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Amending and Changing the Seismic Behavior of K-bracing by Yielding Damped Braced Frame (YDBF)

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Abstract

An inactive control method is to prepare the kinds of dampers as inactive energy wasting factor for metallic structure buildings. Yielding metallic dampers (or excurrent) are metallic devices which can waste energy in an earthquake by the effect of non-elastic changes of metals, also in the braced systems of structure buildings, they can improve resistance against earthquake and their damages control potential significantly. With regard to the geometry of K-bracing and the weaknesses which are by the effect of a resultant of two compressive and tensile forces of Bersnon, Iran's earthquake regulation in 2008 has exerted some limitations for using of this system. Therefore, in this research we tried to eliminate these limitations to some extent by using of metallic dampers. For doing this research, by using of two software of finite components (sap2000, Abaqus) with static non-linear analysis, we achieved the same purpose. This kind of dampers due to the simplicity of their installation and low cost of them can be applied both in new and existing buildings.

Keywords: non-linear static analysis, k-bracing, Yield Damped Braced Frame (YDBF)

1. Introduction

The foundation of the method of designing the usual systems resistant against earthquake is according to the resistance and rigidity against lateral load that for example,lateral bracing system, shear wall, bending resistant frame and dual or mixed system can be mentioned. The behavior of a structure which has been influenced by seismic loads, depends on its capacity in wasting the earthquake energy to high extent. Among mentioned cases, bracing systems despite of much welcome also have defects which have persuaded the scientists to use of more advanced systems in order to improve the seismic behavior of them by eliminating the defects of bracing systems. Meantime, the defects of K-form bracings in which the probability of formation of plastic joint in the pillar is a lot can be expressed in a manner that in the regulation, using of it has created limitation. Steel regulation, version 87 has divided the bracing systems into two groups of (SCBF: special) and (OCBF: usual) and it has expressed that in SCBF bracing system, using of K-bracing is prohibited; and in OCBF for the buildings maximum up to two floors on the base level and also the buildings with low and medium importance, K-bracing can be used.

In recent years, modern systems resistant against earthquake have been expanded in which the main view is to minimize the amount of hysteretic energy wasted in the main members of the structure and transfer it to the auxiliary pieces. For achieving this purpose, there are two main methods and views that one of them like using of the base separation system tries to reduce the input energy to the structure and another one concentrates on the energy wasting mechanisms in the structure. Therefore, it can be said that in modern methods, the factors of resistance, rigidity and plasticity are studied, and not providing each one of these factors will cause unsafety of the structure against earthquake. From the kinds of dampers as the factor of inactive energy wasting, metallic yielding dampers (or excurrent) are metallic devices which can waste the energy in an earthquake by the effects of non-elastic changes of metals. In fact, these dampers yield in bending, torsion, axial or shear states. The first idea of using of yielding dampers for the structures resistance at the time of earthquake was started for the first time in 1972 by theoretical work. These dampers flow at the time of loading and consequently cause to amortize much amount of input energy to the structure.

