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Evaluation of the Mechanism of Impact Test Setup

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Abstract:
Structural elements such as shear walls, columns, beams, slabs, pipes, profiles, etc. no matter what material they are produced of could be imposed upon sudden dynamic impact loading throughout their service periods. Although design procedures of the seismic codes include vertical and horizontal load combinations, the effect of impact loading is usually ignored. Impact experiments are performed on different materials and objects by considering several techniques. In this study, it is aimed to investigate the working mechanism of impact drop weight test setup with the essential measurement devices such as accelerometer, load cell, lvdt, and data logger. For this purpose, details of impact experiments for various test specimens are presented. The time-dependent experimental outputs are also evaluated. In addition, the suggestions about the verification of experimental results under impact loading are proposed in the end.

Keywords: *impact loading, measurement devices, structural elements, test setup*

1. Introduction

Concrete, steel, and wood are the most widely used construction materials in the manufacture of the elements of the structures. Behavior of these elements has been a major field of interest. It is significant to be knowledgeable with the positive and negative sides of the materials. Engineers decide the most appropriate material type by considering the efficient load combinations. Generally; dead, live, and lateral load effects such as seismic and wind loads are taken into consideration in the design phase of structural elements. However, sudden impact loads may induce larger effects in the structural system in a very short span of time.

Impact loading is a kind of sudden dynamic loading whose intensity may reach very high values suddenly. Impact effect originates at the strike moment between two objects in which stress changes occur on the mechanical characteristics of these objects. There are several impact incidents owing to several reasons such as rock falls, landslides, vehicle collisions, floods, tsunamis, explosions, and crane accidents. Due to these reasons, the studies about impact loading have increased in recent years [1-4].

There is not a valid standard for impact experiments yet. However, test limits and information about test devices are available in ASTM E 23 [5]. So, researchers develop different impact test setups due to the regulations in this standard [6-9]. A drop-weight hammer apparatus is the most significant part of the impact test setup. By this way, impact energy is applied on test specimens. Furthermore, measurement devices are also utilized to obtain test data during the experimental study until test specimen reaches failure damage situation. Also, numerical studies are carried out to determine the relevancy between experimental and analysis results [10-14].

In this study, the general mechanism of impact test setup is approached. In accordance with this purpose, different setups with measurement devices are investigated. Besides, various test specimens having different support conditions are also presented. Measurement techniques, evaluation of test data, and the procedures in the verification of experimental results are discussed in the end.

2. Test Equipment

There aren't great numbers of studies about impact test setups in the literature because of the high costs of the measurement devices and the difficulties in the design limits. Also, manufacture steps of test specimens is tiring and requires plenty of time. Impact loading is applied by a drop weight hammer apparatus from different drop heights. Besides, additional weights can be fixed to the hammer. By this way, various levels of input energies are implemented on the specimens. Generally, high strength steel material is used for the hammer apparatus that is placed between the two slides of the test setup. Castermid material having a high value of mechanical strength is utilized in the production of the four wheel-shaped members of the hammer to restrain the frictions during the experiments. An example of technical drawing of the hammer apparatus is shown in Figure 1 [15].

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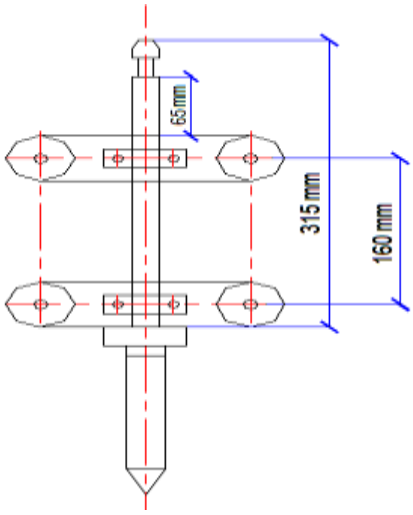


Figure 1. Hammer apparatus

Test specimens are placed on the base platform of the test setup. This thick platform is placed on a smooth ground. High-strength steel plates are used in the manufacture of base platform. Another important point of the test setup is providing the support conditions of the test specimens. With this design, support devices are utilized. These devices are placed on different sides of the specimens to restrain the vertical and horizontal movement during impact experiments.

Generally, accelerometers, lvdt, dynamic load cell, data-logger systems, and optic photocells are used as measurement devices in the experimental study. The input energy on the specimens that changes owing to the weight of the hammer and the drop height is regarded according to the measurement limits of these devices. High-strength steel plate and neoprene rubber layer are placed at the impact point to minimize the local fractures and distribute the impact loading along the specimen. Working mechanism of the test setup with measurement devices is given in Figure 2 [16].

