Compressive Strength and its Statistical Information of Normal and SBHS Steel Plates

Saitama University Dang Viet Duc, Yoshiaki Okui, Koichi Hagiwara
Nagaoka University of Technology Masatsugu Nagai

I. Introduction

The bridge high performance (SBHS) steels with advantages of high yield strength and good weldability have been standardized as SBHS500 and SBHS700 in Japanese Industrial Standard (JIS)[1] since 2008. However, they exhibit different inelastic behaviour from normal steels, as almost no yield plateau and greater yield-to-tensile strength ratio. Therefore, it is necessary to examine the applicability of the current compressive strength design equation of JSHB[2] to steel plates with the new steel grades.

The modern design specifications for steel structures trend toward a partial safety factor method based on statistical studies, as in AASHTO. In such specifications, statistical information, such as the mean value and standard deviation, is necessary to determine the safety factor and nominal strength.

In this paper, the statistical distribution of normalized compressive strength of 4 edge simply supported plate is investigated by employing the Monte Carlo simulation and the response surface method. In addition the influence of inelastic behaviour of SBHS steel on the compressive strength is discussed.

II. The nonlinear FE steel plate model

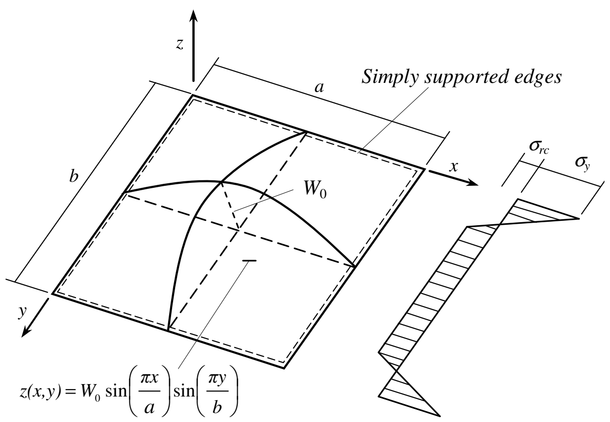

Fig. 1 Plate model with idealized residual stress distribution and sinusoidal initial deflection surface

In the FEM plate simulation, the assumptions of isotropic elasto-plastic hardening, von Mises yield surface and associated flow rule are applied to steel material modeling. The assumed uniaxial stress-strain relations of 6 steel grades are idealized from experimental data. The four edges of a plate are assigned as simple supports. The distributions of residual stress and initial deflection are idealized as shown in Fig.1. The compression is induced by displacement control in one loading edge. The ABAQUS S4R shell elements are used for meshing the plate model with mesh size 30x30 elements

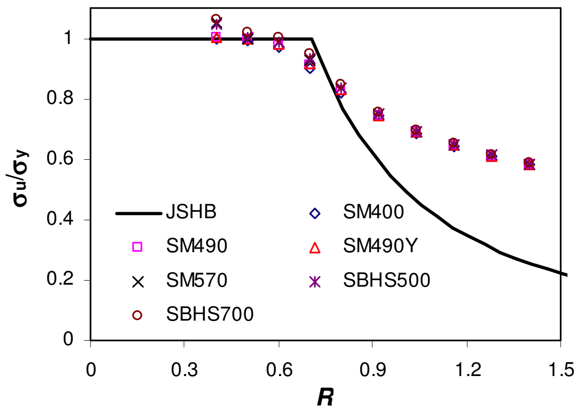

Fig. 2 Normalized compressive strength of plate with 6 steel grades in the case $W_0/b=1/400$ and $\sigma_{rc}/\sigma_y=0.23$

Fig.2 shows a comparison of the normalized compressive strengths (σ_u/σ_y) of steel plates with different steel grades in the case of $\sigma_{rc}/\sigma_y=0.23$ and $W_0/b=1/400$, which are obtained from the measurement data[3]. The compressive strengths of steel plates with six steel grades are quite similar in the whole range of R. The most significant difference occurs at R ≈ 0.7 and R ≈ 0.4, and the normalized compressive strength of SBHS700 steel plates is about 6% greater than that of SM400 steel plates. For R > 0.4, the compressive strength of SBHS steel plates with greater yield ratio is greater than that of the normal steel plate with lower yield ratio.

III. Scatter of compressive strength

In the Monte Carlo simulation, the response surface method is applied instead of the full deterministic FE analyses. A response surface is an approximated function of the initial deflection and the residual stress. Totally, 114 plate model FE results with consideration of six steel grades are employed to identify a response surface. The response surface for R = 0.8 is illustrated in Fig.3.

