FUNDERMENTAL EXAMINATION ON HYSTERESIS MODEL OF STEEL MEMBERS BY EXPERIMENTAL RESULT OF SHAKING TABLE TEST

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Introduction

- Shaking table test is the most effective method to examine the earthquake resistant performance of structural system under severe earthquake.
- Experimental results are also effective to examine the hysteresis models used in response analysis.

Introduction

- With the development of computer and numerical analysis methods, response prediction of steel structures based on time history analysis is gaining more and more popularity. Different hysteresis models of story, member and material are being used. It has become an important topic that how hysteresis models influence the results of response analysis in evaluating earthquake-resistance performances of steel frames.

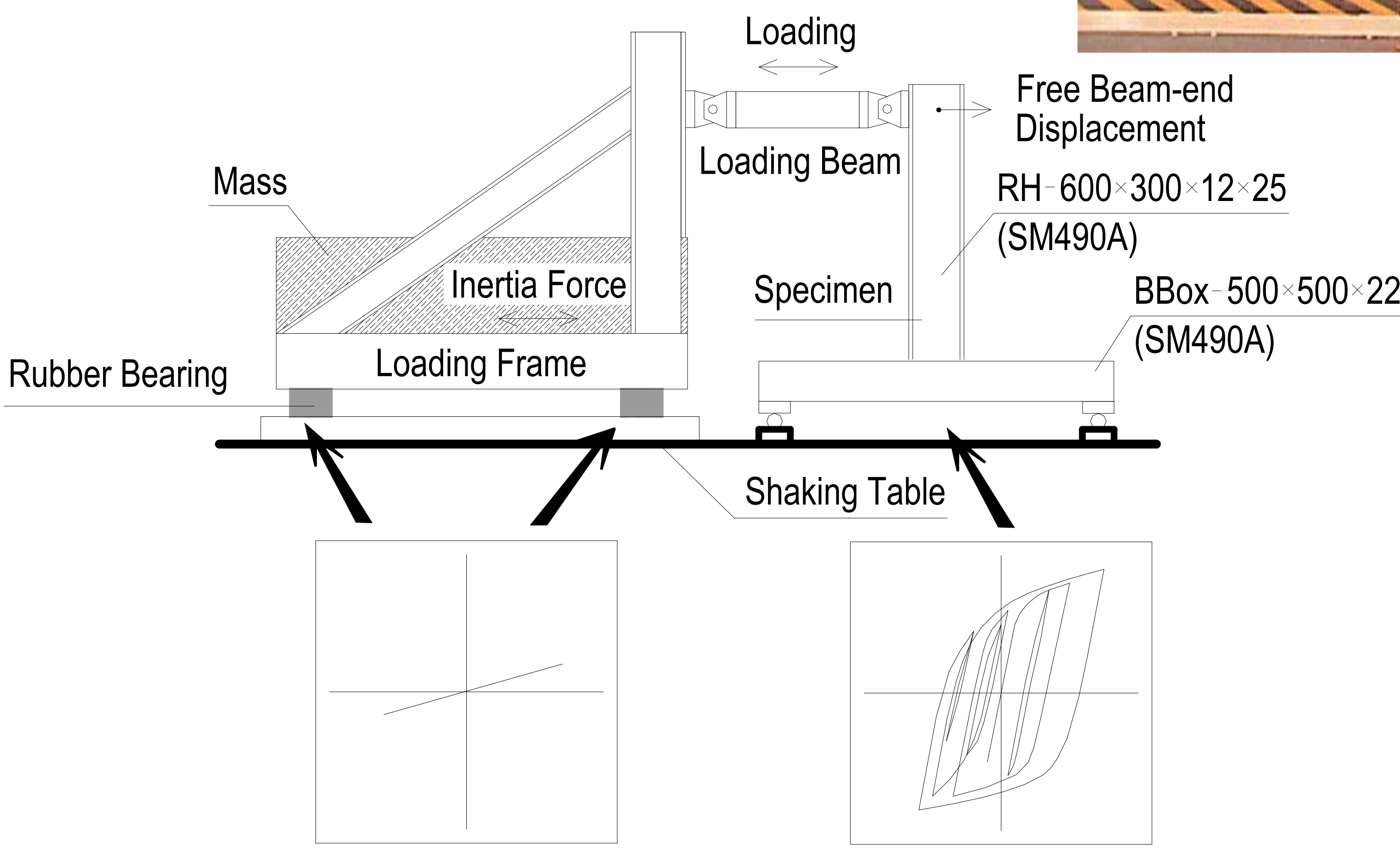
Introduction

- At first, experimental method of full scale real time shaking table test of partial steel frame is briefly introduced. Using this system, structural performances of steel structures, i.e. plastic deformation capacity of beam-to-column connection determined by brittle fracture, was investigated.
- One feature of this experimental method is its simple set-up as to be considered a SDOF system.
- So experimental results can be easily used to examine the hysteresis models used in response analysis.

