance [22].

K. S. Patil et.al discussed about optimum design of reinforced concrete flat slab with drop panel according to the Indian code (IS 456-2000). The structure is modeled and analyzed using the direct design method. The optimization process is done for different grade of concrete and steel. The comparative results for different grade of concrete and steel is presented in tabulated form. Optimization for reinforced concrete flat slab buildings is illustrated and the results of the optimum and conventional design procedures are compared. The model is analyzed and designed by using MATLAB software. Optimization is formulated in nonlinear programming problem (NLPP) by using sequential unconstrained minimization technique (SUMT) [23].

K. M. Pathan et.al observed that the shear walls, if not used for full height of the structure, are also have same effectiveness in resisting the lateral loads. Here, an attempt is made to work out the height of Shear walls which will be just sufficient in resisting the lateral loads as good as the shear walls having full height equal to the height of the structure itself [24].

H. Rahangdale et.al analyzed G+5 Storey building in Zone IV with some preliminary investigation by changing various position of shear wall with different shapes to determine parameter like axial load and moments. This analysis is done by using Standard package STADD-pro [25].

V. K. Rahman 1 et.alpresented the comparison of RCC and pre-stressed concrete flat slab. This work includes the designed estimates for RCC and pre-stressed concrete flat slabs of various spans. The aim of this work is to design RCC as well as pre-stressed concrete flat slabs for various spans and then to compare the results. Programming in MS EXCEL is done to design both types of flat slabs. The idea is to reach a definite conclusion regarding the superiority of the two techniques over one another. Results reveal that a RCC flat slab is cheaper than pre-stressed concrete flat slab for smaller spans but vice versa is true for larger spans [26].

Ramos, et.al studied about the punching failure mechanism resulted from the superposition of shear and flexural stresses near the column, and is associated with the formation of a pyramidal plug of concrete which punches through the slab. It is a local and brittle failure mechanism. The work reported the experimental analysis of reduced scale pre-stressed flat slab models under punching [27].

K. S. Sable et.al analyzed seismic behavior of building for different heights to see what changes are going to occur if the height of conventional building and flat slab building changes [28].

Bhunia et.al focused to determine the solution for shear wall location in multi-storey building based on its both elastic and elasto-plastic behaviors. An earthquake load is calculated and applied to a building of fifteen stories located in zone IV. Elastic and elasto-plastic analyses were performed using both STAAD Pro 2004 and SAP V 10.0.5 (2000) software packages. Shear forces, bending moment and story drift were computed in both the cases and location of shear wall was established based upon the above computations [29].

J. Sabouri et.al told that a comparative study has been carried out concerning some parameters such as strength, stiffness, lateral displacement, cracking development and steel weight. Moreover, shear walls have been compared through considering the ratio of strength to steel weight and their ductility and the results revealed that slit and coupled shear walls showed more favorable performance [30].

S. J. Sardar et.al said that a 25 stories building in zone V with some investigation is analyzed by changing various location of shear walls for determining parameters like storey drift, storey shear and displacement by using standard package ETAB [31].

A. A. Sathawane et.al studied to determine the most economical slab between flat slab with drop, flat slab without drop and grid slab. The total length of slab is 31.38 m and width is 27.22 m. Total area of slab is 854.16 sqm. It is designed by using M35 Grade concrete and Fe415 steel. Analysis of the flat slab and grid slab has been done both manually by IS 456-2000 and by using software also. Flat slab and grid slab has been analyzed by STAAD PRO. Rates have been taken according to N. M. C. C. S. R It is observed that, the flat slab with drop is more economical than Flat slab without drop and grid slabs [32].

P. V. SumanthChowdary et.al studied the solution for shear wall location and type of shear wall in seismic prone areas. The effectiveness of RCC shear wall building is studied with help of four different models. Model one is bare frame system and remaining three types are different shear wall buildings. An earthquake load is applied to 8 storey building located in different zones. The performance of building is evaluated in terms of lateral displacements of each storey. The analysis is done by using structural finite element analysis (SAP2000) software [33].

