International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

The Performance Analysis of the Difference Types of Steel Bracing for the Reinforced Concrete Building

Ayaanle Ali[A]**, Erdal Coskun**[b]**,**
[A]institute of Civil Engineering, Structural Engineering Program, İstanbul Kültür Üniversitesi
[B] Department of Civil Engineering, İstanbul Kültür Üniversitesi

***Abstract*: - In general, reinforced concrete building is mainly designed only to resist the gravity loads that acting on the structure, therefore, while designing the moment resistance frame, engineers do not pay more attention to the earthquake loads that can cause the building collapse. This study is concerning about the retrofitting of the existing structure by using steel bracing system, so in this study steel bracing is used as an active part of the lateral load resisting system of the structure. The main objective of this research is to check the performance of the concentric bracing system by using static nonlinear pushover analysis and static linear system (equivalent method). This study is deeply investigating the comparison of the different types of CSB system to reach one of the most effective during the earthquake. The different types of steel bracing systems tested during this study are, x- bracing, diagonal bracing system, inverted bracing system, and zipper bracing system, and the various RC structures used during this study are three-story building, five-story building, nine-story building, twelve-story building.**

Keywords: Earthquake, pushover analysis, steel braced, seismic, retrofitting.

.

INTRODUCTION

The steel bracing system is one of the methods of retrofitting system intended to insert the existing structures that damage during the earthquake. The function of the steel bracing is to resist the lateral loads acting on the building. Lateral loads are the forces coming from the wind and earthquake wave when they act to the structure. Steel bracing commonly made on a steel, and it helps the structures for protection of the lateral loads, and also it takes part in the energy dissipation within internal tension and compression during the earthquake. Structural elements like column and beam they help the structure from the loads that coming in the vertical direction, and the function of the steel bracing is the protection of the horizontal lateral loads. The inserting steel bracing depends on the type of damage of the structure but commonly, steel bracing is used to put in the openings between the vertical elements but steel bracing can be internal and external it depends on the condition of the building. There are two types of steel-bracing, and they are (concentric steel-bracing and eccentric steel-bracing); therefore, this research is concerned the concentric steel-bracing system. There are two types of concentric bracing system, and they are: concentric steel bracing (CBF) and the special concentrically bracing (SCBF). The difference between these two concentric systems are, SCBF can absorb more deformation in tension and compression than CBF. SCBF uses to give the soft story stability for the seismic loads that acting on the building.

OBJECTIVES AND SCOPE OF THIS STUDY

The importance of this investigation is to assess the performance of the concentric bracing system during seismic activities. The performance of the steel-bracing in the RC buildings has analyzed by SAP2000.
The following are the objectives of the study.

- The enhancing the safety of the existing structures that harm during the seismic tremor.
- Checking the performance of the various types of concentric steel bracing system through the existing Rc structure.
- Evaluation of the impacts of the horizontal loads acting on the building.
- Increasing safety against the horizontal loads that are acting on the structure during the seismic activity.

THE PUSHOVER ANALYSIS METHOD

This method is a applying direct lateral-loads on the frame, starting from zero to a value of cross bonding to an exact displacement- level and determining the possible weak members and the failure members of the structure. The performance of the building is evaluating by using hinges position at the target-displacement or the performance-point corresponding to an exact earthquake- level. The acceptable performance is the demand is less than the capacity of all the hinges positions as the loading and assessment procedures are only virtually correct concerning the real-earthquake hazards.[1]

HISTORY OF PUSHOVER ANALYSIS:

The list of the researchers studies the pushover method are as follow: -

- (Fajfar and Fischinger-1987) these researchers propose the N2 method as a non-linear procedure is appropriate to design the regular building oscillating mainly in a single mode.
- (CSM) capacity spectrum method approved ATC-40 (ATC 1996), was the first introduced in the 1970s through freeman as a quick assessment procedure for the evaluation of vulnerability structures during the earthquake (Freeman 1975; Freeman 1978). The analysis procedure is compers to the capacity of the building in a curve called pushover-curve and the demand of the ground-motions under construction in the way of elastic response spectrum. [2]

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

- (Mahaney-1993) this researcher proposed the acceleration-displacement-response-spectrum (adrs) that the spectral-acceleration versus spectral-displacement is plotting in a curve, with a period (T) stands for the radial lines. The crossing of the capacity-spectrum and the demand-spectrum make available of the displacement-demand and the inelastic-acceleration—the capacity spectrum method was-updated (FEMA-440 2006).[3]
- The federal-emergency-management-agency first introduced Coefficient-Method (CM) in the USA (FEMA-273 1997) and then developed a pre-standard for the rehabilitation of the structures in seismic hazards FEMA-365 (2000). Later this method is updated into FEMA-440 (2006).

