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The Probabilistic Analysis of Steel Moment-Resisting Frame Structures Performance under Vehicles Impact

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ABSTRACT: Over the recent decades, with spreading unusual events such as fire, blast, and vehicles collision, studying the behavior of structures subjected to abnormal loadings has been attracted the attention of researchers and structural engineers. Among the various scenarios of impact loads, the collision of light and heavy vehicles to the external column of steel buildings accidentally and or intentionally is important as a research and an applied topic. The impact loads caused by vehicle collisions to the column of buildings are usually not considered in the design, so it's necessary that the effect of these loads should be studied on the nonlinear performance of structures. In this study, the steel moment-resisting frame structures 2, 5, 8 and 12-story with intermediate ductility are designed for gravity and seismic loads and then nonlinear dynamic analyses are conducted under the impact induced by Light and heavy vehicles collision to corner column of side axis by OpenSees software and fragility curves are proposed based on the different damage levels. Finally, structural responses of studied frames are investigated and compared due to the collision impact with different velocities until the occurrence of dynamic instability. The results showed that the impact induced by light vehicle collision at velocities 80, 100, 140 and 130 km/h and impact induced by the heavy vehicle at velocities 50, 60, 80 and 70 km/h has been caused dynamic instability in the desired frames 2, 5, 8 and 12-story, respectively.

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1- Introduction

In the last decade, due to the increasing terrorist threats all over the world, much attention and attempts have been paid to the design and analysis of resistant structures against abnormal loads. Traditionally, structural engineers designed and analyzed buildings against usual lateral loads such as earthquake and wind, but in some cases, the investigation of the nonlinear performance of structures against abnormal loads such as vehicles impact and blasts is important, too [1]. Regarding assurance to performance of structures has always been an important principle for engineers and designers, and since complete assurance to the quantity of a potential natural or unnatural accident is not possible. So, it's necessary to investigate the nonlinear performance by extracting structural responses and fragility curves are considered logical [2]. Some papers have been conducted in this field. Park et al. [3] analyzed the sensitivity of a steel moment-resisting frame due to column removal. The Monte Carlo Simulation method (MCS) and the First-Order Second Moment method (FOSM) have been used. The results showed that the random variable of yield strength of beam was the most effective parameter in the design of the frame under the effect of column removal. Kim et al. [4] evaluated the behavior of 3-story steel moment-resisting frame structure under the effect of vehicle impact to the external corner by fragility curves with different velocities. Santos et al. [5] investigated the failure of common types of beam-column joints of the steel moment-resisting frame subjected to vehicle impact and the results showed that the reduced beam connection (RBS) caused the beam yielding mechanism and had better performance against impact loadings. Sadeghi et al. [6] evaluated the reliability of the structure of a 2-story steel moment-resisting frame under the impact of a light vehicle, taking into account the uncertainty in the materials and applied loads, using simulation-based methods. The results showed that the control variates-based subset simulation method (CSS) compared to MCS method, with fewer samples and shorter computational time, it estimates the probability of failure with an acceptable error.

In this study, the probabilistic framework is proposed based on fragility curves of the steel moment-resisting frames with different stories under the effect of light and heavy vehicle impact with different collision velocities. Finally, the dynamic instability velocity is obtained for every scenario.

2- Methodology

In this study, three-dimensional structures with 2, 5, 8 and 12-story and a lateral bearing system of intermediate steel moment- resisting frame in both longitudinal and transverse directions are considered. These structures are designed

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based on Iranian design regulations (Codes 6 and 10 of National Building Regulations [7, 8]) and Standard No. 2800, 4th Edition [9] on soil type II in a very high risk zone (A = 035 g) with ETABS software [10]. They are designed by LRFD method. Dead and live loads of stories are applied at 500 and 200 kg/m^2, respectively, and the critical criterion in designing the models of the building is drift. By examining the results, the ratio of demand to capacity in all its structural elements was far less than one. The two-dimensional frame of the side axis is extracted and modeled for nonlinear dynamic analysis under impact loads in OpenSees software [11]. Dead and live loads applied to the mentioned frames are 1500 and 600 Kg¬/¬m, respectively, and the used steel materials in the beams and columns are ST37 type with the values such as an elasticity modulus 200,000 MPa, a yield stress 240 MPa and ultimate stress 370 MPa are considered. Then, two-line uniaxial steel materials with kinematic and isotropic hardness are assumed based on Steel01 model with a hardness of 3% [3]. Therefore, probabilistic analyses are conducted.