K Galal discussed the efficiency of each model in representing both the global and local behaviour of RC shear walls. The objective of this paper is to provide a state-of-the-art on the recent advancements and challenges in the area of modeling of RC shear walls [34].

S. R. Thorat et.al studied the dynamic behavior of reinforced concrete frame with and without shear wall and concrete braced frame. The purpose of this study is to compare the seismic response of above structural systems. Axial forces and moments in members and floor displacements were compared [35].

M. Varma et.al discussed a method designated as Equivalent Load Method, in which equivalent load is calculated using Grashoff-Rankine formulae, and is considered to be acting on the slab. The deflection calculated using equivalent load method is found to be closer to experimental values. The negative deflection has been tackled in literature by applying a factor of 0.7 to cracking moment (Mr). The deflection thus calculated again differs considerably with the experimental values. In the paper, with the method, a procedure has been proposed in which instead of the factor 0.7 being applied to Mcr; cracking moment of inertia is proposed to be used in place of effective moment of inertia. The deflection thus calculated has been found to be comparable with experimental results. Experimental data obtained and data available in literature have been used to validate the procedure. Experimental work has been carried out for two end conditions i.e. fixed supported and simply supported two-way RC slab. Six separate specimens were casted for both end condition of different thickness, sizes and for different loads [36].

M. R Islam et.al discussed about a ten-storied building with shear walls in two directions with respect to the direction of lateral load acting on the building has been studied here. The finite element based software, ETABS (version 9.6) has been used for determining the moment at different area objects due to the lateral load and Simpson's one-third rule has been used to calculate the line moment from mesh area [37].

2. General Data

2.1. Building Data

a) Story height (per floor): 10 ft.
b) Length in global- X direction: 54 ft.
c) Length in global- Y direction: 60 ft.
d) Each slab panel: 18 ft×20 ft.

2.2. Column, Shear Wall and Slab Properties

a) Material: Reinforced concrete.
b) Column size: 15 inch × 15 inch.
c) Slab thickness: 7 inch.
d) Shear wall length: variable
e) Shear wall thickness: 12 inch.

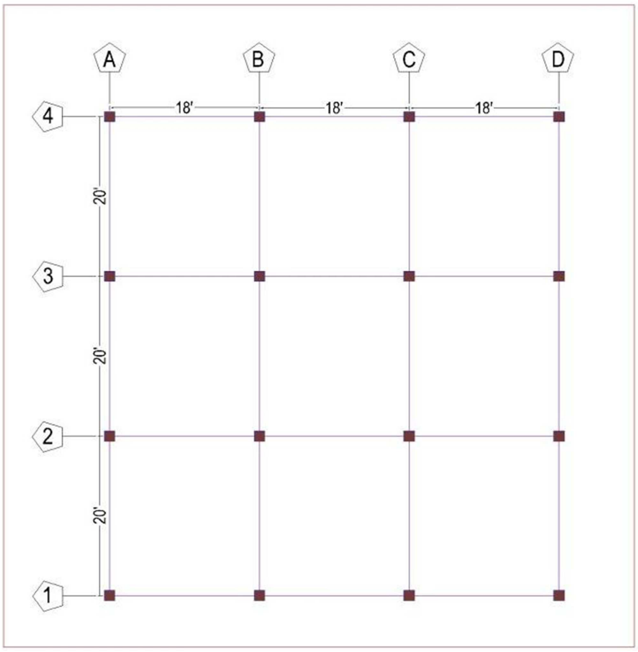

Figure 1. *Typical floor plan without shear wall.*

2.3. Load Applied

Table 1. *Vertical load applied on the building.*

Load type	At the roof (psf)	Rest of the story (psf)
Dead load	112.5	162.5
Live load	0	40

2.4. Material Properties

a) Compressive strength of concrete, f'_c = 4000 psi.
b) Yield stress of steel, f_y = 60,000 psi.
c) Modulus of elasticity of concrete, E = 3,600,000 psi

2.5. Strip Define

One-fourth of short span around the column defined as column strip in both directions-long and short while rest of the length at the middle defined as middle strip (Shown in figure-2). Column length and three times of slab depth (c+3h) around the column defined as effective strip.

