

## Testing Research of Hematite Concrete Beam Under Impact Loading

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**Abstract.** This study investigates the impact behavior of hematite concrete beams using drop-weight facility. Reasonable experiment scheme is designed, different tups were used and varying drop weights and heights were applied. This study measures impact loads, mid-span accelerations, and strains at the top and bottom edges of the beam. The time histories of impact force, the time histories of strain and the time histories of displacement are obtained. The destruction whole pictures are obtained by high-speed photograph. When the strain rate ranges between  $1.1 \text{ s}^{-1}$  and  $5.1 \text{ s}^{-1}$ , rate effect is significant.

### Introduction

Radiations are found in nuclear power, industrial, medical, scientific research and other fields, It is a great threat to natural environment and human health. With the development of society, people gradually pay attention to the radiation problem [1]. Radiation protection concrete has a low cost, high reliability, wide application, and some other advantages. Thus they are widely applied to large radiation protection construction. While at present, for the study of the radiation protection concrete is still in the initial phase, and the research in dynamic characteristics is especially insufficient.

On account of the problem, in this study, hematite as the usually radiation protection material is selected to be aggregate. Eight groups of hematite concrete beam whose concrete mark is C25 and apparent density is  $3600 \text{ kg/m}^3$  are designed. We have tested the dynamic properties of hematite concrete beam by utilizing drop-weight facility. The time histories of impact force, the time histories of strain, the time histories of displacement and some mechanics parameters of hematite concrete are obtained.

### Specimen making and Apparatus

**Specimen making.** This experiment adopts the hematite sand and stone which produced in HeBei, and the P.O 32.5 cement which produced in HengYang. According to the study of ChongMing Wu [2], we have designed the cube compressive strength 25MPa, apparent density  $3600 \text{ kg/m}^3$  and specimen size  $100 \times 100 \times 400$  hematite concrete beams. Through the test debugging, finally the mix proportion is determined as follows:

water: cement: hematite sand: hematite stone = 0.63:1: 3.58: 5.6

After 28 days standard conservation, whose cube compressive strength of hematite concrete is measured to be 27.3 MPa, and apparent density is  $2980 \text{ kg/m}^3$ , which comply with the design requirements.

**Apparatus.** Experiment apparatus are adopted as follows: the XJL-98 Drop-weight facility, drop hammers that range from 1 kg to 5 kg in weight and possesses a maximum drop height of 2 m, dynamic signal analyzer, whose measurement sampling frequency is 96Hz, DH5862 programmable charge amplifier, the high-speed photograph, whose largest shooting frequency is one million frames per second.

### Data testing and Analysis

According to the principle that changing the height and quality of drop hammer to design different conditions which can control the input energy and strain rate. The experiment adopts the same height of drop hammer 1.5 m and different quality respectively 1 kg, 2 kg, 3 kg, 4 kg, and the same quality of drop hammer 3 kg and different height of 0.5 m, 1 m, 1.5 m, 2 m eight kinds of working conditions. For general, so as to not break universality of the test, three pieces are selected for each working condition, the mean number is selected to analysis. After testing a variety of gasket material. We found that it's better to use plastic aluminum spacer, which demonstrates that the groups of test data are stable, whose deviation is tiny, it can achieve the stability of impact.

**The momentum and impulse statistics.** By data processing in a variety of drop hammer impact conditions, the momentum and impulse statistics are shown in table 1, among them, the impulse is calculated by integrating the time histories of impact force. The momentum is calculated by some reasonable assumptions that the hammer does freefall motion, ignores any air resistance and rebound, namely  $P = m \sqrt{2gH}$  ( $g=9.8 \text{ m/s}^2$ ). Analysis results show that the elastic impact conditions (G151, Z305) due to the impact energy is not enough, the hematite concrete beam remain in the dynamic elastic phase, the momentum and impulse are approximate equal, which demonstrates that the impact process basic meet the theorem of momentum, whose energy is lossless. As for other six kinds of impact damage conditions, due to the input energy increased, fracture have been taken place. As it's show in the table 1, with the input energy increased, the impulse loss increased, which indicates that the residual velocity of hammer is also increased. This conclusion can be proved from the falling speed of hammer after the beam fractured.

