

DETERMINATION OF THE IMPACT BEHAVIOR OF CONCRETE AND REINFORCED CONCRETE BEAMS

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Abstract- Behavior types of structural members under various loads have been a main field of interest in engineering sciences. There have been several studies performed about determining the behavior of members under tensile, compression, bending and torsion loads until today. However, terrorist attacks and destructive earthquakes have aroused interests of scientists and engineers about solutions of impact problems. In this study, behavior of concrete and reinforced concrete beams under impact loads is investigated. For this purpose, a testing apparatus has been created. Data obtained from experimental study are compared with the analysis results of ABAQUS finite elements program.

Key Words- Impact Loads, Concrete and Reinforced Concrete Beam, ABAQUS

1. INTRODUCTION

Structures and structural members are under the effect of various loads in their economic lives. Structural members as column, beam, slab and wall are subjected to earthquake and wind forces as well as person, property, machine and their self loads. The structure is generally under the effect of two main loads as static and dynamic loads. While static loads are permanent ones, dynamic loads occur suddenly and effect structures for a length of time. Since, destructive damages may happen due to dynamic loads, the response of the structure against these loads shall be estimated correctly.

Impact effects are the changes on mechanical properties of members due to stresses occurring at the strike moment between objects. Car, helicopter, plane strikes, ship strikes to abutments, water structures and petrol platforms, explosions in military establishments, projectile and missile strikes, crane accidents while carrying members and stone and rock falls to structures located in roadsides are the examples of impact incidents.

Impact tests on structural members are based on the investigation of impact loads by using different test devices and determination of the damages due to weight falling testing apparatuses. While standardization studies about impact tests are proceeding, there is not a standard in respect of test methods and procedures yet. However, a big progress is made in studies about testing apparatuses and impact limits in ASTM (American Society for Testing Materials) E23 Standard [1].

Performed studies about impact effect are determining the mechanical properties of members under high stress values. On the other hand, testing apparatuses are designed to overcome the deficiencies occurred by dynamic effects. Impact reactions,

crack failures, energy capacities and damage situations are determined by the help of these studies in the literature [2-11].

In this study, concrete and reinforced concrete beams having 150x150x710 mm sizes are produced in the laboratory. Afterwards, these two beams are tested under the effect of impact loads. Falling numbers, crack progresses, time varying acceleration, velocity, displacement and impact force values are obtained after tests. Furthermore, testing apparatus is modeled in ABAQUS [12] finite elements analysis program. Finally, test and analysis results are compared and suggestions are proposed.

2. TESTING APPARATUS

There is not an available standard about testing apparatus for impact tests yet. For this reason, testing apparatus and measuring devices are decided after literature review. The studies show that weight falling testing apparatus is the best way to investigate the shear, bending failures and deformations in structural members under impact effect. The testing apparatus for this study is designed in accordance with this purpose. This apparatus is based on free falling of a steel hammer and striking to different sized members from various heights. The devices as accelerometers, ring force sensor, data logger, connection wires, optic photocells and a computer are used in the tests as well as testing apparatus.

Key features of weight falling devices are investigated after studying the performed articles and the apparatus is created. With this apparatus, different sized and weighted members can be tested under impact loads. In this way, structural members can be compared according to various parameters and support conditions.

It is stated that eccentricity is one of the most important factors effecting the results in tests. Secondary effects appear if the hammer does not hit the center of gravity of the member. To avoid this situation, eccentricity is set to zero while producing the testing apparatus. Working mechanism of the apparatus is given in Figure 1.

