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AN EXPERIMENTAL STUDY ON DYNAMIC BEHAVIOUR OF A GALVANIZED TOWER-SHAPED STEEL STRUCTURAL CONNECTION SUBJECTED TO HIGH SPEED TENSION LOADING

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SUMMARY

We have mentioned in our previous paper the experimental results of the static and the high speed tensile loading on the tower-shaped steel structure paying attention to the joint which is conceivably one of the most critical sections of the said structure.

This paper describes the outline of our quantitative consideration of the relation between stress and strain on the basis of the results of both the previous experiment as mentioned above and the recent experiment of the static and the high speed tensile loading on specimens composed of steel angles and gusset plates.

INTRODUCTION

When the tower-shaped steel structures are subjected to the earthquakes, the fluctuating velocity winds and other external disturbances, it can be assumed that the mechanical properties of the material will vary from those of the material under static conditions due to the influence of loading speed (effect of strain rate velocity).

For instance, Dr. M. Wakabayashi and his group (Ref. 1) reported the change in mechanical properties due to the influence of the strain rate velocity observed through the experiment of monotonic tensile loading using steel round bars and steel deformed bars. However, these past studies are concerned with the raw material and it has not been clarified whether or not experimental results are also applicable to the dynamic behavior of connections which seem to be the most critical part in the steel structural frame.

Taking notice of the above situation, the purpose of this study is to clarify the characteristics of the change in mechanical properties of the following joints generally used in the tower-shaped steel structures by an experiment of monotonic tensile loading:

(1) Butt welded joint in galvanized tower-shaped steel structures
(2) Joint through shear strength of galvanized regular bolts

HEIGH SPEED TENSION LOADING EXPERIMENT

Test speciment All the test specimens are taken from the steel of 4.5mm in thickness and the angle of L60x4 conforming to japanese Industrial standard G3101, SS41 such than the longitudinal axis of the specimens is parallel to the specimens are shown in Fig.1 to Fig.6.

Experimental method For the monotonic tensile loading experiment, an loading apparatus making use of energy of rotations of a flywheel has been developed. The loading apparatus and details of the holding of the spesimens are shown in Fig.7 and Fig.8 respectively. The loads are measured by a loadcell placed through a spherical bearing on the top of the reaction frame.

The displacement of the gauge length on the test specimens was measured by 2 sets of the inductance type of displacement transducer. The measured values were put on a data recorder through dynamic strain meters.

Evaluation of loading speed Since there exists a definite linear relation between a fixed number of rotation of the flywheel and the strain rate velocity as shown in Fig.9, the relation has been made clear in advance by the preliminary experiment, which leads to permit controlling the loading by controlling the strain rate velocity of each test specimen. At this experiment, the loading has been repeated until each test specimen has broken with the number of rotations of the flywheel fixed.

For evaluation of the speed of loading on the test specimens corresponding to fixied number of flywheel rotations, the following definition were employed to obtain velocity of stress intensity and strain rate velocity, and to arrange the results of the experiment.

(1) Velocity of stress intensity: A gradient divided by the actual sectional area of each test specimen, where the gradient is the one within an elastic limit shown in the time history of load obtainable from the results of the experiment.
(2) Strain rate velocity: An increase per unit time of the gauge length of the test specimen within a plastic limit, divided by the guage length.

The velocity of stress intensity obtained when the load was applied in this experiment is 15 to 150 ton/cm^2/sec. and the strain rate velocity is 5 to 170%/sec.

STATIC LOADING EXPERIMENT

Test Specimen The test specimens were of the same shape and dimension as those used for the monotonic tensile loading and fabricate under the same welding and galvanizing conditions as shown in Fig.1 to Fig.6.

Experimental Method A30 ton oil hydraulic universal testing machin was used for loading. The load-displacement relation was indicated on X-Y recorder and the strain was on a digital static strain meter.

EXPERIMENTAL RESULTS

Fig.10 shows a sample of the relationship of load to deformation obtained in a experiment of various test specimens. The relationship is indicated using envelope curves by the velocity of load application with the applied load and deformation plotted along the Y axis and X axis respectively. It has become evident by this relationship that as the loading velocity enlarges, the yield load and the ultimate load on every kind of connection increase by 1.1 to 1.5

time those in the static loading.

The relation between the mechnical properties and the strain rate on the base metal subjected to high speed loading has been presented by use of various equations on the logarithmic principle (Refs. 2, 3, 4). However, no equation on the connection have been set up. In this paper, since the strain rate on the connection in the course of high speed loading was scattered at each step of the loading, the velocity of stress has been employed instead as a parameter, and the mechnical properties on each connection has been presented on the logarithmic principle as shown by Eq.(1).

$$PD/PS = a + b \, \ell n \, \dot{\sigma} \tag{1}$$

Where Pd and Ps are Mechnical properties in the course of high speed and static tensile loading, $\dot{\sigma}$ is velocity of stress intensity(ton/cm^2/sec), and a and b are constants determined by the experimental results as shown in Table 1 using the least squares method.

