Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(1) (2021) 83-86
DOI: 10.22060/ceej.2018.13812.5481

Application of Lower Grade Steel on Dynamic Behavior of X-braces in Shear Part 2: Advanced Nonlinear Static and Incremental Dynamic Analyses (IDA)

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ABSTRACT: In the first part of this paper, the theory of design of X-braces using different steel grades was introduced and its effects on different frames verified using nonlinear static analyses. It was found that using lower grade steel in X-braces increases the stiffness, energy absorption capacity, damping, and ductility of the system and decreases its lateral drift. To completely investigate the behavior of steel structures with X-bracing systems in design with different steel grades and consider their dynamic behavior, the frames with different stories studied using advanced nonlinear static and Incremental Dynamic Analyses (IDA). The results are presented as comparative diagrams and tables. The near and far-field earthquakes used for dynamic analysis of sand and their seismic performance were studied. Therefore, this research can lead to a better investigation of the seismic behavior of X-braced systems in design with different steel grades. The proposed theory along with analyses shows that building codes and steel seismic design specifications can consider the effects of steel grades in seismic parameters definition of structures. The comparative diagrams and tables show that the seismic behavior of X-braces designed with lower-grade steel improves considerably. Also, the response of structures under near field earthquakes is bigger than related parameters under far-field earthquakes. Also, with an increase in height of the frames and governing bending behavior (relative to shear behavior) and more effects of columns in lateral deflection of frames, the effects of lower-grade steel in the overall behavior of taller buildings decreases gradually.

Review History:

Received: 12/6/2017
Revised: 5/16/2018
Accepted: 7/10/2018
Available Online: 9/15/2018

Keywords:

X-bracing
Advanced nonlinear static analysis
Incremental dynamic analysis (IDA)
Energy dissipation capacity
Steel grade

1. INTRODUCTION

Continue from the first part of the paper that introduced Low-Grade steel (LGS) and its application on the dynamic behavior of X-braces in Shear using theoretical formulas, Advanced Nonlinear Static and Incremental Dynamic Analyses (IDA) [1-15] used to complete the study of X-braced frames that were designed using different steel grades. Therefore, different frames with 4, 7, 10, and 15 stories (named as XBF4, 7, 10, and 15) are analyzed and discussed comprehensively.

2. NONLINEAR STATIC ANALYSIS

Three methods of nonlinear static analysis (Coefficient Method, Capacity Spectrum Method, Adaptive pushover analysis, and N2 Method) were used for this study. According to obtained results, the target and yield displacements of designed frames with LGS were less than frames designed with conventional Structural Steel (SS). The difference between these values reduced by increasing the height of the structure due to the flexural behavior of frames and greater roles of columns in the lateral displacement of frames.

In addition, the ductility of LGS systems increased relative to SS systems. The seismic parameters of frames are summarized in Table 1. All values are given in millimeters.

3. NONLINEAR DYNAMIC ANALYSIS

Nonlinear dynamic analysis methods such as the Time History, IDA, and MIDA along with used for the study of frames under near and far-field Earthquake records. The records were Gowzalli, Düzce, Kapmand, ChiChi, and Kocaali for near field and Kocaali, Northridge, Kobe, Imperial, and Hector for far-field earthquakes.

As shown in Fig. 1, the results of all IDA curves are located in the elastic area until the acceleration of 0.05 g. The dispersion of results related to various earthquake records increases with an increase in spectral acceleration. Due to the higher structure stiffness in LGS frames, the dispersion of results is lower, but large deformations in some stories induced larger dispersion in curves of SS frames. In general, the lateral displacement of LGS frames was less than SS frames.

In lower height frames the shear behavior governs the total frame behavior that is mostly related to X-braces stiffness. While, in taller frames, the moment behavior governs that mostly related to columns sizes. Since the size of the columns is considered unique in LGS and SS frames, the dispersion of

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Table 1. Target (Sd_p) and yield (Sd_y) displacements and ductility (μ) from Capacity Spectrum analysis.

Frame	XBF4	XBF7	XBF10	XBF15
$Sd_{P(SS)}$	30	66.7	148.4	258.4
$Sd_{P(LGS)}$	21.6	55.1	121.8	237
$Sd_{y(SS)}$	23.42	51.2	118.2	218.9
$Sd_{y(LGS)}$	16.1	42.7	98	198.4
$\mu_{(SS)}$	1.28	1.28	1.25	1.18
$\mu_{(LGS)}$	1.33	1.3	1.27	1.19
$\frac{Sd_{P(LGS)}}{Sd_{P(SS)}}$	0.72	0.82	0.82	0.92