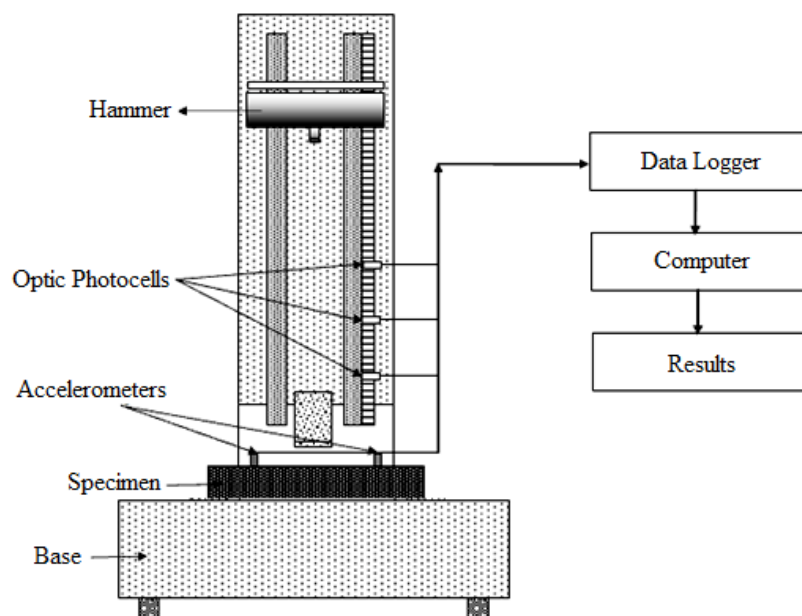


Figure 1. Testing apparatus

The basic approach in weight falling test apparatus is changing the potential energy to kinetic one at impact moment. This energy conversion causes rapid stress concentration on the members. Loss of energy during free falling is gained by the member. 1000x1000x70 mm sized apparatus base is made of steel plates and it performs as an absorber. Optic photocells are located on the apparatus and they measure time from the first movement of the hammer to the impact moment.

3. EXPERIMENTAL STUDY

150x150x710 mm sized concrete and reinforced concrete beams are produced in the experimental part of the study. Concrete class is determined as C30 after testing the strength of cubic concrete samples at the end of 28 days. While longitudinal reinforcements are 2 ϕ 6 on the top, they are 2 ϕ 8 at the bottom of the beam. 5 stirrups are used in the section and their diameters are 8 mm. Concrete covers are taken as 20 mm. Height of the hammer is 80 mm from the beam and weight of the hammer is 10 kg. Beam section and reinforcements are given in Figure 2.

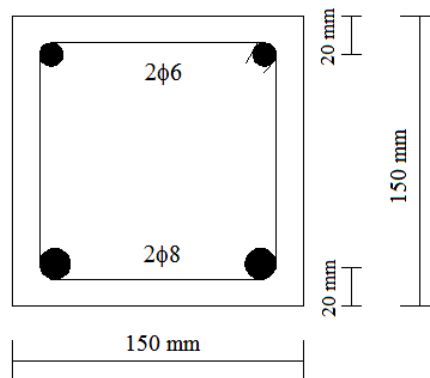


Figure 2. Beam section and reinforcements

Beam molds are manufactured from plywood forms. First of all, reinforcements and concrete covers are located and concrete is poured into the molds. Afterwards vibration is performed for a while. Finally, concrete surfaces are straightened with a trowel. Production of beam members is seen in Figure3.



Figure 3. Beam members

Beams are located into curing pool for 28 days to complete the setting duration. Then, the beams are painted by using a ceiling paint to observe the crack and damage failures much better. After determining the accelerometers places on the beams, 4 holes have been made by a slow speed drill without causing any damage on the members. Brass devices are placed in the holes by steel dowels. These special devices transfer all kinds of effects to the members almost without any loss. In addition, brass devices restrain the movements of the accelerometers.

In impact tests, point loading is applied by steel hammer to the member. However, the hammer does not fall to the member directly. Because, when it hits the member, point loading appears and it makes a hole on the member. In addition, collapsing occurs and it makes impossible to take any measurement from the member. So, a steel plate shall be used to obstruct this situation.

The inner reaction is distributed along the member. Rubber layer delays the occurrence of inner peak load. By this way, the member gains time to completely take the load applied by steel hammer. A neoprene rubber layer takes part between the steel plate and the beam member in the tests. Geometrical placement of the steel plate, rubber and accelerometers on the beam are given in Figure 4.

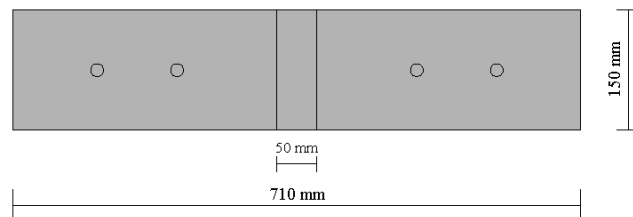


Figure 4. Testing equipment on the beam

After support conditions are provided for the beam, accelerometers and force sensor are placed. All measurement devices are connected to the data logger with particular cables. Strict attention is paid to prevent the cables from any damage. Finally, data logger is connected to computer to transfer the test information. Prepared concrete beam member is given as an example in Figure 5.



Figure 5. Concrete beam member on testing apparatus

Friction factor which effects the results during tests is almost set to zero. The connection between the hammer and shafts is provided by disk wheeled designed members. Optic photocells placed on the apparatus make available to see the time of free falling movement from beginning to the end. By this way, velocity of the hammer can be calculated. Moreover, total falling number is seen on the screen. During the tests, data obtained from accelerometers is saved by the data logger and transferred to the computer. The results are evaluated by using special software.

