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SURVEYING THE EFFECT OF METAL CROSS BRACE IN CONCRETE STRUCTURES

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ABSTRACT

Studying past earthquakes in Iran have shown that many of the reinforced concrete buildings do not have enough resistance against earthquakes. There are various methods to strengthen reinforced concrete structures such as shear walls and metal cross brace, the cover sheet, post-tension and infills, among which using metal cross brace is more common and sometimes shear frame is used along with shear wall and metal cross brace. By increasing the area of the harness cross brace, shear force is reduced by the frame and after a certain extent, it does not have a special role in absorbing earthquake shear force, then it is necessary to examine the structural behavior. Brace and frame behavior was similar in the lower classes and absorbing the earthquake shear by each one in the lower and middle classes is roughly equal. In order to study the combinational behavior of metal cross brace and the effects of cross brace area on the behavior of reinforced concrete structures and the percentage of shear absorbed and lateral displacement of the structure, here a ten-storey reinforced concrete structure in 4 stages will be analyzed. In stage one, only the shear frame, in the second stage, frame and shear wall and in the second stage, frame along with shear wall and metal cross brace will be explored. Building structure and stability depends on its structures and constructions. Construct or any building or structure has two important tasks to undertake. The first task is that the structure can have aptly stability in different environmental conditions such as cold, heat, wind, storm or flood and earthquake and if it is the peoples' accommodations or equipment, it should provide safety of life and property of its citizens. The second task of the structure is that it should be coordinated with the functional concepts and aesthetic requirements of architecture and coordinate of our environment and have inherent flexibility and consistency while having violence and inherent strength.

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KEY WORDS

metal cross braces, concrete construction, concrete structure with metal cross brace, concrete structures, metal cross brace.

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INTRODUCTION

In stage one, only the shear frame, in the second stage, frame and shear wall and in the second stage, frame along with shear wall and metal cross brace will be explored.

For the parametric study, reinforced concrete structure with 5 spans 4 meters in X direction and four 3-meter span is in Y direction have been selected. Residential use of floor dead load of 650 kg / m2, load volume of 150 kg / m2 live load floors and roof of 200 kg / m2 are considered. Putting cross brace and shear wall in the X direction on axis 1 and 5 is ok in terms of architecture. The place of shear wall and cross brace have also been specified in **[Figure-1]**. Compressive strength of concrete (cylindrical sample) is considered f"c = 2800 kg / cm2. Major metal yield stress fy = 3000 kg / cm2 and stirrups fy = 2400 kg / cm2 have been considered. Floor height is 3 meters. Lateral load system in X direction (East - West), complex system of space shear frame, cross brace and shear wall and in Y direction (North-South) is only space frame. To load, 519 and 2800 Iranian Regulation and for the design of reinforced concrete, ACI Regulations and for metal members, AISC Regulation were used. To calculate the earthquake load, semi-static method of Regulation 2800 has been used. Ceilings are assumed to be rigid. Earthquake force is applied to the structure only in the X direction and according to the second compound (1.87 E) 0.75. The analysis is done in four stages. In the first stage of analysis, three-dimensional frames is influenced under vertical loads and 25%seismic forces. Here, the frame members should tolerate an increase in the vertical load, 25% of earthquake force, recommended according to Procedures 2800 (structural F25). Also, at this stage, reinforced concrete frames is influenced under vertical load and 100% of that earthquake force **[Figure- 3** Structures FWI). The purpose of this two-step analysis is that dimensions of walls and beams and columns are determined in such a way that frame can tolerate 25% of earthquakes force and walls 75% earthquake force in order that the design is economic and optimal.

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In the third stage, frames is analyzed with shear walls and metal cross brace under the vertical load and 100% of seismic force and the interaction of shear walls and metal cross brace has been studied on reinforced concrete frame **[Figure- 4]**Structures FWBI). In the fourth stage of analysis, the frame with cross cross brace without shear wall is influenced under the vertical load and 100% of the earthquake force. The area of the required cross brace to strengthen the existing reinforced concrete structure has been determined. **[Figure-5]**- Structure FBI).

1. Article

In the structure, F is reinforced frame structures, W is shear wall and B metal cross brace.