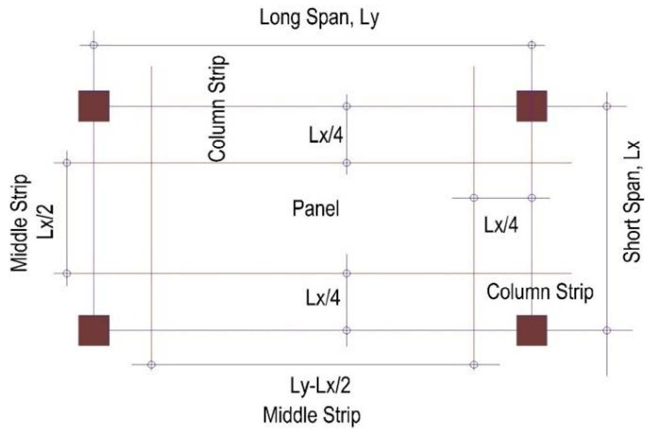

Figure 2. *Strips details.*

2.6. Mesh System

For the finite element analysis, the slab area is meshed. Around a particular column, each slab panel is meshed into 14 blocks in the direction of global-Y (20 ft.) and 12 blocks in the direction of global-X (18 ft.).

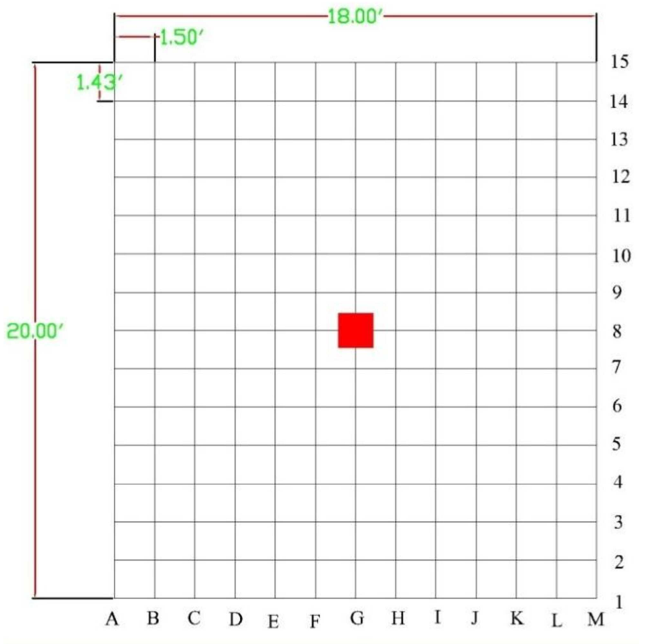

Figure 3. *Typical mesh system for a slab for this study.*

2.7. Loading System

Lateral earthquake force is acting on the perpendicular direction of shear walls length. In this study, the length of shear wall varies but the load direction acting on the shear wall is remained same.

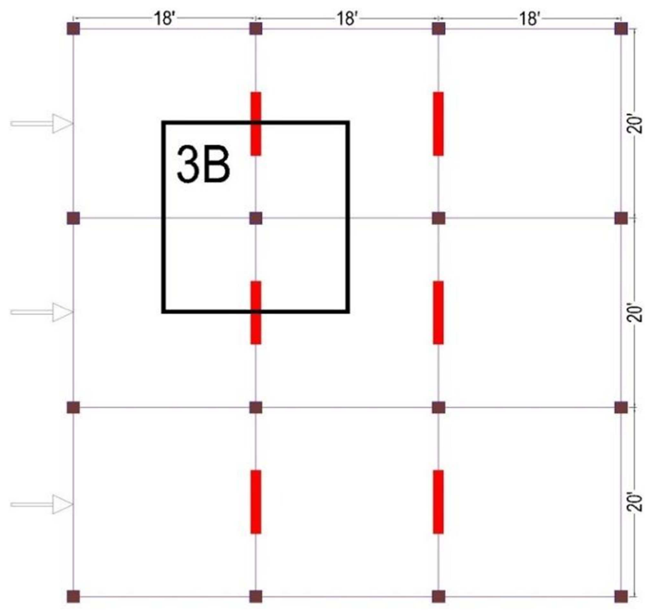

Figure 4. *Load acting to the perpendicular direction in SW.*

Earthquake load is applied in global X- direction and the moment (m_{11}), due to earthquake load, is only considered for this study. This moment (m_{11}) is calculated and provided by ETABS software [5].

