第I部門 Seismic Design Method of Steel Bridge Piers using the Fiber Model

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1. Foreword

The 1995 Hyogo-ken Nanbu Earthquake promoted widespread research efforts consisting of both experimental and analytical studies for the purpose of understanding the performance of steel bridge piers under seismic loads. The 1996 revised seismic design specification stipulated that ductility design method be used and performance be based on a nonlinear dynamic analysis using a hysteretic restoring force model. The fiber model uses a stress-strain hysteretic restoring force model[1)] and therefore can consider changing axial forces within a rigid frame. For this reason the fiber model is considered more accurate over other models.

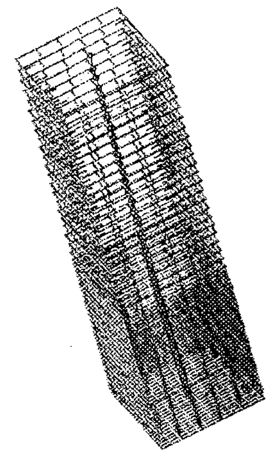

Fig.1 A rectangular specimen

2. Nature of Research

In this research, the fiber model is used for analysis of single rectangular and circular specimens of approxiamately 1/3 scale[2)] under pushover and cyclic loading pattern. Strain (on the compression face) and curvature (at base) are considered as parameters for expressing the allowable displacement of each pier.

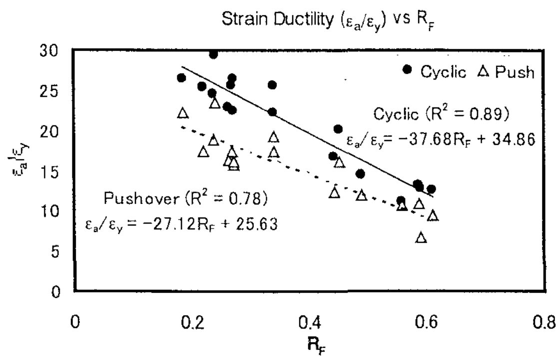

Fig. 2 Results for Strain Ductility

3. Rectangular Pier Results

Seventeen rectangular piers were analysed for strain and curvature. Allowable strain (ε_a) is defined as strain when the pier has been deflected to the displacement at ultimate load as defined by an experimental cyclic loading test. Results of strain ductility ($\varepsilon_a/\varepsilon_y$) were graphed against width thickness to flange ratio R_F (Eq.1) and a strong negative correlation was found for both pushover and cyclic loading patterns (Fig.2). Allowable curvature (ϕ_a) is defined as the difference of compression and tension face allowable strain per unit width (Eq.2). Similarly, a strong correlation was found with curvature ductility (ϕ_a/ϕ_y) against R_F (Fig.3). In comparison, strain ductility results shows that pushover analysis yields lower results than compared to a cyclic analysis. However, for curvature ductility, pushover and cyclic analysis results are almost identical.

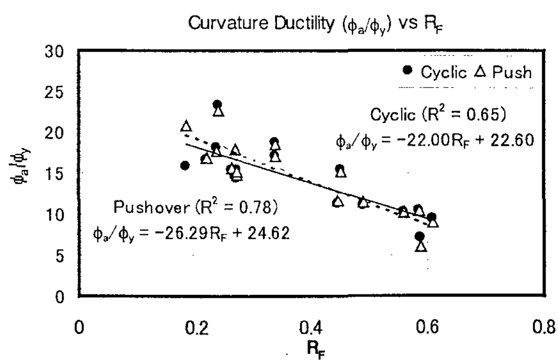

Fig. 3 Results for Curvature Ductility

$$R_F = \frac{b}{t_F}\sqrt{\frac{12(1-\nu^2)}{4\pi^2}\frac{\sigma_{yF}}{E_F}} \quad \textbf{(Eq. 1)}$$

$$\phi_a = \left(\frac{\varepsilon_{a,tension} - \varepsilon_{a,compresssion}}{B}\right) \quad \textbf{(Eq. 2)}$$

4. Parameter Analysis

The results of the strain and curvature were correlated against other standard parameters such as width to rib thickness ratio R_R, slenderness ratio λ and axial force ratio N/N_y. However the highest correlation remained with R_F against strain from a cyclic analysis (R^2=0.89). Next, combinations of parameters were investigated and a better correlation arose from multi-parameter $R_R x R_F(1-N/N_y)$ (R^2=0.92). However, the uncomprehensibility of $R_R x R_F(1-N/N_y)$ is not enough to outweigh the increase in correlation.

