DYNAMIC PERFORMANCE OF H-BEAM UNDER IMPACT LOAD

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1. Introduction

There are many kinds of structures exposed to potential impact loads by the collision of a moving body like protection structures for natural hazard as rock fall, landslide and avalanches. Rock fall disaster is a one of natural hazard as the motion on the slope such as an occurred rock fall on road N364 in December 2004. Protection against rock fall is among the most importance to prevent incident. Consequently, many protective structures should be considered and constructed in the mountain area to protect a rock fall disaster [1]. The dynamic behavior of these structures under impact is always complex and closely related to the type of structure and dynamic material properties.

In this study, firstly series of experiments is introduced which was achieved to examine the dynamic behavior of steel beams as a simple protective structure. Continuously, application of FEM for these results is investigated to confirm validity and effectiveness of this numerical method. An equation is proposed to estimate performance, namely the maximum and residual displacements of the beam based on the collision energy and yield bending strength by numerical results obtained by FEM.

2. Experimental Method

2.1 Specimen

Details of the beams, as an H-beam,illustrated in Fig.1. Table 1 shows the material properties of the different specimen. For beam types A1.5, A2 and A3, the span length is 1500 mm, 2000 mm and 3000 mm, respectively. For types B2 and C2, the span length is 2000 mm. Young's modulus of all beams is 206 GPa. The real yield stress, which obtained from material testing, is 311 MPa for section A, 305 MPa for section B, and 354 MPa for section C, respectively. However, yield bending capacity P_y is calculated by 240 MPa as a minimum yield stress of steel.

2.2 Test setup

Fig. 2 illustrates the apparatus which were used for the falling impact experiment. The H-beams were tested by a steel weight under impact which is dropped from a specified height. The used falling weight in the experiment obtained 450 kg of mass on all beams. Measured items were the impact forces, reaction forces at supports, displacements and strains of beam. Table 2 is a summary of the conducted experiment in this paper. A beam type A2 was tested with different combinations of velocity. For another beam types, tests were performed under constant condition which the impact velocity is 4 m/s.

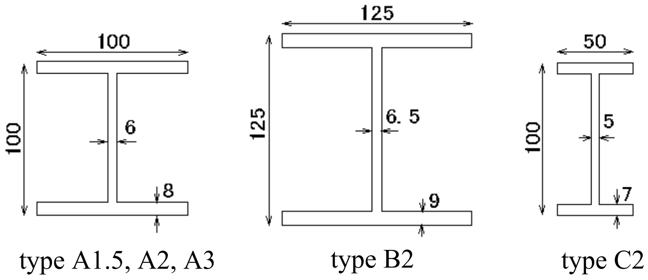

Fig. 1 Details of sections of H-beams

Table 1 Material properties of H-beam specimen.

Beam type	Width x height x thickness (mm)	Span (m)	Yield bending capacity P_y (kN)	Bending stiffness EI (kN.m^2)	Natural period T_0 (ms)
A1.5	100x100x6x8	1.50	48.4	756	6.7
A2	100x100x6x8	2.00	36.3	756	11.9
A3	100x100x6x8	3.00	24.2	756	26.8
B2	125x125x6.5x9	2.00	64.3	1678	9.4
C2	100x50x5x7	2.00	18.0	374	12.8

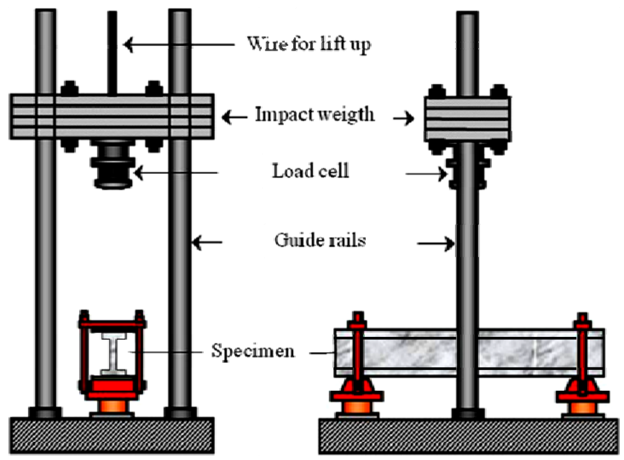

Fig. 2 Experimental apparatus

2.3 Analysis of samples

The accuracy of the FEM analysis was evaluated by comparison with experimental results. The impact behavior

