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SEISMIC PERFORMANCE OF STEEL BUILD- UP BATTEN COLUMNS

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ABSTACT

Several steel batten columns suffered damage during the past earthquakes especially during the Bam earthquake of 2003 in south east of Iran. Performance of steel batten columns during the past earthquakes revealed that these structural members are seismically vulnerable. This study aims to demonstrate that current design provisions cannot satisfy the seismic requirements of such columns. For this purpose different available code provisions were compared to each other. Then a group of batten column was designed according to different codes. The seismic behavior of the columns was evaluated by using numerical analysis. The results of analyses were compared to performance of batten columns during the past earthquakes. Results of this study showed that some shortcomings in design code provisions as well as improper construction are the main reasons for seismic vulnerability of steel batten columns. Finally, some technical comments are presented in order to improve the seismic performance of steel build-up batten columns.

Introduction

Steel build up batten columns are common types of columns in some countries. The experience of the past earthquakes revealed that these columns don't have acceptable seismic performance. For instance, in Bam earthquake of 2003 in South-eastern Iran, several steel framed structures with batten columns collapsed due to weakness of batten columns (Hosseini Hashemi and Jafari, 2004) (Eshghi et al., 2004). Hence, investigation of seismic performance of steel batten columns is an important task in high seismic risk regions.

Many studies on the behavior of batten columns have been done by different researchers. In most of these studies the behavior of the batten columns due to the gravitational loads are investigated. In the other words, most of the researchers neglected the effect of the lateral loads on the behavior of steel batten columns (Hosseini Hashemi and Jafari). Meanwhile, there are no detailed seismic provisions for the design of build-up batten columns.

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Sahoo and Rai(2004) investigated the effect of cyclic loads on build-up columns, Jafari and Hashemi [4], experimentally investigated the buckling load of batten columns and showed that in most of the cases, the local buckling of the steel columns were occurred near the bottom of the column. Jafari [5], presented some provisions for preventing damage to steel batten columns in high risk regions. The objective of this study is to investigate the major failure modes of the batten columns. For this purpose, performances of the batten columns in damaged buildings during the past earthquake were observed. Numerical analyses were carried out in order to study the seismic performance of different build up batten columns. And the results of analyses were compared to seismic performance of full scale damaged columns.

Performance of the Batten Columns during the Past Earthquakes

Following the intense earthquake of Bam in south-east of Iran on December 2003, the unsatisfactory behavior of steel batten columns was observed. Many steel buildings in the Bam region had batten columns. The major failure mode in most of these buildings was buckling of batten columns. Overall and/or local buckling of the columns and failure of the battens were the most observable failure modes of the batten columns.

Overall buckling of the columns

In many of the damaged columns, overall buckling was occurred. It is significant that the buckling was occurred about the hollow axis of columns. A sample of overall buckling in batten columns is presented in Fig1.

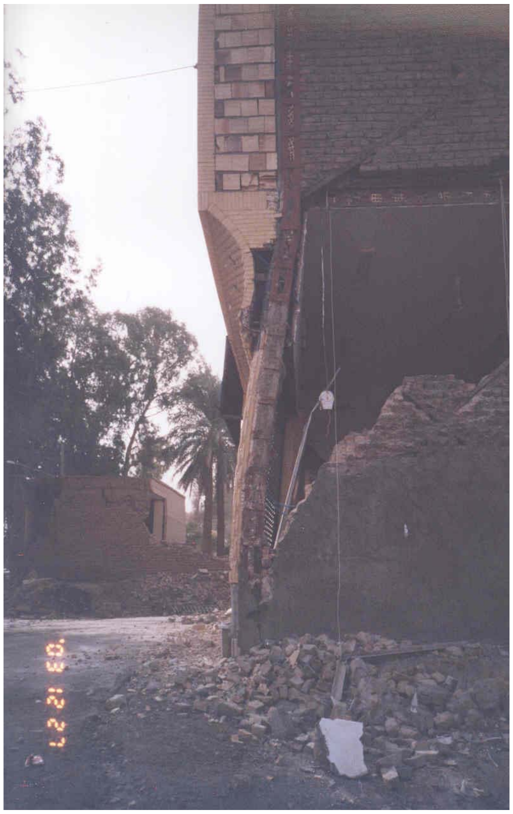

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Figure 1. Overall buckling of a batten column