Concrete and reinforced concrete beam members are tested until collapsing from 80 cm height and until the effect of 10 kg weighted hammer. Inner effects are determined by using accelerometers for each fall. Time varying acceleration, velocity, displacement and impact load values of the beams are investigated.

3. FINITE ELEMENTS ANALYSIS

In this part, obtained experimental results are compared with ABAQUS finite elements analysis program which is widely used in academic studies by researchers. For this purpose, testing apparatus and beam members are completely modeled in the program as seen in Figure 6.

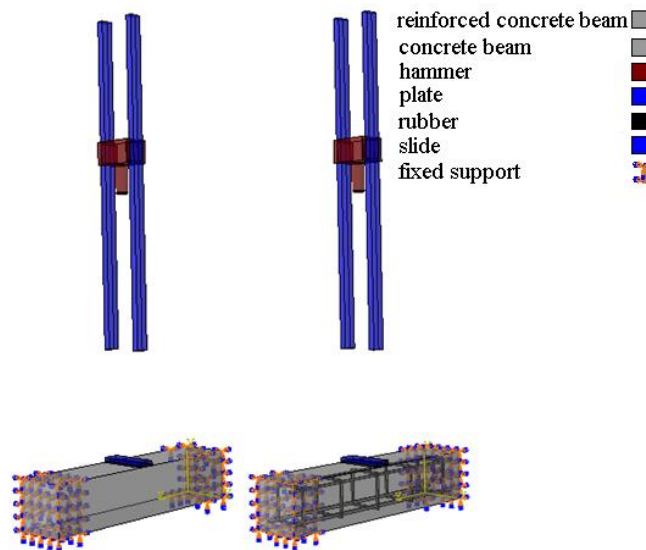


Figure 6. ABAQUS models of beams

Quadratic tetrahedral elements of type C3D10M are utilized in all parts of the models. 32944 number of nodes and 21856 number of elements for hammer, 117450 number of nodes and 81055 number of elements for concrete beam, 2x529 number of nodes and 2x240 number of elements for slides, 1038 number of nodes and 461 number of elements for rubber, 1623 number of nodes and 900 number of elements for plate, 185821 number of nodes and 130312 number of elements for reinforced concrete beam and 9176 number of nodes and 3374 number of elements for rubber are used in the numerical analysis. Finally, maximum experimental and analysis results for concrete and reinforced concrete beams after first falling are given in the following figures.

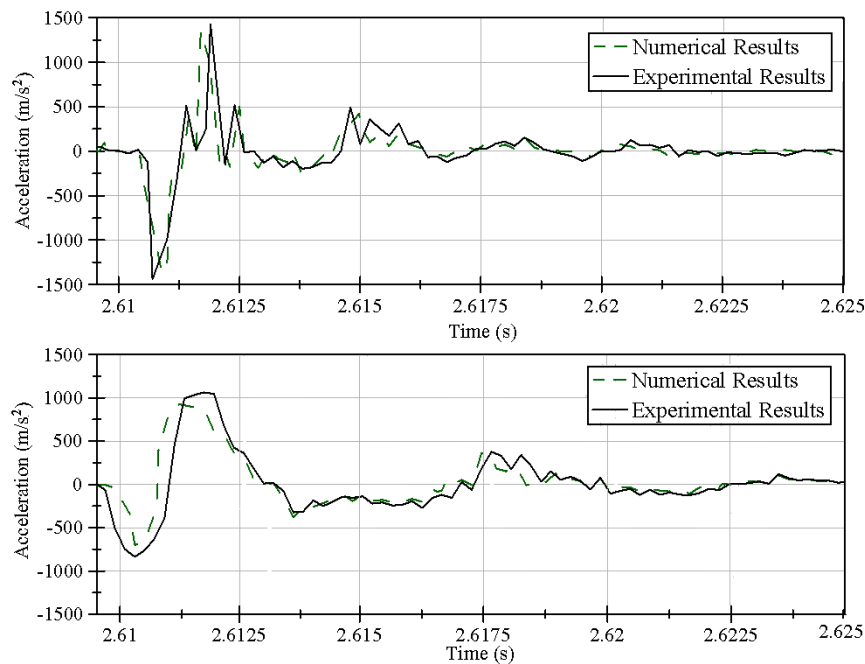


Figure 7. Maximum acceleration-time values for beams

Top diagram belongs to concrete beam in Figure 7. Acceleration values for concrete beam are bigger than reinforced concrete one as given in Figure 7.