In recent years in order to achieve better seismic behavior, the Yielding Damped Braced Frame (YDBF) has been designed in the intersection place of crisscross braces which acts according to excurrent plastic materials. This close central frame that its four corners have been linked to the diagonal members, undertakes the duty of absorbing and wasting the energy in middle and severe seismic stimulations. In fact when earthquake occurs, central excurrent damper acts in the form of a fuse and prevents from the damage to the main members of structure like beams and pillars by absorbing and amortizing the energy ad limiting the exerted lateral loads. This issue has been proved in the tests which have been done in 1988 by Sabouri (Sabouri, 2004). Jurukovski& et al have done tests on the frames equipped with Yielding Damped Braced Frame and the frames without this kind of damper. The results indicate that the frames equipped with YDBF have more resistance, plasticity and the ability of absorbing energy than the frames without this kind of damper (Jurukovski, 1995). Ciampi and Ferretti in 1990 with a research on bracing with special form studied the energy wasting in two states with screw and rigid link and studied the ability of bracing members in amortizing energy (Jurukovski, 1998). Chen & et al studied the hysteretic behavior of buckling strained braces made from steel with low excurrent extent (LYS). The tests results of 4 test samples with large scale in addition to express the advantages of buckling restrained braces in increasing the amount of resistance, flexibility and energy wasting capacity, have indicated that using of steel with low excurrent has low deformation and high rigidity strain for bracing system (Ciampi & Ferretti, 1990). The optimum opening percent of these systems has been studied by Rofeh Grinzhad and the frame with opening of 12% has indicated the best amount of energy wasting with proper displacement in comparison with other models (Chen Chen & Liaw, 2001). The results of tests and numerical studies of Shane and Sung in studying the hysteretic behavior of ADAS1 dampers made from steel with low excurrent extent (LYS) and steel A36 indicate the improvement of seismic behavior of ADAS dampers, ability of high energy absorption and also uniform yield of damper member in facing with dynamic loads in the event of using of LYS (Roufegarinejad & Sabouri, 2002). The behavior of central yielding dampers with building steels and steels with energy absorbers with different opening percent in one-floor frames has been studied by Sabouri and Saneiepour that the results indicate the improvement of hysteretic behavior and increase of the ability of energy absorption by frames in the event of replacement of steel energy absorber instead of usual building steel, also the frame with 20% opening has had the best performance in comparison with other samples (Sabouri, 2004).

In this article, it has been tried to amend the behavior of K-bracing by knowing the seismic performance of central yielding dampers from building steel, and they can be used in the structures with more than two floors for designing and retrofitting. For this purpose, at first one-floor and on-opening mouth frames have been modeled in Abaqus software and the same model with similar sections has been considered in SAP2000 software. The results of two studied software are compared and they are studied with regard to the calibration results of 5-floor modeled frame and analysis of added load.

2. Methodology

Incremental non-linear static analysis as one of the methods of seismic assessment of structures is useful especially in non-linear deformation range. Recently, FEMA and ATC regulations suggest the static non-linear analysis method «push over» for studying the structure behavior in non-linear behavior domain, this method is simple and at the same time it has high accuracy, and primary hypotheses in calculations can be exerted easily (Katebi, 2002). Non-linear static method is the middle extent of very simple method and high extent of linear static and very accurate non-linear dynamic method. Very high sensitiveness of dynamic methods to the input data and also the need to much expertise and being time-consuming, closeness of the model behavior in this method to the real model, lack of need to amend output results and direct use of results for controlling and designing are some properties of dynamic methods, but in linear methods and also in non-linear dynamic methods, output results need to be amended and they should be studied by experienced expert. With existence of proper accuracy in determining the final behavior of structure in terms of the distribution manner of plastic joints, kind and manner of formation of failure mechanism state, general and relative displacements of demand, final forces of members and with the help of this method, a very good comparison of the structure behavior can be done before and after strengthening it and we can estimate the responding amount and the efficiency of redesigning which has been done on the primary model. With the help of this method, the safety amount of structure both in terms of resistance and final displacements of floor and structure can be assessed by comparison with permitted corresponding amounts related to the structural and unstructured members (Katebi, 2002).

2.1 Purpose Displacement

The purpose displacement δ_t is the maximum displacement of the mass center of roof under lateral loading and it is obtained from the following relation:

$$\delta_t = C_0 C_1 C_2 C_3 S_a \frac{T_e^2}{4\pi^2} g$$

2.2 Loading Model

In Abaqus model, we placed the frame in the highest level of frame under a horizontal displacement, also in SAP2000 software in real form, the seismic and gravity loadings according to the sixth issue of national provisions of building have been done, then it has been under an incremental static loading. Non-linear static analysis is sensitive to the kind of lateral loading model exerted on structure. Distribution of lateral load on the structure model should be similar to what will occur at the time of earthquake as much as possible in order to create critical states of deformation and internal forces.

First Kind Distribution

As the first kind distribution, the lateral load should be calculated by one of these three methods and it should be exerted on the structure model. For the structures that their main period is higher than 1s, only the third method of this kind of load distribution can be used.