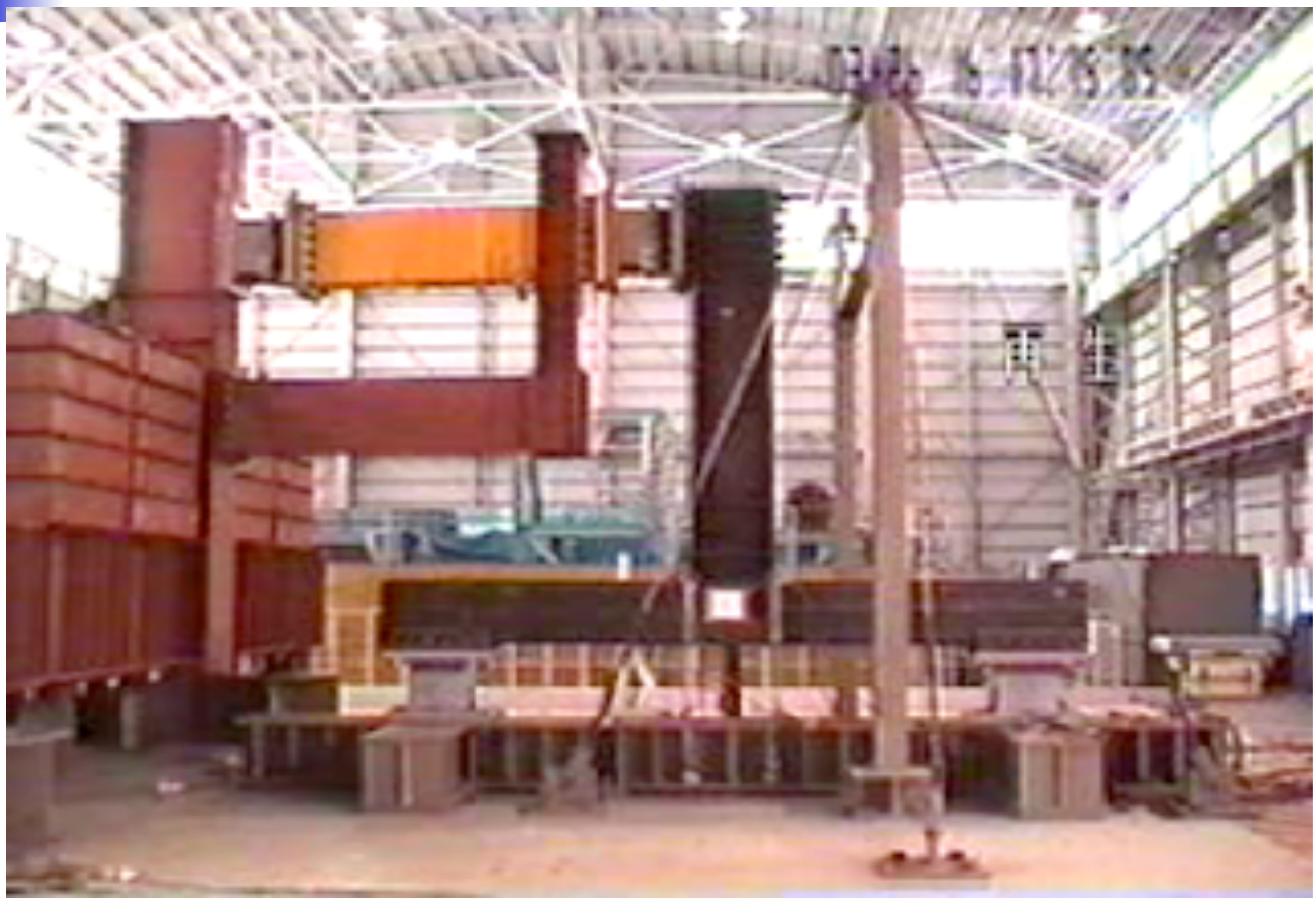
Introduction

- Next, fundamental examination of hysteresis model of steel members used in response analysis is discussed. SDOF systems with bi-linear models as well as multi-linear elasto-plastic models considering Bauschinger effect were considered in the response analysis. Models with their parameters that matched the experimental results well were examined.

