STEEL BAR FRACTURE OF REINFORCED CONCRETE COLUMN UNDER EXTREMELY STRONG SEISMIC LOAD

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1. Object

In order to obtain the damage ratio and damage distribution of steel bar fracture in multi-story reinforced concrete frame (RC frame) under extremely strong ground motion, the dynamic loading test of RC column and seismic response numerical analysis of RC frame are carried out.

2. Steel bar fracture test of RC column

Steel bar fracture of cantilever RC column, which is subjected to strong cyclic lateral load (F) and varying axial load (N) simultaneously as shown in Fig.1, has been tested. As an example of test result, the time histories of column deformation, steel bar strains and restoring force of RC column specimen are shown in Fig.2, in which the steel bar fracture is explained by the dashed line. According to the test results, the steel bar fracture of specimen is considered as the very low cycle fatigue behavior.

3. Analysis method of steel bar fracture

On the basis of the behavior observed in the test results, the analysis method of steel bar fracture, which is expressed only by the loading cycles to fracture (N_f), is derived by the use of the Coffin-Manson equation and the Palmgren-Miner rule. In order to apply the analysis method to the seismic response analysis of multi-story RC frame, the fracture condition of steel bar is expressed by the column deformation (δ_c) under the conditions of the strain distribution and stress distribution explained in Fig.3.

Fig.4 shows the time histories of the plastic strains (ε_1, ε_2) of steel bar calculated by the column deformation (δ_c). The strain amplitude of every cycle to calculate the damage ratio of column is also shown in Fig.4. The plastic strain cycles until the steel bar fracture are calculated by the presented method and compared with the test results in Fig.5. We can see that the lower limit of the test results $(N_f)_{Test}$ is approximated by the calculated cycles $(N_f)_{Cal}$.

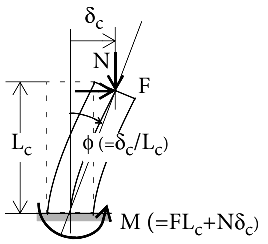

Fig.1 Loads of RC-column (F, N) and restoring force (M) of fixed-end

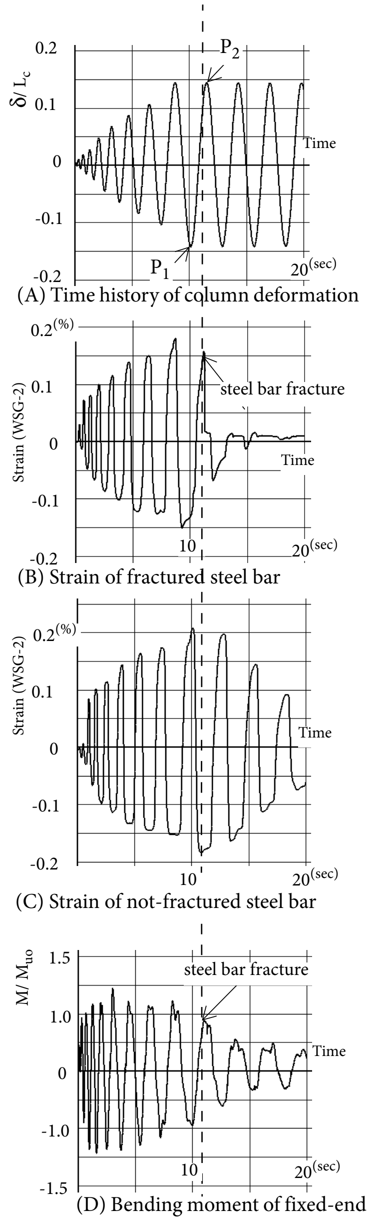

Fig.2 Time history of steel bar strain to show the steel bar fracture

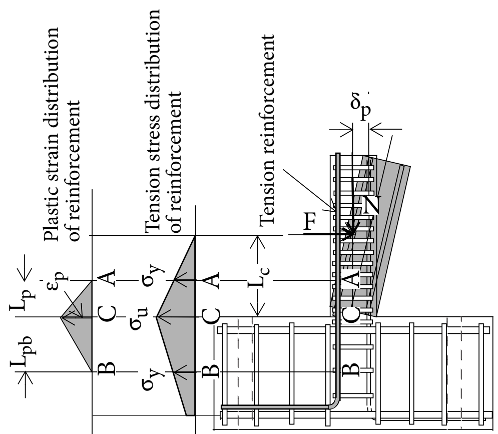

Fig.3 Plastic strain distribution and stress distribution of tension steel bar

4. Damage of steel bar fracture in seismic response of RC frame

By the use of the presented analysis method of steel bar fracture, the seismic responses of RC frame under extremely strong ground motion recorded in Hanshin Earthquake 1995 (JMA-KOBE) are calculated. Some of the calculated results are shown in Fig.6 and Fig.7 in which T: the natural period of frame, r_c: the column over design factor (the ratio of column strength to beam strength), p_t, p_c : the tension and compression reinforcement ratios. The damage ratio (D_{cr}) and damage distribution of steel bar fracture are expressed by the thick lines perpendicular to the members. The thick lines are also explained by the numerals in the figures.

