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[1.] Ali NIKKAR, [2.] Hamid Reza KHALAJ HEDAYATI, [3.] Milad ARKANI

A STUDY ON USING PRE-BENT STEEL STRIPS AS REDUCER THE SYSTEM'S RESPONSES

[1-3.] DEPARTMENT OF CIVIL ENGINEERING, SHOMAL UNIVERSITY, AMOL, IRAN

ABSTRACT: *In this study, a new type of seismic energy-dissipative devices in the form of braces based on pre-bent strips has been utilized. In this approach, moment-resistance frame systems have been used in 3 and 5 story and various models. The height of stories and all span length are 3m. In order to compare the response of models, braced (with damper) and unbraced (without damper), have been modeled. Pre-bent steel strips have been used in braced frames. Bilinear strain-stress model of mild steel has been used in this simulation. The responses of structures with dampers and without dampers under dynamic loading have been compared. A series of time history inelastic dynamic analyses have been conducted and the results show the feasibility and effectiveness of using the utilized devices as seismic dampers to reduce structural responses such as base shear, acceleration, velocity and displacement of stories.*

KEYWORDS: *Pre-bent strips, response of structure, damper, energy dissipation*

INTRODUCTION

The pre-bent strip is treats like geometrical nonlinear metal that it's stiffness changes in instigation frequency to adjust the system. In this metal strips, if the deforming occur in the considered direction and limits, it shows damping reaction and react as a springy element with its nonlinear geometrical treat that cause the vibratory isolation. When the pre-bent strip reposed under axial forces and make super deforming, cause the material act as an rigid material, that absorb the energy and damp vibrations. A beam with primary bending with tangly fulcrum at one end and roller fulcrum at the other has been examined as a damping system in reference [3]. A column with primary bending has been examined in 2 dimensions as a kind of damping system in reference [4]. In reference [5] a column has been considered in 3 dimensions with rigid diaphragm. The pre-bent strip has been examined on shaking table, in a simple and experimental model in [1]. In this article the results of examining and modeling are presented and samples of some modeled structures with damper and without damper are included in this article, to show the results. Nonlinear elastic dynamic analyzing method is used for this investigation, like 3, 5 story frames in 2 spans, in 3 dimensions under different accelerogram with finite element method. And the results of structure's responses are considered like base shear and etc.

STIFFNESS OF NONLINEAR ELASTIC BUCKLING FOR PRE-BENT STEEL STRIPS

In this part, the pre-bent strip is examined separately. Both ends of the pre-bent strip are tangly and it is deforming figure [1] approximately the curvature zone is calculated from the below function.

$$\theta(s) = q.F(s) \qquad (1)$$

where

$$F(s) = \sin(\frac{2\pi s}{L}) \quad \frac{L}{2} \le s \le \frac{L}{2} \qquad (2)$$

L is the length of the pre-bent strip and q is the tangent in conjunction point in S=L/4.

The primary angel of the tangent of arc is ϑ_s. It can be calculate from below function, before external axial forces act upon the strip.

$$\theta_o(s) = q_o.F(s) \qquad (3)$$

where q is the primary slop in the conjunction point, the strip's axial deform that impressed by axial force is calculated from the below function.

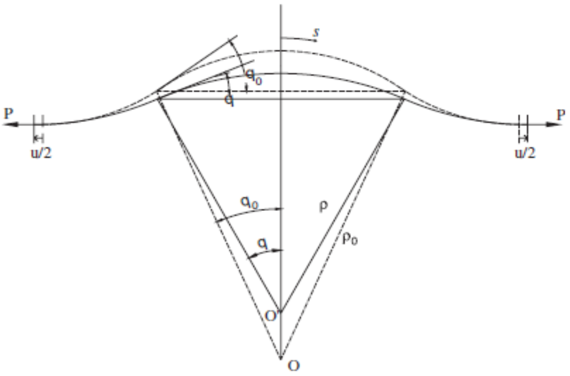

Figure [1]: pre-bent steel strip after and before tension loading

$$u(q)=\int_{-\frac{L}{2}}^{\frac{L}{2}}\left[\cos(\theta(s))-\cos(\theta_o(s))\right]ds=\int_{-\frac{L}{2}}^{\frac{L}{2}}\left[\cos(q\sin(\frac{2\pi s}{L}))-\cos(q_o\sin(\frac{2\pi s}{L}))\right]ds \tag{4}$$