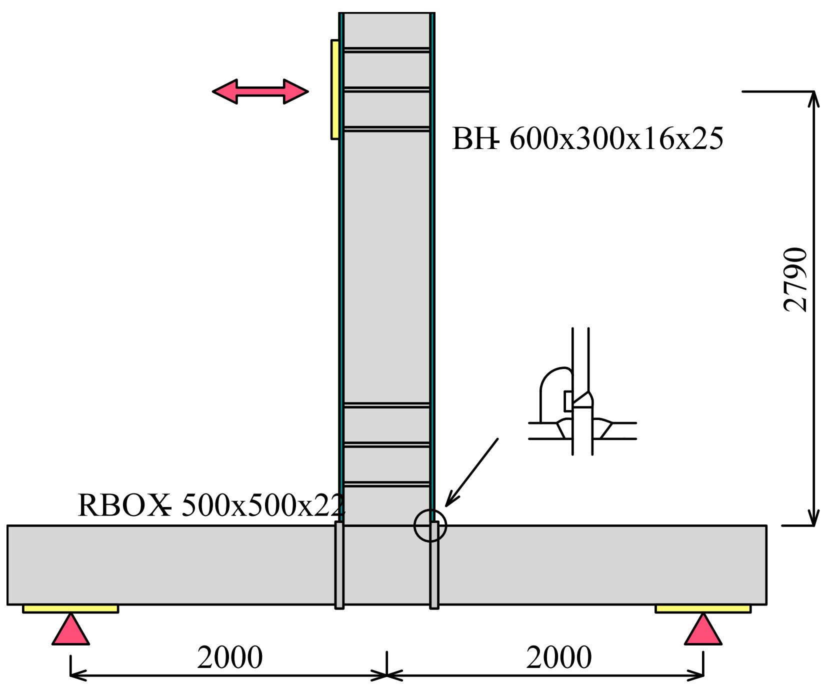
Shaking Table Test

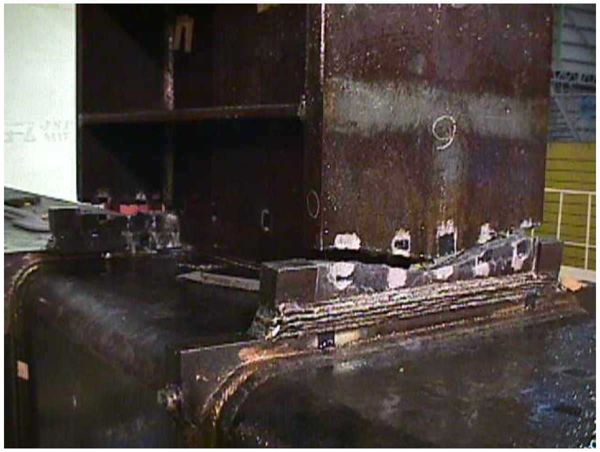


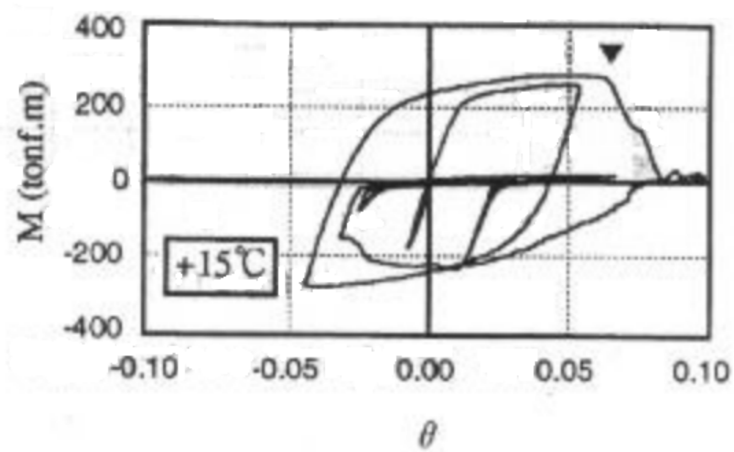
Shaking Table Test Movie



Shaking Table Test
Example of Experimental Results

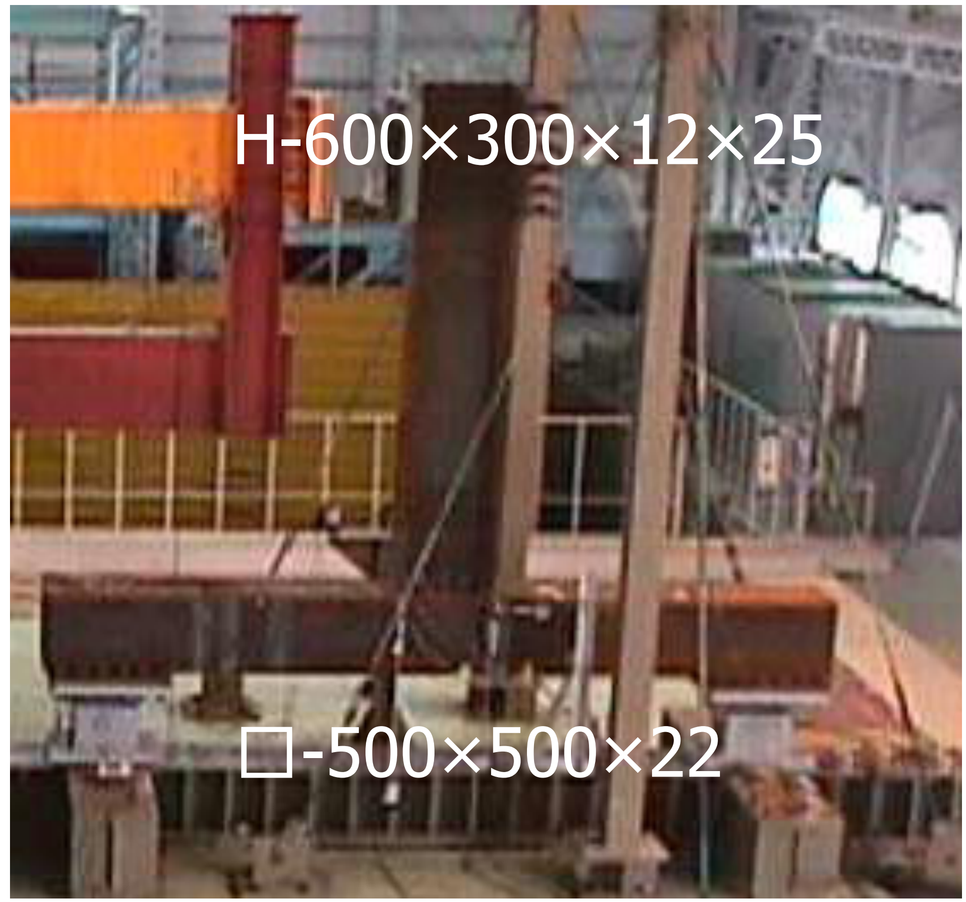






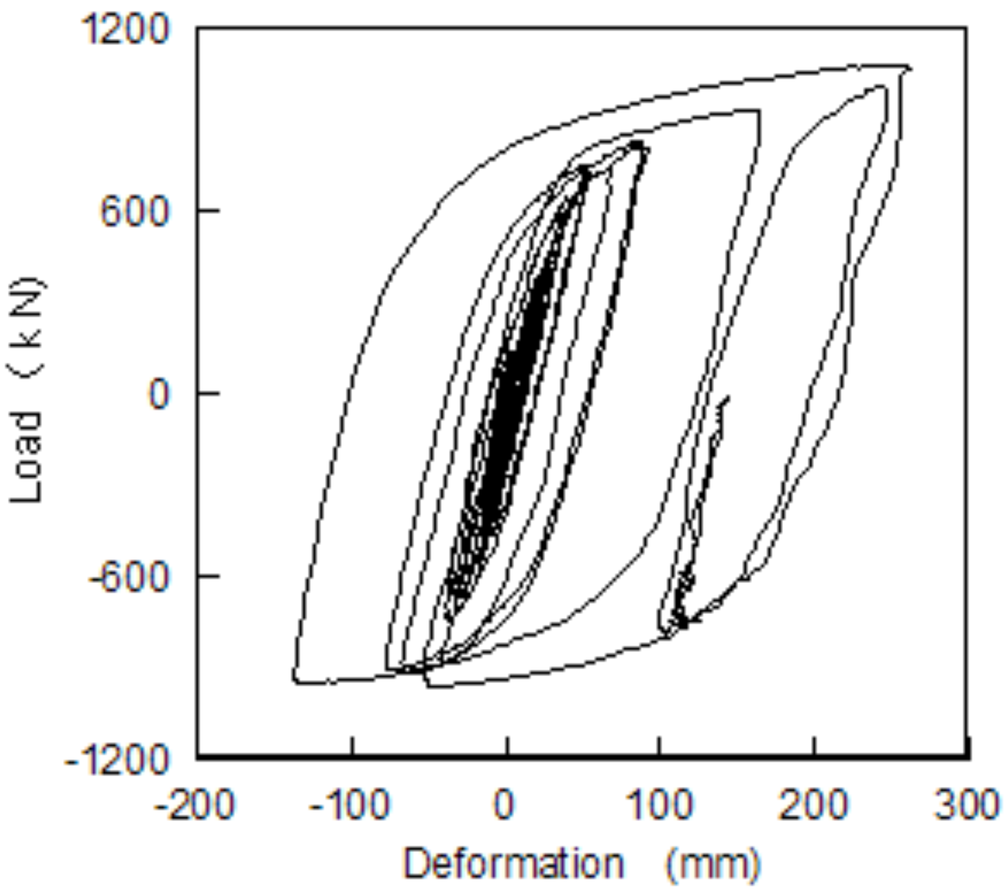
Response Analysis Data for examination

- One of the experimental results is used as the reference to compare with analytic responses.
- Specimen is full-scale partial frame with wide frange section beam of RH-600x300x12x25 and RHS section column of BBox-500x500x22.