First level:

After analyzing the structures, lateral displacement curves in various storeys for the analysis stage has been shown in **[Figure -6]**. In the first phase, three-dimensional frames was influenced under vertical load and 25% earthquake force. As can be seen in [**Figure- 6**, the frame has been displaced in shear mode in F25 structure. The maximum displacement is on the tenth floor of 6.23 mm. The amount of displacement and cutting absorbed by the mold for this purpose are calculated as the quantity of cross brace and shear walls causing the frame to withstand only 25% of the earthquake is achieved. The dimensions of the columns and beams at this stage is used at a later stage as the criteria. In this process, the frame is influenced under vertical load and the total earthquake load (structural F100). According to **[Figure- 6]**, reinforced concrete frame has been deformed as shear and lateral displacement on the tenth floor is 94 mm, which is about four times with F25 structures.

Second level:

At this stage, the frame with four different shear wall is analyzed in various states under vertical load and 100 earthquake force and the following cases are discussed. **[Figure- 7]**shows the effects of wall thickness shear effect on the cutting rate absorbed by the frame. By absorbed cutting rate, the ratio of the shear frame tolerated by columns or cross brace in each category to total cutting on each floor. First, it was tried that absorbing earthquake force by the frames is as much as 25%. If the thickness of the walls is very low (in all classes 7 cm - Structure FW2), although the frame destroys 25%earthquake force down on the floor, force attraction by the frame increases in other storeys and structure displacement will also be very high. In order that structure displacement in the second stage becomes similar with frame displacement only under 25% earthquake force (F25), it is necessary that the thickness of the walls at 80 cm 10 cm in both floors is reduced, respectively, and reach 40 cm on the tenth floor which these thicknesses are not executable (FW3). In this case, although the absorption of the earthquake by frame in the floors is about 25%, the force absorption in the first floor by the frame is about 5% **[Figure-7]**If the thickness of the walls to be considered reasonably and administratively (FW1), that is, 20 cm at the bottom of the wall thickness and reaches 2.5 cm in both floors, as can be seen from **[Figure- 7]**, the structure shows a more balanced behavior. Since this state is considered as criterion, it is discussed below:

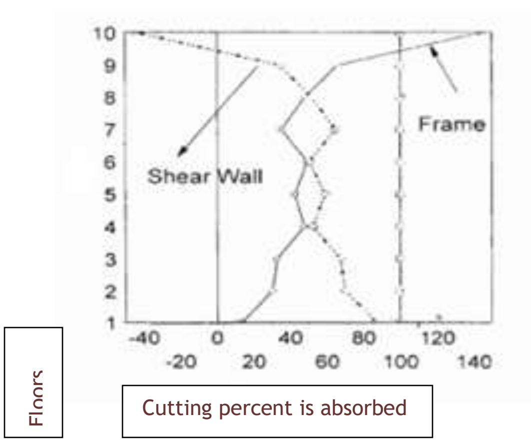

Fig:1. Iinteraction frame - double shear (structural fw1)

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[Figure- 8]shows frame and shear wall interaction in structures (fw1). As seen in this figure, the frame determines 13.3% in the lower part and shear wall absorbs 86.7% of earthquake force. Force absorption by the frame in the second to 9th floor varies between 30 and 65%. Due to the interaction of the frame and the wall, the wall has a bending behavior; in the upper parts, the frame helps the wall and as seen, force absorption by the wall is 45%. That means that not only the wall does not absorb earthquake, but also produces a force in the direction of earthquakes force. For this reason, the frame on the second floor absorbs about 5.14 percent of earthquake force, which is not very good. To address this problem, the wall in the upper floors is cut. The following mode was emerged by these analyses (fw4).

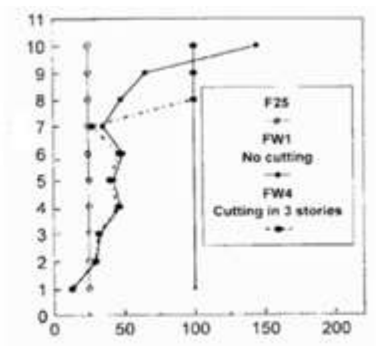

Fig: 2 . The effect of shear walls cut at the top on cutting absorbed by the frame

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[Figure- 9]shows that if the shear walls in the three top floor is interrupted (h * h / h = 0.7, not interrupted floor height of the wall and h total height of the building.) the percentage of earthquakes force absorption by the shear wall will not be negative in any floor and the earthquake in the three upper floors is tolerated by the frame. this method is more economical and no significant difference can be seen in terms of displacement.