With getting integral from above function and using the Tailor expansion the slope can be calculated following to q_o and u without considering the functions with more degrees of q:

$$q=\left[q_o{}^2-\frac{2u}{L}\right]^{0.5} \tag{5}$$

In addition, strain energy U^s and elastic potential U^p, can be written like the below functions:

$$u^s(q)=\frac{1}{2}E\int_{-\frac{L}{2}}^{\frac{L}{2}}I(s)(\theta'-\theta'_o)^2ds=\frac{1}{2}E\int_{-\frac{L}{2}}^{\frac{L}{2}}I(s)(q-q_o)^2(F')^2ds \tag{6}$$

$$u^p(q)=P.u(q)=P\int_{-\frac{L}{2}}^{\frac{L}{2}}\left[\cos(q_oF)-\cos(qF)\right]ds \tag{7}$$

E is elasticity module and

$$I(s)=\frac{1}{12}b(s)t^3 \tag{8}$$

And for each desirable sections of pre-bent strip, (t) is the thickness and b(s) is the width of the equivalence point in strip. The total potential energy is considered like below:

$$V(q)=u^s(q)+u^p(q) \tag{9}$$

Axial force (p) is calculated according to the minimum work theory, from the below method:

$$\frac{\partial V(q)}{\partial q}=E\int_{-\frac{L}{2}}^{\frac{L}{2}}I(s)(q-q_o)(F')^2ds+P\int_{-\frac{L}{2}}^{\frac{L}{2}}IF.\sin(q.F)ds=0 \tag{10}$$

And the axial force (p) will be:

$$P=\frac{E\int_{-\frac{L}{2}}^{\frac{L}{2}}I(s)(q-q_o)(F')^2ds}{\int_{-\frac{L}{2}}^{\frac{L}{2}}IF.\sin(q.F)ds} \tag{11}$$

With getting integral from function (11) and using the Tailor expansion, the below function is reached without considering the above functions:

$$P=P_{cr}(1-\frac{q}{q_o})(\frac{1}{4}(1+\beta)+\frac{1}{\pi^2}(1-\beta))(-1+\frac{q^2}{8})^{-1} \tag{12}$$

$P_{cr}=4\pi^2\frac{EI}{L^2}$ *and with replacing (5) in (12) conclude:*

$$P=P_{cr}(1-q_o(q_o{}^2-\frac{2u}{L})^{0.5})(\frac{1}{4}(1+\beta)+\frac{1}{\pi^2}(1-\beta))(-1-\frac{u}{4L}+\frac{q^2}{8})^{-1} \tag{13}$$

That $\beta=b_o/b_n$, b_n is the width of pre-bent strip in each desirable section and b_o is the width of the strip in primary section without slenderizing, that in this paper $\beta=1$ is considered.

MODELING AND ANALYZING

According to the standard NO.2800, we get 3 couple accelerogram to design the structure for loading in Abaqus software. In this way the scale factor is calculated, that used in equal static method for designing software like ETABS. Then the designed structure in Abaqus software has been reposed under dynamic forces or accelerograms. The procedure of the normalization is in the below description in conformity with standard NO.2800.