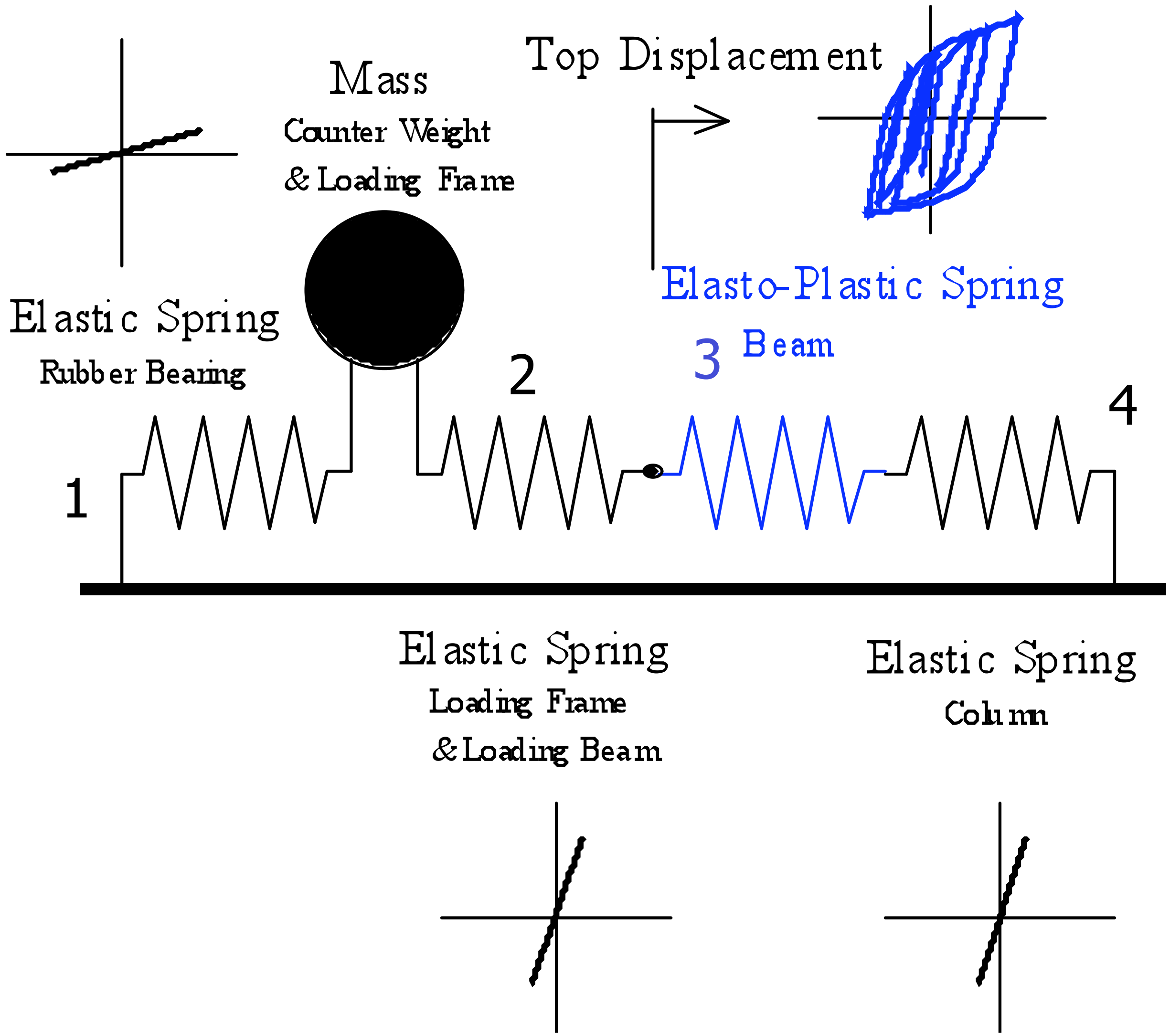


Response Analysis Data for examination

- NS component of JMA Kobe Record which was scaled to a peak velocity of 1.0 m/s, was used in the excitation.
- Steel beam of the specimen was plastified but not ruptured under the first excitation, and the column remained elastic



Response Analysis
Spring-mass Vibration Model

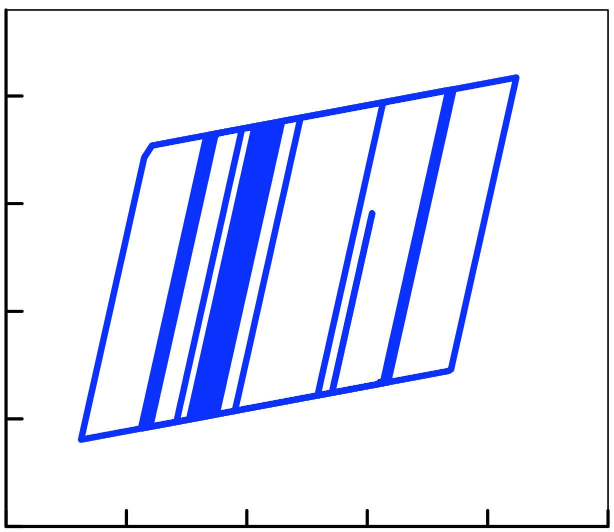


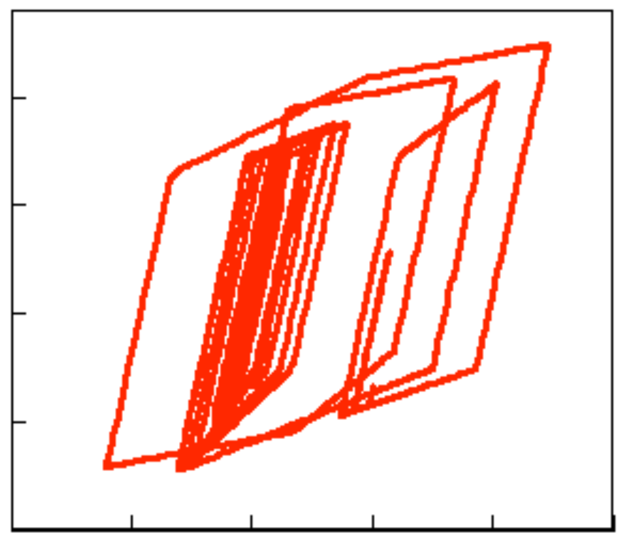
Response Analysis Parameter

Parameters of the hysteresis model were:

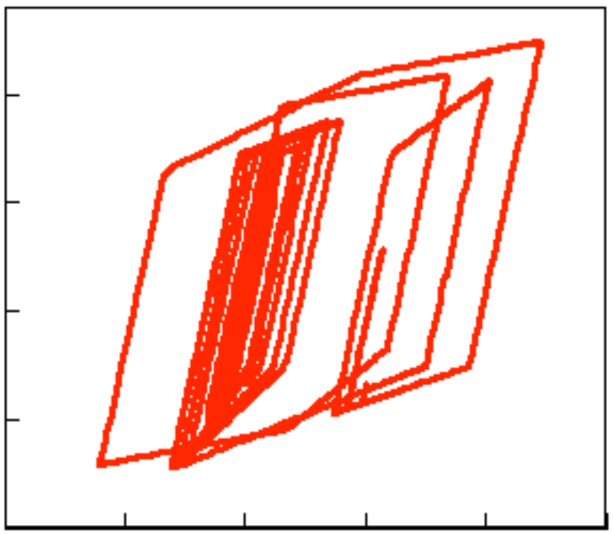
1) Types of hysteresis model (2 types)

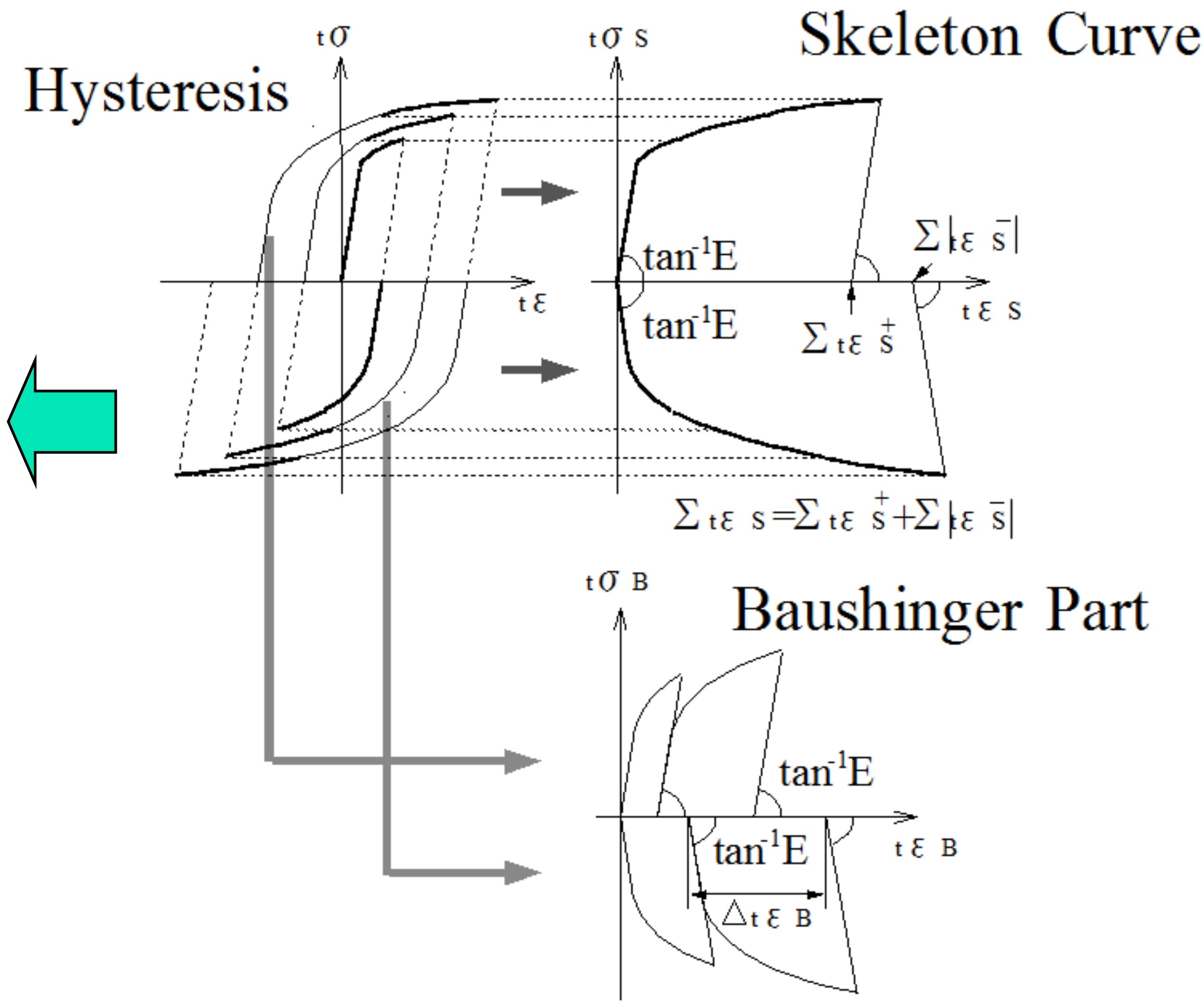
Bi-linear (including elastic-perfectly plastic) models and Multi-linear elasto-plastic models considering Bauschinger effect; (Akiyama and Takahashi 1990)