5. Conclusions

In the seismic response of RC frame under extremely strong ground motion, we can see that the damage distribution is complicated and the damage ratio is quite high in some cases even if the RC frame is designed well in accordance with the seismic design code of Japan. From the calculations we need pay attention to the steel bar fracture as one of the critical design conditions of multi-story RC frame.

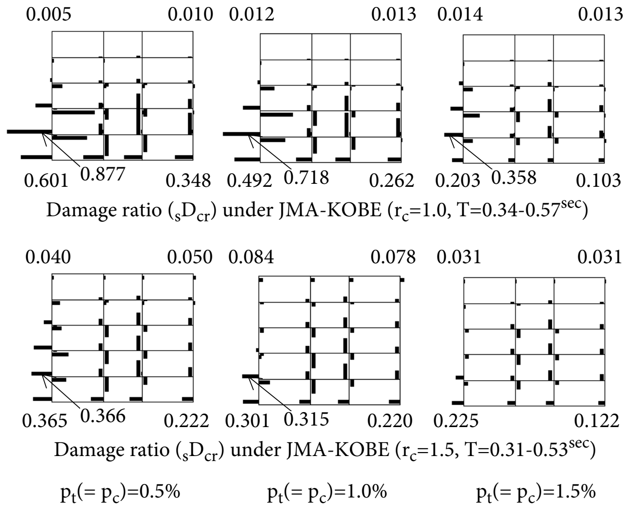

Fig.6 Seismic response damage of 5-story RC-frames

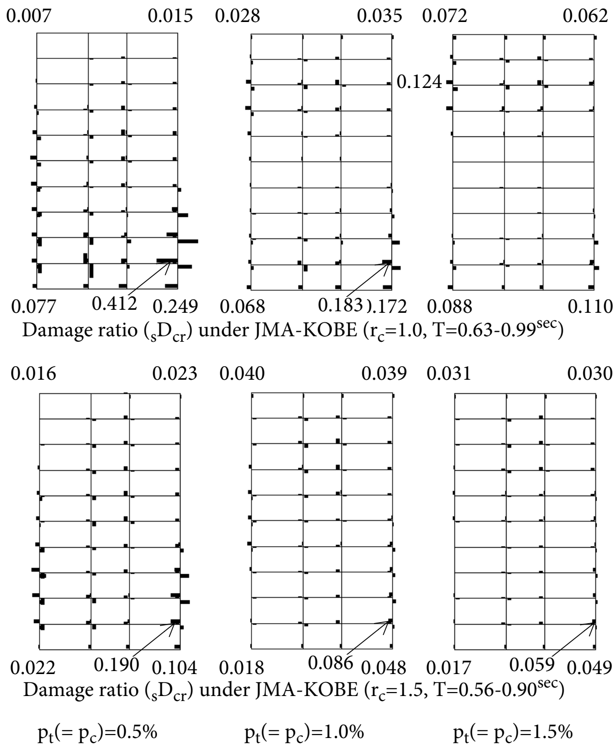

Fig.7 Seismic response damage of 10-story RC-frames

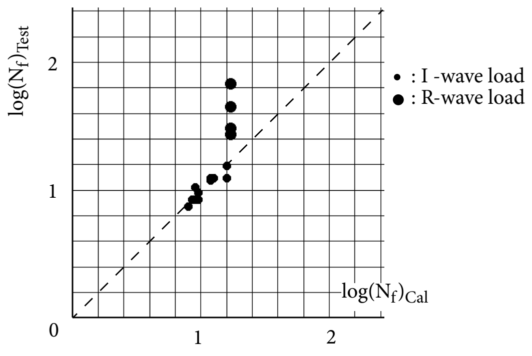

Fig.5 Comparison of calculated steel bar fracture by the very low cycle fatigue $(N_f)_{Cal}$ and test results $(N_f)_{Test}$

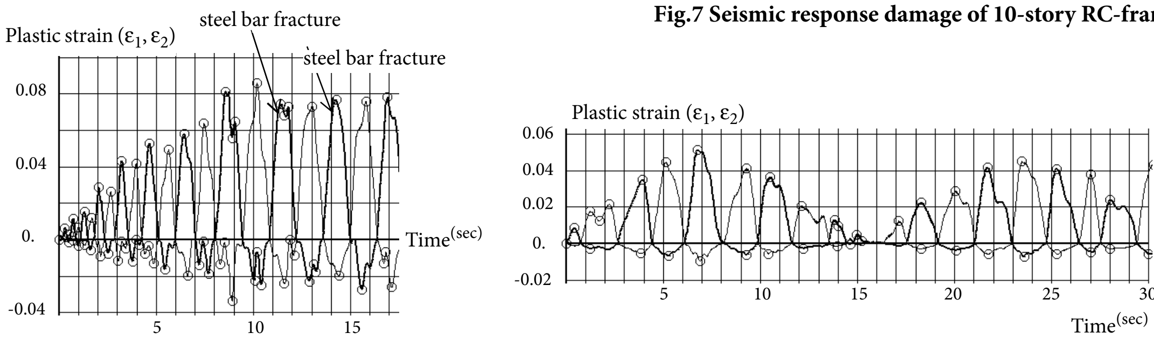

Fig.4 Time histories of steel bar strain and cycles obtained from the column deformation of specimen