# Experimental Study on Low Cycle Fatigue and Hysteresis of Shear Panels with Low Yield Strength Steel under Dynamic Loading

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## Summary

In this experimental study, static and dynamic cyclic loading tests were conducted for shear panels using steel grade LY225 under the conditions of up to approximately 63%/s of shear strain rate, and approximately 2-10% of shear strain amplitude. The influences of strain rate on low cycle fatigue and hysteresis behavior were evaluated.

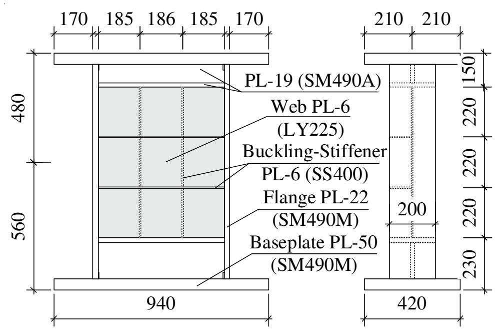
**Keywords:** passively controlled structures; strain rate; hysteresis energy absorption; temperature change; fatigue curve.

## 1. Introduction

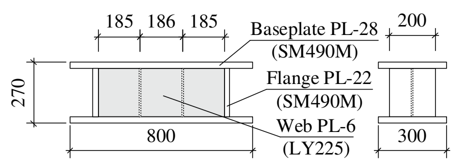
When comparing a static loading with a dynamic loading, for low yield strength steel grade LY100 and LY225, it is known that there will be increased in the maximum stresses. Meanwhile energy absorption per unit time grows large by using it as a damping member, it is expected that temperature rise becomes significant. Therefore, if damping members are used to centralize the energy absorption from an earthquake; hysteresis behavior and low cycle fatigue may be affected by the temperature rise of the low yield strength steel materials. In this experimental study, static and dynamic cyclic loading tests are conducted for shear panels using steel grade LY225. The influences of effects under dynamic loading such as the strain rate, temperature rise with respect to the hysteresis energy absorption behavior and low cycle fatigue are evaluated.

## 2. Test outline

There are two group of specimens. Specimens “3*3-Spe”(twelve specimens) as shown in *Fig. 1(a)*, and specimens “1*3-Spe”(six specimens) as shown in *Fig. 1(b)*. Steel grade LY225 was used for shear panel web of all specimens. Steel plates of the same thickness as the shear panel web were used as buckling-stiffeners. The buckling-stiffeners spacing to shear panel web thickness ratio is around 30. Baseplates were welded to the top and bottom ends of all specimens. Loading parameters are shown in *Table 1*. All the loading test patterns were cyclic loading with constant target deformation amplitude, using sine wave of defferent amplitude and frequency. In dynamic loading test, the test pause for 5-10 minutes after



*(a) 3*3-Spe*



*(b) 1*3-Spe*

*Fig. 1: Shapes of Specimens*

specified repeat count cycle were completed.

## 3. Test result and Investigations

### 3.1 Hysteresis characteristics

The influences of effects under dynamic loading such as strain rate and temperature change on the hysteresis behavior of the static loading were examined.

As shown in *Fig. 2*, when $\Delta_d\tau$ in all specimens was grouped according to specific temperature at 59ºC. We can observe that $\Delta_d\tau$ vary according to temperature. Thus, we can conclude that temperature dependence was important to be incorporated in the proposed theoretical model as the total of non-linear viscous element and *f(T)* depending on temperature (Note : By reffering to a published document, the rise of stress was modelled as a series consisting of the non-linear viscous element and the elastic spring [1]).

### 3.2 Low cycle fatigue

It was supposed that the hysteresis energy absorption of shear panels using steel grade LY225 when it became fatigue was constant regardless of strain rate. Under dynamic loading, fatigue of shear panel was defined as the cycle which absorbed equivalent energy during static loading of the same deformation amplitude. When we based on this assumption, the shear strain and fatigue relationships are shown in *Fig. 3*. The shear panel reaches fatigue in static loading when stress decreased more than 10% of maximum applied forces. In *Fig. 3*, it shows fatigue life during dynamic loading was almost in accordance to static loading.

## 4. Conclusions

The following findings were obtained for shear panels with buckling-stiffeners spacing to web thickness ratio of around 30, and temperature range of around 10-100ºC under the limited loading apparatus and parameter.

1) Hysteresis model of the shear panel dampers in the dynamic loading was obtained as the total of non-linear viscous element depending on strain rate and linear element depending on temperature.

2) Fatigue behavior during dynamic loading was almost in accordance to static loading when focus in the hysteresis energy absorption. However, the strain rate may influence the fatigue performance when the strain rate is larger than the loading parameters not covered by current experiments and if pause in loading interval are not provided.

## 5. References


[1] Kazuhiko KASAI et al. “Curved Hysteresis Model of Structural Steel under Cyclic Loading Part 7,8”, *Summaries of technical papers of annual meeting AIJ*, C-1, 2008, pp.907-910


*Table 1: Loading Parameters*

| Specimens | No. | Target deformation amplitude | Frequency [Hz] |
|---|---|---|---|
| 3*3-Spe | 1 | $\gamma_t$=±2.00% | Static |
| | 2 | | 0.16 |
| | 3 | | 1 |
| | 4 | $\gamma_t$=±2.63% | Static |
| | 5 | | 1 |
| | 6 | $\gamma_t$=±4.55% | Static |
| | 7 | | 1 |
| | 8 | | 2 |
| | 9 | $\gamma_t$=±6.67% | Static |
| | 10 | | 1 |
| | 11 | $\gamma_t$=±10.0% | Static |
| | 12 | | 1 |
| 1*3-Spe | 13 | $\gamma_t$=±2.90% | Static |
| | 14 | | 0.13 |
| | 15 | $\gamma_t$=±3.56% | Static |
| | 16 | | 0.13 |
| | 17 | $\gamma_t$=±8.10% | Static |
| | 18 | | 0.08 |

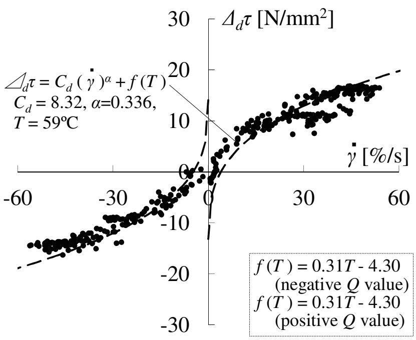



*Fig. 2: $\Delta_d\tau$ - $\dot{\gamma}$ Relationship*

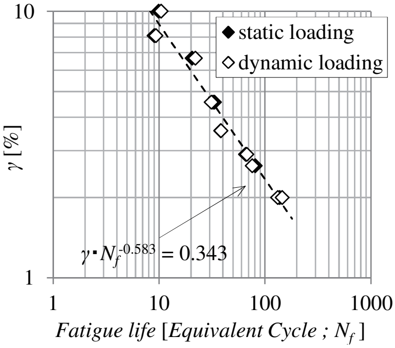



*Fig. 3: Fatigue life*