Behaviour of Concrete Beams under Point Impact Loading

Vikas Jain[1] Ms. Preeti Kuhar[2]
[1,2]R.P Educational Trust Group of Institutions, Karnal India

Abstract— Impact can merely refer to the collision of two objects. Impact can also be in the form of collision, vibration, blast or explosion etc. The study of projectile impact has been an area of great interest for scientist for about two hundred and fifty years. But for the last four decades this field has become very important for both developed and developing countries. As today the power of a nation is judged on the basis of technology. Every country is investing lot of money for the defense sector and India too is one among them. Every country is developing new missile technology and also the safety device to have a powerful defense sector.

Key words: Reinforced Concrete Beams, Concrete Beams under Point Impact Loading

I. Introduction

Due to different accidental or intentional events, related to important structures all over the world, impact loads have received considerable attention in recent years. The impact on a structure can be in different forms such as collisions, explosion or blast, vibrations etc. The design and construction of public buildings to provide life safety against explosions is receiving renewed attention of structural engineers. For many urban settings, the proximity to unregulated traffic brings the terrorist threat to or within the perimeter of the building. For these structures, blast protection has the modest goal of containing damage in the immediate vicinity of the explosion and the prevention of progressive collapse. Much research has been carried out in last years concerning the behavior of structural elements and materials under impact loads. Experimental results about the behavior of steel, concrete and fiber reinforced panels subjected to impact can be found in the bibliography.

There are new threats and worries in the context of general war and crime, and some kind of accidents. These may cause injury or damage of civil engineering structures. Even residential buildings and other dwelling units are very commonly attacked for spreading panic by using explosive devices. Missiles and Inert projectiles of spherical or cylindrical shape, hitting the structures with high kinetic energy are potent threats to the survival of structures. Thus as concrete our main construction material it is necessary to know its behavior under such type of loads i.e. impact load.

Concrete is the most commonly and widely used material for construction of building and other civil engineering structures. However, it does have some major limitations such as brittleness and poor tensile strength. Concrete is low strain material and its tensile strength is about 1/10 to 1/20 of its compressive strength. Usually, steel is used to overcome the shortcoming of poor tensile strength, either in the form of embedded bars (unstressed) or pre stressed tendons (stressed), and the composite material thus formed are called reinforced concrete or pre stressed concrete. Concrete and steel are altogether different materials and therefore, reinforced concrete is utterly non homogenous and is short of ductility. In addition to the above limitations of brittleness and poor tensile strength, concrete has some more faults, such as, it is stress rate sensitive material i.e., its mechanical properties depend on the rate at which it is stressed concrete exhibits stress rate sensitivity in all the three loading configurations, i.e., compression, tension and flexure. Various techniques have been used to test concrete beams at high rates of straining, such as,

– Free fall drop weight tests;
– Work of fracture tests;
– Explosive tests;
– Hopkinson's Split Bar tests;
– Charpy/Izod tests; and
– Fracture mechanics tests.

In all of the above test methods there is an attempt to quantify the energy required to achieve failure. However, because both the failure criteria and the physical processes by which failure occurs vary from test to test, comparisons between any of the above tests are very difficult. In this study, free fall drop weight tests were carried out on concrete beams to assess their impact performance.

II. Objective of Study

Detailed reviews of the past investigation show that the work done on impact loading on concrete structure requires much consideration. The present study is "Behavior of concrete beam under point impact loading". In view of the above following are the objectives of present study.

– To determine the No. of blows having same energy, which the beams takes before failure.
– To determine the strain energy of concrete beam before failure.
– To determine the maximum deflection of the beam with in same concrete grade having varying area of steel.
– To observe the crack pattern generated on reinforced concrete beam due to impact load.

III. Material and Methodology

The raw materials used in this experimentation were locally available and these included Cement sand aggregates

A. Specimen

To perform this experiment 9 Reinforced Concrete beams of cross section 100x100 mm^2 and of length 500mm were cast of three different grades of concrete mix. viz. M20, M25 and M30 with Ordinary Portland cement. The concrete beams cast are under reinforced, balanced and over reinforced for each grade. The normal strength beams, made with Ordinary Portland cement with a maximum aggregate size of 20 mm, had the following mix proportions cement, fine aggregate and coarse aggregate 1: 1.5: 3, 1: 1.2: 2.4 and 1: 1: 2 respectively.