- ☐ *All of the accelerograms scaled to their maximum value. It means that the maximum value of each the accelerogram is determined as gravity acceleration (g).*

- *Acceleration response spectrum of each scaled couple accelerograms, are determining by considering 5 % damping ratio.*
- *The response spectrum of each couple accelerogram, are combining by square of power 2 summation method and make combined unique spectrum.*
- *Combined response spectrums are calculated and being compared with standard design spectrums within 0.2T and 1.5T. The scale factor is chosen as the averages in each position should be more than 1.4 times as their similar position in standard spectrum.*
- *The determined scale facture should be cross to the scaled the accelerogram in paragraph A, and being used in dynamic analyzing. The result of this paragraph is used in designing structures in software such as ETABS.*

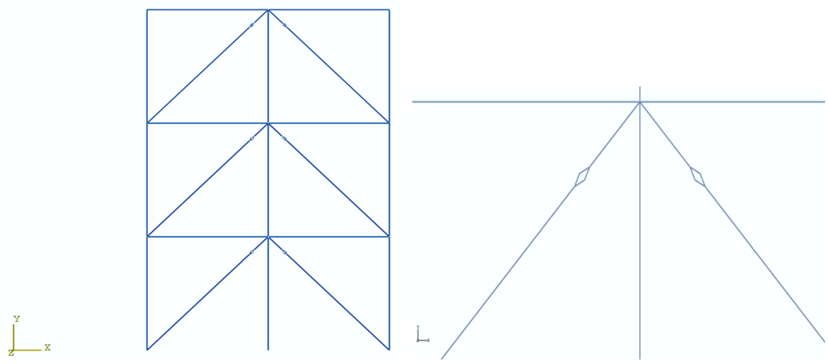

Figure 2: The numerical model of 3 stories with damper

The results of modeling with Abaqus software for 3 story frames with 2 spans, with damper and without it fig [2], are shown in fig [3]. That the structure reposed under Northridge accelerogram with PGA=1, in the direction of bracing and damping system.

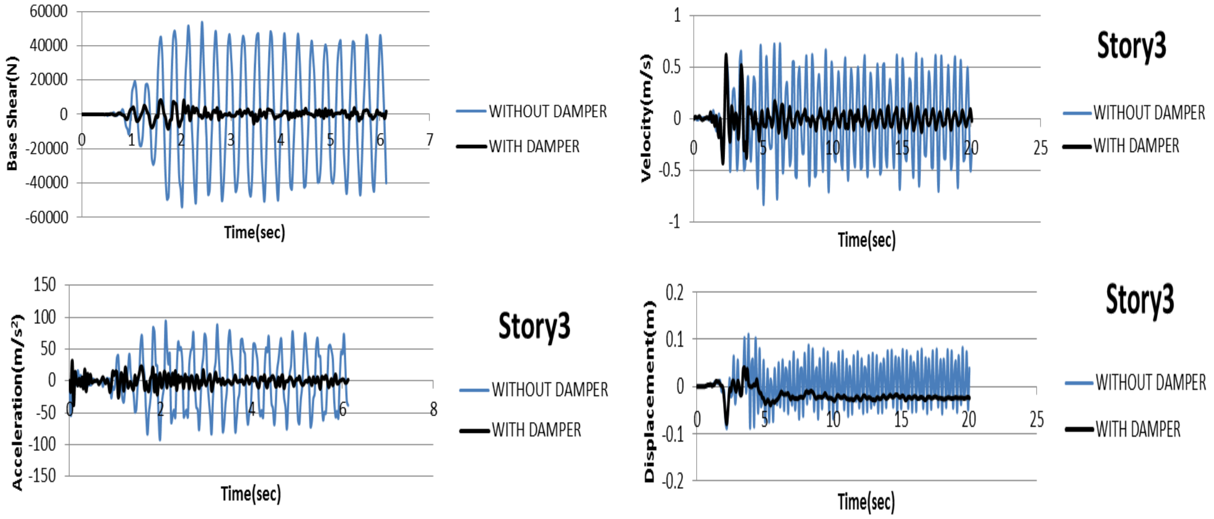

Figure 3: The results of modeling 3 story frames with 2 spans

In the 3 story modeled frames with 2 spans, the pair of dampers are used in 2 parts of braces and reduce the base shear till 50 %.