ASSESSMENT OF THE PUSHOVER METHOD PROCEDURE

The pushover procedure performed to the analysis of the lateral base-shear and the roof-displacement relationship of the building. The pushover-curve for the structure, including the initial linear, in which the frame members are deforming in their elastic Behavior to the inelastic region, where the beam and the column members start developing plastic-hinges. If the lateral deformation continues, the other plastic deformation happens to the structure.

MODAL PUSHOVER ANALYSIS (MPA):

This method has been establishing to account for the more significant mode effects. This analysis method is highly exact if the building is very deforming into the zone of stiffness and failure in strength. This method is making on the supposition of the standard model-analysis that extended into an inelastic system. The seismic response is determined in the modeling development of the seismic effects by pushover analysis using force distribution in each mode. The calculation of the complete reaction of the structure is obtaining by combining these model responses through the SRSS model combination method.

METHODOLOGY:

This part is the modeling and base-shear analysis of the structures. The most significant part of this is about designing the RC models and checking their strength by SAP2000 programming. SAP2000 programming is utilizing the RC model during this study, and it's using for checking the quality and limit of the structural components before reaching the highest expecting displacement of the model. The analysis method used during this study is a pushover method.

DISPLACEMENT DURING PUSHOVER ANALYSIS

The force-displacement method shows that the displacement modification curve below has higher precision and can be used for tensile frames through a computer because the computer software can't do displacement-based for the pushover method. So, the displacement force method must be making, even if it has lower precision. The computer analysis will adjust the incremental dynamic, which represents 2% of the displacement process, to decrease the variation of the pushover curve in the building response using the pushover method. Also, to get the non-linearity behavior of the building, the pushover curve must be defined. [4] [5]

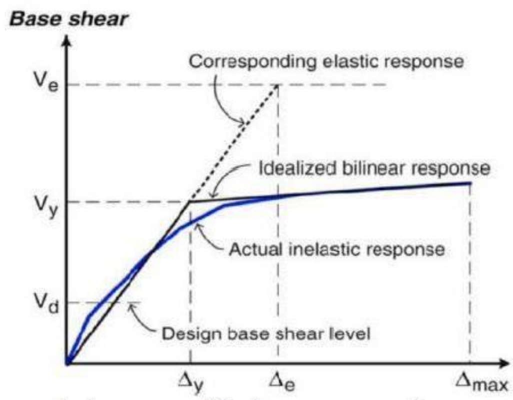

Figure 1: Displacement modification curve [4][5]

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

PLASTIC HINGES

The occurrence of the plastic hinges is the building by using the pushover method will vary according to the no of story, also the type of bracing system and the type of plan shape of the structure. The plastic hinges will reach different limits according to the deformation of the steel bracing system because of the failure moment underground motion. In this study, plastic-hinges will be under three properties. (IO) immediate occupancy, (LS) life safety, Cp collapse prevention, A, B, C, D, E according to the condition of the hinges. This part, the comparison between the same no of stories and the plan shape, will be analyzed by the pushover curve on the X and Y-axis. [4]

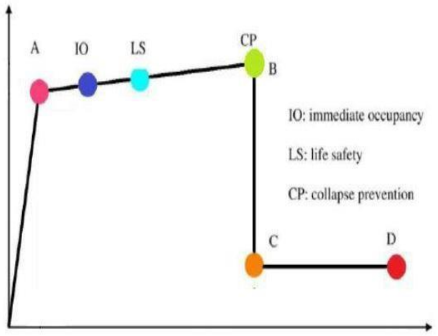

Figure 2: Type of plastic hinges [4]

MODELING

This model is existing residential RC buildings, located in Gazimağusa, North Cyprus designed with 10% probability of being exceeded in 50 years or 475-year return period [34**].**

Table 1: [7]

THE PROPERTIES FOR THE GEOMETRICAL PLAN:

The properties for the geometrical plan dimension:

- The floor plan dimension is 31m^2.
- The base width and length of each room are 36M^2.
- The height of each story is 3.5M.
- The building type is a residential structure.