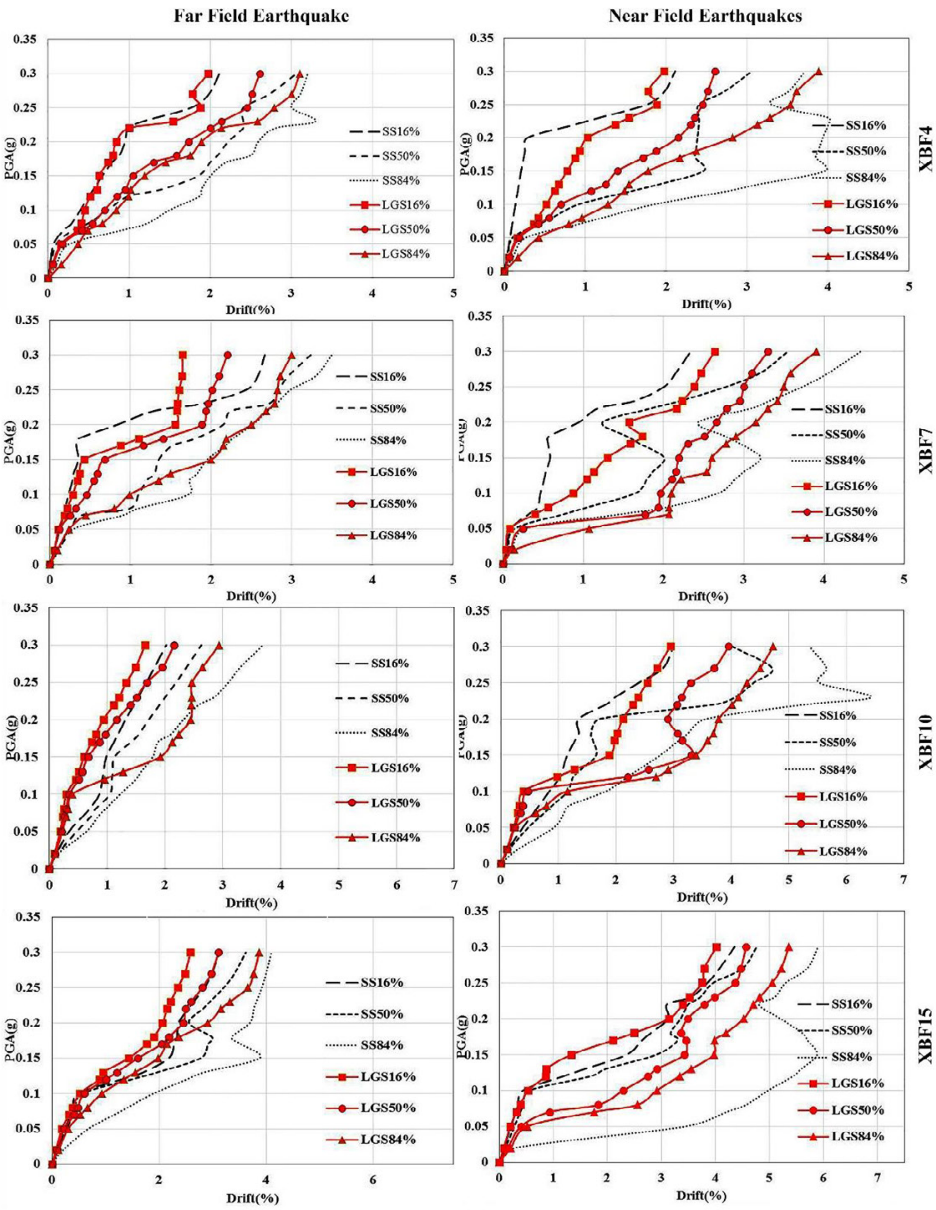

Fig. 1. IDA analysis results for Near and Far-field earthquakes.

IDA results is less in taller frames.

4. PERFORMANCE LEVEL OF FRAMES

The IDA results show that LGS frames satisfy higher performance levels in a specific spectral acceleration. So that, the performance level LS (Life Safety) for LGS frames with 4, 7, 10, and 15 stories revealed the spectral acceleration equal to 29, 32, 27, and 23 percent higher relative to SS frames, respectively. Also, the increased flat line between the start of the nonlinear region and fracture stage in LGS frames shows its higher energy dissipation capacity.

5. CONCLUSIONS

The proposed behavioral theory of design of X-braces using different steel grades in the first part of this paper completed using advanced nonlinear static and dynamic analyses to better investigate of seismic behavior of X-braced systems in design with different steel grades. It was found that using lower grade steel in X-braces increases the stiffness, energy absorption capacity, and ductility of the system and decreases its lateral drift. The proposed theory along with analyses showed that building codes and steel seismic design specifications can consider the effects of steel grades in seismic parameters definition of structures. The comparative diagrams and tables show that the seismic behavior of X-braces designed with lower-grade steel improves considerably. Furthermore, the response of structures under near field earthquakes is bigger than related parameters under far-field earthquakes. Also, with an increase in height of the frames and governing bending behavior (relative to shear behavior) and more effects of columns in lateral deflection of frames, the effects of lower-grade steel in the overall behavior of taller buildings decreases gradually.

6. Acknowledgement

This research was supported by Shahr-e-Qods Branch of Islamic Azad University.

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HOW TO CITE THIS ARTICLE

P. Ebadi, M. Moradi, Application of Lower Grade Steel on Dynamic Behavior of X-braces in Shear Part 2: Advanced Nonlinear Static and Incremental Dynamic Analyses (IDA), Amirkabir J. Civil Eng., 53(1) (2021) 83-86.

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