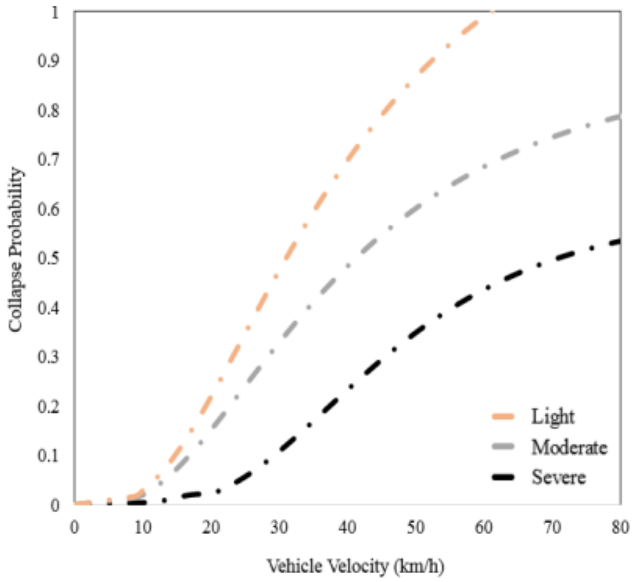

Fig. 1. Fragility curve of the 2-story frame under light vehicle impact

3- Results and Discussion

The side axle frames with 2, 5, 8 and 12-story are modeled in OpenSees 2.5.0 software. After performing nonlinear dynamic analyses under the effect of impact due to the collision of a light and heavy vehicle at different velocities (velocity step 10 km/h), software outputs such as maximum response Structures such as first-floor displacement, drift, base shear, first-floor acceleration, rotation of damaged beam, column axial force, and vertical displacement of beam-column connection at velocities Which causes the occurrence of dynamic instability. Finally, in order to probabilistically analyze the performance of the mentioned structures due to the impact loads caused by the collision of light and heavy vehicles according to different levels of damage, Fragility curves are presented. In the studied frames of 2, 5, 8 and 12-story, the collapse rate at the level of severe failure has decreased by 86, 58, 90 and 87%, respectively. Also, the median collapse rate of the studied frames of 2, 5, 8 and 12-story under the impact of light vehicle collision at low to severe failure level is 60, 58, 54 and 55, respectively. Also, the average collapse velocity under the impact of a heavy vehicle has increased by 40, 50, 49 and 50%, respectively. In the following, the fragility curves of 2 and 8-story frames are presented for light and heavy vehicle impact in Figures 1-4.