Local buckling in of the columns

In some cases, local buckling of the chords of the column was observed. The main reason for occurrence of such failure was transferring the bending moment from semi rigid connections about the hollow axis (See Fig 2)

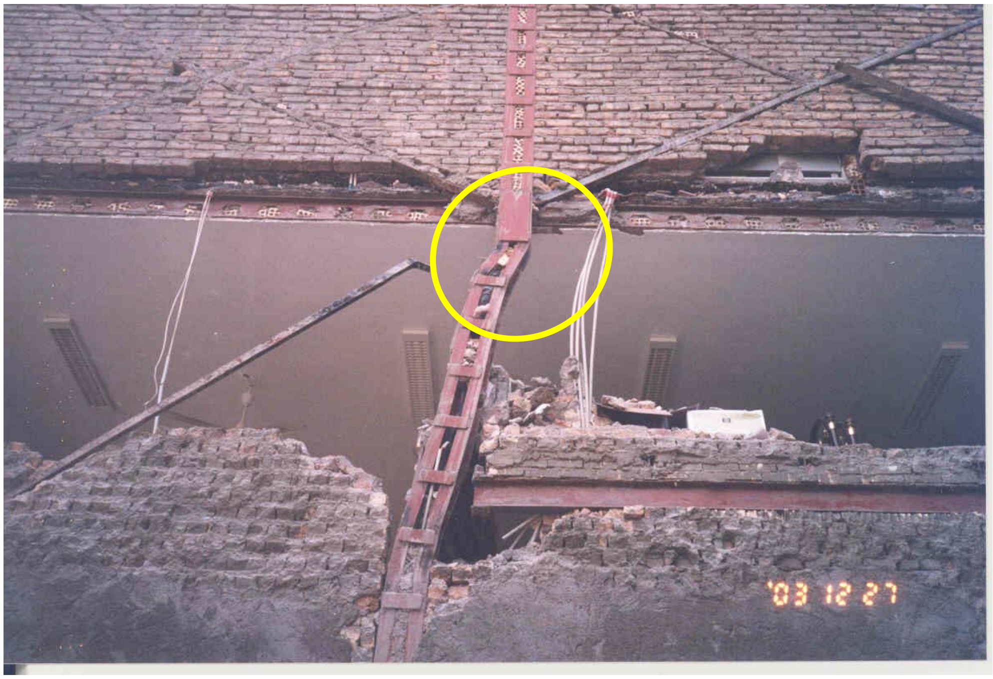


Figure 2. Local buckling in a batten column

Failure of the Batten Plates:

Failure of the batten plates may cause separation of chords and severe decrease in axial capacity of the columns. In some of the damaged columns, failure of the batten plates was observed (See Figure 3). The most common failure modes in batten plates are as follows:

- Plastic shear deformation of battens
- Rupture of battens
- Rupture of batten-to-chord welded connections

Following the failure of a batten plate, progressive failure in the other battens may occur. The main reason for such progressive failures is increasing the distance between the adjacent battens. Moreover, the applied bending moment in adjacent battens may increase due to the failure of a batten plate.

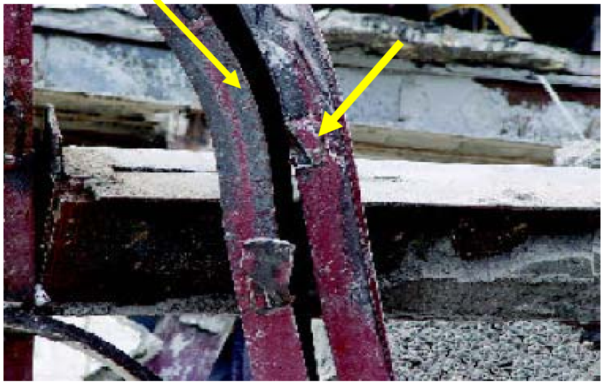


Figure 3. Damage to batten plates (Hosseini Hashemi and Jafari 2004)