Third level:

at this stage, frames with shear walls and metal cross brace influenced under vertical loads and one hundred percent seismic forces and the effect of cross brace and its surface on the behavior of a reinforced concrete building strengthened by two shear walls on each floor is investigated. in this section, instead of two shear walls of second level, two cross cross braces are considered **[Figure-4]**. in this level, it has been tried that the displacement changing load achieved in the first and second level becomes similar with displacement by relocating the cross brace level and in another state, shear force absorption by the frame in the third and second level becomes similar. the multiple analyzes show that if for all properties, structures fw1 is used only for cross cross brace, first and second floors with an area of 48 square centimeters, channel 16 with an area of 48 cm2 and in the third and fourth classes, two channel 14 with an area of 41 cm2 and in the fifth and sixth channel, two channel 12 with an area of 34 cm2 and in the 7th and 8th floors, two channels with an area of 27 cm2 and at the ninth and tenth floors, two 10channels with an area of 27 cm2 were used. relocation of the second and third levels becomes similar (structures fw1, fwb1). **[Figure- 7]** indicates this issue. as

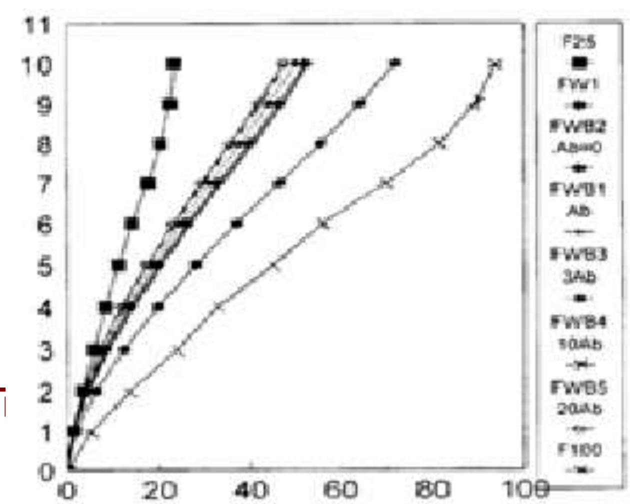

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Fig:3. Area bracing effect on the lateral displacement (stage iii)

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can be seen in [**Figure -10]**, even if the area cross brace are 10 times (structural fwb4) displacement of structure at this stage cannot be equal with the first stage (25% of earthquake force and covers only, the structural f25). thus, it can be concluded that if in a reinforced concrete structure, the lateral displacement exceeds the allowed limit in order that a certain amount of cross brace area can be influenced and then it will not have a specific effect on structure's behavior. also, if a cross brace is not used (structure fwb2) lateral displacement significantly increased.