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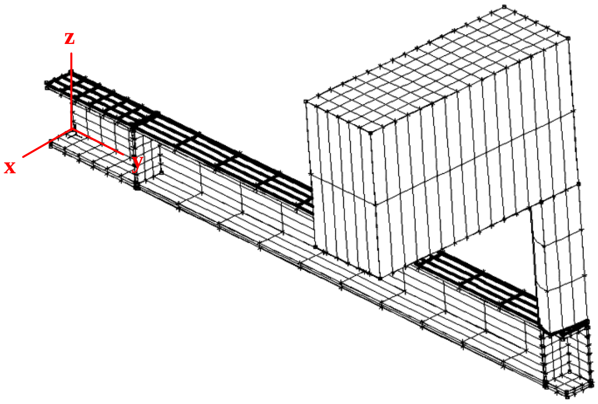


Fig. 3 Finite element model of quarter part

of the H-beams were analysed by using the finite element code ADINA (Automatic Dynamic Incremental Nonlinear Analysis) [2]. The finite element model were used for beam type A2 evaluated in Fig. 3.. A bilinear model was used for steel beam, where α parameter varies between 0.1% and 10% of Young's modulus *E* were used for the hardening modulus *E'*. In cases of 1 m/s and 2m/s of impact velocity, 0.1% of *E* was used for *E'*. Also 10% of *E* was used in cases of 3 m/s and 4 m/s of impact velocity. 206 GPa of Young's modulus and 357.65 MPa of initial yield stress under impact conditions were used for analysis in all beams, and also falling weight was varied to perform the analysis model.

Table 2 Overviews of experiment

Beam type	Falling weight m (kg)	Impact velocity V_{col} (m/s)	Kinetic energy E_{col} (J)	Momen-tum M_{col} (kN.ms)
A1.5	450	4	3600	1800
A2	450	1	225	450
A2	450	2	900	900
A2	450	3	2025	1350
A2	450	4	3600	1800
A3	450	4	3600	1800
B2	450	4	3600	1800
C2	450	4	3600	1800

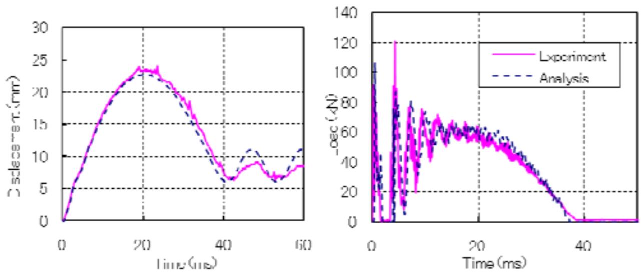
3. Results and discussion

Fig. 4 shows the relationship between maximum displacements, impact loads and time duration with the comparison of experimental and results were analysed in case of 2 m/s of impact velocity in beam type A2. The result from this FEM model is in good agreement with the experimental results. Consequently, it is considered that this FEM model can apply to estimate the maximum and residual displacements of H-beams which are even in the inelastic range.

Fig. 5 shows the relationship between maximum and residual displacements δ_{max}, δ_{res} to span length L ratio δ/L and kinetic energy E_{col} to yield bending capacity P_y and span length L ratio E_{col}/P_yL. The maximum displacement and residual displacement shown in Fig 5a and 5b Therefore, it can be observed linear relationship and approximations were presented as Eqs. (1) and (2).

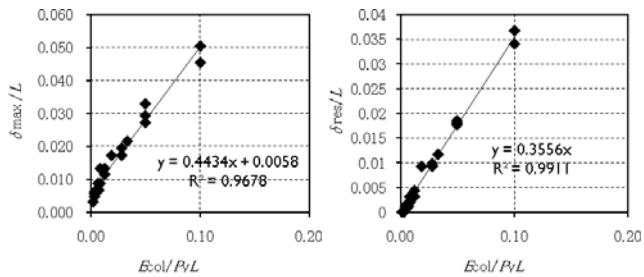
$$\frac{\delta_{max}}{L} = 0.4434\frac{E_{col}}{P_y L} + 0.0058 \qquad (1)$$

$$\frac{\delta_{res}}{L} = 0.3556\frac{E_{col}}{P_y L} \qquad (2)$$



(a) Displacement relationship (b) Impact load relationship

Fig. 4 Time responses of displacement and impact load at midspan for beam type A2, V_{col}=2 m/s.



(a) Maximum displacement relationship (b) Residual displacement relationship

Fig. 5 Relationship between the displacement-span length ratios δ/L to kinetic energy-yield bending capacity E_{col}/P_yL.

4. Conclusions

Analysis of impact behavior of steel beam by FEM was investigated by using experimental data to expect the impact behavior of beams. Those investigations performed in several dimensional sections and different span lengths of beam under various impact conditions with considerations of rate effects. The estimation equations of maximum displacement and residual displacement of H-beam in the inelastic range were also shown as important index of performance of H-beam.

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