SEISMIC BEHAVIOUR OF MIXED STEEL STRUCTURES

F DANESH[1]

SUMMARY

Recently many modern steel structures suffered from local failures during the Northridge and Kobe earthquake. On the other hand, the results obtained from previous investigations clearly indicated that the semi-rigid connection is feasible and indeed more economical than the rigidly-connected frame.

In this type of structure, the problem is that when the number of stories increases, the interstorey drift that mostly controls the ultimate state also increases. To overcome to this difficulty, one solution is that to design a structure with flexible connections and with no excessive deformation. In this research a mixed steel structure is designed in which the connections in external frames are rigid and the partial strength semi-rigid connections are used in internal frames.

The comparison between the time history response of mixed steel structures with rigid and semi-rigid ones indicated that the former is capable of sustaining larger earthquake excitation than the others. This provides an attractive alternative to fully welded steel frames, where problems of brittle fracture have been recently identified.

INTRODUCTION

The results obtained from Previous investigations clearly indicated that the semi-rigid connections are feasible and indeed more economical than the rigidly-connected frame (Astaneh et al., 1991, Elnashai, et al., 1994). It is also shown that in low storey frames, partial strength semi-rigid steel frames with connection capacities in the range of the 30% - 70% of the moment capacity of the beams satisfied the code requirements for both serviceability and collapse limit state. The response of such structures as a whale is well below its rigid counterpart.

The problem is that when the number of storeys increases, the interstoreys drift that mostly controls the ultimate state also increases. To overcome to this difficulty, one type of structure that is called “mixed steel structure” is defined. In mixed steel structure, the external frames are designed with rigid connections to control the structure from excessive deformation. The partial strength semi-rigid connections are used in internal frames such that the connections act as a dissipative part in this type of structures. To compare the seismic response of this structure with the others, the ten and fourteen storey steel frames with different types, as rigid, semi- rigid and mixed frames are designed and subjected to different records. In the following section, the results of dynamic response of these frames are presented and compared.

1

2 THEORY AND ASSUMPTION

In design of partial strength semi-rigid connections, the top and seat with double angles connections are used and for moment-rotation relationship one bilinear model approach (Danesh, F., 1996) is selected. The moment capacity of all semi-rigid connections is 70% of the plastic moment of the connected beams. The external frames with rigid connection are designed such that the beams act as a dissipative part and the plastic hinge

occurred in the beams and the rule of strong column-weak beams is considered in these frames. While in internal frames, the connections act as a fuse to dissipate energy and the plastic hinges occurred in this part of the structure. It's therefore, the columns and beams are designed directly and it is not necessary to obey the rule of strong column-weak beams.

3 PARAMETRIC STUDY

Frames Configuration

In this study, ten and fourteen storey structures with different types of frames such as rigid, semi-rigid, and mixed were used. The frame configurations are indicated in table 1. The fundamental periods and the weights of all frames are shown in table 2.

Table 1: Frames configuration

Frames	Number of storeys	bays	connections	Height
R10	10	2	Rigid	3.60 m
M10	10	2	Semi-rigid & rigid	3.60 m
S10	10	2	Semi-rigid	3.60 m
R14	14	2	Rigid	3.60 m
M14	14	2	Semi-rigid & rigid	3.60 m
S14	14	2	Semi-rigid	3.60 m

Table 2: Fundamental periods and weights of the frames

Frames	Periods	Weights (tons)
R10	2.13	20.68
M10	2.41	21.57
S10	2.53	22.28
R14	2.60	34.74
M14	3.00	35.47
S14	3.2	35.41

Analytical Results

The computer programme "Drain -2DX" is used for nonlinear dynamic analysis of these frames. All of the frames are subjected to three records.

The time history acceleration of the ground motions should be scaled such that all of the employed ground motions possess comparable intensities. Selections of records for analysis all frames are based on the classification of accelerograms according to the level of a/v ratio. The specifications of three records are indicated in Table 3.

Table 3: Ground motion record properties

Records	Earthquake event	Peak Acceleration	Time duration
Nagan	Iran- Nagan	709.46 cm/s^2	5
Tabas	Iran-Tabas	915.36 cm/s^2	25
Park Field	Canada-Park Field	621.954 cm/s^2	20

The full information and results of this study are given in reference Bahrami, A., 1999. To compare the interstorey drift of all frames at design acceleration (0.35g), they are subjected to three records that are normalised to o.35g. The results are shown in Table 4. As indicated in this Table, the interstorey drifts of all frames for these records except for the Park Field record are low and reasonable. However the mixed and semi-rigid structures are more flexible than rigid structures but the interstorey drifts are very closely. The comparison of interstorey drifts for all frames for three records is shown in Figure 1. As illustrated in these Figures the interstorey drifts of mixed structures are lower than semi-rigid ones.