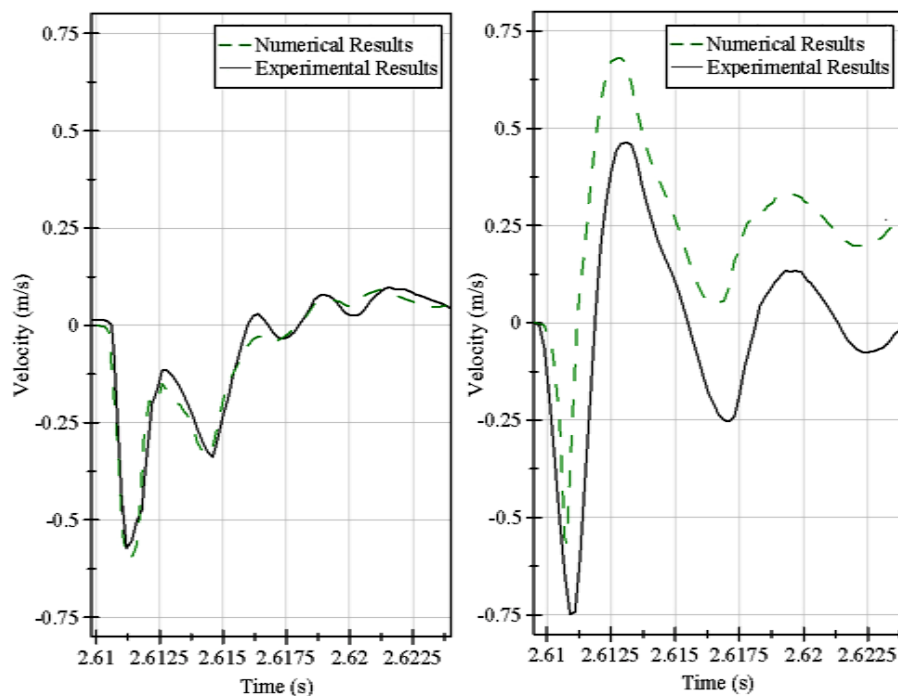


Figure 8. Velocity-time values for beams

Left diagram in Figure 8 pertains to concrete beam. Velocity values are obtained by integrating acceleration values and the difference between numerical and experimental results are bigger for reinforced concrete beam.

