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Experimental Studies on Laced Steel Concrete Composite Elements Extreme Loading Condition

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Abstract: *In recent times many places are threaten to terrorist attack and chemical explosion in Industry can create structure to collapse. Till now we design the structures to with stand in earthquake. Therefore designer should carry out earthquake resistant design with the blast resistant design knowledge in mind in order to be able to select the most suitable framing scheme that provide both earthquake and blast resistance. Ductility and structural integrity are essentially required for structures subjected to suddenly apply dynamic loads such as shock loads. Reinforced Concrete (RC), the most widely used construction material, possesses considerable mass, excellent Fire-resistance characteristics and can also absorb large amount of energy, if provided with proper detailing. However, one of the disadvantages of concrete is the possibility of spalling/scabbing when it is subjected to shock loading, which weakens the core and affects the integrity of the structure. Among the alternative systems of construction, Laced Reinforced Concrete (LRC) and Steel-Concrete Composite (SCC) construction are found to possess properties that are promising for shock resistant structures.*

In this study, it is indented to design the flexural elements to with stand in extreme loading condition such as blast loading. Effect of blast load on building structural element is found out by equivalent experimental set up for different methodology. The basic characteristics of LSCC system, Experimental investigations are carried out on beam specimens, which are representative of proposed LSCC system, under monotonic and reverse cyclic loads using 60° lacing angle. Behaviour of LSCC system under monotonic load was found to be excellent with only 10-20% load drop and support rotation more than 12°.Spalling of concrete cover is a common problem with RC structural elements subjected to reverse cyclic loading. But, in LSCC beams, steel cover plates prevent the spalling of concrete core. LSCC beam is found to have high rotational capacity as compared to that of LRC and RC beams and SCC beams with other form of connectors. Thus, a new form of Steel-Concrete Composite beam is proposed and experimentally evaluated. LSCC system is found to possess the essential properties, namely, high ductility, support rotation and structural integrity for resisting suddenly applied dynamic loading. Feature scope of this project as design the structural elements to particular blast loading condition, check any new alternative blast resist system adequacy or not and search any new materials to make structural elements with standing in blast effect.

Keywords*—Ductility, Explosion, LSCC, LRC, FLSCC.*

I. INTRODUCTION

Structures are designed to be cost effective, while providing safe and serviceable paths for loads, including accidental loads, which may result due to natural or man-made activities. Natural hazards like earthquake, cyclone, etc. induce time-dependent loads that are severe and sudden, that get transmitted to structure. Loading on a structure due to explosion or impact can result due to man-made activity, which may either be accidental or with intention. Shock loads caused by sudden release of large amount of energy such as bomb blast, thunder and lightning are known as blast loads. This energy release sets up a blast wave, which travels at supersonic speed in the radial direction from the centre of explosion. The blast wave induces high intensity transient pressure pulse of a few milliseconds duration, and traverses a structure with varying amplitudes and duration.

Loads due to blast and impact are impulsive in character and last only for a fraction of a second. However, these loads can cause extensive damage to the structure, if they are not properly accounted for in the design. Therefore, such loads are identified as high intensity transient loads or shock loads. Response characteristics of structure to blast and impact load is entirely different from those of other loads. It is essential to understand the behavior of structures to arrive at an economical design. The structures usually undergo large plastic deformation and absorb energy before attaining a stable configuration or fracture. A deep insight into the relationship of shock loads and the structural deformation/fracture behavior will help to develop a structural system with significantly enhanced energy absorption to realize better shock resistant performance of structure. The main objective of the present study is the development of a construction-friendly structural system that can resist the shock loads. A new form of Laced Steel-Concrete Composite (LSCC) system is proposed, after analyzing the limitations of existing systems. LSCC system consists of perforated steel cover plates, which are connected using lacings and transverse / cross rods and infilled with concrete. The proposed LSCC system is devoid of welding.

II. BLAST EFFECT ON BUILDING STRUCTURE

An explosion is a result of a sudden release of energy. There are a number of possible situations that may cause an explosion such as that of a sudden relief of compressed air in a tire, a sudden release of pressurized steam in a boiler or that from detonation of high explosives. Detonation involves a quick chemical reaction that propagates through the explosive as a shock wave at a supersonic velocity. A shock wave is defined as a discontinuity in pressure, temperature and density. The pressures immediately behind the detonation front in the explosive can be 10–30 GPa.