Figure 3: Building geometry

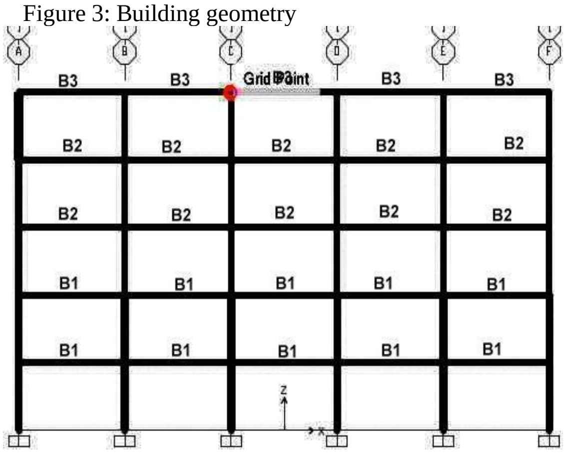

Table 1: Dead and live load details of beams

Load Name	Load Type	Detail	Value
Dead	**Dead Load**	**Slab self wt (6" thickness)**	**3.60 kN/m^2**
		Floor Finish	**1.43 kN/m^2**
		Partition Wall	**1.43 kN/m^2**
		Wall load	**8.1 kN/m**
Live	**Live Load**	**On floor**	**3 kN/m^2**

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

Table 2: Reinforcement details - beams

B_1 (400 × 350 mm^2)		
At left and right supports	Top bars	**A_s = 3800 mm^2**
	Bottom bars	**A_s = 2200 mm^2**
B_2 (400 × 350 mm^2)		
At left and right supports	Top bars	**A_s = 3423 mm^2**
	Bottom bars	**A_s = 1722 mm^2**
B_3 (400 × 350 mm^2)		
At left and right supports	Top bars	**A_s = 1670 mm^2**
	Bottom bars	**A_s = 1540 mm^2**

Table 3: Reinforcement details – columns

Floor level	**Interior columns**		**Exterior columns**	
	Size (mm × mm)	Reinforcement	Size (mm × mm)	Reinforcement
Ground floor	450mm*450mm	20mm@- #8bars	450mm*450mm	20mm@- #8bars
First floor Second, third	450mm*450mm	20mm@- #8bars	450mm*450mm	20mm@- #8bars
Fourth floor	350mm*350mm	18mm@- #8bars	500 ×500	18mm@- #8bars
Fifth floor	350mm*350mm	18mm@- #8bars	500 × 500	18mm@- #8bars