Table 1 The momentum and impulse statistics  
under different impact working conditions

Working conditions	Mass m /kg	Height H /m	Impulse I /(N·s)	Momentum P /(kg·m/s)
G151	1	1.5	5.2	5.4
G152	2	1.5	10.2	10.8
G153	3	1.5	12.4	16.3
G154	4	1.5	14.3	21.7
Z305	3	0.5	9.1	9.4
Z310	3	1.0	10.6	13.3
Z315	3	1.5	12.3	16.3
Z320	3	2.0	13.8	18.8

**The time histories of impact force.** The same height and different quality time histories of impact force is shown in fig.1, the results show that with the input energy increased, the peak load increased, peak load presented, loading and unloading rate rised. In the working condition of G151 the hematite concrete beam did not break, which occurs dynamic elastic impact, the relative impact time is shorter, while the other three kinds of working conditions the beams are all broken, the impact time became longer, the duration of the impact time slightly increased, the response time, discharge time is roughly the same. The same quality and different height time histories of impact force is shown in fig.2, The results show that with the input energy increased, the peak load increased, the working condition of Z305 impact time is longer. Under the same quality, the other three kinds of working conditions whose impact response time is the same, peak load premised, impact time slightly shorter.

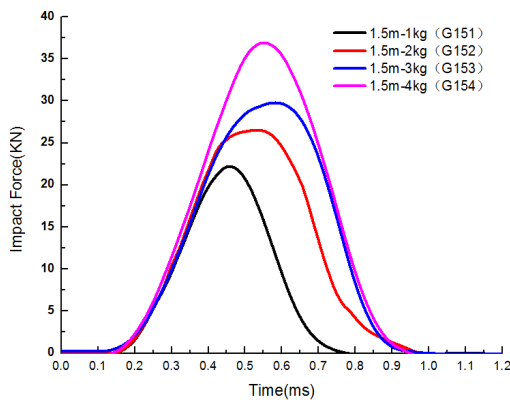


Fig.1 The same hight (1.5m) time histories of impact force

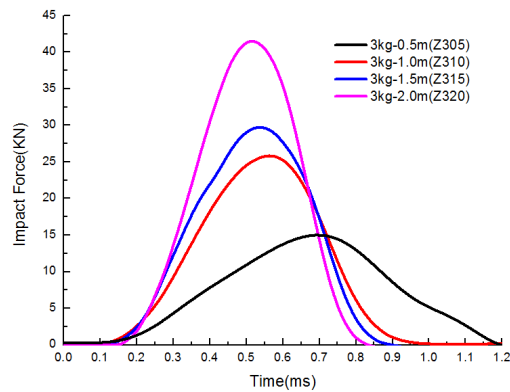


Fig.2 The same quality (3.0kg) time histories of impact force

**The time histories of strain.** Through setting up six longitudinal strain test point in the tension and compressive zone of the beam, the data is obtained after statistics. As for the same height of 1.5 m and the same quality of 3kg, whose time histories of strain is respectively shown in fig.3-4 (figure in the tensile strain is negative).

The results show that the two kinds of elastic impact working condition (Z305, G151) both its tensile and compressive strain are increased at present and then declined, finally there is a little of residual deformation. In the impact fracture working conditions, the hematite concrete beam produced distortion under impact load, its tensile and compressive strain approximate symmetry before destroyed. With the load achieve the bending strength of tension zone the beam cracks, the tensile strain increased rapidly. In the process of fracture development, the compressive strain continue increasing, finally when the crack developed through the beam, while the compressive strain decline.