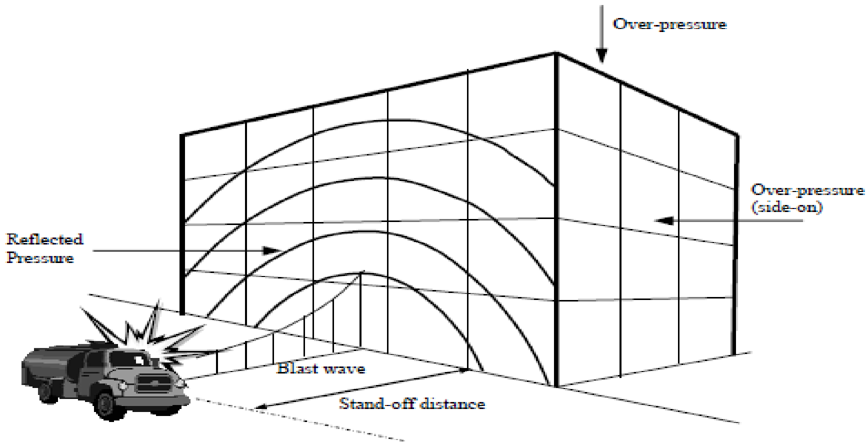

Fig.1 Blast Load effect on Building

An explosion in air creates a blast wave as a result of the large accumulation of energy pushing back the surrounding atmosphere. This violent release of energy will be followed by the spherical expansion of the blast wave into the surrounding air. As the blast wave propagates through the medium, nearly discontinuous increases in pressure, temperature and density are obtained. As the shock front propagates the air particles are accelerated in the direction of the travelling front, which results in a net particle velocity. Figure 2 shows an idealistic representation of a blast wave profile at a given distance from the centre of explosion. The blast wave is illustrated with the time axis at ambient pressure in the figure. The arrival of the blast wave creates an almost instant increase from the ambient pressure to the peak overpressure. The arrival of the shock front is immediately followed by pressure decay down to the ambient pressure. This first part of the blast wave is termed the positive phase. Then, the pressure will continue to decay below the ambient pressure until the minimum negative pressure is reached, after which the ambient pressure is obtained once more.

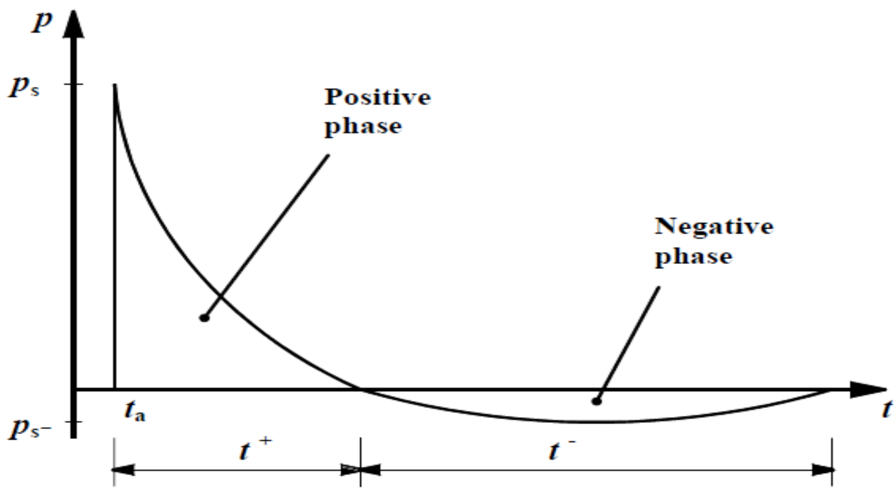

Fig. 2 Pressure- Time History

The second part of the blast wave is termed the negative phase and usually exhibits a longer duration than that of the positive phase. In design, the negative phase is normally less important compared to the positive phase. However, in some cases it is important to also consider the effects of the negative phase, e.g. when considering damage of windows or in a case with heavy structures having a response time longer than the positive phase. Besides the peak overpressure it is also of importance to consider the impulse density.