The relationship of loading velocity to strain in the direction of axis containing a single plane logitudinal wave is indicated by Eq.(2) on one-dimensional theory proposed by Karman (Ref. 5).

$$\text{when} \quad v \leqq C_1 \varepsilon_y \qquad \sigma = kE\frac{v}{C_1} \qquad C_1 = \sqrt{\frac{kE}{\rho}} \tag{2}$$

$$\text{when} \quad v > C_1 \varepsilon_y \qquad \sigma = \sqrt{kEE_P}\left(\frac{v}{C_1} - \varepsilon_y\right) + \sigma_y$$

where v is loading velocity, ρ is density, ε_y is yield strain, E is coefficient of longitudinal elasticity, k is ratio of rigidity of base metal and that of connection as shown in Table 2, and E_P is rigidity in plastic limit of the relation of static tensile loading to deformation expressed by means of bylinear form.

CONCLUSION

The following have been concluded from the experiment on the loading which was carried out to make clear the mechnical behaviour of the connection of the galvanized tower-shaped steel construction to the high speed loading.

1. As the loading velocity enlarges, the yield and ultimate load on the bolted connection will increase. However, the ratio of the increase is not so conspicuous as that in case of the base metal.
2. The relation between the mechnical properties and the velocity of stress intensity on each connection has been expressed on the logarithmic principle.
3. The relation of the velocity of loading and the produced stress on each connection has been set up on the one-dimensional theory.

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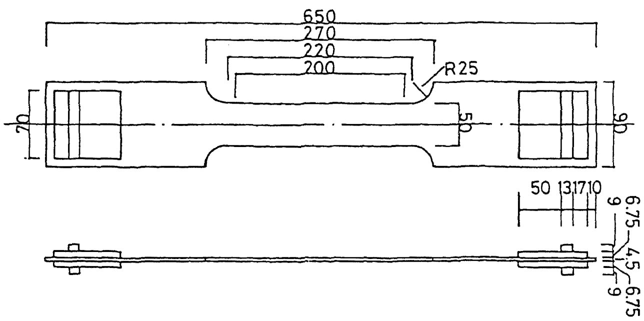