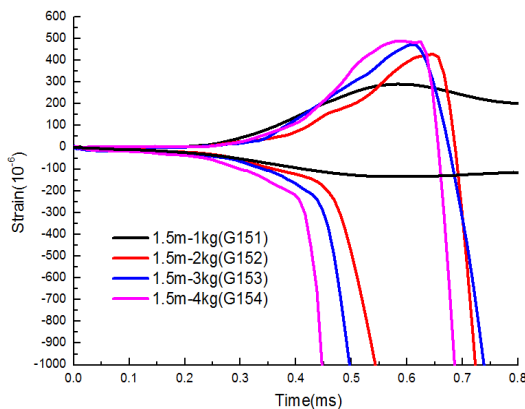


Fig.3 The same hight (1.5m) time histories of strain

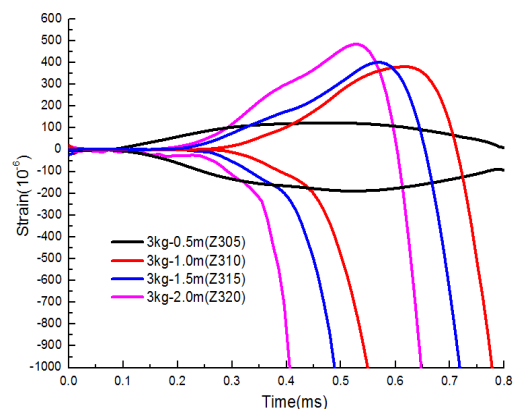


Fig.4 The same quality (3.0kg) time histories of strain

**The time histories of displacement.** The time histories of displacement is obtained by quadratic integration the acceleration time histories curve, the time histories of displacement is shown in fig.5-6. Analysis results indicate that at the beginning, the elastic impact (G151,Z305)the displacement of beam increased and then declined,it is because of energy input,the cumulative displacement grow to the maximum when the momentum tends to zero, and then the rigid spring back of beam caused by impact load which leads to the decrease of displacement. Two reasons are explained why the static displacement of beam is not equal to zero: • the displacement generated by the static load of hammer itself , the micro cracks produced amount of damage which leads to the weakening of the bending stiffness and so residual displacement is left. The other six break conditions show that with the input energy increased, the growth rate of displacement is increased.

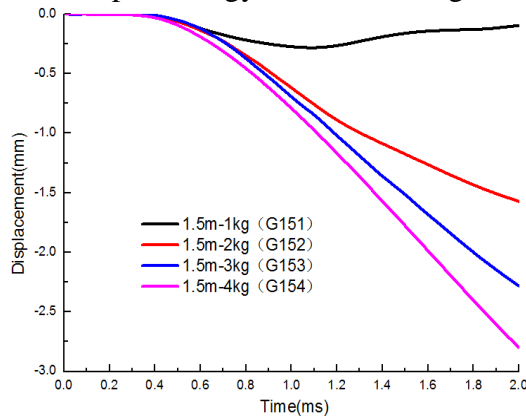


Fig.5 The same height (1.5m) time histories of displacement

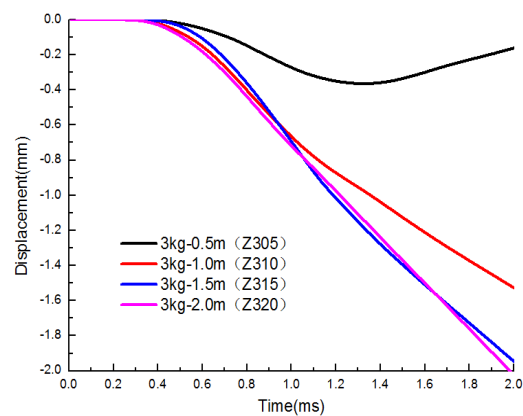


Fig.6 The same quality (3.0kg) time histories of displacement

**Fracture analysis.** As for dynamic three-point bending of hematite concrete beam, the crack time, crack load and the ultimate tensile strain are important mechanical parameters which could measure its dynamic characteristics. Therefore, this paper tries to analysis the date of breakage beam, in order to obtain the corresponding dynamic parameters. The strain mutation points are choosed to be break point of beam by taking a derivative with the time histories of strain, the derivative value of breakage point are choosed to be strain rate. The analysis results are shown in table 2, all of the hematite concrete beam cracks at the moment of about 0.44 ms, with the increase of the input energy the strain rate is increased, the ultimate tensile strain is at about 230 microstrain, the load of crack increased, it demonstrates that the rate effect of the bending strength is significant. The dynamic increase factor (DIF) of hematite concrete demands further study.

