Measurement of Field Blast Testing Data using High Speed Data Acquisition System for Steel Fiber Reinforced Concrete

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***Abstract*—This paper reports on a measurement of field blast testing data for steel fiber reinforced concrete using high speed data acquisition system. In this experiment a field blast test was conducted by the Blast Research Unit of University Pertahanan Nasional Malaysia to investigate the behavior of steel fiber reinforced concrete panel subjected to air blast loading. The steel fiber reinforced concrete panels were subjected to air blast loading using plastic explosive (PE4) weighing 1kg each at standoff distance of 0.3 meter. The parameters measured are air blast pressure, free field blast pressure and also acceleration of the slab using high speed data acquisition system and the result is presented in this paper.**

Keywords- High Speed Data Acquisition System, Air blast Loading, Steel Fiber Reinforced Concrete.

I. INTRODUCTION

Experimental field blast testing on structure is rarely executed in Malaysia. However, various blast testing for research purposes has been done in Canada and Australia [1-2]. The main purpose of the blast test conducted on structure is to investigate the behavior of the materials under blast loading, the compliance of the materials according to international standards, and also for the disposal of explosive waste. The preparation for a field blast test is a very tedious task which involves preparing the test specimen, predicting the blast load, using technologically advance device such as high speed data acquisition system and validating the experiment [3]. Figure 1 show the various components involved in the field blast testing program.

The measurement of the shock wave, displacement and strains is an important element in the field blast testing with regards to the performance or structural response towards blast loading. Field blast testing has been performed by researchers to determine the response of concrete structures to various types of explosion.

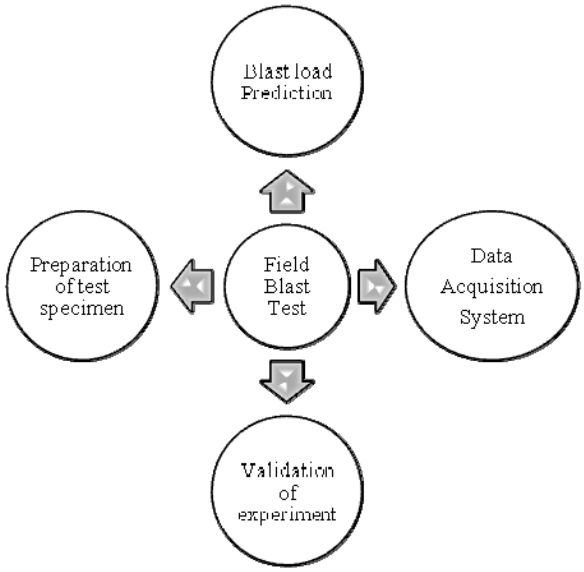

Figure 1. Field blast testing component

Andras et al [4] had carried out a full-scale high explosive (HE) field tests on concrete slabs in order to verify and validate the computer models and to determine the effectiveness of the aluminum foams as a protection layer that is capable of mitigating blast wave loads. The concrete slabs were supported by a heavy precast concrete structure. The panels then were exposed to a blast generated by the explosion of 1000 kg hemispherical TNT charge at a distance of 20 m. The instrumentation and diagnostic systems in the tests included was a 32 channel high frequency data acquisition system, blast wave pressure transducers, displacement gages, strain gages and accelerometers. In addition high speed photography was applied to record the entire explosion process.

S. Lan et al [5] had carried out an extensive field blast test on series of composites structural component. The test components include normal reinforced concrete slabs, steel fiber reinforced concrete slabs and also steel concrete sandwich panel. A total of seventy four specimens were tested using a charge weight ranging between 8 and 100 kg of high explosives and each at standoff distance of 5 m. In this test, pressure sensors were mounted on the supports of specimens recorded the air blast overpressure.

The objective of this research is to measure the field blast testing data for steel fiber reinforced concrete (SFRC) panel using high speed data acquisition system which includes software, signal conditioner, sensors, transducers and cables that are connected to the test specimens.