III. LACED STEEL-CONCRETE COMPOSITE

New user friendly laced steel-concrete composite (LSCC) system possessing the essential properties for blast resistant construction, namely, ductility and structural integrity, is proposed. LSCC system comprises of thin steel cover plates provided with apertures / perforations, through which reinforcements in the form of lacings are introduced and held in position with the help of transverse / cross rods, after which concrete is filled in between the cover plates. This method of fabrication avoids welding in total.

Fig.3 Lased Reinforced Beam

Dimensions of the beams are 200 mm x 150 mm. Simply supported span of the beams are 1 m. Typical arrangement of test set-up is shown in Figure 3. The concrete mix of M40 is used with mix proportions of 1:2.17:2. A total number of 6 beams of size 1m X 200mm X 150mm, were casted using wooden moulds. These specimens were removed from moulds after 24 hours and cured for twenty eight days in water using gunny bags before testing.

Table.1 Details of beam specimens

Beam Specimen	Longitudinal reinforcement at top	Longitudinal reinforcement at bottom	Shear reinforcement
A	2.3mm thick plate	2.3mm thick plate	60° lacing 8mm (1 Pair) plus 10mm rod
B (1% steel fiber)	2.3mm thick plate	2.3mm thick plate	60° lacing 8mm (1 Pair) plus 10mm rod
C	10mmϕ bars	12mmϕ bars	8mmϕ stirrups

Load frame of capacity 50T is used as testing apparatus, where the load is transformed as two point load to the beam, where the point load is applied at L/3 distance from the centre or mid point of the beam. The load is gradually applied till the ultimate load is attained. Due to some laboratory restrictions, the load could not be applied till the spalling of concrete

IV. LOAD SETUP

Load displacement responses of FLSCC-60 & LSCC-60 beams tested under monotonic load are shown in Table. The maximum displacement at yielding of FLSCC-60 & LSCC-60 is found to be respectively. Cyclic loading is carried out in FLSCC-60 & LSCC-60 where three cycles are repeated. Loading upto value of imposed displacement and unloading, loading in reverse direction and unloading constitutes one cycle.

Energy absorption, strength and stiffness degradation of the LSCC system can be evaluated from the load-displacement response of the beams. Therefore, it is essential to measure the response of the beams in terms of displacement, strains etc. Strains attained in the plates and lacings and displacement of the beam are measured. The data is recorded automatically using a data acquisition system.

Fig.4 Experimental setup of Beam in Loading Frame

At mid span, strain gauges S1, S2, S3, S4 along same line and S5,S6,S7,S8 along same line are fixed on the front side of cover plate. Strain gauges are fixed at 100 mm on either side of mid-span. LVDT's with ±100 mm traverse are placed at mid-span and at 286 mm distance on either side of mid-span to measure the displacement. Figure 4 shows the experimental setup in the laboratory and applying the load by jack and response in note down by LVDT.

V. Experimental Results

Table. 2 Load Vs Deflection for RC, LSCC & FLCC respectively

RC			LSCC			FLSCC		
P	$\Delta_{L/3}$	Δ_{mid}	P	$\Delta_{L/3}$	Δ_{mid}	P	$\Delta_{L/3}$	Δ_{mid}
kN	mm	mm	kN	mm	mm	kN	mm	mm
0	0	0	0	0	0	0	0	0
5.8	1.1	0	5	0.5	1	5.9	0.3	0.5
14	1.4	1	10	1.4	2	16	1.4	1.1
18	1.7	1	15	1.9	2	26.2	2	1.6
24	2.3	1	20	2.3	3	36.7	3.1	2.2
29	3.1	1	25	2.7	3	47.9	4.5	3.1
36	3.4	2	30	3.2	4	58.1	5.7	3.8
41	4.5	2	35	3.7	4	70.2	8	4.4
45	5.4	3	40	4.2	4	81.8	9.1	5.1
9	5.7	4	45	4.6	4	93.5	10.8	6
57	6.8	5	50	5.1	5	98.3	11.1	6.6
62	7.7	6	55	5.6	5	105	11.9	7.1
68	8.2	6	60	6	6	114	12.8	7.9
78	9.1	7	65	6.5	6	127	14.2	8.8
84	9.7	8	70	7.4	7	-	-	-
89	10.5	9	75	7.9	7	-	-	-
-	-	-	80	8.8	8	-	-	-
-	-	-	85	11.1	10	-	-	-

The experimental results of Cyclic loading on Flexural member for Reinforced concrete, Laced Steel Concrete Composite and Fiber Reinforced lased steel Concrete composite for Load Vs Deflections relationship are note down in Table 2.