5.Cycle Influence Analysis

The cyclic analysis pattern was doubled in order to investigate the cycle influence on strain and curvature. Results showed an increase in negative strain producing a larger strain ductility ($\varepsilon_a/\varepsilon_y$) for compression face. However no change in curvature occured since the strain difference remained relatively unchanged. This indicates that curvature ductiliy (ϕ_a/ϕ_y) has an advantage over strain ductility ($\varepsilon_a/\varepsilon_y$) since in the range of allowable displacement the cyclic pattern makes no influence to the results.

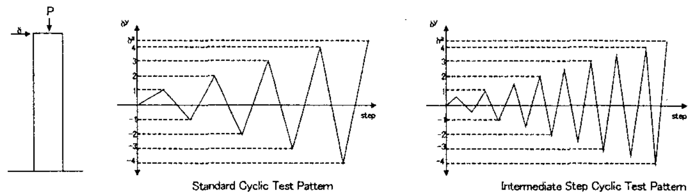

Fig. 4 Cyclic Pattern

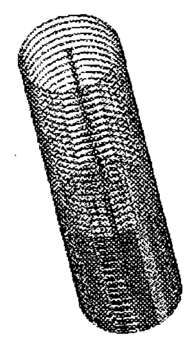

Fig. 5 A circular specimen

6. Axial Force Influence Analysis

Omitting the axial force causes strain to increase postively leading to a lower strain ductility for the compression face. However, the strain difference between compression and tension faces remains unchanged thus yielding no effect on curvature. Furthermore, cyclic anaylsis produces almost identical strain and curvature results to that of pushover. This is because without any axial force, strain values do not diverge to one side but oscilates symmetrically around zero.

7. Circular Specimens

For seven circular specimens analysis was conducted and a very high correlation with R_F was achieved (R^2=0.98). Similarly, the pushover analysis had lower strain results on compression face but similar results for curvature when compared to a cyclic analysis.

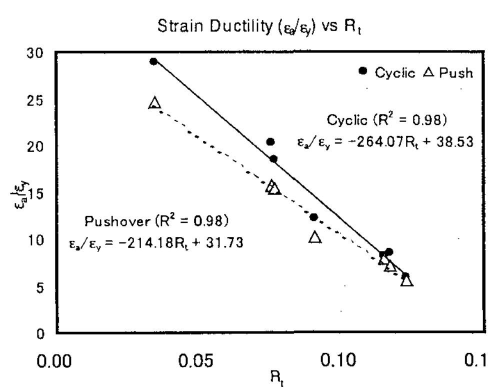

Fig. 6 Strain Ductility Results

8. Fiber Model Problem Points

In the fiber model, strain is very sensitive to the allowable displacement determined by the cyclic experiment test. As a result, the allowable strain does not agree highly with experimental strains and thus curvature is recommended as the more reliable seismic performance criterion over strain.

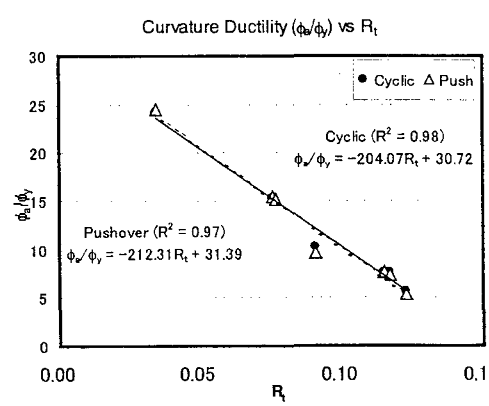

Fig.7 Curvature Ductility Results

9. References

1) Nakasu, K., Ono, K., Nishikawa, K., & Nonaka, T. Research related to the Setting of Restoring Force Model using the Fiber Model for Steel Bridge Piers based on Experimental Results. Japan Society of Civil Engineers, 55th Annual Academic Meeting, I-A143, 1999.9.

2) Public Works Research Institute of the Ministry of Construction and five organisations: Ultimate Limit State Design Method of Highway Bridges Piers under Seismic Loading, Cooperative Research Report, No. 219