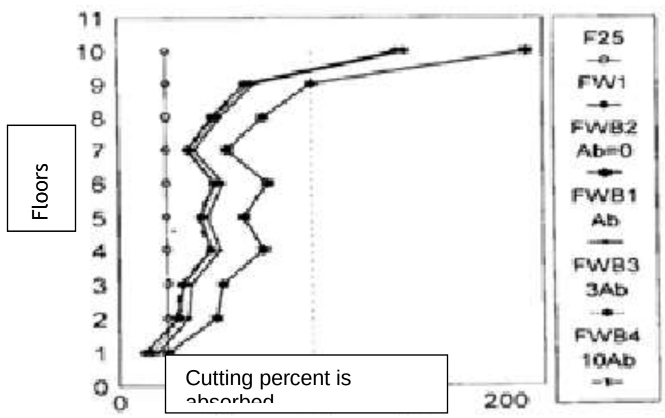

Fig: 4. The effect on the absorption area braces for earthquake

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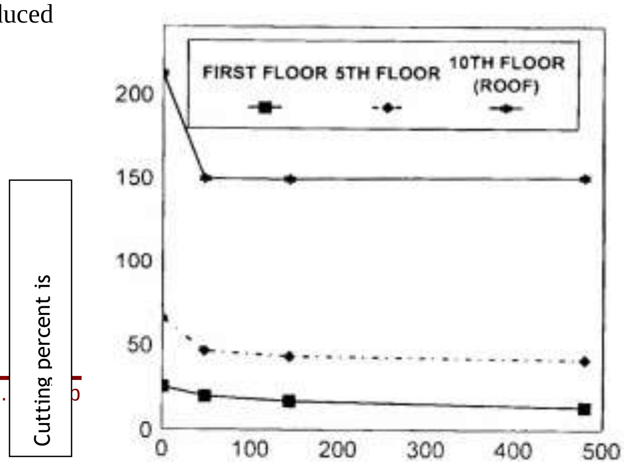
[Figure- 11]shows the absorption method of earthquakes force by the frame for the first, second and third levels of analysis as well as the effects of cross brace on structure's behavior. if the area of the cross brace is selected 3 times higher than the above mentioned, absorption percentage in the two structural frame fw1, fwb3 becomes similar, however, fwb1 structure presents an almost similar curve with fw1 structure. so finally fwb1 structures at this stage will be used as the criterion. according to the results, optimum surface for cross brace for designation is suggested. if the cross brace are removed from the system (e.g., fw2 frame structure and two shear walls) absorption cutting earthquake increases so that in the last floor, cutting absorption by the frame reaches 200%; in other words, shear walls have negative effects and lean on the frame. by increasing the cross brace area, cutting absorption by frame is reduced especially on the top floor. it can be claimed that the negative effect of shear walls is reduced from 200% to 150%.



Area braces

Fig:5. The impact on the absorption area braces for earthquake by frame (the third stage of analysis)

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[Figure- 12]specifies changes of earthquake cutting absorption by frame than the area cross brace. as can be seen, cutting absorption by the frame is reduced by increasing the cross brace area from a certain limit (about 50 cm), cross brace do not have a special role in absorbing earthquake cutting; in other words, not every type of reinforced building concrete can be strengthened by metal cross brace. to determine the exact extent, different buildings with different height spans should be analyzed and eval

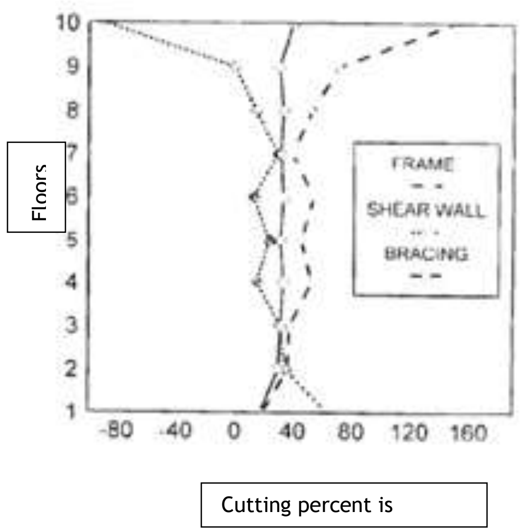

Fig:6. Interaction frame, shear wall and bracing (structures fwb1)
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[Figure- 13]shows the interaction between frames, shear walls and metal cross brace in the structure fwb1. it can be observed from this figure that the behavior of the cross brace and the frame at the bottom is similar to each other. the frame is experienced a very high cutting at the top, while the cross brace has a similar behavior at the top and bottom. despite the cross brace, earthquake absorption by the wall is reduced, but cross brace absorbs the force at the last floor and on the other hand, negative wall cutting increases.

in fw1structure, cutting absorption above is done by the wall 44% and while fwb1 structure has been considered 84%. this figure also shows that the wall cutting in the top floors does effect on the earthquake absorption by frame; however, it increases negative cutting of the wall.
fourth level:

in this level, the frame along with metal cross brace without shear wall under the influence of vertical load and one hundred percentage of earthquake force has been analyzed. in the structure's model, all shear walls have been removed and instead metal cross brace was used. thus, the effect of cross brace on the behavior of a bending space frame of reinforced concrete will be examined. for the lateral displacements of structures in the second phase (frame with shear wall without braces) and the fourth phase (frame with cross brace without shear walls) becomes

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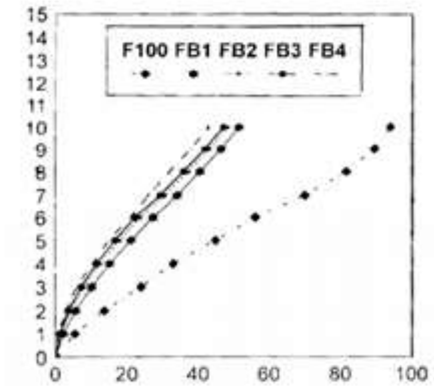
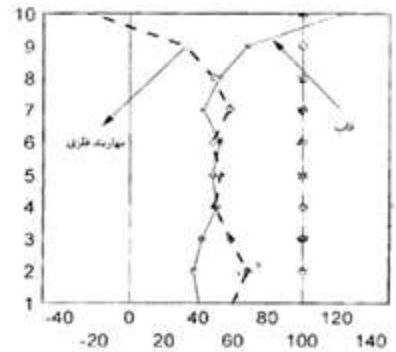
similar, the cross braces in fwb1 structures was used (structural fb1). in this state, absorbing earthquake force by frame on the first floor is about 40%.