1-Distribution proportional with lateral load distribution with linear static method for the times that at least 75 percent of the structure mass contributes in the first mode, in the event of selecting this distribution, the second kind distribution should be selected from the uniform kind.

2-Distribution proportional with the first mode form for a time that at least 75 percent of the structure mass contributes in the first mode.

3-Distribution proportional with lateral forces obtained from spectral linear dynamic analysis with considering the number of modes that at least 90% of the structure mass contributes in the analysis.

Second Kind Distribution

In the second kind distribution, lateral load should be calculated with one of these two methods

1-Uniform distribution of load with regard to the structure weight in each floor.

2-Changeable distribution in which lateral load distribution due to the status of the non-linear behavior of the structure model should be changed with a valid method in each step of increasing the load (International Research-Institute of Seismology. 2006).

2.3 Definition of Plastic Joints

The manner of defining the plastic joints has been explained in the regulation of existing structures amendment, figure (1) is in this form that the member behavior from point A which is without loading up to an effective yielding point (point B) is in linear form and there is a reduced rigidity in linear form between the points B & C, and with a sudden reduction in the resistance against load,from point C it reaches to point D and it remains fixed up to point E and finally in this point, resistance is reduced to zero. For determining the slope from A to B for each element, the usual methods of analysis can be used. The slope from point B to C with ignoring the gravity loads effects on deformation of member is considered between 0 to 10% of the primary slope, unless another slope to be recognized by better test and analysis. Point C also has a width equal to the member resistance and it has a length equal to the displacement amount in which severe reduction of resistance is started. If it is clear that response amount will not pass from point C, the force- deformation relation can be indicated only with points A, B and C instead of all points of A to E. The numerical amounts for given pointsexist in the sixth chapter for modeling and controlling the first degree structure performance related to the instruction of existing structures amendment (International Research-Institute of Seismology. 2006).

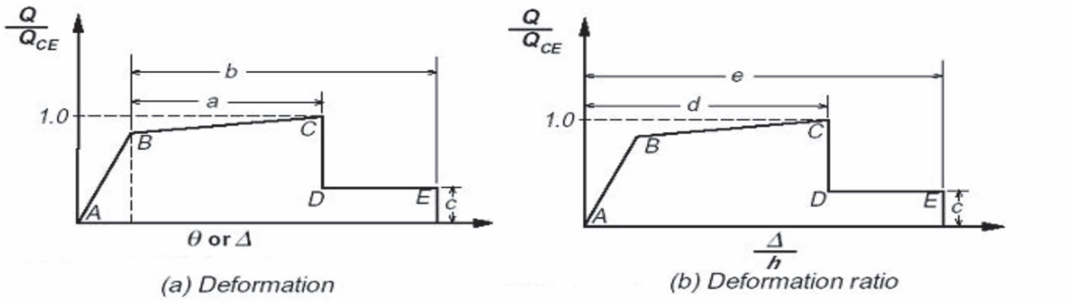

Figure 1. Plastic joints of the brigades introduced in the regulation

3. The Specifications of the Selected Frames for Studying

Beam, pillar and braces: in this research according to the regulation 2800, the third edition of the frames has been designed and usual steel is used for the beam and pillars.

Elastic and isotropic part: v=0.3 , E=210000 MPA

Non-elastic and kinetic part: σy=240 MPA , E=2000 MPA

The sections of central damper frames: these rectangular sections in the solid steel form from energy absorber steel genus are used with the following specifications.

