can be calculated using Eqs. 1 and 2 as a result of pushover analysis, and the results are shown in Fig. 3. As shown in the figure, the Ω and μ_T of steel SMFs tended to decrease with increasing number of stories. In addition, the Ω is evaluated to have a value lower than 3.0, which is the system overstrength factor (Ω_0) proposed for steel SMF in ASCE 7 (2017).This means that the steel SMFs that was designed using MRSA does not exhibit the intended maximum base shear strength regardless of height. In addition, the decrease in Ω and μ_T as the height increases indicates that the collapse rapidly occurs before the wide range of damages intended by the seismic design criteria occur.

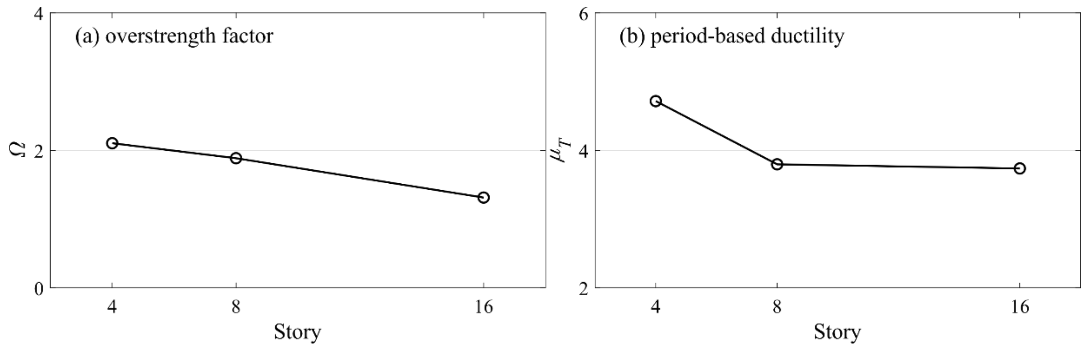

Fig. 3 Overstrength factor (Ω) and period-based ductility (μ_T) based on pushover.

Fig. 4 shows the median IDA curve resulting from IDA according to the procedure proposed in FEMA P695 (2009), IDA curve for specific ground motion, and P_c of steel SMFs. Fig. 4a shows the median IDA curve as a result of IDA. In the figure, the horizontal and vertical axes represent the maximum inter-story drift ratio (θ_{max}) and intensity of ground motion at upper limit period, T. Where, T is $C_u T_a$ as the upper limit of the period according to ASCE 7 (2017). According to the median IDA curve, it was evaluated that it showed an elastic response regardless of the structural height until the θ_{max} reached 0.04 rad. A sudden collapse occurred after yielding in all steel SMFs, and this phenomenon was severe as the structural height increased. It is thought that the sway mechanism occurred as the P-Delta effect increased due to the increase in the lateral displacement of the structure. This tendency also occurred in the Ida curve for the specific ground motion shown in Fig. 4b.

As a result of seismic performance evaluation of steel SMF shown in Fig. 4c, it was evaluated that the P_c increase as the structural height increased. Due to this tendency, the 4-story steel SMF which is a low-rise building was evaluated as having a target seismic performance, but, 8- and 16-story steel SMF which mid- and high-rise building did not achieve the target seismic performance required by ASCE 7 (2017).

Figs 4d, e, and f show the distribution of plastic hinges near collapse due to a specific ground motion in Fig. 4b. as shown at the top of the center in Fig. 4, black, blue, and red marks indicate yield strength, maximum strength, and fracture, respectively, and show the damage of the nonlinear spring located in all structural members. As shown in the figure, the structure that was designed using MRSA was evaluated to have a distribution of damage to the columns and beams throughout the structure. In addition, it was evaluated that the damage to the beam was wider than that of the column, which is the intended result by the moment ratio criterion in the design of the steel SMF. Because of the wide distribution of damage to the structure, it was evaluated that it exhibited the same ductile behavior as intended in the steel SMF. However, the distribution of the fracture hinge is evaluated to be relatively concentrated in the lower part of the structure, and collapse occurred due to the sway mechanism at the location where the damage is concentrated. Therefore, in the case of mid- and high-rise steel SMF, which was designed using MRSA according to the current seismic criteria, despite the ductile behavior as intended, collapse is occurred caused by the rapid lateral displacement due to the P-Delta effect at an early time. In order to improve the vulnerability, it is necessary to delay the collapse due to the P-Delta effect, and it is considered that additional control of lateral displacement is necessary.