B. Material Properties

These mixes were prepared with 10 mm & 20 mm crushed stone as coarse aggregate having fineness modulus as 7.98 and locally available Badarpur sand was used as fine aggregate. Concrete mixes were designed as per IS: 10262-1982, Trial mixes were prepared and 150x150x150 mm^3

cubes were cast to find out 28 days strength. The results of the finalized mix after 28 days of curing, mix ratio along with water cement ratio used is given in Table below and the properties of required materials are observed as below,

Concrete Grade	Mix (by weight)	W/C ratio	Average Compressive Strength (MPa) 28 days
M20	1:1.5:3	0.45	36.67
M25	1:1.2:2.4	0.45	40
M30	1:1:2	0.45	50.4

Table 1: Properties of Concrete Mix

Sl. No.	Property	Observed Value
1	Fineness modulus	3.56
2	Specific gravity	3.64
3	Bulking of sand(for 2% of water)	5.26
	Bulking of sand(for 4% of water)	7.53

Table 2: Properties of Fine Aggregate,

Sl. No.	Property	Requirements as per IS:4031	Observed Values
1	Initial setting time	30 minutes	42 minutes
	Final setting time	600 minutes	400 minutes
2	Compressive strength (mix ratio1:3)		
	7 days	22	0.0
	28 days	31	10.5
3	Percentage of water requirement for normal consistency	30 % – 35 %	29

Table 3: Properties of Cement

Sl. No.	Property	Observed Value
1	Yield strength of steel	388.21 MPa
2	Elastic modulus	202200 MPa
3	Percentage Elongation	13.45

Table 4: Properties of Steel

C. Reinforcement

Longitudinal reinforcement provided in the beam is as per IS: 450-2000. It has been listed below and also shown in Figure below. The designation to beam is given as concrete grade followed by U, B & O for under reinforced, balanced & over reinforced beams respectively, for example M20U i.e., concrete of compressive strength 20Mpa with under reinforced section. In addition to this 6mm dia. steel bars are provided on the compression face to hold the shear stirrups. We have used mild steel 6mm diameter as compression member and 8mm and 6mm diameter bar as tension member. The shear reinforced arranged with the minimum spacing 100mm. The shear force calculated for the beam came out to be very little thus the shear reinforcement provided is minimum fulfilling the criteria of IS: 456-2000. The shear reinforcement provided is also shown in Figure below.

Beam Type	Required Number of Bars	Area of Steel A_{st} (mm^2)
$M_{20}U$	2 # 6 ϕ	56.55
$M_{20}B$	3 # 6 ϕ	84.82
$M_{20}O$	2 # 6 ϕ 1 # 8 ϕ	106.78
$M_{25}U$	3 # 6 ϕ	84.82
$M_{25}B$	2 # 6 ϕ 1 # 8 ϕ	106.78
$M_{25}O$	2 # 8 ϕ 1 # 6 ϕ	128.83
$M_{30}U$	2 # 8 ϕ	100.53
$M_{30}B$	2 # 8 ϕ 1 # 6 ϕ	128.83
$M_{30}O$	3 # 8 ϕ	150.79

Table 5: Reinforcement Details for Beams

IV. Experimental Observations

In the following table 6 the deflection recorded by the data logger and the observation of the cracks are presented.

Hit No.	Deflection (mm)	Tension	Compression
1	16.53	No crack	Few aggregate parted
2	18.97	No cracks	Few aggregate parted
3	19.07	No cracks	Remains same
4	15.41	1st crack found	Again parted
5	4.96	Remains same	Almost to fail
6	4.96	Crack increased	Failed

Table 6: Deflection of Beam $M_{20}U$ with Number of Blows

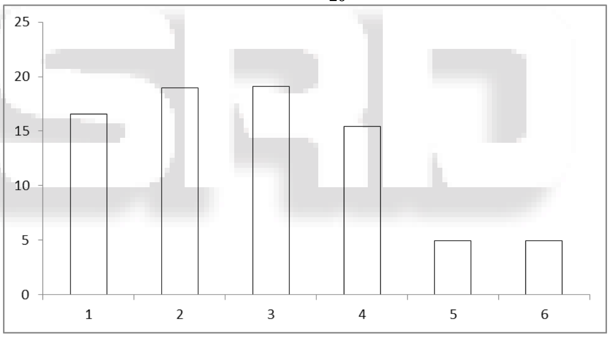

Fig. 1: Maximum Deflections with Number of Blows for Beam $M_{20}U$

V. Discussion of Test Results

On the basis of the results presented here, it is clear that concrete is a very strain rate sensitive material. Normal strength plain concrete and high strength plain concrete both showed higher impact strengths and also higher fracture energies at higher stressing rates.