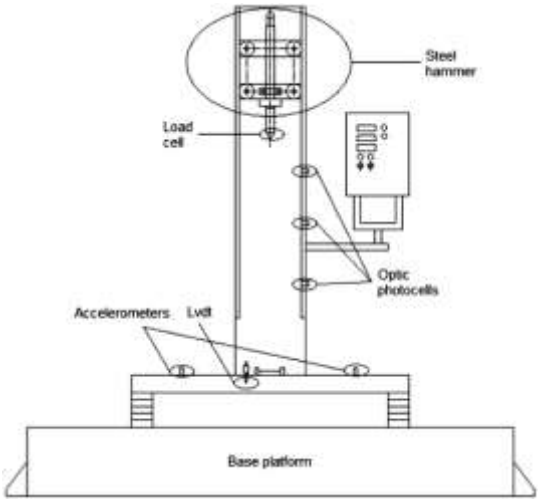
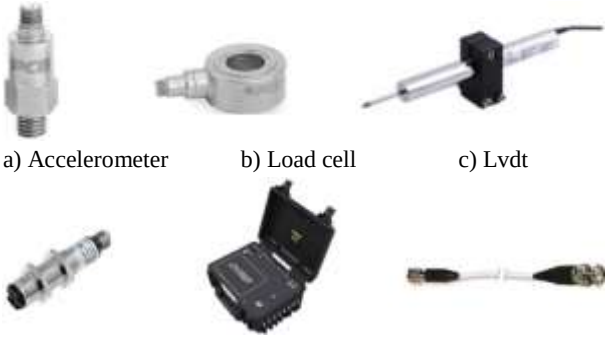


Figure 2. Test setup

Piezoelectric accelerometers are connected to the different parts of the test specimen to measure the acceleration values. This type of accelerometers is proper for impact experiments as they are capable of measuring any vibration motions exhibited by the specimens under impact loading. Dynamic load cell that determines the variation of impact loading over time is placed in the head part of the hammer and moves with the hammer in the experimental study. The load cell can measure the big signals with small waves in a very short time period.

Linear variable differential transformer (lvdt) is used to measure the displacement values around impact point by its spring mechanism. Lvdt has a wide range of operation temperature and it is capable of changing the mechanical movement of an object into electrical signals. The drop duration and numbers are determined by optic photocells in the experimental study. In addition, optic photocells activate the locking mechanism of test setup to inhibit the rebound impacts of the hammer apparatus. All measured values are transferred to the channel sections of the data logger system very fast with the help of low-noise coaxial connection cables without any loss. After that, experimental results are displayed in the computer environment. Measurement devices are shown in Figure 3.



a) Accelerometer b) Load cell c) Lvdt

D) OPTIC PHOTOCELL E) DATA LOGGER F) CONNECTION CABLE

FIGURE 3. TEST SETUP

3. Impact Experiments

Impact experiments are carried out for a variety of test specimens. After test specimens are produced, measurement devices are emplaced in their specific positions. Support conditions are ensured by special support devices. Input impact energy is performed on test specimens due to the weight of the hammer apparatus and drop height.

Impact experiments are continued until failure damage situation is observed. In this situation, maximum displacement occurs and the specimen is not able to resist any further impact loads. A high-technology camera may also be used to observe the development of the damages during the experimental study. Some examples of test setup with different test specimens are presented in Figure 4.

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Figure 4. Test setup

After experimental study is completed, the obtained test data is evaluated by the software of measurement devices. Afterwards, time-dependent acceleration, displacement, and impact load graphs can be generated for each drop of the hammer apparatus. Furthermore, absorbed energy capacities of the specimens are also determined by impact load-displacement graphs. So, experimental data can be visually evaluated in the end.

4. Conclusion

Impact loading is considered as a significant dynamic loading type that shall be considered especially in hazardous conditions. There is not a specific part for the design of structural elements under impact loading. However, there are several examples of impact incidents as outlined in the above sections. The literature review exhibits that the drop weight test setup with necessary measurement devices is the best solution to investigate the impact behavior of test specimens.

Crack and fracture formations during experimental study give idea about impact responses of the test specimens to the researchers. On the other hand, it is not easy to constitute the perfect experimental conditions in terms of support conditions, friction effects, and connection of test devices. In addition, capacities of the measurement devices are exceeded when a high level of input energy is implemented.

At this point, numerical studies could be an important alternative to evaluate the experimental results. Statistical methods, machine learning techniques, and well-known finite elements analysis programs may be used in the evaluation of experimental outputs. Finally, it is thought that the experimental outputs should be compared with well-accepted numerical methods. The error rates of both results shall be discussed to present the accordance between the experimental and numerical studies.

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