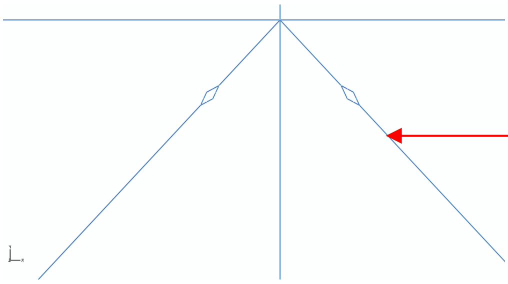

Figure 4: Pre-bent steel strip

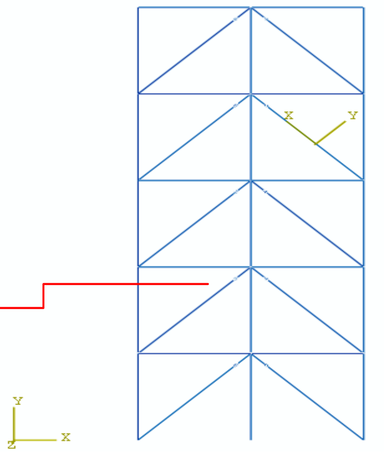

Figure 5: The model of 5 story frames

For more examining, 5 story frames with 2 span fig [4] with damper fig [5] is reviewed with the same situation and the results are shown fig [6]. That the structure reposed under Northridge accelerogram with PGA=1, in the direction of bracing and damping system.

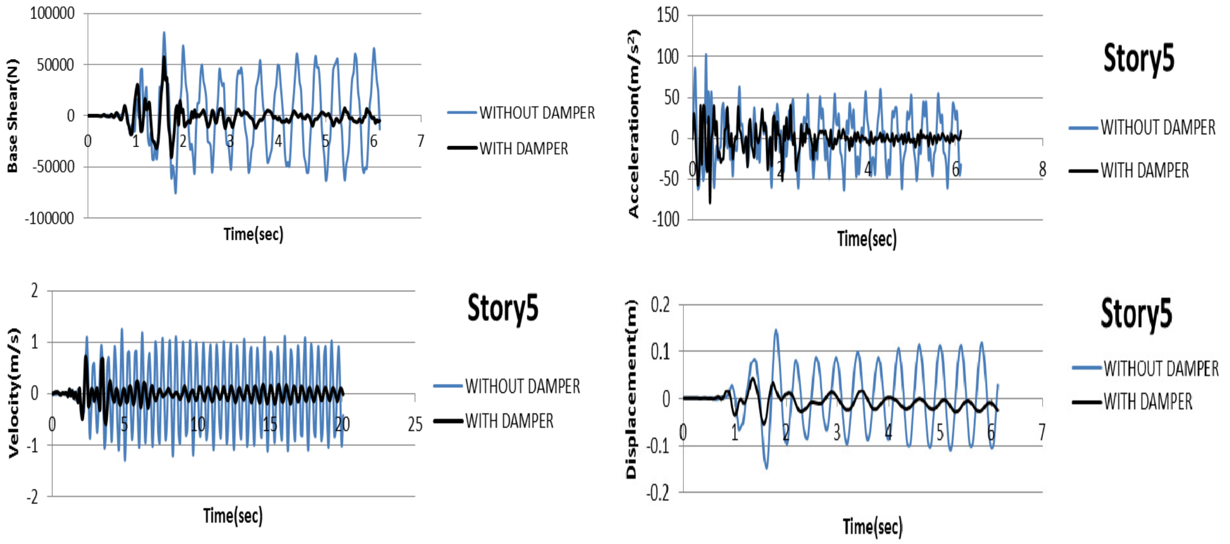

Figure 6: The results of modeling 5 story frame with 2 spans

As the graphs of figure 3 and 6 shown, the dampers played helpful role to decreasing the base shear, displacement, and accelerogram of the stories. The base shears and displacement of the stories are important criterions for designing and energy attracting or structure demolition.

CONCLUSIONS

According to these modeling and examining, pre-bent strip system cause, decreasing the base shear 40% and also reducing the story spectrum responses from 35 till 50% and again 30% in story displacement and velocity. The economical and simple design and also the execution of the pre-bent steel strip as damping systems show us that has suitable efficiency in damping.

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