Design basis of batten columns

Equivalent Slenderness

Despite the prevalence of batten columns in low seismic areas such as some European countries, there are no seismic code provisions for the design of these columns. General requirements for design of batten columns are presented in design codes such as Part 10 of INBC (INBC, 2008), BS 5950, AISC- LRFD 2005, etc. Although the design relations of batten columns in different codes aren't the same, the main approach of the available design codes is the same. Moreover the columns designed by different code provisions are almost the same. All of the above mentioned codes introduce a coefficient for modifying the slenderness ratio of columns. A main difference between batten columns with continuous web columns is buckling of batten columns about the hollow axis. In such a case the effect of shear flexibility on buckling of the batten columns about the hollow axis should be considered. In order to consider such an effect, the differential equation of buckled column should be derived by considering the shear curvature as well as bending curvature of the batten columns. By solving the above mentioned differential equation a relation for modifying coefficient may obtain.

Design of Batten Plates

As mentioned before, batten plates are important parts of batten columns. The batten plates should be designed to resist the shear forces, between chords induced by bending actions. The proposed design procedure in designed provision is based on the axial behavior of the columns. In other words, if the bending moment about the hollow axis applies to the column, the shear force along the batten becomes much larger than that considered in the design codes.

Numerical Analyses

Numerical analyses carried out in order to investigate seismic performance of batten columns. For this purpose four configurations of batten columns were modeled. The specifications of models are shown in table 1. Four-node nonlinear shell elements have been used for modeling of batten columns (See Fig 4). Three of the arrangements have been passed the requirements of part 10 of the INBC and one of them has not been passed such requirements. The latter one was a typical sample of non engineering fabricated columns in rural areas of Iran. All of the models were cantilever columns, fixed at the bottom and released on top. Static analyses were performed. For this purpose lateral cyclic displacements have been applied on top of the models. As shown in figure 5, the displacement history was according to ATC-24.

Table 1. Specification of models

Model	Chord Section	Distance of chords (mm)	Batten Plates	Distance of battens (mm)	P/P_a*
A	IPE 120	200	PL 200x60x6	250	0.6
B	IPE 120	200	PL 200x60x6	250	0.8
C	IPE 120	200	PL 200x60x6	500	0.6
D	IPE 120	200	PL 200x30x6	500	0.6