Response Analysis Parameter

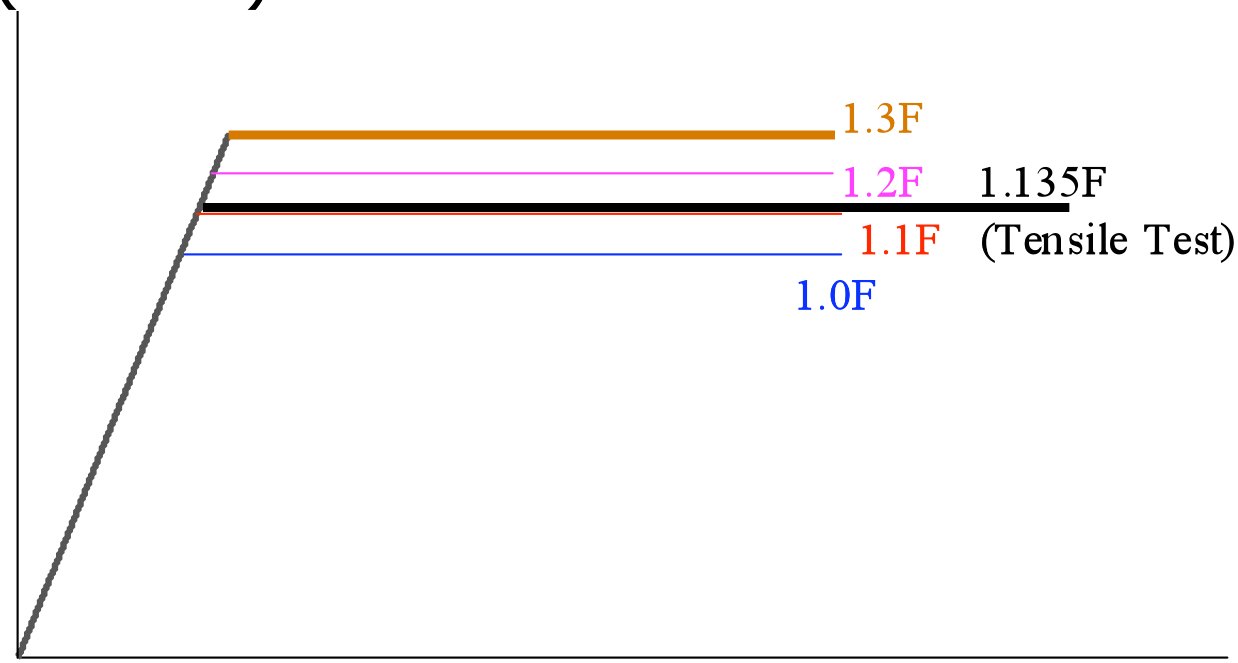




Response Analysis Parameter

2) Yield point (5 levels)

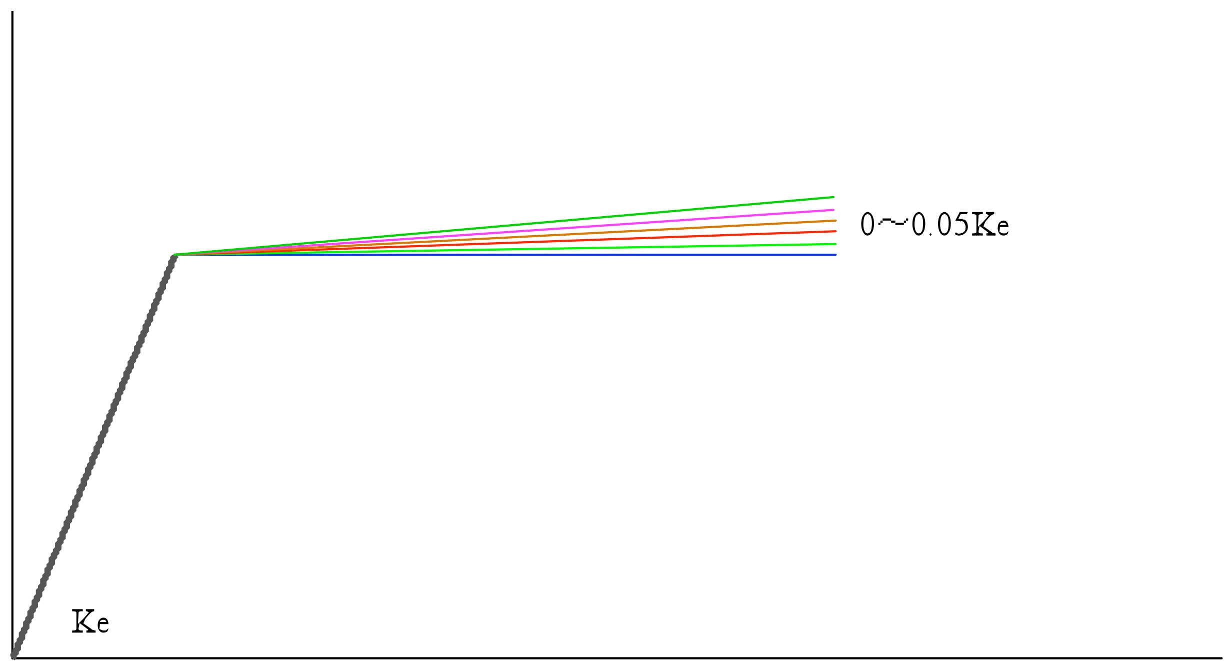
Nominal yielding strength of SM490A (According to the Japanese Code, F=325 N/mm^2), 1.1 F, 1.2 F, 1.3 F, and the result of tensile strength test (369 N/mm^2) (1.135 F)



Response Analysis Parameter

3) Second stiffness (6 levels)

Second stiffness ratio (k_2/k_e): 0, 1%, 2%, 3%, 4%, 5%



Response Analysis Estimation

- Estimation of the analytic response compared with the experimental data was based on the summed squared errors of load ($_eQ$) and displacement ($_e\delta$) at free beam-end according to the time history response.

