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Static and dynamic cyclic performance of a low-yield-strength steel shear panel damper

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ABSTRACT

Low-yield-strength steel 100 (LYS100) is widely applied to design a metallic shear panel damper for its high ductility. A low-yield-strength steel shear panel damper (LYSPD) with the maximum shear strain of 70% is developed and verified by static incremental cyclic loading in previous research. In this paper, further research on the performances of the developed LYSPD including the fatigue characteristic is carried out by static and dynamic constant cyclic tests. Four different shear strain amplitudes (20%, 30%, 40% and 50%) are selected in both static and dynamic tests. Two frequencies, 0.5 Hz and 1 Hz, are adopted for each of the four amplitudes in dynamic tests. Large differences such as stress softening, fatigue cycle deterioration, and temperature increase caused by high strain rate and internal friction are observed in dynamic tests. The test results suggest that the seismic performance of the LYSPD may be overestimated by static tests and the dynamic tests are essential to guarantee the reliability of the LYSPD.

1. Introduction

Shear panel dampers (SPD) are widely developed to dissipate the energy and to reduce or avoid the damage of the primary structures such as bridge and building, as demonstrated in Fig. 1 [1,2]. Generally speaking, the passive metallic damper for seismic applications in structure must exhibit: a) adequate elastic stiffness to withstand small earthquake and wind; b) yield strength not exceeding that of the structure; c) high energy absorbability; d) stable hysteretic force-displacement response which can be modeled easily; e) good low-cycle fatigue performance. As the low-yield-strength steel 100 (LYS100, yield strength 100 N/mm^2) possesses such merits as low yield strength, large deformation capacity and good low-cycle fatigue performance, it is undoubtedly a proper metallic material for SPD [3–5].

Failure in the LYSPD caused by repeated loads is typically attributed to the accumulation of a small number of cycles of large amplitude strains, which are normally considered within the plastic range for the gross section. Tension–compression cyclic tests are conducted on LYS100 for investigating the stress–strain behavior within the plastic range and the potential low-cycle fatigue characteristics in most researches [6,7]. However, the performance of the LYSPD would be affected by the stress concentration resulting from the emergence of the out-of-plane buckling, the formation of tension field and the material deterioration caused by welding and so on. That means the fatigue performance of material LYS100 can't reflect the real fatigue performance of the LYSPD. Therefore, the LYSPD mechanical properties and low-cycle fatigue characteristics should be verified by tests directly. On the other hand, for the limitation of test equipments, the full-scale LYSPD cyclic tests are concentrated on static tests currently [8,9]. However, the temperature of the steel LYS100 will increase for the high speed loading and internal friction. And the stress–strain relation would also be affected by high temperature [10,11]. To understand the performance of the LYSPD under dynamic loading and improve the credibility of application, the dynamic cyclic tests are put forward in this paper.

Recently, extensive experimental research has been undertaken at the Seismic Research Center of Aichi Institute of Technology in Japan in order to investigate the energy dissipation capacity (deformation capacity) of shear panels made from LYS100. A compact LYSPD serving as the bridge damper, with 70% shear strain (horizontal displacement/height) which is the largest deformation capacity at present in the world [12], is developed and verified by $\pm 5\%$ shear strain static incremental hysteretic loading. Here, further investigation on the static and dynamic hysteretic performance of the developed LYSPD is attached importance on. Useful information taken as the preliminary design references such as mechanical properties and low-cycle fatigue are provided, compared and discussed based on constant static and dynamic tests.

2. Specimen details and test setup

2.1. Specimen

Tensile coupon tests for LYS100 are conducted and the obtained stress–strain curves are shown in Fig. 2. The yield strength σ_y defined by the 0.2% offset value of LYS100 $\sigma_{0.2}$ is 100 N/mm^2 and the elongation

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