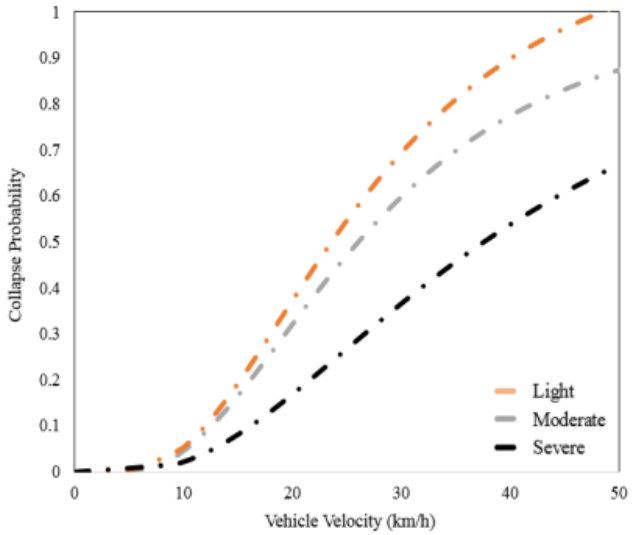

Fig. 2. Fragility curve of 2-story frame under light vehicle impact

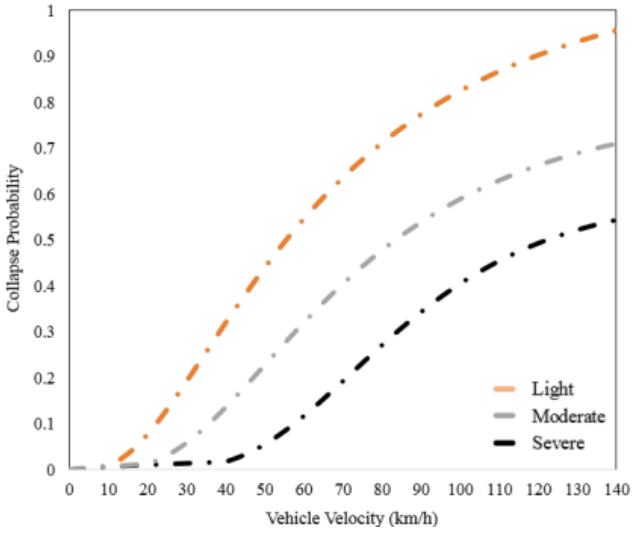

Fig. 3. Fragility curve of 8-story frame under light vehicle impact

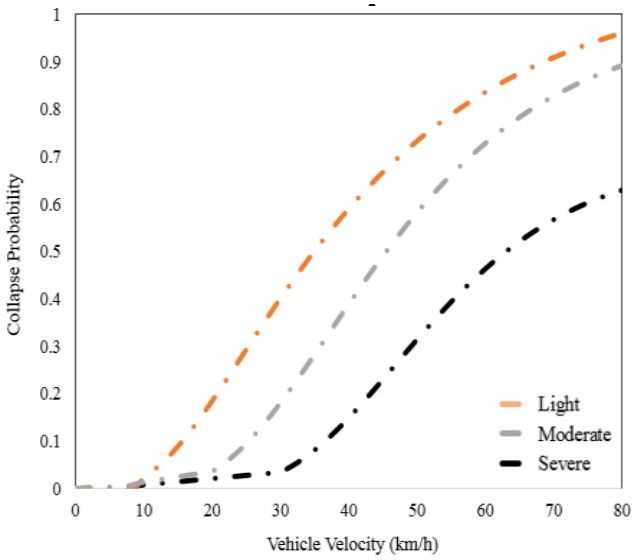

Fig. 4. Fragility curve of 8-story frame under heavy vehicle impact

4- Conclusion

In this research, first, four structures of steel moment-resisting frames with 2, 5, 8 and 12-story are designed according to the regulations and then the two-dimensional frames of their side axis are extracted and they are analyzed under the effect of Light and heavy vehicle impact by OpenSees software. By reviewing and comparing the results of the analyses, the following notes can be mentioned:

- By increasing the collision speed of the vehicle, the velocity that caused the dynamic instability in the desired frames is obtained. The velocities of 80, 100, 140 and 130 km/h for light vehicles and 50, 60, 80 and 70 km/h for heavy vehicles caused dynamic instability of frames with 2, 5, 8 and 12-story, respectively.

- Among the studied frames, 8-story frame showed more collapse capacity than other prototypes and also, the 2-story frame indicated less collapse capacity against vehicle impact, so that 8-story frame was able to tolerate 140 and 80 km/h and 2-story frames up to 80 and 50 km/h speeds under light and heavy vehicles collision, respectively.

- The results of probabilistic analyses of the structures in question showed that, for example, in the short frame, the mean collapse velocity for low, medium and severe damage levels under the impact of a light vehicle were equivalent to 27, 37 and 69 km/h, respectively and under the impact of a heavy vehicle were equivalent to 22, 25 and 37 km/h, respectively.

- With the obtained results in this study, it can be said that in the event of an impact due to the collision of vehicles, the collision speed can be determined for the occurrence of dynamic instability of different structures, in which case the structures in question are also encountered with progressive collapse.

References

[1] K. Mehdizadeh, A. Sadeghi, and S. V. Hashemi, The Performance Investigation of Steel Moment Frames with Knee Braces subjected to Vehicle Collision, Journal of Structural and Construction Engineering, (2019). (in Persian).

[2] K. Mehdizadeh, A. Karamodin, and A. Sadeghi, Progressive Sidesway Collapse Analysis of Steel Moment-Resisting Frames Under Earthquake Excitations, Iranian Journal of Science and Technology, Transactions of Civil Engineering, (2020).

[3] J. Kim, J. Park, and T. Lee, Sensitivity analysis of steel buildings subjected to column loss, Engineering Structures, 33(2) (2011) 421-432.

[4] M.M. Javidan, H. Kang, D. Isobe, and J. Kim, Computationally efficient framework for probabilistic collapse analysis of structures under extreme actions, Engineering Structures, 17(2) (2018) 440-452.

[5] A. F. Santos, A. Santiago, M. Latour, and G. Rizzano, Robustness analysis of steel frames subjected to vehicle collisions, Structures, 25 (2020) 930-942.

[6] A. Sadeghi, H. Kazemi, and M. Samadi, Reliability Analysis of Steel Moment-Resisting Frame Structure under the Light Vehicle Collision. Amirkabir Journal of Civil Engineering, (2020). (in Persian).

[7] INBC, Design Loads for Buildings. Tehran: Ministry of Housing and Urban Development, Iranian National Building Code, Part 6, (2013). (in Persian).

[8] INBC, Design and Construction of Steel Structures. Tehran: Ministry of Housing and Urban Development, Iranian National Building Code, Part 10, (2013). (in Persian).

[9] BHRC, Iranian code of practice for seismic resistant design of buildings, Tehran: Building and Housing Research Centre, Standard No. 2800, (2014). (in Persian).

[10] ETABS-Three Dimensional Analysis of Building Systems. Manual, Computers and Structures Inc., Berkeley, California, (2016). https://www.csiamerica.com/

[11] [OpenSees, Open System for Earthquake Engineering Simulation Manual, Pacific Earthquake Engineering Research Center, University of California, Berkeley, CA, (2007). http://opensees.berkeley.edu.

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