II. EXPERIMENTAL WORKS

The concrete test panels used for the experiment are Normal Reinforced Concrete (NRC) and Steel Fiber Reinforced Concrete Panel (SFRC) as shown in Figure 2. The panel was reinforced on both tension and compression face with 10 mm diameter steel at 200 mm centre-to-centre in both ways. The panel measures at 600 mm × 600 mm and a thickness of 150 mm.

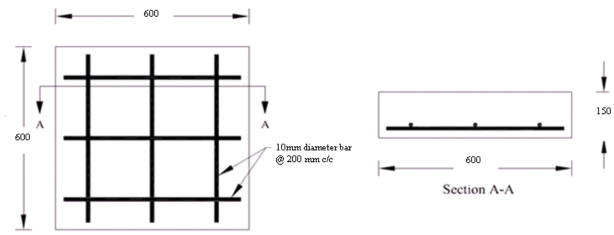

Figure 2. Geometry of the NRC and SFRC concrete test panel

NRC and SFRC were mixed using a proportion of cement: water: aggregate: sand at 395 : 190 : 1143 : 701 kg/m^3. The steel fiber reinforced concrete mix incorporated 1.5 % of hooked-end steel fibers which is made of mild carbon steel as shown in Figure 3.

Figure 3. Hooked end steel fiber

III. FIELD BLAST TESTING PROGRAM

A field blast test was conducted at an undisclosed military facility. The panels were placed on a proper steel frame testing rig which was fabricated at the Fabrication Laboratory of the Engineering Faculty of the University Pertahanan Nasional Malaysia . The width of the blast testing rig from the plan view is 700 mm face turned towards the blast. The height of the test frame is 1000 mm, including a 150 mm thick concrete base. Two C-channel support was welded on the testing rig to hold the test concrete at its side.

The test panel was placed into the C-channel support as a two-way slab with a span of 600 mm. An inverted L shaped wooden timber support was erected to hold the plastic explosive (PE4) charge. The vertical distance at the centre of the explosive and the panel were set to 0.3m. Plastic explosive (PE4) was arrange in a spherical shape and was suspended to the L shape wooden support using steel wire. The actual concrete test panel and typical test set - up shown in Figure 4.

Figure 4. Concrete test panel and field blast test set up

IV. HIGH SPEED DATA ACQUISITION SYSTEM

The measurement of the blast pressure and acceleration is an important element with regards to the performance or structural response towards blast loading. This parameter is measured using a high speed data acquisition system which includes software, pressure sensor, blast pressure probes, accelerometer and cables that are connected to the test specimen.

In this experiment high speed data acquisition system with sampling rate up to 2MHz and eight hardware-timed digital I/O lines were used to measure the structural response towards blast loading. In addition to this the sensors are also chosen specifically to ensure that they are able to response and provide signals within microseconds range. The data acquisition system and instrumentation were located inside a protected concrete building approximately 40m from the blast testing location.

Free field blast pressure time profiles were measured using three PCB™ free field blast pressure probe which was located at specific distances of 2.5m, 6.0m and also 9.5m from the centre of the explosive and connected directly to the data acquisition system. The probes were positioned at the height of 0.95m from the ground as shown in Figure 5.

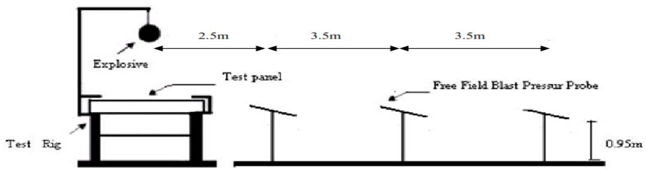

Figure 5. Free field blast pressure probe set up arrangement.

Piezoelectric ICP® Accelerometer with a maximum measurable shock of 10,000g were fixed using adhesive mounting at the centre of the concrete slab and were connected to the data acquisition system module.

Piezoelectric ICP® pressure sensor was used to measure the blast overpressure at the blast location. The sensor has an ability to capture high frequency up to 500 kHz was fixed underneath the C-channel support of the testing rig and connected via cable to the data acquisition system module. The blast measuring instruments is shown in Figure 6.