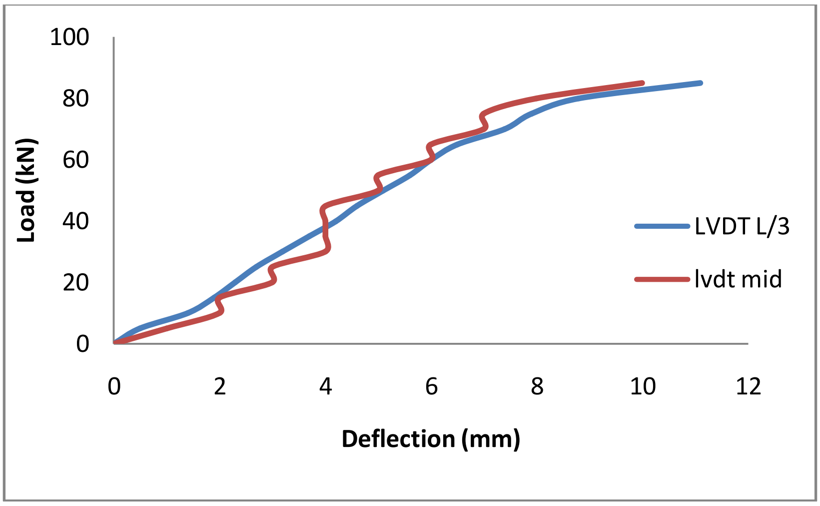

Fig 5 LSCC Load Vs Deflection

The figure 5, 6 & 8 Shows that Load (P) Vs Displacement measured using LVDT in mid span (Δ_{mid}) and L/3 span from either side average ($\Delta_{L/3}$).