Table 4 : Maximum interstorey drifts at 0.35g (design acceleration)

Frames	Nagan	Tabas	Park field
R10	0.0100	0.0155	0.0278
M10	0.0120	0.0167	0.0362
S10	0.0126	0.0182	0.0364
R14	0.0092	0.0143	0.0300
M14	0.0105	0.0147	0.0328
S14	0.0110	0.0170	0.0303

To determine the capacity and the failure criteria for all frames and to compare with each others, all of the frames are again subjected to three records. In these analyses, the scale of maximum acceleration of each record is increases until the frames are achieved the maximum values at ultimate state.

All of the frames are mostly suffered from soft storey mechanism and rarely the interstorey drift is the controlling failure criterion. These are shown in Table 5. The maximum interstorey drifts and the failure accelerations for all models are illustrated in Table 6.

Table 5 : Failure Criterions for all models under different records

Frames	Nagan	Tabas	Park field
R10	Soft storey	Soft storey	Soft storey
M10	Soft storey	Soft storey	Soft storey
S10	Soft storey	Soft storey	Soft storey
R14	Soft storey	Soft storey	Soft storey
M14	Soft storey	Soft stroey	Drift
S14	Soft storey	Soft storey	Drift

As shown in this Table, the mixed steel structures are achieved higher accelerations and then, the capacity of this type of structure are higher than rigid steel structure. The comparison of mixed steel frames with semi-rigid steel frames, indicate that the capacity of semi-rigid steel frames are higher than mixed steel frames but the displacement deformation of the formers are much higher. It is therefore, the mixed structures are capable of sustaining larger earthquake excitation than the rigid structure with no excessive deformation.

Table 6 : Maximum interstoey drifts and accelerations at failure criteria

Frames	Nagan		Tabas		Park field	
	accel.	drift	accel.	drift	accel.	drift
R10	0.57g	0.014	0.18g	0.016	0.18g	0.016
M10	0.61g	0.017	0.33g	0.015	0.24g	0.025
S10	0.85g	0.024	0.48g	0.022	0.28g	0.029
R14	0.74g	0.016	0.64g	0.020	0.08g	0.012
M14	0.90g	0.018	0.69g	0.023	0.29g	0.030
S14	1.16g	0.023	0.58g	0.020	0.30g	0.030

The behaviour factors for all the frames are evaluated and shown in Table 7. As illustrated in this Table, the mixed steel structures have a higher behaviour factor except for the frame S10 when subjected to Park field record. While the displacement deformation of these types of structures are mostly less than semi-rigid steel frames. It is therefore, this type of structure has the benefit of sustaining higher acceleration with no excessive deformation.

Table 7: The behaviour factors of all frames under different records

Frames	Nagan	Tabas	Park field
R10	3.70	2.60	2.80
M10	4.70	4.40	6.80
S10	4.50	4.40	7.80
R14	4.10	4.60	2.80
M14	6.00	8.60	8.40
S14	6.10	6.10	7.00

4 CONCLUSION

In this paper, the behaviour of steel frames with rigid, semi-rigid and mixed connections subjected to different records was studied. In nonlinear dynamic analysis of semi-rigid and mixed steel structures a bilinear model for predicting the moment-rotation of top and seat angles with double web angles connection was implemented in computer programme. Hearafter, the main observations are as follows:

1- The mixed steel structures are behaved very well. All interstorey drifts for this type of structure are mostly less than semi-rigid steel frames and are comparable to rigid steel frames.

2- The comparison between rigid and mixed steel structures indicates that the latter has a higher capacity and also higher ductility.

3- However the semi-rigid frames have achieved higher acceleration but the behaviour factors of mixed steel structures are bigger and then this type of structure is capable to dissipate more energy with no excessive deformation.

5 REFERENCES

Astaneh, A. and Nader, N., 1991, "Cyclic behaviour of frames with semi-rigid connection", Proceedings of the Second International Workshop Connections in Steel Structures II (Behaviour, strength and design), Pittsburg, Pennsylvania.

Elnashai, A.S. and Elghazouli, A.Y., 1994, "Seismic Behaviour of Semi-rigid Steel Frames", Journal of Constructional Steel Research, vol. 29, Nos. 1-3, pp. 149-174.

Danesh, F., 1996, "Seismic behaviour of Steel Frames with Semi-rigid Connections", Ph.D. thesis, ESEE Section, Imperial college, University of London.

Bahrami, A., 1999, "Non-linear Dynamic Behaviour of Rigid, Semi-rigid and Mixed steel structures", Msc thesis, Civil Engineering Department, K.N.Toosi University, Tehran, Iran.