2.8. Momen tm_{11}*,* m_{22} *and* m_{12} *Significance*

a) m_{11}: Direct moment per unit length acting at the mid-surface of the element on the positive and negative 1 faces about the 2-axis.
b) m_{22}: Direct moment per unit length acting at the mid-surface of the element on the positive and negative 2 faces about the 1-axis.
c) m_{12}: Twisting moment per unit length acting at the mid-surface of the element on the positive and negative 1 faces about the 1-axis, and acting on the positive and negative 2 faces about the 2-axis.

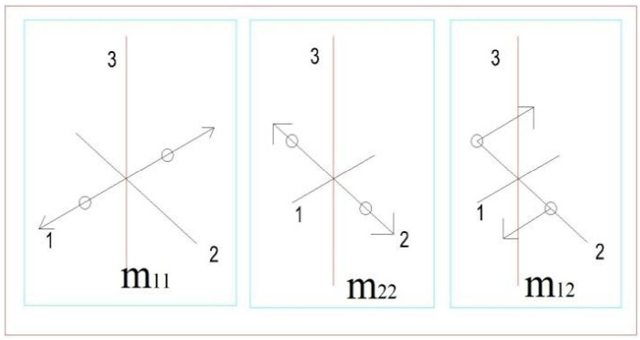

Figure 5. *Cartesian moment tensor.*

2.9. Earthquake Load Calculation

The calculation was done by equivalent static force method in excel sheet. The used data has been taken from BNBC-1993 code [3].

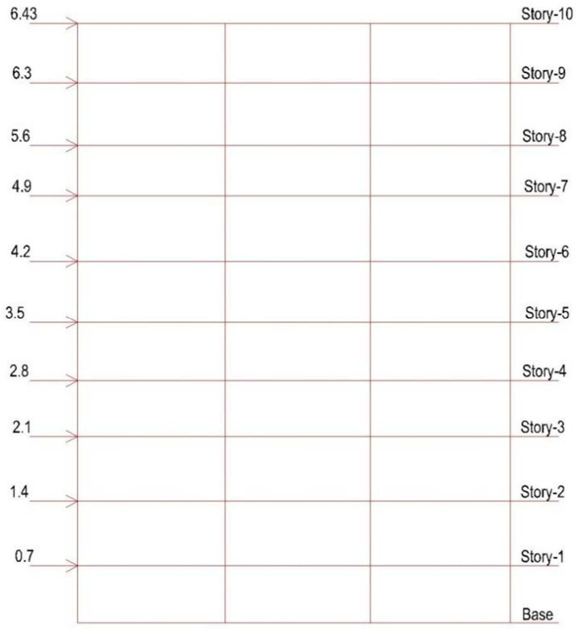

Figure 6. *Elevation view of ten-storied building (point load applied on column line-4 in kips).*

Table 2. *Earthquake loaded acted in floors.*

Floor	load (kips)
1st Floor F1	4.22074
2nd Floor F3	8.44148
3rd Floor F3	12.6622
4th Floor F4	16.883
5th Floor F5	21.1037
6th Floor F6	25.3244
7th Floor F7	29.5452
8th Floor F8	33.7659
9th Floor F9	37.9867
Roof	38.6004

The force has been put in ETABS software as point loads.

3. Data Analysis

The moment percentage is generated from the moment (m_{11}) due to lateral earthquake load acting in the Global-X direction. The moment taken from ETABS is sum using Simpson one-third rule for each line. Here, the shear wall which length 4.5ft is considered as SW-1 while 5.5ft as SW-2, 6.67ft as SW-3, 7.5 ft as SW-4 and 8.5ft as SW-5. All the shear walls were taken in the same direction with respect to the load direction.