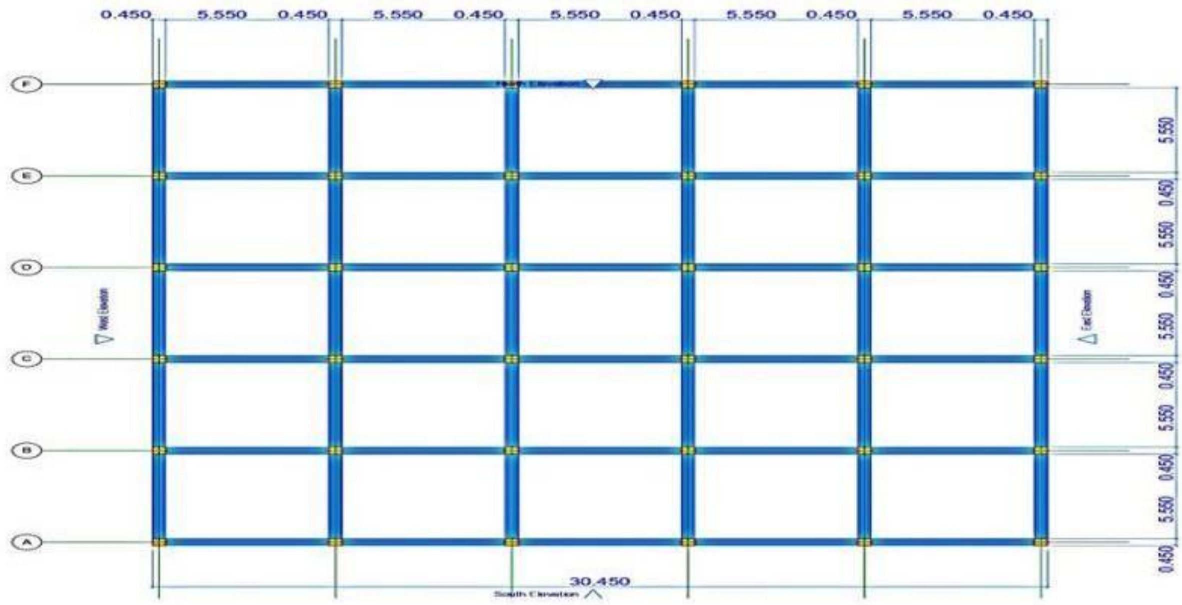

Figure 4: plan of the models

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

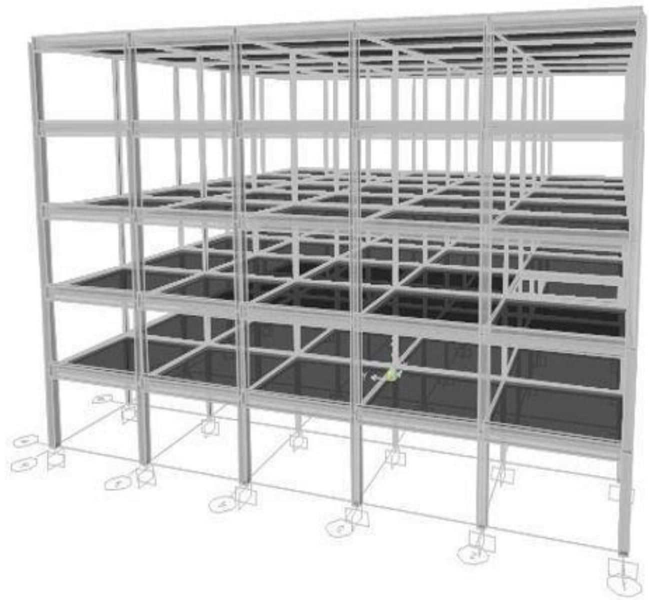

Figure 5: Five story model [2]

STEEL BRACING SYSTEM

The function of the steel bracing is to protect the structure the earthquake loading. Also, steel bracing system increases the strength of the RC building. After more research and application, this idea has become more relevant for seismic protection because of the simplicity of the implementation, and its more relatively cheaper than the shear wall. For example, Sugano and Fujimura performed a series of tests on a frame model of one story, which had been strengthened by a steel bracing system; they compared with a masonry infilled wall. They aimed to understand the effect of each of these systems; then, they found that the steel bracing system has more strength than the masonry filled wall during the seismic activity. [8]

CONCENTRICALLY AND ECCENTRICALLY BRACED FRAMES: -

Steel bracing system is designed primarily to resist the earthquake and wind loads. The members of the steel bracing are intending to work in compression and tension like the truss. Steel bracing members decrease the sheer force and reducing the bending moment on the columns and the beams in the structure, also they decrease the lateral displacement of the building. The earthquake loads are shifting as an axial load in the steel bracing members. It's possible to use different kinds of an eccentrically bracing frame like K shaped in the global bracing along with the building height. Sometimes it's possible to use concentrically steel bracing systems like X, V, Z, diagonal bracing inside the vertical members of the structure.

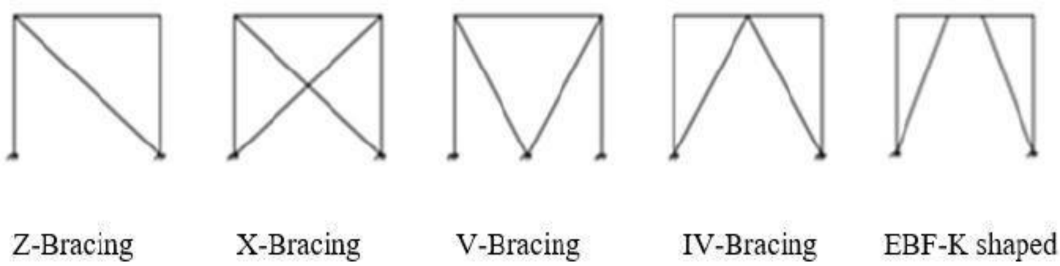

Figure 6: Concentrically and eccentrically braced frames [8]