Fig.1 Shape and dimensions of 1K type

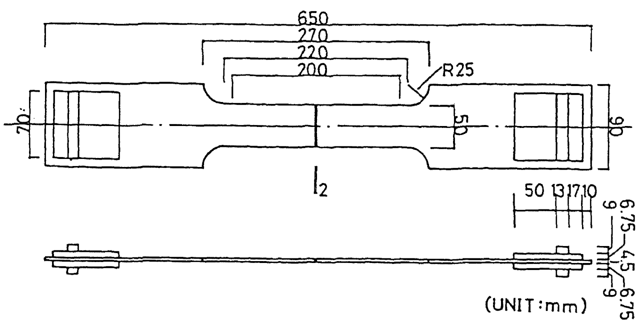

Fig.2 Shape and dimensions of 2M type

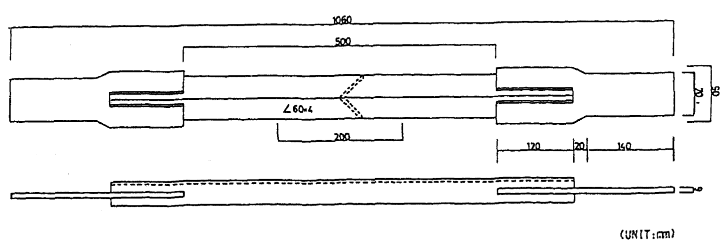

Fig.3 Shape and dimensions of AK type

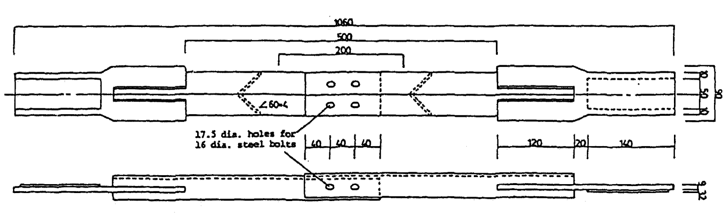

Fig.4 Shape and dimensions of WM type

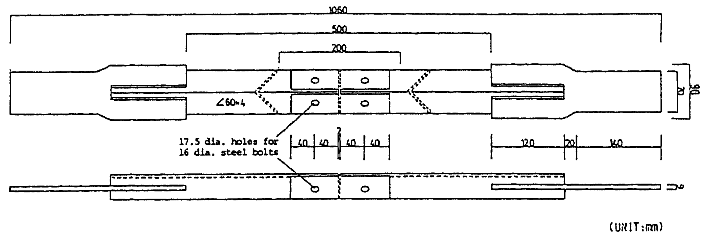

Fig.5 Shape and dimensions of BM type

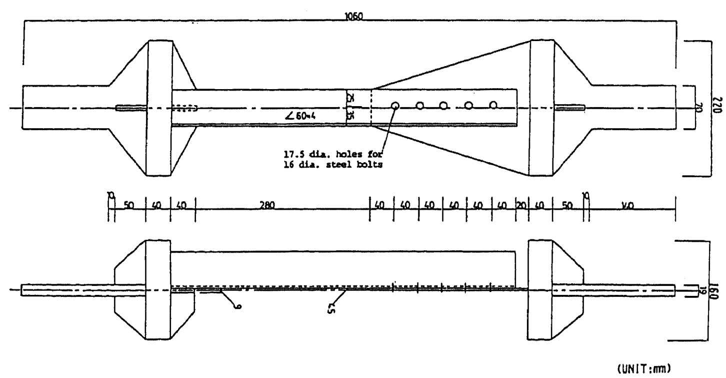

Fig.6 Shape and dimensions of GM type

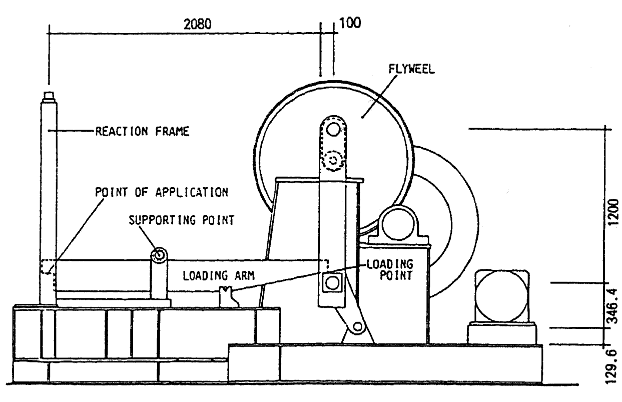

Fig.7 Loading apparatus

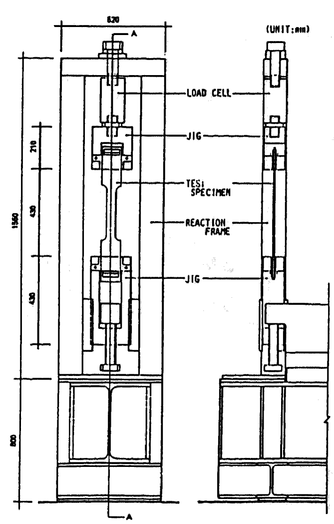

Fig.8 Construction detail of Loading device

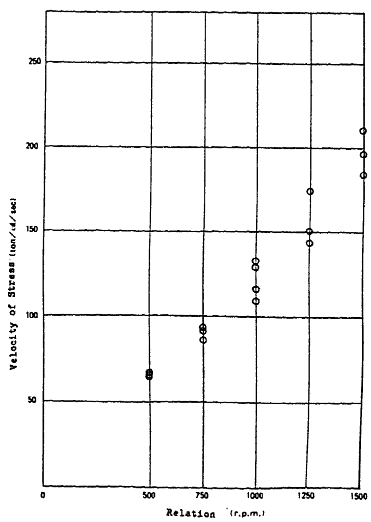

Fig.9 Relation between velocity of stress

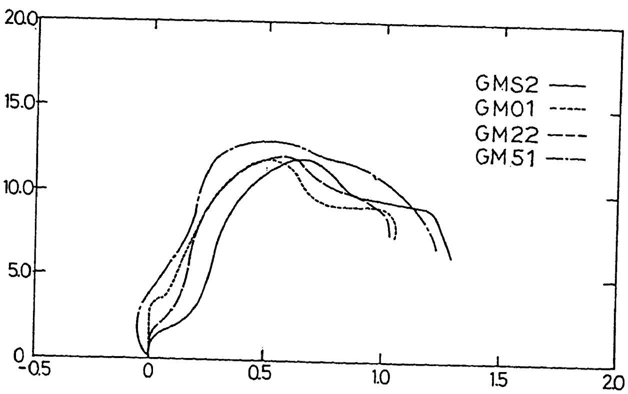

Fig.10 Load-deflection diagram of GM type

Table 1 Constants of logarithmic principle shown by Eq.(1)

Type	Yield load		Ultimate load		k
	a	b	a	b	
1K	1.19	0.036	1.04	0.006	1.00
AK	1.12	0.028	1.03	0.008	1.00
2M	1.12	0.030	1.02	0.009	1.00
WM	1.03	0.019	1.00	0.011	0.12
BM	1.03	0.014	1.03	0.010	0.04
GM	1.06	0.014	1.02	0.005	0.10