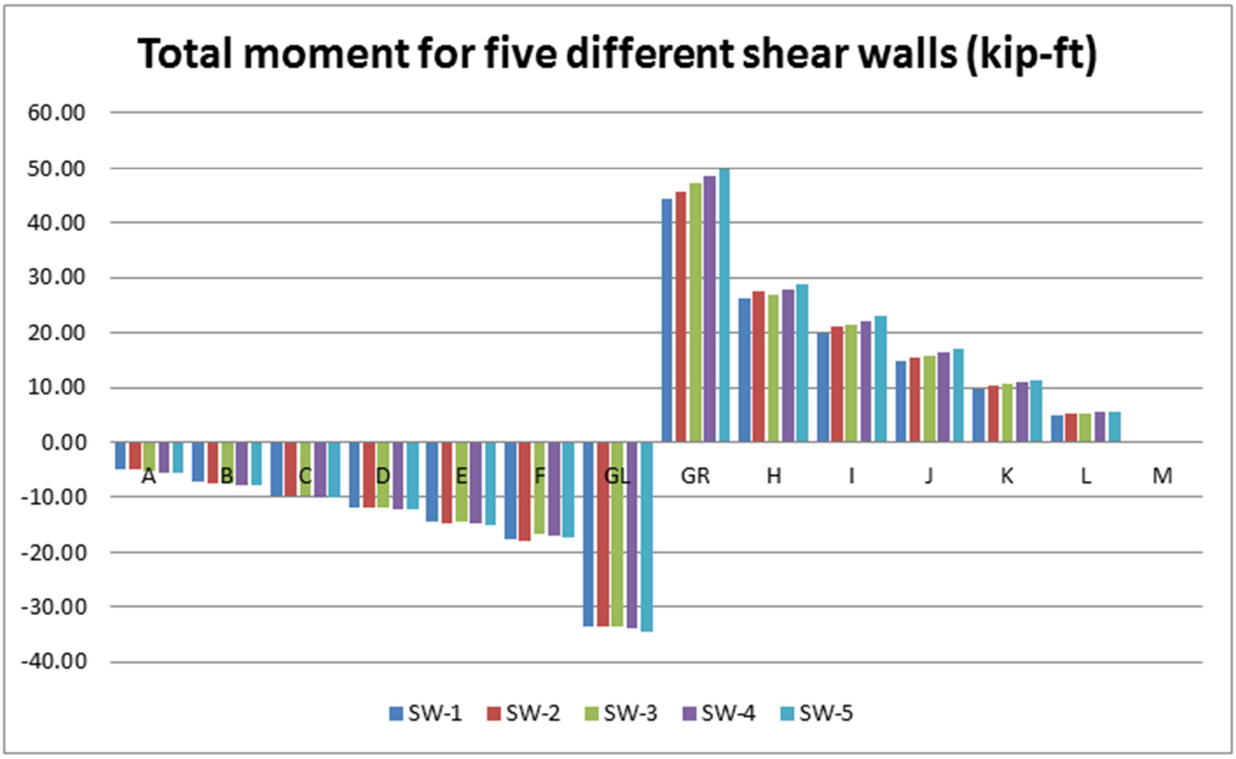

Figure 7. *Moment in each line (kip-ft) for five different shear walls.*

In this study, it is shown that, the properties of moment remained same with the length variation of shear walls such as moment for line A to GL is negative and GR to M is positive for all shear walls. Moment in magnitude has been increased with the incensement of shear wall length but it is very small scale. For line GL, SW-1, which length is 4.5ft, produces negative 33.5kip-ft moment while SW-5, which length is 8.5, produces negative 34.5kip-ft moment and for line GL, SW-1 produces positive 44 kip-ft while SW-5 produces positive 50 kip-ft. Increasing percentage of moment in magnitude is almost same for all other lines.