*P: Axial load of the column

*P_a: Compressive capacity of the column

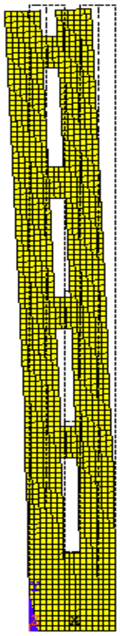


Figure 4. FEM model of the batten columns

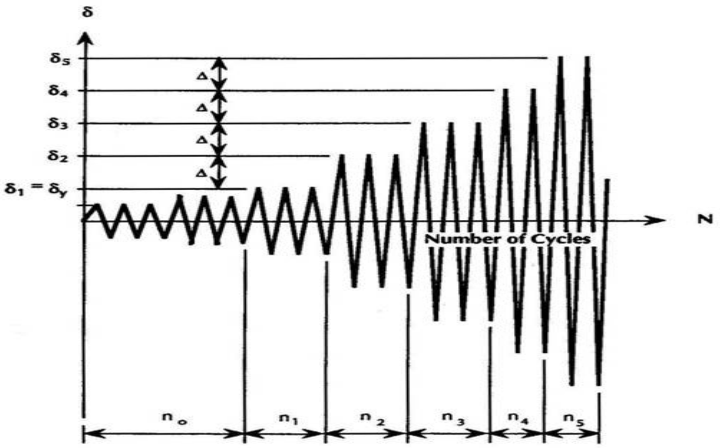
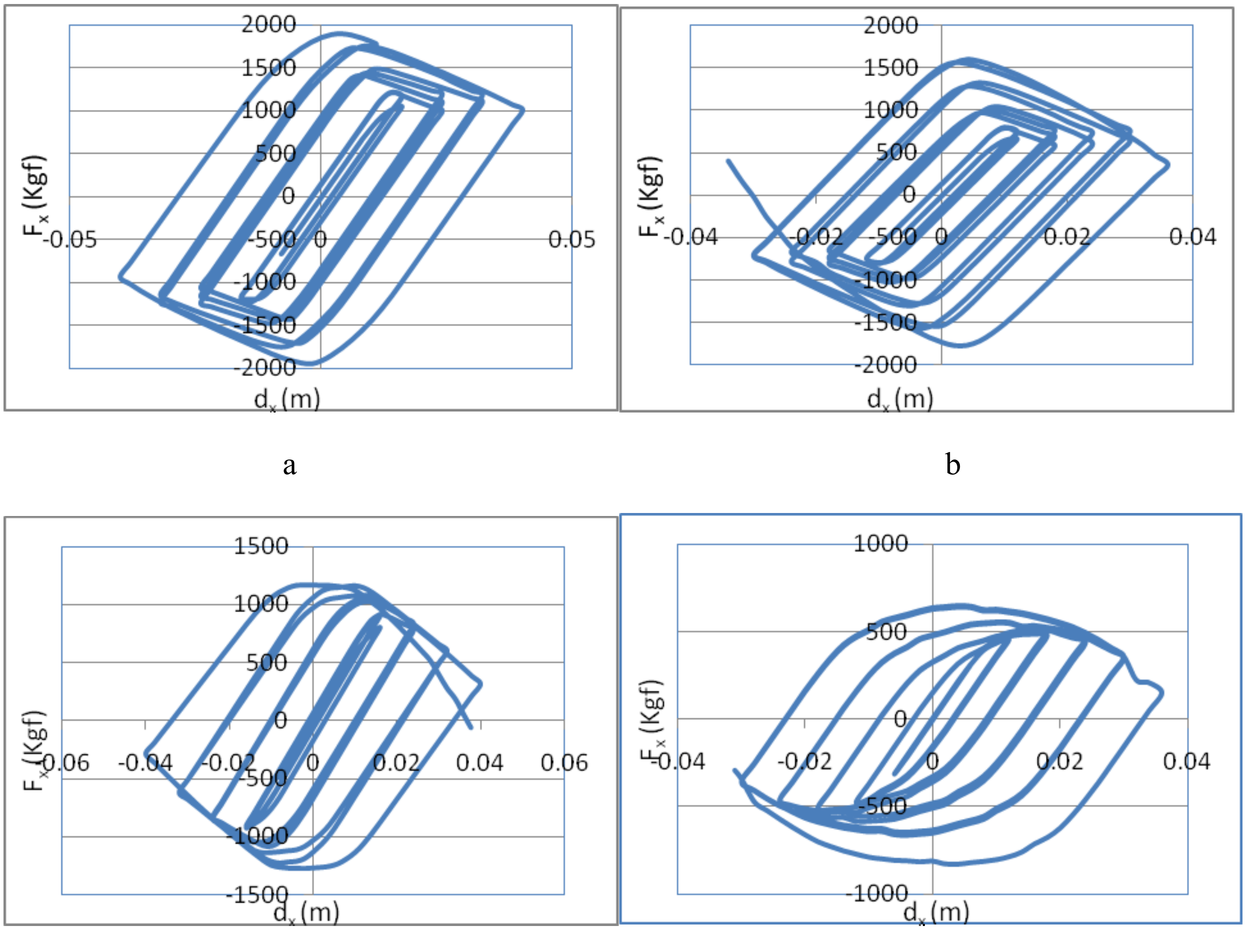


Figure 5. Displacement history of the analyses (According to ATC-24)