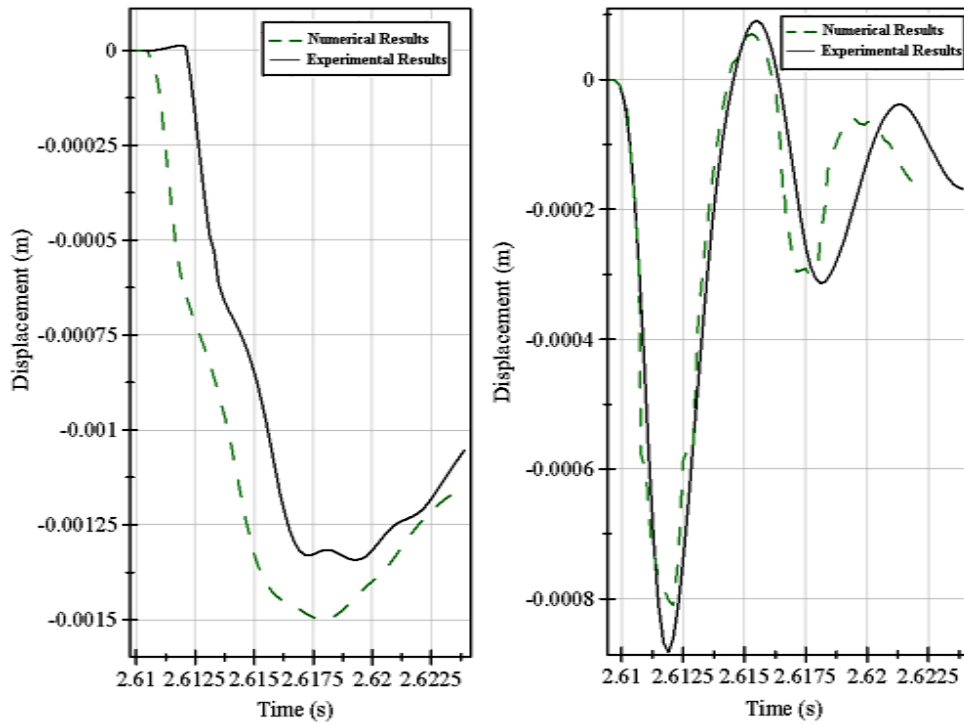


Figure 9. Displacement-time values for beams

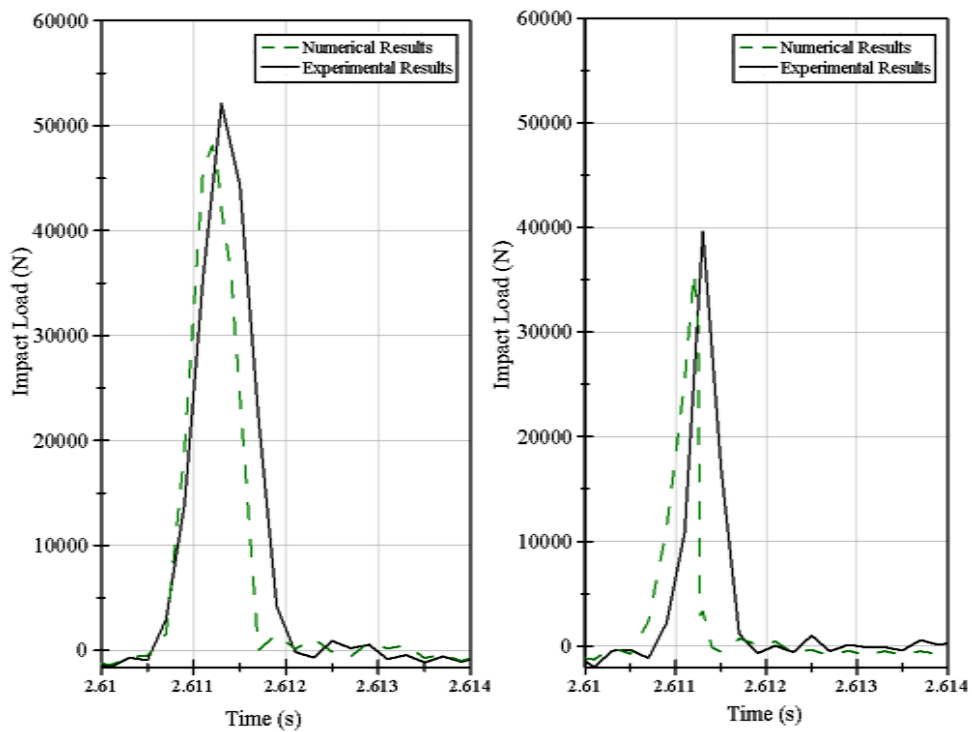


Figure 10. Impact load-time values for beams

Left diagrams in both Figure 9 and 10 belong to concrete beam. Displacement and impact load values are bigger for concrete beam.

4. RESULTS

In this study, concrete and reinforced concrete beams which have 150x150x710 mm sizes are tested under the effect of impact loads. For this purpose, the beams are produced in the first place. Afterwards, these beams are prepared for tests. Testing apparatus which is designed to investigate impact effects is used for experimental part of the study. There are four accelerometers are placed on the members and the results are transferred to the computer by data logger.

In the finite elements analysis part, ABAQUS is used for solutions. Quadratic tetrahedral elements of type C3D10M are used in all parts of the models. Beam members, testing apparatus, rubber and steel plate are modeled in the program. Since stress transfer and strength values are transferred in a short span of time, analysis and time steps are studiously determined. Maximum values that are after performing non-linear dynamic analyses are compared with experimental results. After acceleration values are obtained velocity and displacements values are calculated by integration operations.

The beams whose compressive strengths are 30 MPa, are tested under the effect of 10 kg hammer from 80 mm height. Acceleration-time, velocity-time, displacement-time and impact load-time diagrams are obtained for each beam. It is seen that bigger values are obtained for concrete beam in both analyses and a good relationship is obtained between test and finite elements analysis results.

Due to the longitudinal reinforcements and stirrups, there are differences in falling numbers. More fallings are needed for reinforced concrete beam. Besides that, since reinforced concrete beam is more ductile, more rebounds are observed after each hit in experimental and finite elements analyses. Rebound numbers are bigger in the first hits. While damages and cracks on the beams increase, rebound numbers on the members decrease. This situation shows that, damages and inner cracks of the beam gradually increase after each falling.

First cracks occur in the front face of the beams and start from top to bottom. The cracks on the surfaces occur due to falling numbers. Finally, this study can be improved by testing different sized concrete and reinforced concrete members for different parameters.

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