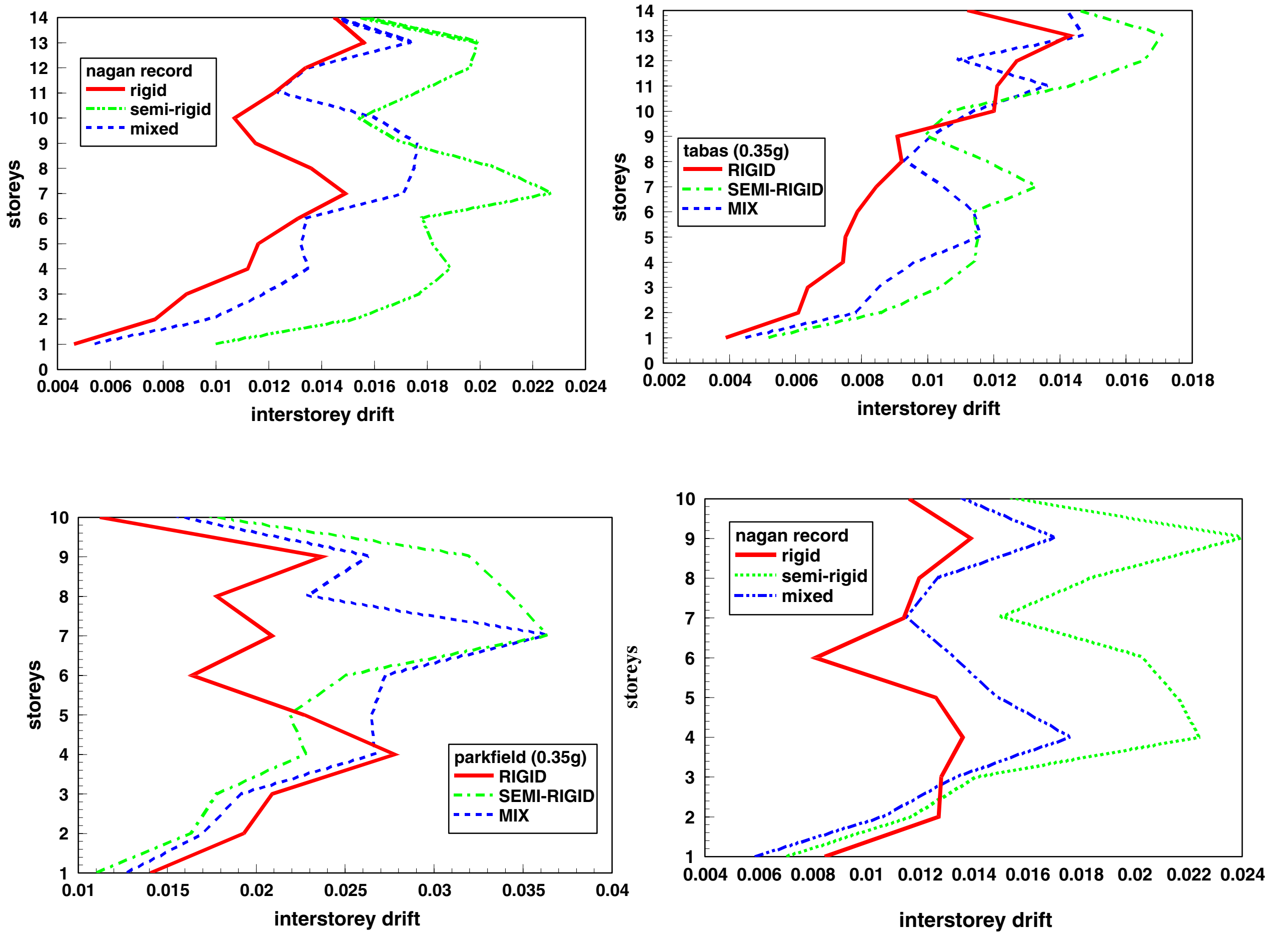
nagan record
rigid
semi-rigid
mixed
storeys
interstorey drift
0.004 0.006 0.008 0.01 0.012 0.014 0.016 0.018 0.02 0.022 0.024
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
tabas (0.35g)
RIGID
SEMI-RIGID
MIX
storeys
interstorey drift
0.002 0.004 0.006 0.008 0.01 0.012 0.014 0.016 0.018
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
parkfield (0.35g)
RIGID
SEMI-RIGID
MIX
storeys
interstorey drift
0.01 0.015 0.02 0.025 0.03 0.035 0.04
1 2 3 4 5 6 7 8 9 10
nagan record
rigid
semi-rigid
mixed
storeys
interstorey drift
0.004 0.006 0.008 0.01 0.012 0.014 0.016 0.018 0.02 0.022 0.024
1 2 3 4 5 6 7 8 9 10

Figure 1