Results and Discussions

The hysteresis loops of the models are indicated in Fig 6. As indicated in Fig 6, the hysteresis loops of model “A” are more stable than model “B”. The only difference of these models was axial compressive load of the models. The distance between battens in model “C” is greater than model “A”; but the other specifications of these models are same. It is observable in Fig. 6 that model “C” is more ductile than model “A” but its capacity is much less than the capacity of column “A”. In column “D” the height of the batten decreased compare to other columns. Other specifications of column this column was same as column “C”. As can be seen in Fig 6.d there is an observable difference between the hysteresis loops of column “D” and that of other models. The reason for such difference is plastic deformation of batten plates (See Fig 7). Hence it seems that damage to batten columns may cause noticeable reduction in capacity of batten columns. It is worth mentioning that column “D” was the only model in which the code provisions have not been satisfied. Hence the results of numerical analyses seem to indicate that configuration and size of the batten plates have eminent role in seismic performance of batten columns. In other words typical existing non-engineering batten columns may be very vulnerable due to the weakness of the batten plates. The results of the analyses also showed that even those batten columns which designed according to available codes may have unacceptable behavior due to lateral loads. As mentioned before, it seems that the main reason for such unsatisfactory behavior is neglecting the effects of lateral loads in design of batten columns.



a

b

c

d

Figure 6. Hysteresis loops of the batten columns a: Model “A” b: Model “B” c: Model “C d: Model “D”

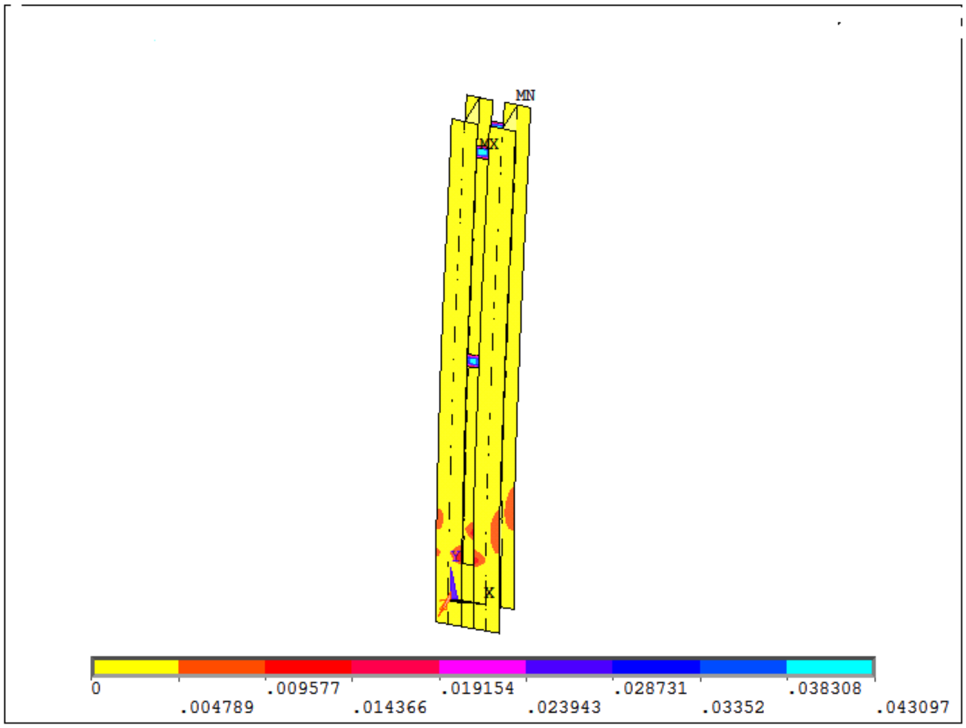


Figure 7. Plastic strain in batten plates of column “D”

Conclusions

Numerical static nonlinear analysis performed in order to investigate seismic performance of steel batten columns. For this purpose four different models prepared. Three of the models were designed according to INBC (Part 10) and one of them had weak batten plates. The results of this study showed that none of the columns had satisfactory behavior due to the lateral loads. Also it was shown that configuration of batten plates is an important factor in seismic performance of batten columns. Results of this study seem to indicate that existing code provisions are not sufficient for seismic design of batten column. For this reason it seems that while there is not acceptable code provision for seismic design of batten columns; such columns should not design and/or fabricated in steel columns in high seismic risk regions.

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