VERY LOW CYCLE FATIGUE TESTING OF STEEL ANGLES FOR EARTHQUAKE LOADING

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1. OBJECTIVE In order to make a seismic safety assessment model for steel structures and members, first of all, it is necessary to investigate the correlations for all of the important physical factors associated with fatigue damage and failure under earthquake loading[1]. The main objective of this study is to identify the quantitative relationships between these factors related to cumulative earthquake damage and ultimate failure through very low cycle fatigue tests for steel angles in about 5-30 cycle ranges.

2. DESCRIPTION OF SPECIMENS AND TEST SETUP The specimens were SS41 grade angles of L-40x40x3 and L-40x40x5. The yield stress and the ultimate tensile strength of the materials were within 339-344 N/mm^2 and 456-470 N/mm^2, respectively. In order to measure local fiber strains after testing, surface marks, with 2mm pitch for a length of 80mm, were induced parallel to the longitudinal axis in the middle part of the specimens, using a Vickers hardness tester. The specimen was pin-supported at both ends. Repeated uni-axial load was applied to the specimen whose length L between pin-supports was 30cm. This causes buckling of the specimen on the compression side, thus developing very high strain level. The load was controlled by the relative axial displacement Δ with constant or increased amplitudes under compressive displacement range, as indicated in Table 1.

3. TEST RESULTS AND DISCUSSION During testing, positive and negative deflection modes in the form of Fig. 1 were observed. Regardless of the deflection modes, visible cracks were initiated on the concave side of deformation while it was stretching. Typical load-displacement behavior of the specimens is shown in Fig. 2. Here load P and relative displacement Δ are normalized by the yield load N_y and the specimen length L, respectively. Inelastic local-buckling caused a sudden decrease in the compressive load-carrying capacity, but a slight decrease in the tensile load-carrying capacity. Visible cracks were initiated in L5CP and L5IP at the 11th cycle and 22th cycle(=the second cycle at the 6th amplitude level), respectively. Just after the first visible crack, the compressive and tensile load-carry capacities were considerably reduced. It is thus found that the ultimate failure is closely related to the initiation of a visible crack.

An example of the relationship between the dissipated energy and the number of cycles is shown in Fig. 3, where E_o is the maximum elastic strain energy that can be stored in the specimen. Since the cumulative energy absorption capacities under the very low cycle fatigue testing are apparently different even among the specimens of the same loading pattern or of the same deflection mode, it is very difficult to correlate quantitatively the actual physical damage during testing with the energy absorption capacity. In other words, energy absorption capacities depend upon the loading condition and the failure mode. Fig. 4 shows typical distributions of local fiber strains accumulated along the longitudinal axis after testing. Visible cracks resulted from a severe concentration of cumulative strains at the critical section. The maximum cumulative net strains, not including the crack opening, related to the crack occurrence, regardless of loading patterns, failure modes, and of width-to-thickness ratios, were in the range of 25-35% on the elongation side and 30-40% on contraction side (see Table 1).

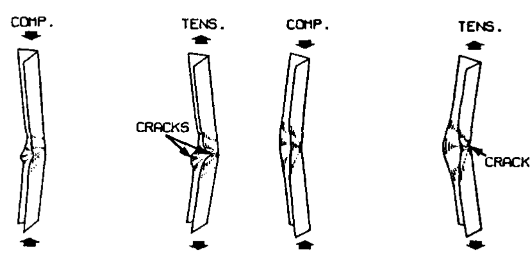
4. SUMMARY Steel angles were tested to trace the details of failure process under large cyclic deformations. It is found that energy absorption capacities depend upon the loading condition and the failure mode. The initiation of a visible crack due to repeated loading is strongly related to the cumulative strains of the order of 30-40%, regardless of loading patterns, deflection modes, and of width-to-thickness ratios.

5. REFERENCE 1) S. Iwai, T. Nonaka, U. Bourgund, H. Kameda: Structural Failure due to Very Low Cycle Fatigue of Steel Members and Elements under Earthquake Loading, Proc. of 8th Japan Earthquake Engrg. Symp., Vol. 2, 1990, pp. 1377-1382.

Table 1 Loading program and test results

Specimen Name	No.	t(mm)	(Δ/L)x100	Mode of Deflection	Max. Strain(%) tens.	Max. Strain(%) comp.
L3IN	4	2.5	-0.5 - 0 (4) -1.0 - 0 (4) -2.0 - 0 (4) -4.0 - 0 (4) -8.0 - 0 (4) -12.0 - 0 (4)	N	-	-
L3CN	5	2.5	-8.0 - 0(30)	N	25.0	-41.0
L3CP	6	2.5	-8.0 - 0(16)	P	27.5	-28.5
L5IN	7	4.6	same as No. 4	N	25.0	-30.0
L5CP	8	4.6	-8.0 - 0(18)	P	32.5	-35.0
L5IP	9	4.6	same as No. 4	P	35.0	-35.0

(Note) C:Constant amplitude, I:Increasing amplitude
P:Positive deflection, N:Negative deflection
t:Thickness of angle leg
Δ:Relative axial displacement, ( ):No. of cycles
L:Specimen length between both pin-supports



(a) positive mode (b) negative mode

Fig. 1 Deflection modes and cracking patterns

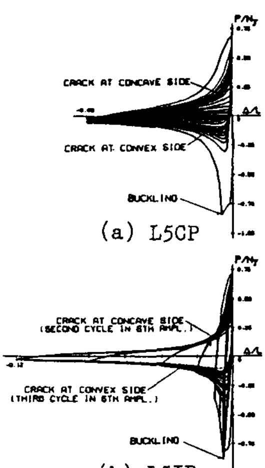


Fig. 2 Load-displacement relations

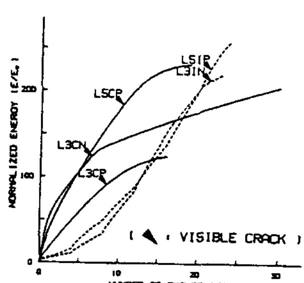
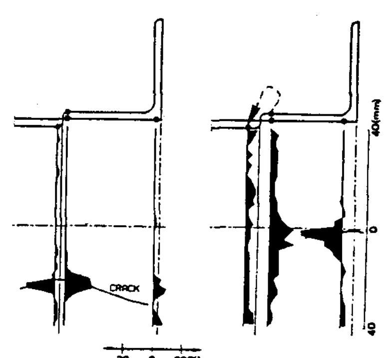


Fig. 3 Comparison of cumulative energy dissipation capacities in the course of increasing No. of Cycles



(a) positive mode (b) negative mode

Fig. 4 Distributions of local fiber strains