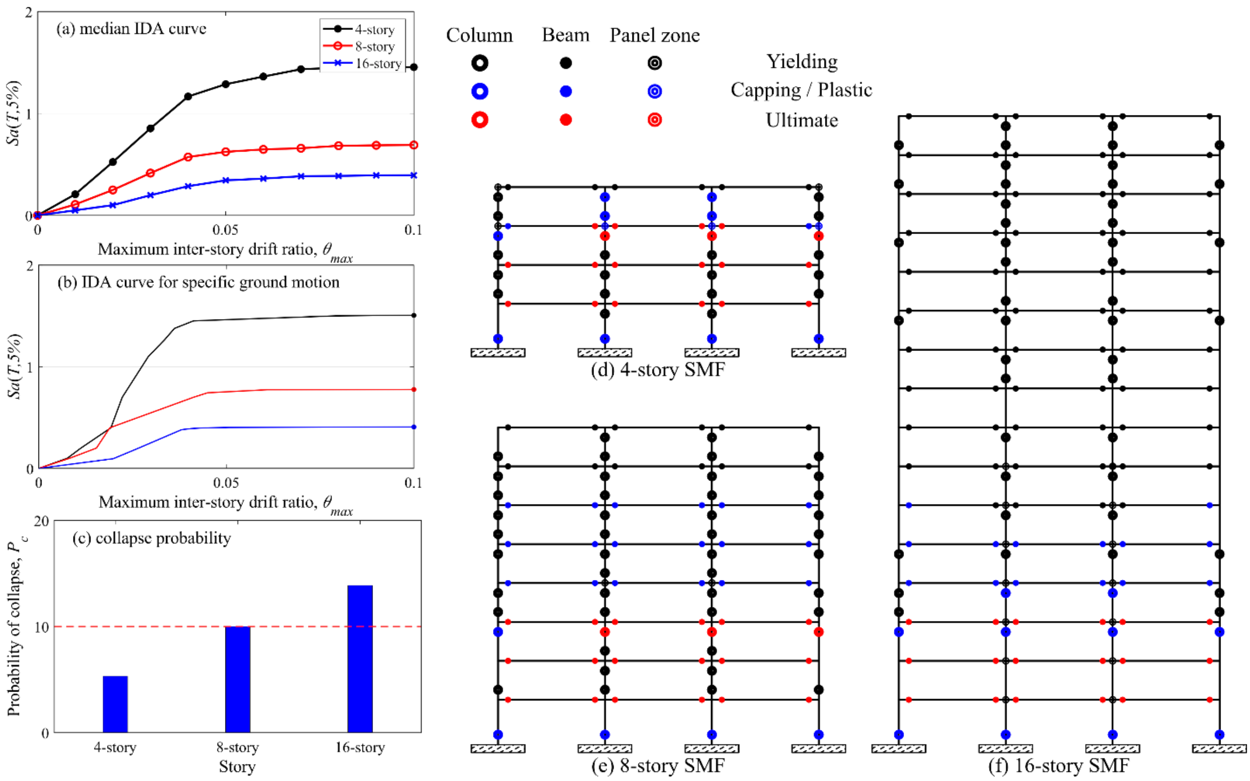

Fig. 4 Median IDA curve and plastic hinge distribution near collapse at dynamic analysis.

5. Conclusion

The purpose of this study is to evaluate the feasibility of the MRSA proposed in ASCE 7 (2017) by evaluating the seismic performance of the steel SMF, which was designed according to current seismic design criteria using MRSA. To this purpose, 4-, 8-, and 16-story steel SMF are designed, and seismic performance evaluation according to FEMA P695 (2009) is performed. As a result of the study, as the structural height increased, the probability of collapse of the steel SMF increased, and in the case of a mid- and high-rise building, the target seismic performance is not secured. The increase in the probability of collapse according to the structural height is evaluated as the cause of the sway mechanism, as the damage to the structure occurred intensively in the lower stories. although all the steel SMFs in which the design was carried out showed ductile behavior due to a wide range of damaged as intended by the seismic design criteria, the intended seismic performance is not secured by the collapse caused by the P-delta effect at an early stage. Therefore, it is judged that an additional design criterion for controlling the lateral displacement is necessary to secure the seismic performance for the mid- and high-rise steel SMFs.

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