Floors

Shift Accessories

Floors

Cutting percent is

Fig:7. Area bracing effect on the lateral displacement (stage iv) bracing and reinforced concrete frames (structuresfb1)

Fig: 158.percent cut absorbed by

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fb1 structure displacement in the roof floor is 4/51 mm, which about half the roof floor structures of reinforced concrete frame is without brace **[Figure- 14]**. in other words, comparing two systems of bending frame with and without cross brace shows that using metal cross brace reduces structure displacement almost 50% and increases structure stiffness as much as two times. deformation of reinforced concrete frame strengthened with cross brace is by a combination of bending and shear mode. **[Figure- 15]**shows the percentage of cutting absorbed by the cross brace and reinforced concrete frame in various floors for fb1 structure. due to the different behavior of reinforced concrete and metal bracing, an interaction occurs between the frame and the brace. down on the floor, cutting absorption is about 40% and by cross brace is about 60%. due to the different behavior of the frame and cross brace in the upper floor, force absorption by the cross brace above is negative; that is to say, not only cross brace absorbs absorb earthquake force, but it generates additional power which the frame should tolerate it. in other words, cross brace does not continue only in the upper floors, the cross brace behavior and the frame in the middle and lower floors are almost the same and the absorption of earthquake cutting by each is equal.
the effect of cross braces area;

after examining the effect of bracing in reinforced concrete frame, in this case, the area of cross braces has been increased and lateral displacement of the structure and the amount of cutting absorbed by the frame brace have been investigated in the fourth stage.

after examining the effect of bracing in reinforced concrete frame, in this case, it increases the area of braces and the lateral displacement of the structure and cutting absorbed by the frame braces have been investigated in the fourth stage. as previously described in the fb1 structure, absorbing earthquake force by the frame in the first floor is about 40%. for the earthquake force absorption by frame on the first floor reach about 25%, the braces area to fb1structure increase 2.5 times (structure fb2). if the area braces increases 5 times compared to fb1 structure, earthquake force absorption by the frame on the first floor reaches 16% (fb3). in fb4 structure, braces area to the structure fb1 has been exaggeratedly 1000 times. in **[Figure -14],** lateral displacement of structures f100, fb1, fb3, fb4 can be seen in different floors. by increasing the braces area, reducing the lateral displacement is not significant. for example, comparing the two structures fb1, fb4 shows that the lateral displacement on the tenth floor decrease from 51.4 mm in fb1structure to 43 mm in fb4 structure (about 16%). it was also concluded that if an existing reinforced concrete structures exceed lateral displacement from a certain amount, a certain amount of

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cross brace area can be influenced and after this certain limit, it will have little effect on the structure and if a cross brace does not use (structure f100), displacement significantly increases.

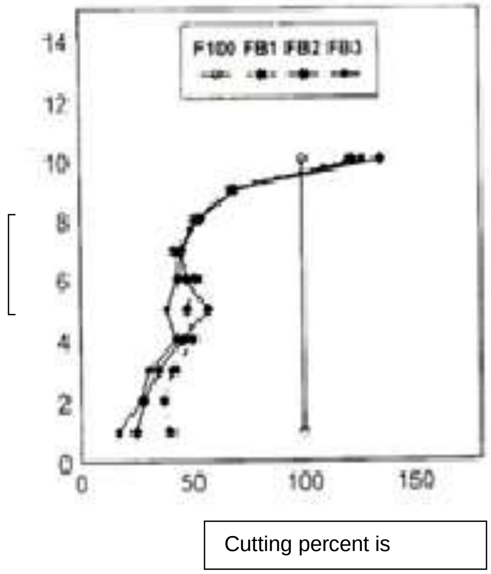

Fig: 9. Area braces absorbed by the frame effect on percent cut

[Figure-16] shows earthquake force absorption by the frame for different values of the cross brace area. according to the derived areas in structures fb2, fb3, fb4 that seem not reasonable executively, it could be concluded that the existing of reinforced concrete structures are better strengthened by shear wall or a combination of shear wall and cross brace. the use of metal braces alone in reinforced concrete structures causes large forces in the frame members (beams and columns) are emerged. in this case, it is necessary to strengthen the members and the foundation which are not affordable economically and has its own problems in terms of implementing as well.