Elastic and isotropic part:v=0.3 , E=210000 MPA

Non-elastic and kinetic part: σy=90 MPA , E=2000 MPA

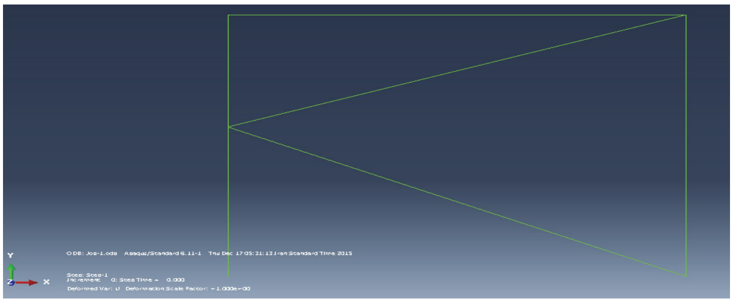

Figure 2. Modeling in Abaqus software

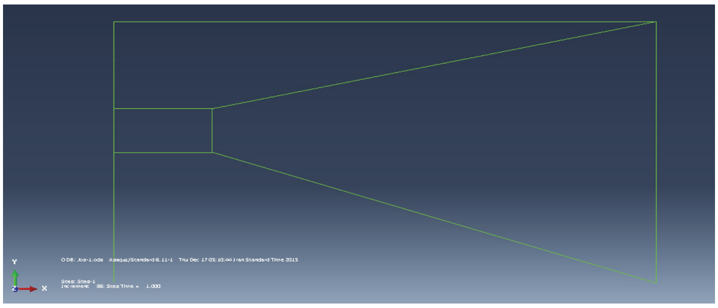

Figure 3. Modeling in Abaqus software

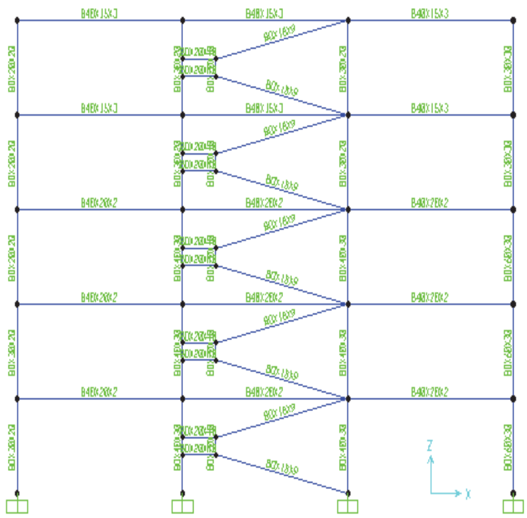

Figure 4. Modeling in SAP software

4. The Behavior of the Studied Structures

According to the accomplished analyses, the curves, deformation, stresses tensor and the place of creating plastic joints in the intended software are seen from figure No.5 to No.8 well. According to these outputs, the manner of formation of plastic joints in one step of non-linear analysis in the frames with twosystems of k-bracing and yielding damper for the states of 5-floor and one-floor has been indicated. Studying the obtained results for above systems indicates that in K-bracing and yielding damper frames with increasing of lateral force, the first plastic joint is formed in damper member so that with a certain base cut, in K-bracing and yielding damper frames, most of the plastic joints have been concentrated in the yielding damper members which are accounted the secondary members in the frame but in K-bracing frames, more plastic joints have been created in the main members of frame. Therefore, the damages of frame have been concentrated in K-bracing and yielding damper systems in the secondary members which are changeable and repairable more easily and with lower cost.

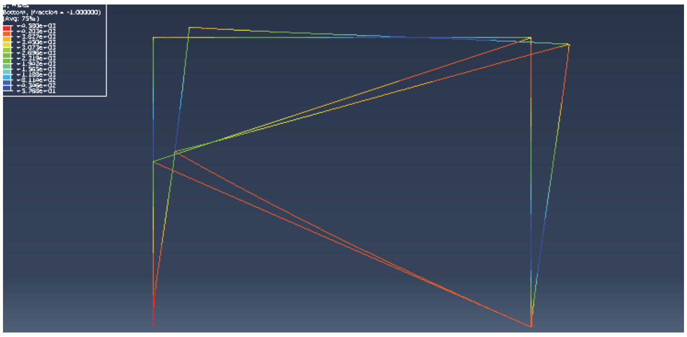

Figure 5. Modeling in Abaqus software (stresses)