Table 2 fracture analysis results

Working conditions	Mess m/kg	Height h/m	Peak load Pmax/KN	Crack timeT c/ms	Crack load Pc/KN	ultimate tensile strain $\epsilon_c/10^{-6}$	strain rate $\epsilon/s^{-1}$
G152	2kg	1.5m	26.5	0.46	24.4	185	1.1
G153	3kg	1.5m	29.8	0.44	25.3	237	3.6
G154	4kg	1.5m	37.0	0.42	31.2	248	4.5
Z310	3kg	1.0m	25.9	0.45	21.1	196	2.2
Z315	3kg	1.5m	29.7	0.43	24.2	229	3.7
Z320	3kg	2.0m	41.5	0.40	32.6	257	5.1

The crack phase, crack extension phase, crack through phase images are obtained by using high-speed photograph to trace the fracture process of working condition Z320. As is shown in the

figure7-9, cracks are marked with the yellow line. To compare the three pictures, the development of cracks process can be observed from the stage of crack phase (about 0.4 ms) to crack through phase (about 0.50 ms), which shows the whole process of fracture happened at extremely short time (about 0.10 ms).



Fig.7 Crack phase

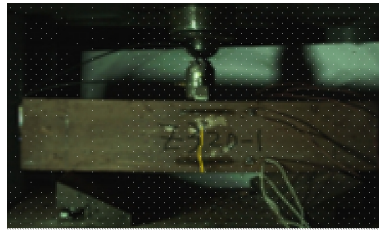


Fig.8 Crack extension phase

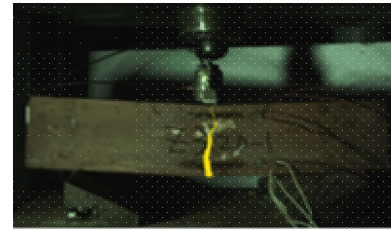


Fig.9 Crack through phase

## Conclusions

The test that the weight and height of hammer respectively 3 kg, 0.5 m (Z305), and the weight and height of hammer respectively 1 kg, 1.5 m (G151) on hematite concrete beams which under the condition of impact load is accomplished. The repeatability of the two dynamic elastic impact process is stable, the time histories of impact force, displacement and strain are obtained. The analysis results indicate that there are initial microcracks in the end of impact which caused certain damage on the beam, and then leads to rigidity weakening and tiny residual deformation.

The working conditions that in the same quality (3.0 kg) and different height under the impact load which tested in the hematite concrete beam, whose strain rate ranged from 1.1 to 4.5 s<sup>-1</sup> are accomplished. The dynamic failure process and some correlative time histories are obtained. The results show that with the drop height of hammer increased, the duration of impact becomes shorter, the strain rate increased, the peak load increased and advanced.

The working conditions that in the same height (1.5 m) and different quality under the impact load which tested in the hematite concrete beam, whose strain rate ranged from 2.2 to 5.1 s<sup>-1</sup> are accomplished. The results show that due to the same impact velocity, the impact growth rate is basic similar in the early, with the increase of quality, the impact time slightly increased, the peak load increased.

Several dynamic parameters of beam are obtained by analyzing the six group cracked hematite concrete beam which under the impact load. The analysis results show that at all working conditions, with the input energy increased, the strain rate increased, the crack moment of beams is happened at about 0.44 ms, and the ultimate tensile strain is happened at about 230 microstrain, the crack load increased, the hematite concrete beam shows a obvious rate effect at the flexural strength.

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