In case of crack pattern almost every beam has shown first crack on first blow. The crack pattern of every beam is almost similar with cracks originating from one of either end or both ends and propagates towards impact edge. The pattern of initiation of cracks in M30 grade concrete beam is reverse where first crack was observed at the center or near the center.

VI. Conclusions

On the basis of experimental testing and analysis it have been concluded that:

– In most of the cases, failure occurred both in compression and tension zones but major failure was observed in compression zone due to disturbance of course aggregates.

- With the increase in the grade of concrete mix it was observed that, crack width was reduced in tension zone and aggregates were separated out in compression zone.
- In the case of lower grade concrete beams, no scabbing was observed, but the width of cracks were larger in tension zone for the same impact energy.
- In the case of low-grade concrete beams, it is observed that the separation of aggregates in compression zone was more, but in the case of high grade of concrete beams number of cracks and crack width were reduced in tension zone.
- Beam $M_{20}U$ required 6 numbers of blows to cause failure and maximum deflection noted was 19.07mm, the strain energy calculated was 0.011kJ theoretical deflection as 0.86mm for the 3rd blow. But in the case of high grade concrete beam $M_{30}O$ require 10 numbers of blows to cause failure the specimen and the maximum deflection observed was 11.65mm at 5th blow and corresponding strain energy and theoretical deflection calculated were 0.007kJ and 0.35mm respectively. It shows that the higher grade concrete would improve impact carrying capacity of the beam. When the grade of concrete increases, more number of blows were required to cause failure.

REFERENCES

[1] N. P. Banthia, Sidney Mindess and Arnon Bentur Impact behaviour of concrete beams", Materials and Structures & Volume 20, Number 4 / July, 1987
[2] N Kishi; H Mikami; K.G Matsuoka; T Ando, "Impact behavior of shear-failure-type RC beams without shear rebar", International Journal of Impact Engineering, Volume 27, Issue 9, October 2002, Pages 955-968
[3] D. M. Cotsovos, N. D. Stathopoulos, and C. A. Zeris "Behavior of RC Beams Subjected to High Rates of Concentrated Loading" Journal of Structural Engineering, Vol. 134, No. 12, December 2008, pp. 1839-1851
[4] H Mikami, N Kishi, & T Ando "Impact resistant behavior of shear-failure-type RC beams under falling-weight impact loading" Wessex institute E-Library, Paper DOI: 10.2495/SU020481
[5] Y. Chen, I. M. May "Reinforced concrete members under drop-weight impacts", Institution of Civil Engineers Structures and buildings ISSN 0965-0911 vol. 162, pp. 45-56, 2009
[6] Saatci, Selcuk,Vecchio, Frank J "Effects of Shear Mechanisms on Impact Behavior of Reinforced Concrete Beams", Effects of Shear Mechanisms on Impact Behavior of Reinforced Concrete Beams, ACI Structural Journal, January 1, 2009
[7] P Sukontasukkul[1] and S. Mindess "The shear fracture of concrete under impact loading using end confined beams" Materials and Structures, Volume 36, Number 6 / July, 2003
[8] Taiping Tang[1] and Hamid Saadatmanesh "Behavior of Concrete Beams Strengthened with Fiber-Reinforced Polymer Laminates under Impact Loading", J. Compos. for Constr. Volume 7, Issue 3, pp. 209-218.
[9] Thabet, A. & Haldane, D., "Three-Dimensional Numerical Simulation of the Behaviour of Standard Concrete Test Specimens when Subjected to Impact Loading," Computers & Structures vol. 79, pp. 21-31, 2001.
[10] Degen, p., Furrer, K, and Jemielewski, J., "Structural Analysis and Design of a Nuclear Power Plant Building for Aircraft Crash Effects," Nuclear Engg. & Design, vol. 37, pp. 249-268, 1976.
[11] Reborn, Ziminermann, Th., and Wolf, J.P., "Dynamic Rupture Analysis of Reinforced Concrete Shells", Nuclear Engg. & vol. 37, pp. 269-297, 1976.
[12] IS: 456-2000, "Code of practice for plain and reinforced concrete", B.I.S., New Delhi.
[13] IS: 8112-1998, "Specification of 43 grade ordinary Portland cement", B.S.I., New Delhi.
[14] Karve and Shah, V.L. "Limit state theory and Design of reinforcement concrete", 3rd Edition, Structure Publishers, 1987, Pune.
[15] B.C Punmya "Mechanics of materials", Lexmi publications, New Delhi.