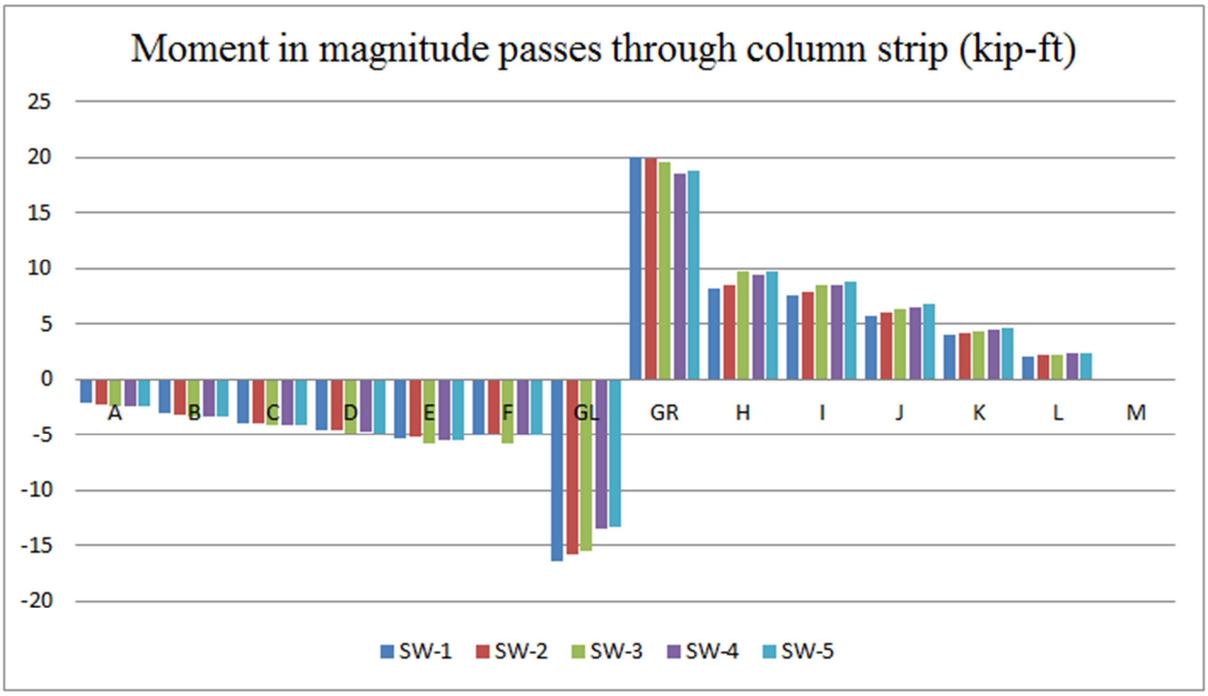

Figure 8. *Moment passes through column strip.*

Earlier, it is seen that, moment in magnitude increase by increase of shear wall length but decrease the percentage of total moment passes through column strip. However, the figure shows that, the moment magnitude passes through the column strip decrease if we increase the length of shear wall. In SW-1, for line GL, this is closet to column and also carries maximum negative moment, produces negative 16 kip-ft moment while SW-5 produces negative 13 kip-ft moment. Almost same behavior is seen for line GR, this is closet to column and also carries maximum positive moment.