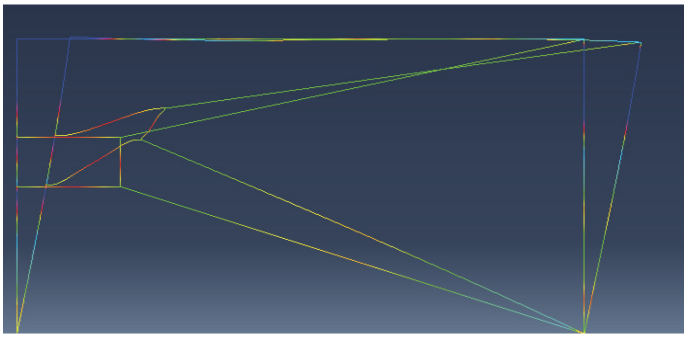

Figure 6. Modeling in Abaqus software (stresses)

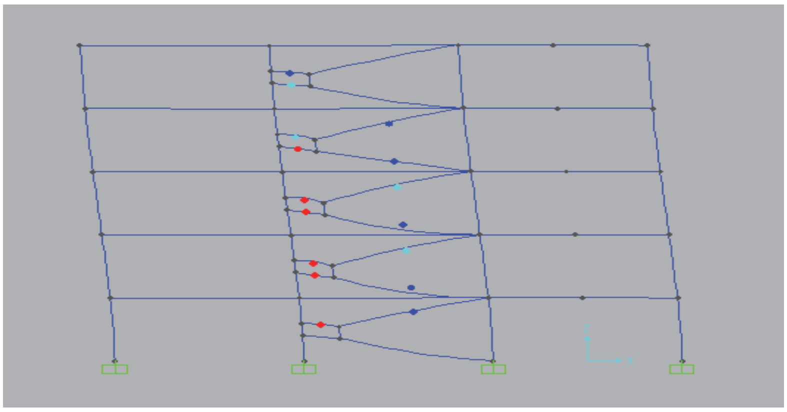

Figure 7. Modeling in SAP software (the frame under the first mode model- the procedure of formation of plastic joints)

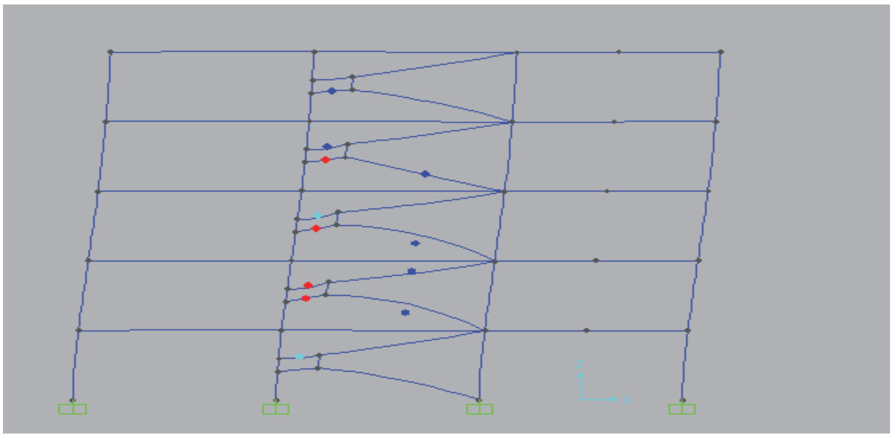

Figure 8. Modeling in SAP software (frame under the rectangular load model- the procedure of formation of plastic joints)

5. Conclusion and Suggestions

For the studied usual frames in this research, the following results can be obtained briefly.

1. In K-bracing and yielding damper frames when the linkages of beam and pillar are connected to each other in joint form, lateral rigidity is provided by yielding damper and deformation under severe earthquakes with bending yielding is provided in the yielding damper elements. Therefore most of the structure damage arising from earthquake is concentrated in the yielding damper which is accounted as the secondary members and also after earthquake, these members are repairable and changeable more easily and with lower cost.

2. With regard to this issue that the main members of the frame aren't damaged very much, it seems that the limitations of Iran's earthquake regulation 2800 about K-bracing frames can be ignored although it needs fuller study.

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