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

RESULT

SAP2000 is utilizing to compute and check the performance response for the various types of steel bracing. The type of structure selected during this study is an RC frame. The pushover method is applying to the models; then, the result is plotting into a curve. The purpose behind choosing this strategy is checking the performance of the steel bracing and its strength. During this investigation, SAP2000 is utilizing to examine the response performance of the different types of CSB steel-bracing when it's been using to the existing RC structure. This study, each CSB steel bracing, has made different displacement, and their strength was different from each other, but the un-braced frame joints are not stiff enough, and failure happens, so the un-braced frame becomes the weakest frame compared to the other frames. The result is showed to a capacity curve figure 7, so the curve is clearly defining that the inserting steel bracing in the existing structure is dramatic increases the strength of the building and allows the building to stand with high lateral loads.
[9]

INTER-STORY DRIFT

The inter-story drift ratio is the maximum percentage drift between two floors divided by their story height. The result of this study shows that the inserting steel-bracing system structure decreases in peak inter-story drift. Story drift for both braced and unbraced structure is shown in Figure 9, the result shows that the upper stories is decreased in a fairly linear manner. Top floors have lesser story drifts compared to lower story drifts because of their low displacement values, when it's inserted the steel-bracing, and the inter-story-drift of the first story is less than the second story inter-story drift which should not have been the case.

DISPLACEMENT OF THE DIFFERENT TYPES OF STEEL BRACING SYSTEM

The comparison of the dynamic load-displacement in the x-direction for the different types of steel bracing is compering during this research investigation. This investigation proves that the top story floors have greater-displacement than the lower stories; also, this study shows that the uses of steel bracing in the building frame it dramatically decreases the effect of the lateral loads and story displacement. During this investigation of the comparison of the different types of steel-bracing is made to know the most irresistible during the seismic activities. So, X-bracing becomes the most useful and good reductions of story displacement. Therefore, the X bracing was helpful to the structures, also as the height of the structure increase the range of the movement will decrease when it's used steel bracing system.