Keyword: bridge high performance steels, compressive strength, residual stress, initial deflection, local buckling.
Address: Civil and Environmental Engineering, Saitama University - 225Shimo-Okubo, Sakura, Saitama, 38-8570, Japan

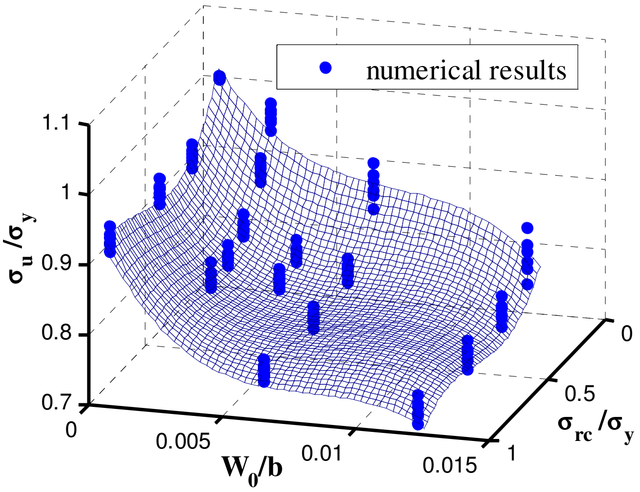

Fig. 3 The response surface shape presented along with FEM results for the case R = 0.8

By processing 10000 random input couples of residual stress and initial deflection, the convergent mean and standard deviation values of compressive strength of steel plates are obtained. In Fig.4, the mean values of the normalized compressive strength with the error bar denoting 2 times of the standard deviation are plotted along with the current JSHB design equation, mean (M) curve and the mean minus 2 times standard deviation (M-2S) curve[3].

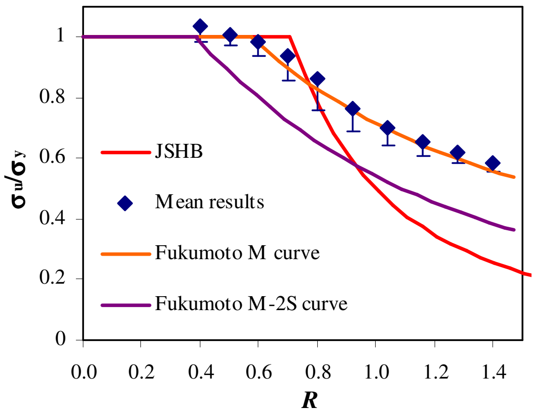

Fig. 4 Comparison among current study, JSHB[2], and results from [3]

As shown in Fig.4, the mean values of normalized compressive strength are similar to those reported by Fukumoto[3], which were based on experimental results. Within the range 0.65≤R≤0.85, the mean values of the current study are slightly larger than Fukimoto M curve[3]. One of the possible reason is that in the current study does not consider steel plates with $W_0/b>1/150$ and within the mentioned range of R, the effect of initial deflection on compressive strength is more significant than other ranges. Based on the level of M-2S of compressive strength, the JSHB design equation is un-conservative within the range 0.5<R<0.8 and over-conservative in the range R>0.85. Also seen in Fig.4, the M-2S curve proposed in [3] is too conservative if compared to corresponding results of the current study.

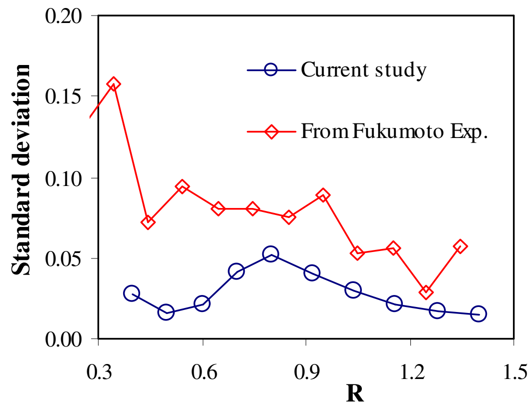

Fig. 5 Comparison of standard deviation values obtained in current study and reported in [3]

In Fig.5, comparing with the standard deviation obtained from experimental results[3], the standard deviation obtained from the current study exhibits about half of that within a range of 0.6<R<1.2 and clearer tendency.

IV. Conclusions

The mean values obtained in the current study are similar to those proposed in [3] but slightly greater within the range 0.7<R<0.9.

The standard deviations of compressive strength obtained in this study exhibits about half of values reported in [3] within a range of 0.6<R<1.2.

Within the range of 0.4≤R≤1.4, the normalized compressive strengths of normal steel and SBHS steel are similar for the same levels of R and initial imperfections. However, the compressive strengths of SBHS grades with larger yield ratio are slightly greater than those of normal steel grades.

References

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2) Japan Road Association: *Specifications for Highway Bridges,* part II. Steel Bridges, 2002

3) Fukumoto, Y. and Itoh, Y.: Basic compressive strength of steel plates from test data, Proc. of JSCE No.334/I-1, 1984.