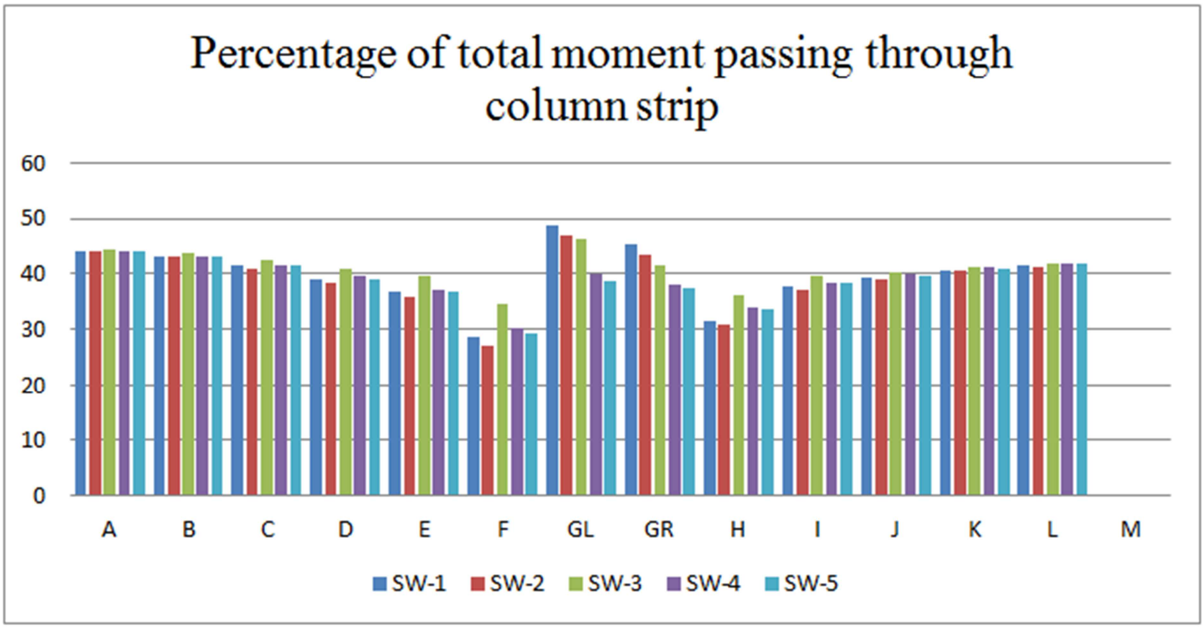

Figure 9. *Percentage of total moment passing through column strip.*

It is also noticed that, in SW-1, around 49 percent of total negative and 45 percent of total positive moment pass through column strip. By increasing of Shear Wall length, moment percentage of total negative or positive passing through column strip decrease. For SW-5, which length is 8.5ft, around 39 percent of positive and 38 percent of negative moment pass through the strip.

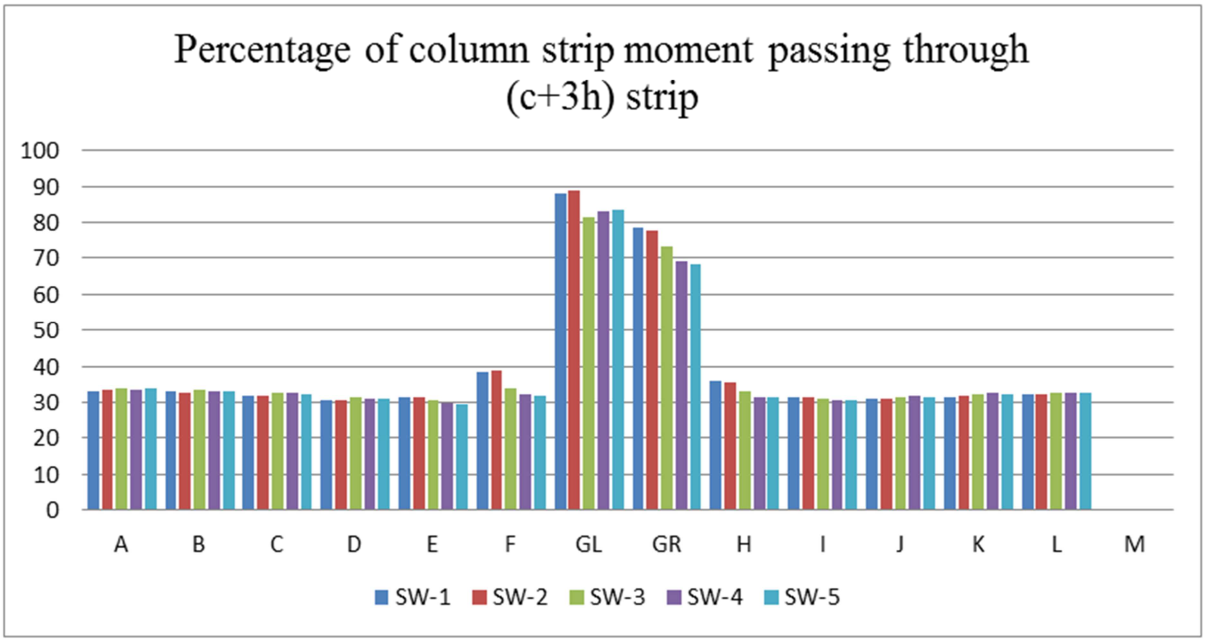

Figure 10. *Percentage of column strip moment passing through (C+3h) strip.*

In SW-1, around 85 percent of column strip moment passes through effective (c+3h) strip while rest of the moment passes through rest of the area of the column strip. By the increasing of shear wall length, the moment percentage of column strip moment passing through effective (c+3h) strip decrease in small amount.