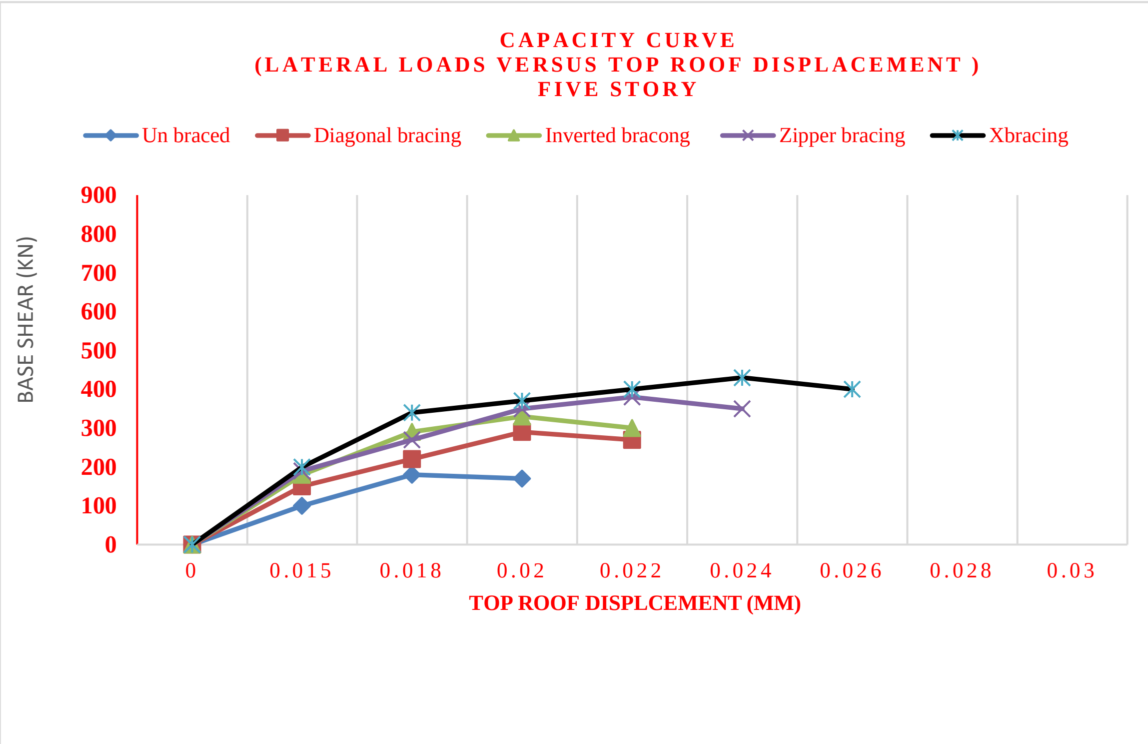

Figure 7: The displacement curve of the five-story building

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

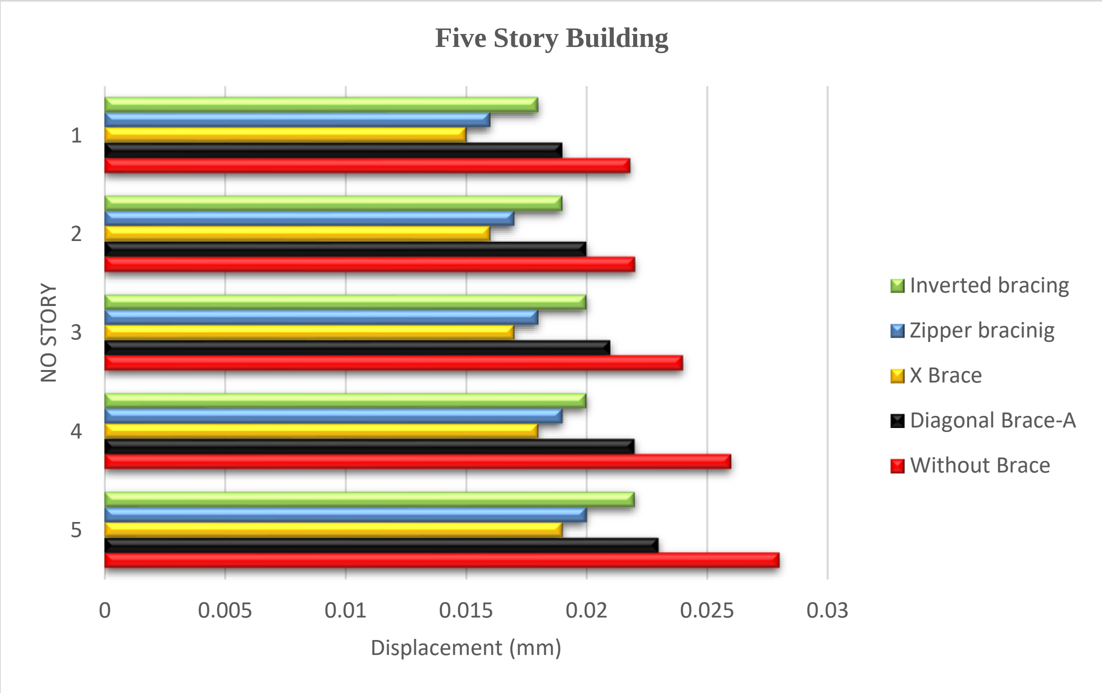

Figure 8: Displacement curve of five story structure

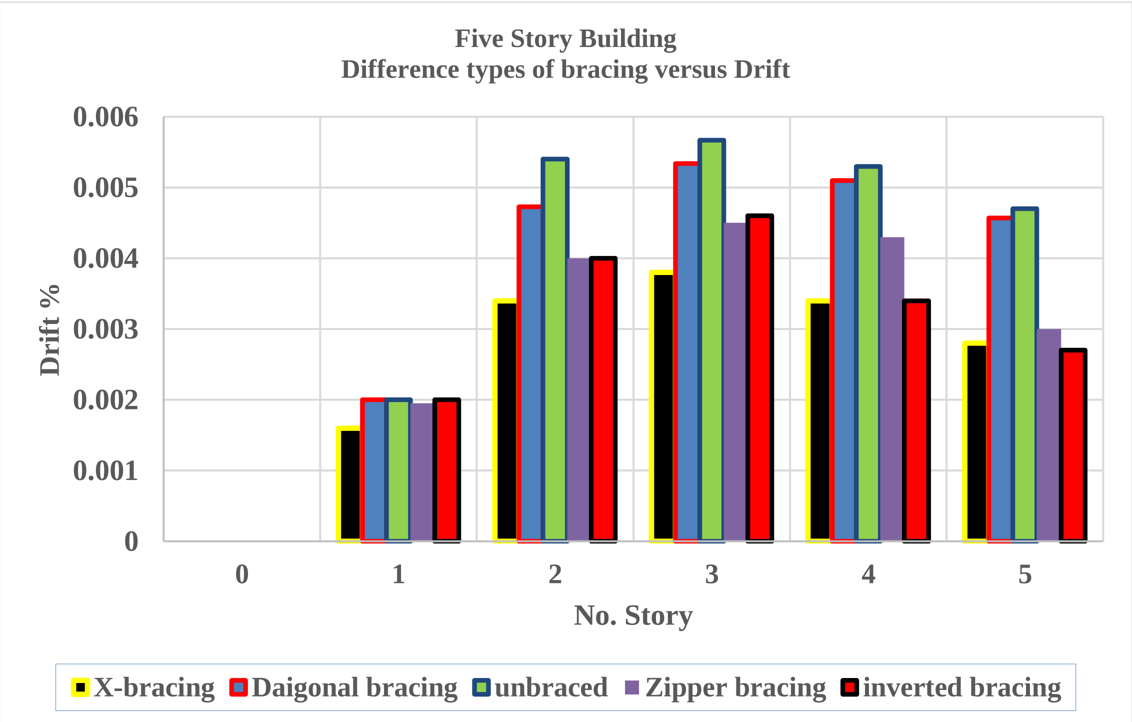

Figure 9: Story drift curve of five story structure

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

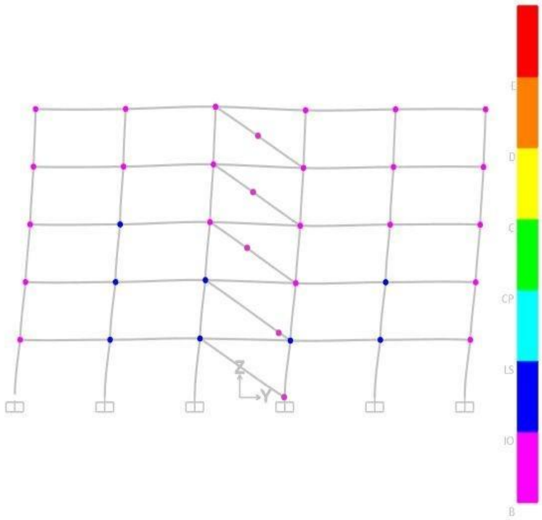

Figure 10: Five story diagonal

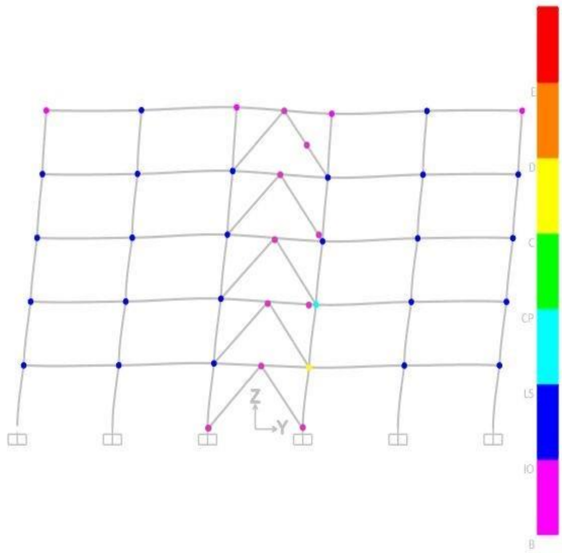

Figure 11: Five story inverted bracing

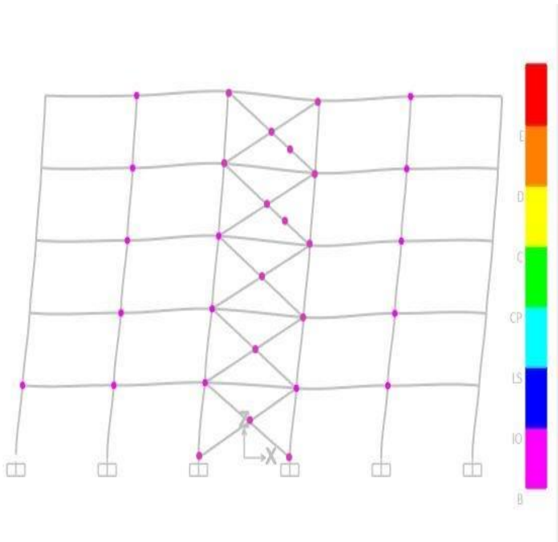

Figure 12: Five story x-bracing

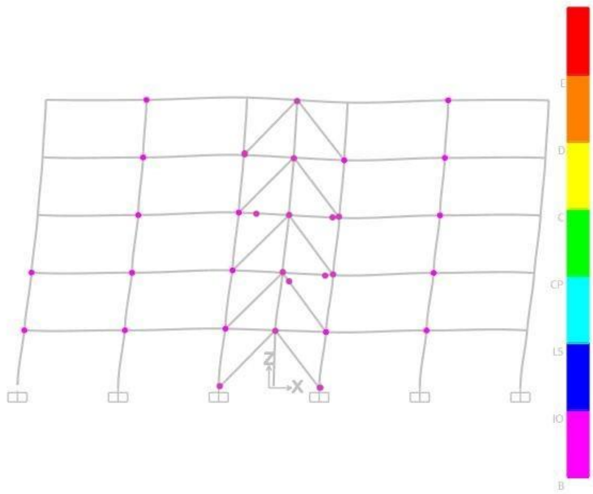

Figure 13: Five story zipper bracing

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 07, July-2020

CONCLUSION

During this study, various types of steel bracing systems have been analyzing as an effective method in the form of retrofitting in the existing RC building. The different various of steel bracing that selected during this study are; (x bracing, inverted bracing, zipper bracing, and