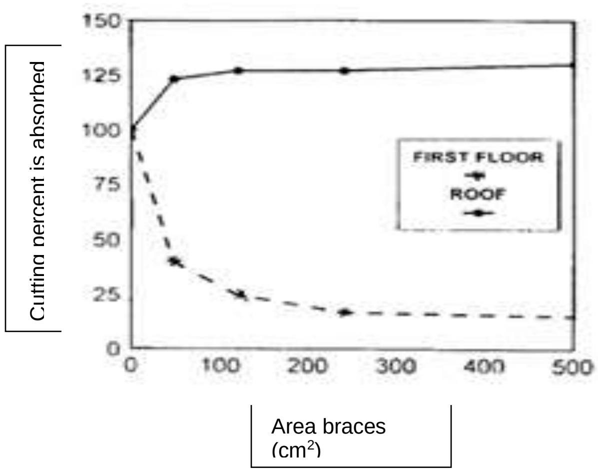

Fig: 10. Area braces absorbed by the frame effect on percent cut

in [Figure -17], the effect of braces area on the cutting percentage absorbed by the frame in the first floor and roof can be seen. on the first floor (dashed curve), shear amount is reduced by the bearing frame with the increase of braces, i.e. the braces in the lower floors help frame and at a certain point onwards, existing cross brace has not much effect on tolerating earthquake cutting. at the roof floor (solid curve), cross brace behavior is reverse. in other words, by increasing the cross brace area, the percentage of absorbed cutting by the frame increases and is more than one hundred percent. according to this conclusion, existing cross brace in the upper floors is not only not helpful, but should be discontinued. the maximum article pages that include text and all its components, including figures and tables, is 8 pages.

CONCLUSION

Using cross braces to strengthen the existing reinforced concrete buildings with shear walls shows that cross brace behavior and frames in the lower floors are similar to each other and in upper floors, earthquake shear force is largely tolerated by frame. It can be observed from the results that cross brace almost constantly tolerates earthquake cutting in the height, while shear wall at the bottom are working well and has a negative effect on the upper floors. Cross brace helps strengthening the structure to a certain extent and determining the optimal amount for braces area needs further research and different structures with different heights and openings should be analyzed and studied. The results showed that in FB1 structure, the lower floor of cutting absorption by the frame and cross brace, upper floors due to the different behavior of the frame and brace and force absorption by the cross brace above is negative, i.e., not only it does not attract earthquake force, but it generates an additional force that the frame should tolerates it. To solve this problem, it is recommended that cross braces do not continue in upper floors. By increasing the cross brace area, the cutting absorption in the lower floors decreases; but in upper classes, cutting absorption is done by the frame. Brace and frame behavior was similar in the lower classes and the lower floors and earthquake cutting absorption by each one in lower and middle classes is almost equal. Comparing two systems of bending frame and metal cross brace reduces lateral displacement of the structure to about 50 percent.

3. Relations, figures and tables

3.2 Figures and Tables

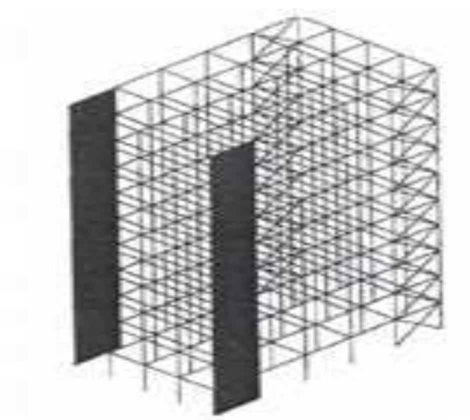

Fig: 11 . third stage analysis - frame shear walls and steel bracings under the force of the earthquake(fwb1)

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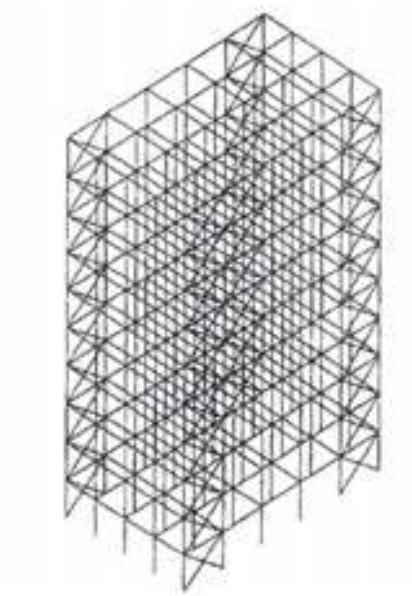