From the above study, it can be summarized that, moment will decrease in column strip with the increase of shear wall length and it will be true upto total middle strip length. But to show the decrease rate (moment decrease per unit length), we consider the line GL and GR as those are carrying maximum negative and positive moment respectively. To understand the decrease rate, four points-A, B, C, D are introduced. Rate change for SW-1 to SW-2 is defined as point A, while rate change for SW-2 to SW-3 is defined as point B, rate change for SW-3 to SW-4 is defined as point C and rate change for SW-4 to SW-5 is defined as point D.

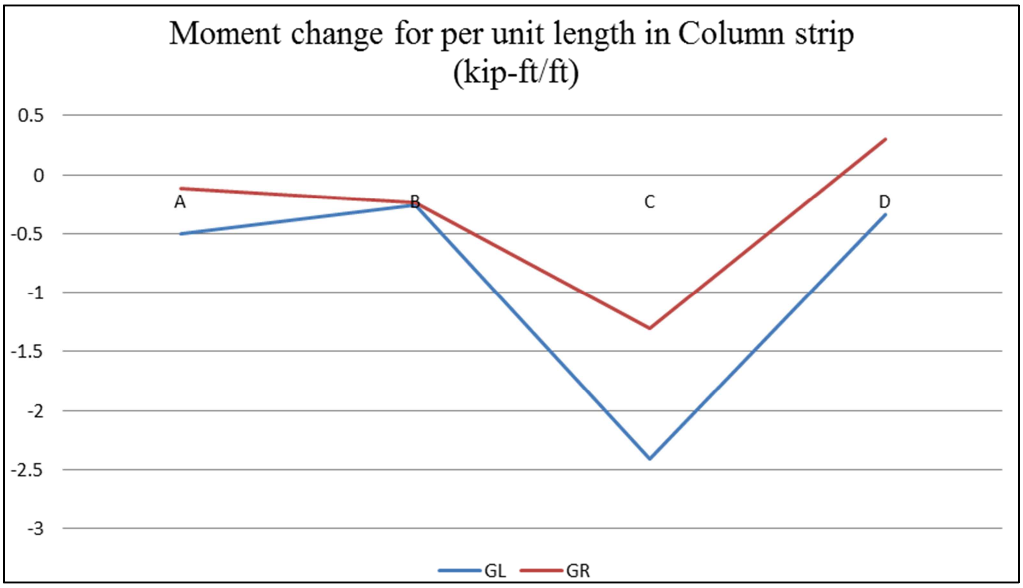

Figure 11. *Moment change for per unit length in Column strip.*

From the study, it is also shown that, the increasing of shear wall length reduces the moment in column strip. From point A to point C decreasing rate is increasing gradually and again after point C decreasing rate is decreasing. It means, if shear wall length is increased after point C, moment decrease in small amount with respect to prior point C. So, the length of shear wall at point C will be preferable length from the study. The length will be 33% approximate (6.67ft under 20ft span) of total span length.

4. Conclusions

From the study, it is shown that, the properties of moment remained same with the length variation of shear walls. Moment in magnitude has been increased with the increasing of shear wall length but it is very small scale. But by increasing the length of shear walls, the percentage of total moment passed through the column strip will decrease and increase in middle strip.

If the length of shear walls increase, the moment magnitude passes through the column strip will decrease and vice versa for middle strip.

Around 85 percent of column strip moment passes through effective (c+3h) strip while rest of the moment passes through rest of the area of the column strip. By the increasing of shear wall length, the moment percentage of column strip moment passing through effective (c+3h) strip decrease in small amount.

It can also be said, the moment at column strip will decrease by increasing the shear wall length and it will be true up to total middle strip length. But it will be difficult to provide the huge amount length of shear wall for financial and room arrangement problem. So, the length 33% (approximate) of total span will be preferable length for optimum from the study.

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