diagonal-bracing). This research of the various type of steel-bracing has been tested by checking their strength limit of the existing structure. During this study, there are differences in height models selected, but in this article, only five-story building is showed, which is utilized and analyzed by the SAP2000 program. The pushover method is applied through all the model. So, the result of this study shows that the X bracing system was the most irresistible during this study compared with the others. X-bracing system increases the strength of the structure; also, it takes part in the energy dissipation of the frame. This result shows that in braced frames the sequence of hinge formation is first in the brace member, after that in the column and then in the beam so, if it increases the joint stiffness and column stiffness it will reduce axial deformation of the structural elements.

REFERENCES

[1] Applied Technology Council, ATC 40: Seismic evaluation and retrofit of concrete buildings (the USA,1996).
[2] Federal Emergency Management Agency, FEMA 440: Improvement of non-linear static seismic analysis procedures (Washington, 2005).
[3] Federal Emergency Management Agency, FEMA 356: Pre-standard and commentary for the Seismic-rehabilitation of buildings (Washington, 2000).
[4] Federal Emergency Management Agency (FEMA). (2000). "Prestandard And Commentary for The Rehabilitation of Buildings" FEMA-356, Washington DC.
[5] Applied Technology Council, ATC-40 (1996)." Seismic evaluation and retrofit of concrete buildings" Vol 1-2, Redwood City, California.
[6] AVAD Turkish website.
[7] Federal Emergency Management Agency (FEMA). (2000). "Prestandard And Commentary for the rehabilitation of buildings" FEMA-356, Washington DC.
[8] S. Kawamata and M. Ohnumas. Kawamata and M. Ohnuma, "Strengthening effect of eccentric steel braces to existing reinforced concrete frames," in Proceedings of the 2nd Seminar on Repair and Retrofit of structuresconference, NSF, annarbor, Mich, USA, 198.
[9] Kunnath, S.K., and E. Kalkan. (2011). "IDA capacity curves: The need for alternative intensity factors" University of California Davis, one shields avenue, Engineering III.