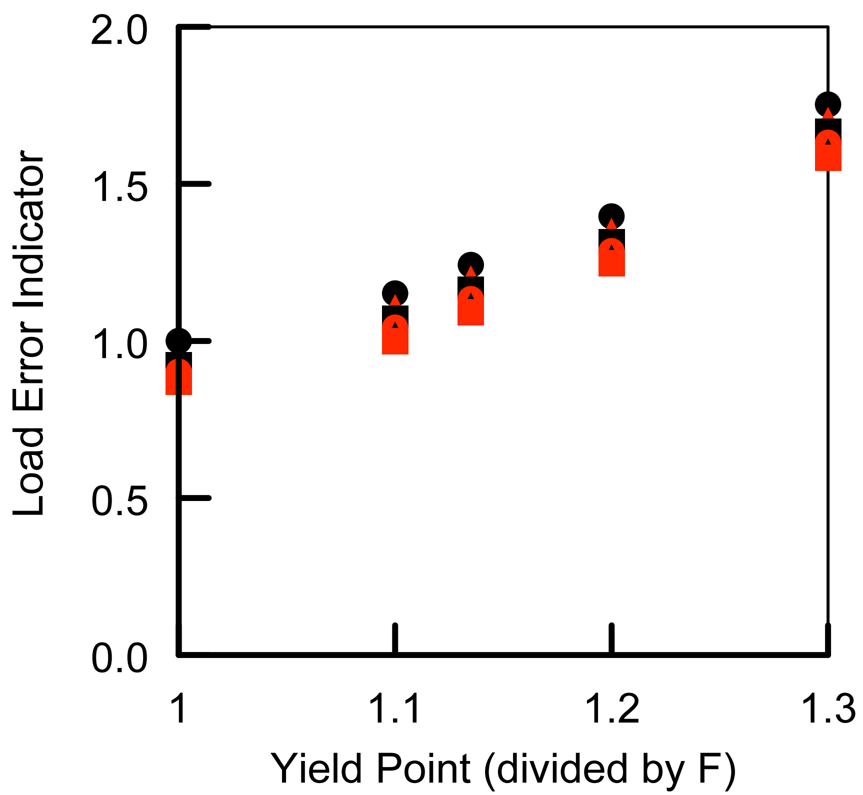
$$_eQ=\Sigma(Q_{a,i}-Q_{e,i})^2 \qquad (1)$$

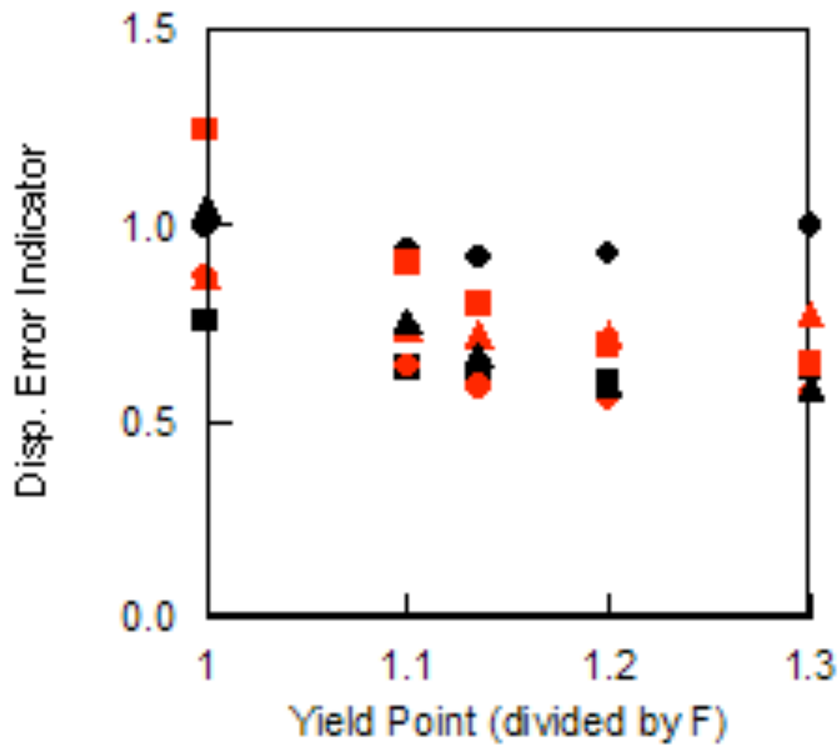
$$_e\delta=\Sigma(\delta_{a,i}-\delta_{e,i})^2 \qquad (2)$$

$Q_{e,i}$ is the experimental load, $Q_{a,i}$ is the analytic load, $\delta_{\varepsilon,\iota}$ is the experimental free beam-end displacement, $\delta_{a,i}$ is the analytic free beam-end displacement

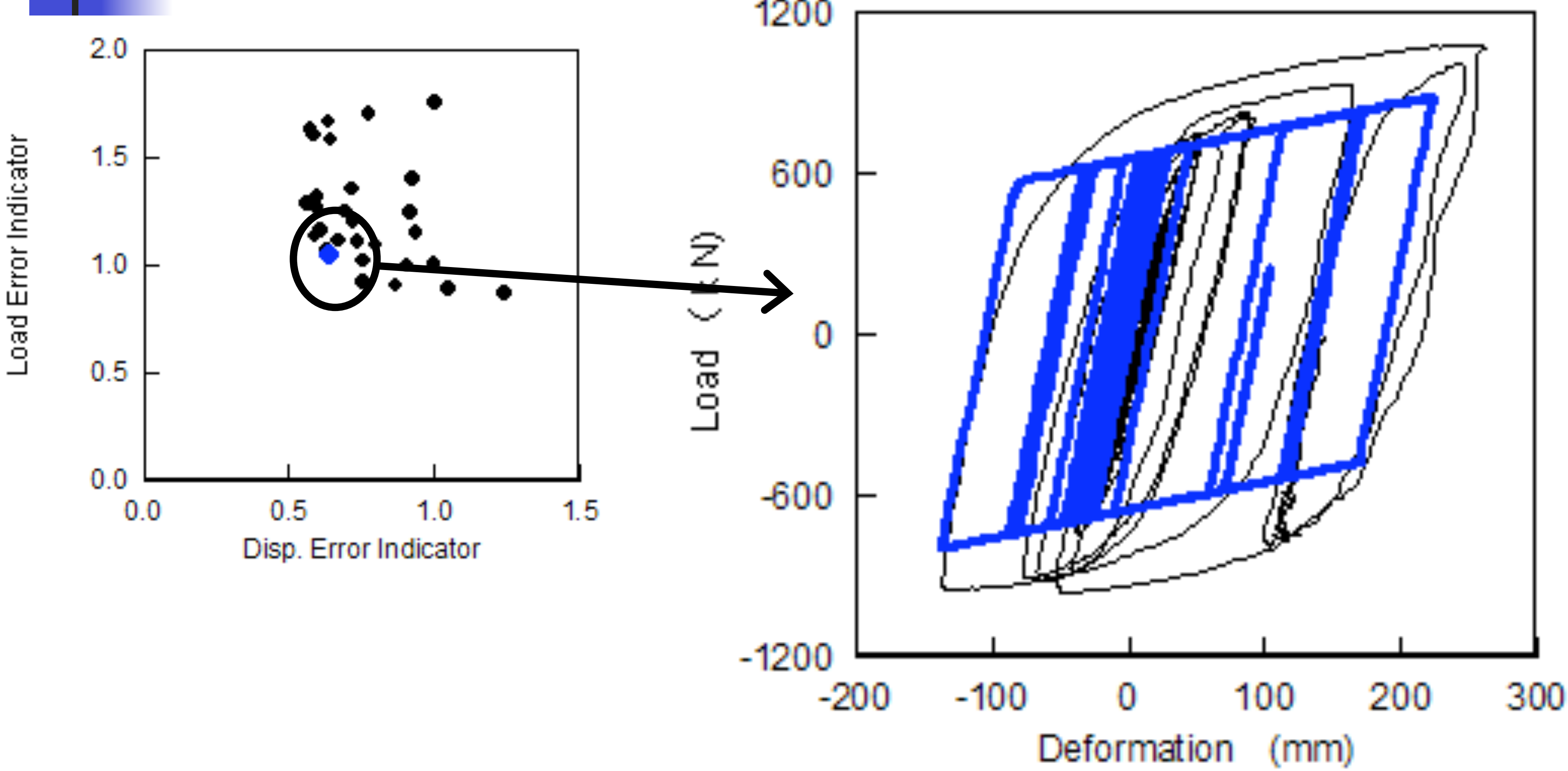
Error Indicators of Bi-linear hysteresis models