(a) Data acquisition module (b) Blast pressure probe (c) Accelerometer

Figure 6. Blast measuring instrument at blast testing site

V. TEST RESULTS

The captured data were then processed and displayed using NI LabVIEW software. The result for acceleration at the centre of the concrete panel is shown in Figure 7 and Figure 8. The acceleration of the NRC is 7600m/s^2 while SFRC recorded 5100 m/s^2 .

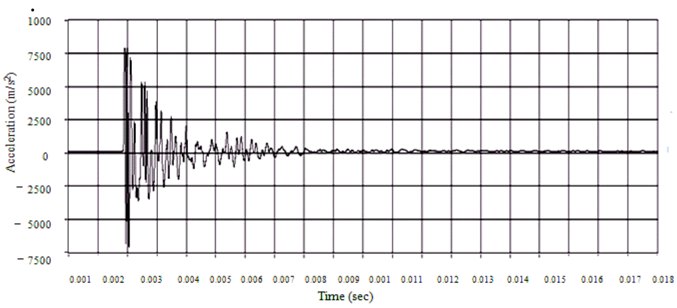

Figure 7. Acceleration time history on NRC

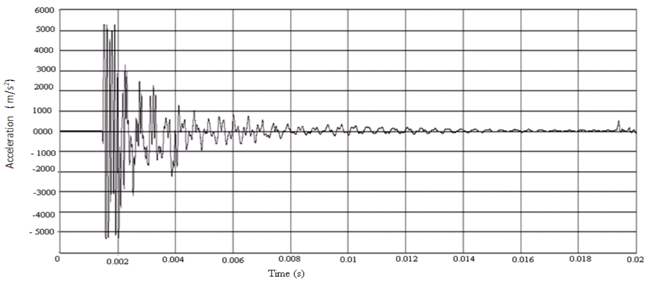

Figure 8 . Acceleration time history on SFRC

The acceleration value obtained has a connection with the failure pattern of the specimen. Acceleration value represents the ductility of the test structure. Higher vibration modes can be associated with larger shear force and lower ductility. Therefore the acceleration test result is an evidence of the low resistance of the NRC to blast loading.

The result for the air blast overpressure recorded at the C -channel support of the testing rig with a standoff distance of 0.3m from the centre of explosive is shown in Figure 9.The maximum overpressure recorded was 3800psi and the pressure wave follows the classical shape of blast wave pressure history.

The result for the blast wave pressure at the distance of 9.5m from the centre of the explosive is shown in Figure 10. The results show that the blast pressure from a blast decreases rapidly over distance and time.

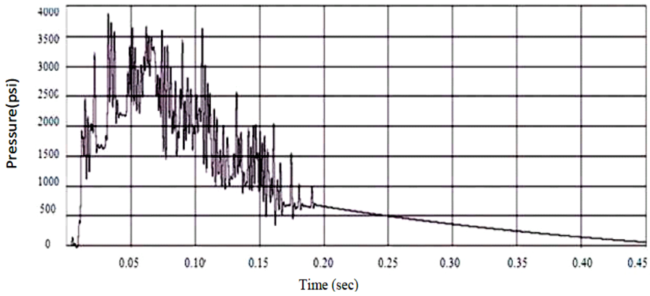

Figure 9. Blast overpressure history at the C-channel support

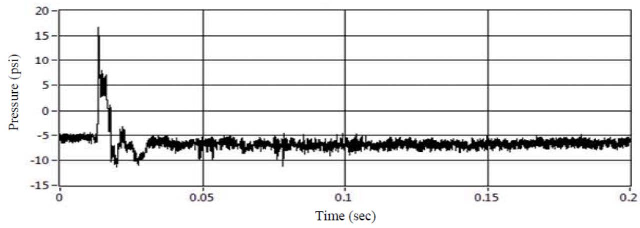

Figure 10. Pressure-time at the distance of 9.5m

VI. CONCLUSIONS

The field blast testing measurement results were successfully obtained using the high speed data acquisition system. In addition it was also found that high speed data acquisition system is a useful tool to assess the behavior of concrete panels subjected to air blast loading and therefore it shall be incorporated in the blast testing program. However, several adjustments need to be made according to the test requirement and the availability of facilities at the test site.

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