Fig:12. The third stage frame analysis and bracing

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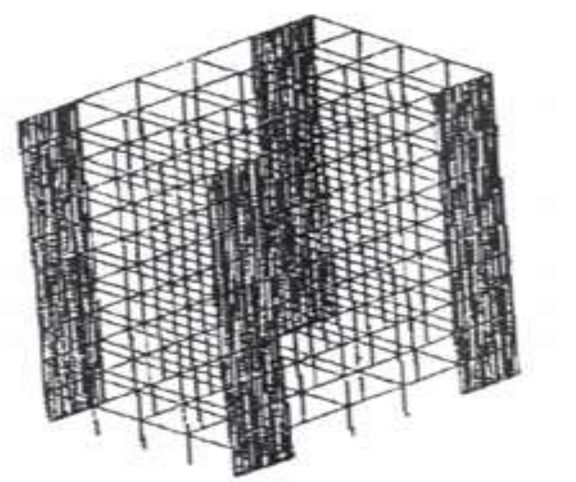

Fig: 13-the second stage analysis of frame and shear walls(fw1)

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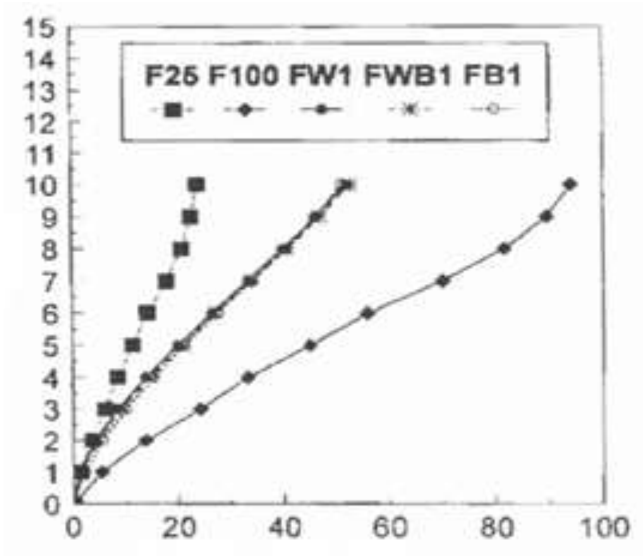

Fig: 14. Wall thickness shear effect on the absorption earthquake cut by frame

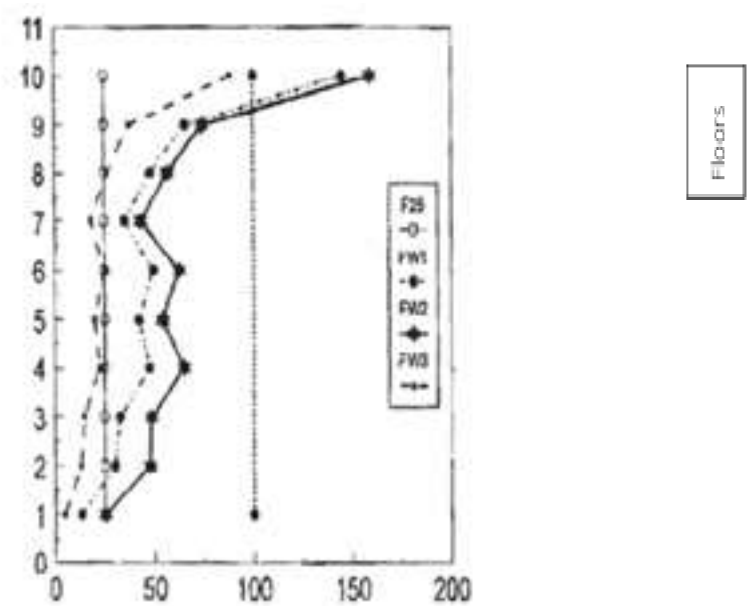

Fig: 15. Change lateral structure in the various classes for four Analytics

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CONFLICT OF INTEREST

Authors declare no conflict of interest

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None

FINANCIAL DISCLOSURE

None

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