●k2/ke=0.0 ▲k2/ke=0.01 ■k2/ke=0.02
●k2/ke=0.03 ▲k2/ke=0.04 ■k2/ke=0.05



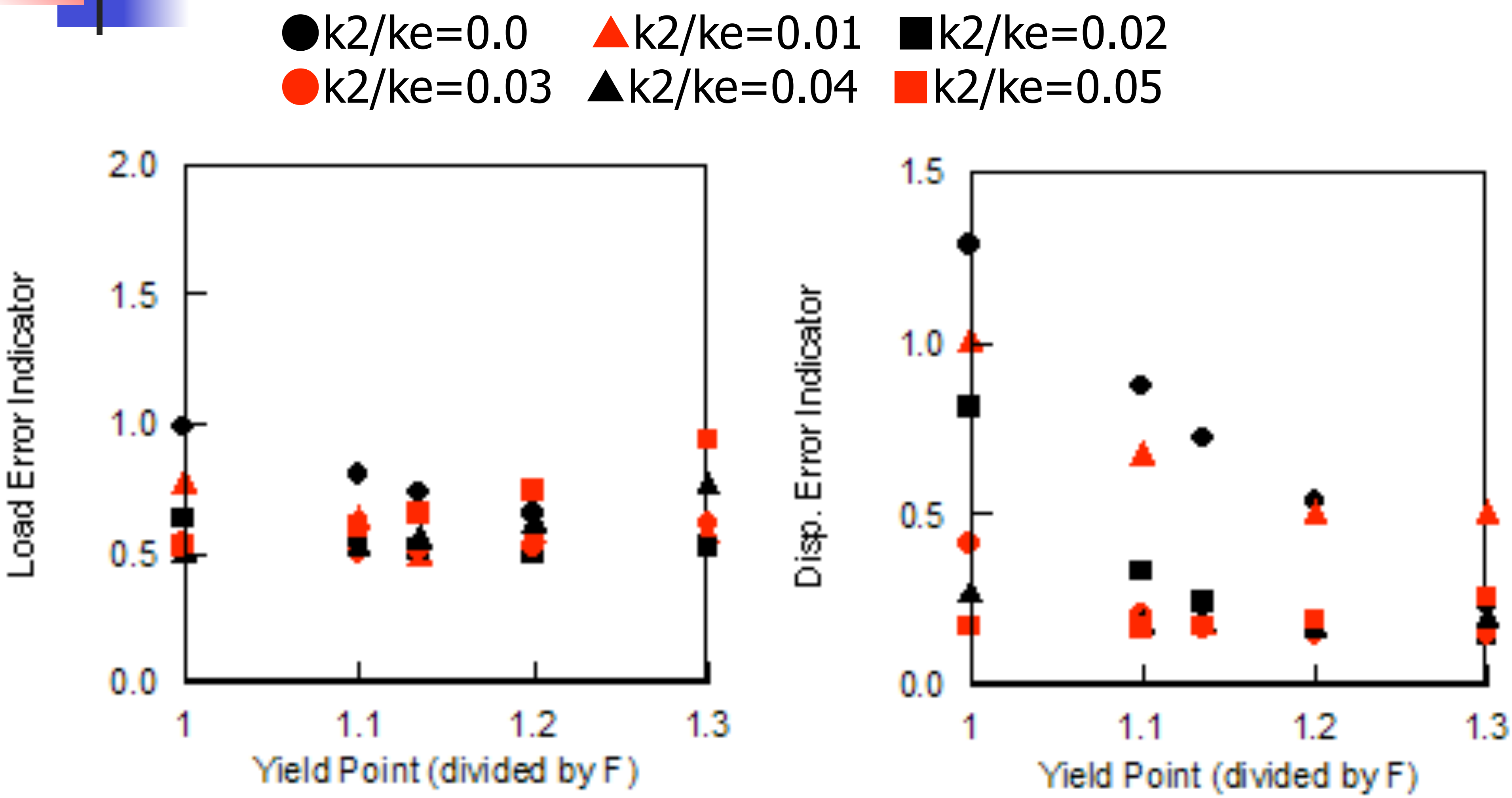


Comparison of the Load-Deformation Relationships

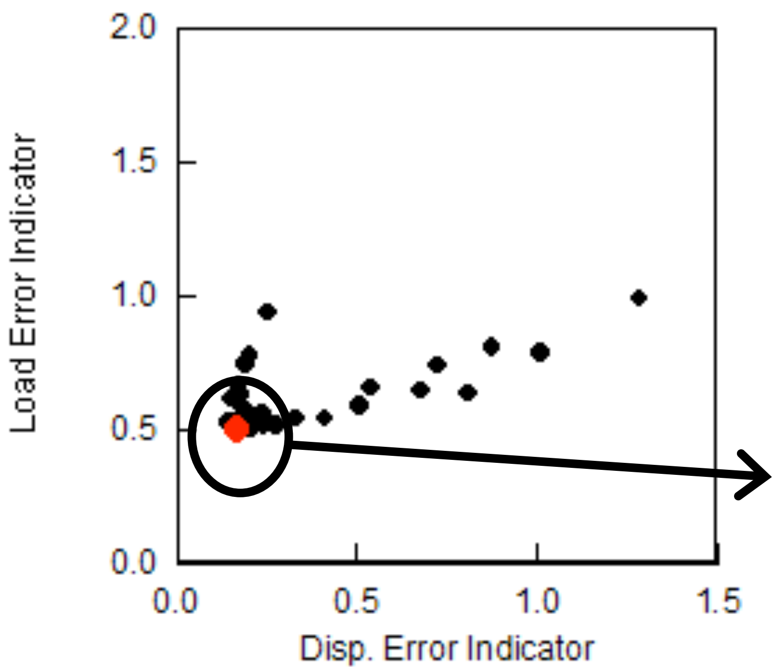


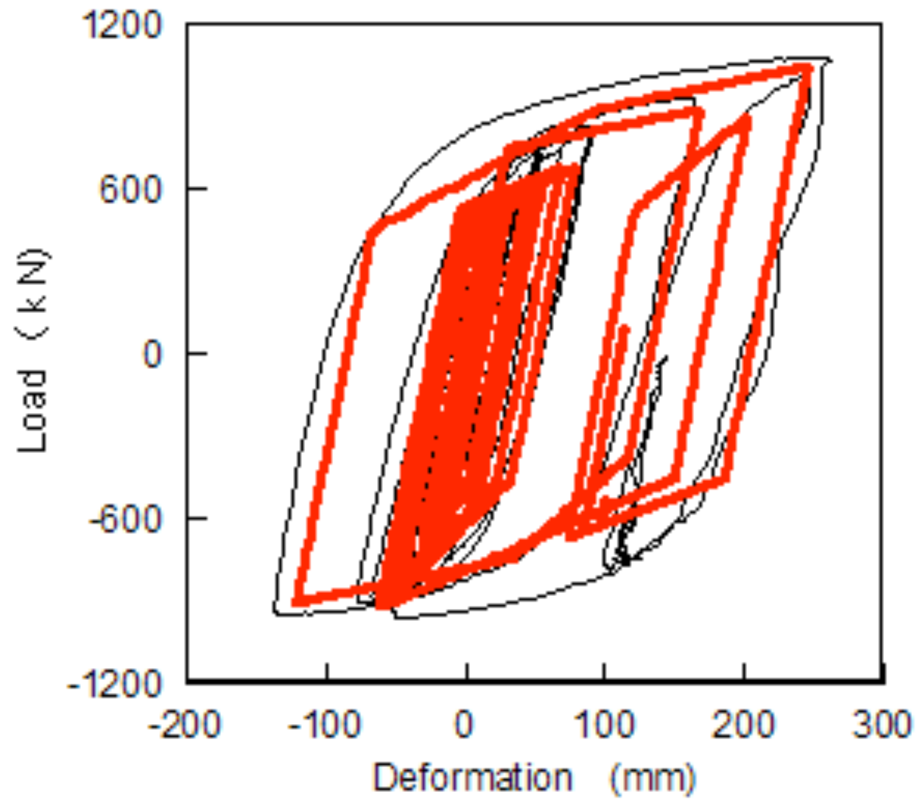
1.1F, K2/Ke=0.02

Error Indicators of Multi-linear elasto-plastic models considering Bauschinger effect



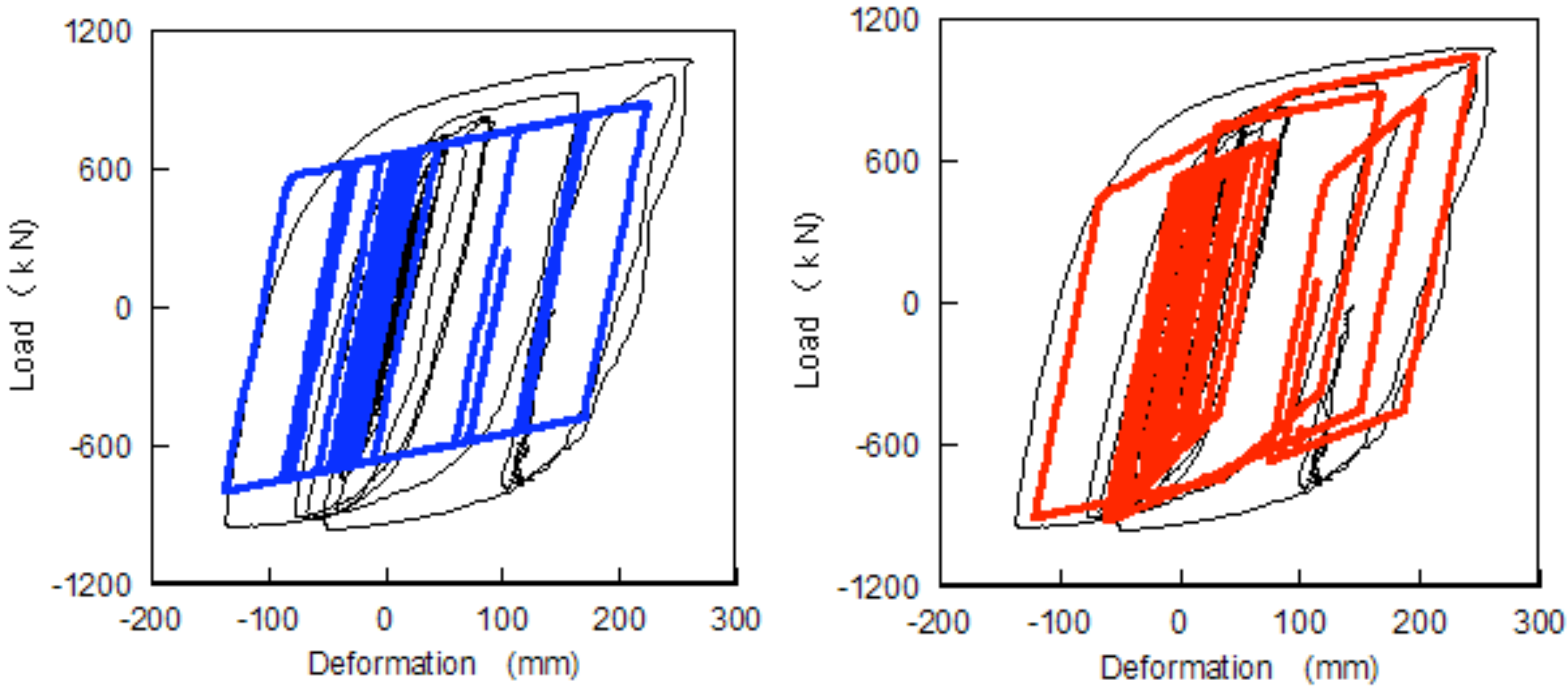
Comparison of the Load-Deformation Relationships





1.2F, K2/Ke=0.02

Comparison of the Load-Deformation Relationships



CONCLUSION

- Analytic responses of a series of Bi-linear and Multi-linear hysteresis models were compared to the result of a full-scale shaking table test, and models with their analytic responses close to the experimental result were pointed out.
- Analytic responses of Bi-linear models with yielding point slightly lower than their tensile test strength and the second stiffness ratio set to 2%~3% had better correspondence with the experimental result.
- In case of multi-linear models considering Bauschinger effect, when using Bi-linear skeleton curve, analytic responses of models with yielding point slightly higher than their tensile test strength and the second stiffness ratio set to 2%~3% were close to the experimental result.
- Furthermore, the difference between analytic responses and experimental result were smaller when Bauschinger effect was taken into account in hysteresis models.