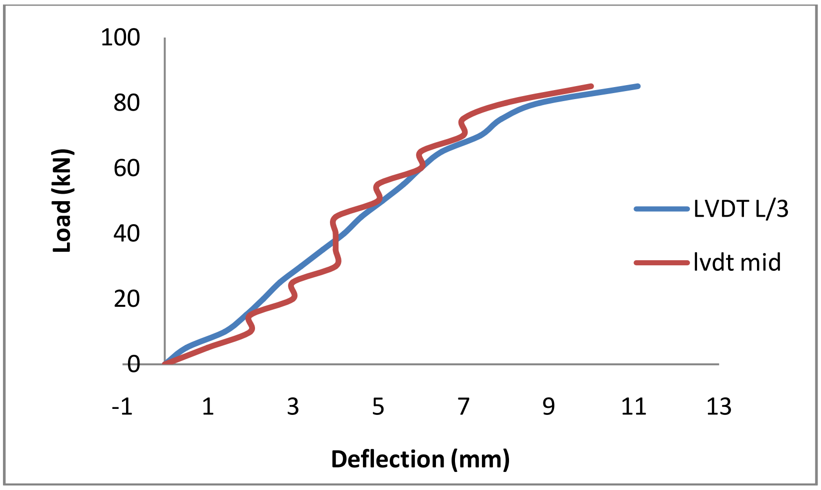

Fig 6 FLSCC Load vs Deflection

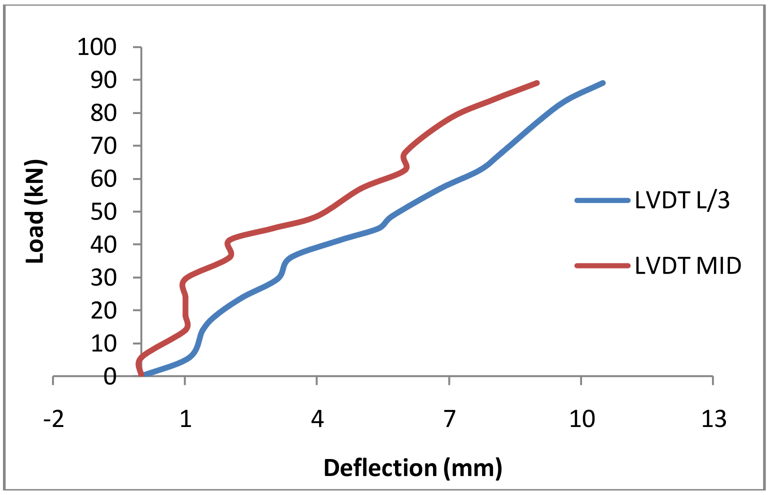

Fig 7 RC Load vs Deflection

VI. RESULTS AND DISCUSSION

The Comparative study done by experimentally is showing in figure 8. The figure 8 gives information about FLSCC is higher load carrying capacity as well as prolonged response to show the higher ductility as compared to other. The reason for FLSCC higher ductility is fibers are control the micro cracks in Dynamic loading. The LSCC also having specified increase in load carrying capacity as well as ductility property as compared to Conventional reinforced concrete this is due to the Lacing in the flexural members gives confining to concrete and avoid sudden failure in the element.

1. Experimental investigations on Laced and RC beams are carried out under monotonic and reverse cyclic loads.
2. Ductility of LSCC beam with 60° lacing is found to be more than that of RC beam, while their moment carrying capacities are higher comparatively, i.e., FLSCC= 20.38Kn-m where as LSCC and RC are 17.01KN-m and 13.6KN-m respectively.
3. Maximum load attained under both sagging and hogging moment conditions are found to be comparatively high for FLSCC (139KN) than LSCC (116KN) and RC(95KN).
4. Envelop of cyclic load-displacement response indicates softening after reaching a peak value
5. The Load Vs Deflection, Load Vs strain and Moment Vs Curvature for the beam specimens are studied.

The crack pattern and spalling of concrete in dynamic loading are checked during experiment is shown in Figure 9.

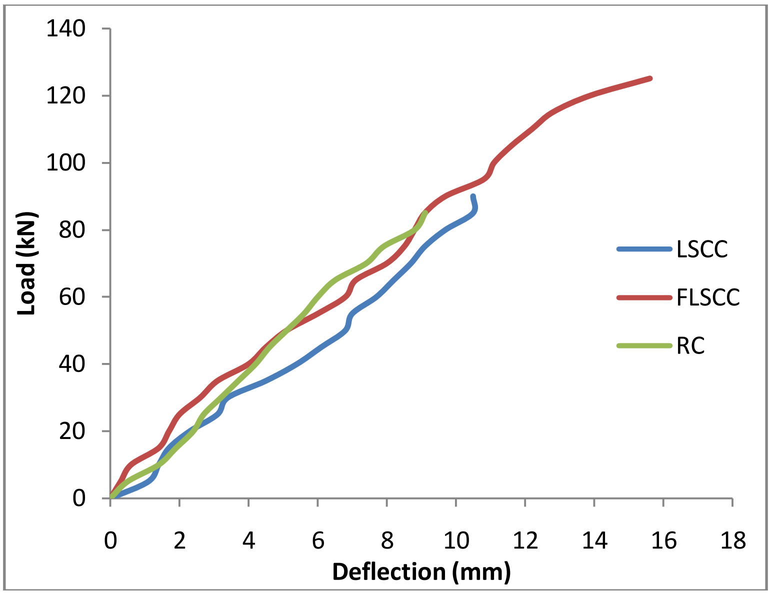

Fig 8 Comparison of LSCC, FLSCC and RC


Fig 9 Crack pattern in beams

VII. CONCLUSION

There for in this study concluded Ductility and structural integrity are essentially required for structures subjected to suddenly applied dynamic loads such as shock loads. Reinforced Concrete (RC), the most widely used construction material, possesses considerable mass per unit cost, excellent fire-resistance characteristics and can also absorb large amount of energy, if provided with proper detailing. However, one of the disadvantages of concrete is the possibility of spalling/scabbing when it is subjected to shock loading, which weakens the core and affects the integrity of the structure.

The laced system has the following advantages over Conventional system

- Higher ultimate load capacity
- Spalling of concrete is restricted
- Increased ductility
- Economic comparatively
- No requirement of form work
- Capable of withstanding impact loads

The following are the suggestions for future research:

Here equivalent blast load effect is considered by cyclic loading. But if we want to incorporate real behavior of elements behavior under blast load scale down detonation (Charge) is applied on scaled model under controlled explosion. Here chosen beam element is not so much attracted by blast loading because it's an line element if we considered wall or slab then blast load effect is more by high surface area. The crack with measurements also required for new material invention for Blast resist materials. The behavior of lased reinforcements study is also required by providing electrical strain gauge.

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