Study on Strucutral Behaivour of RC Sandwich Deep Beam

G. Kranthi Kumar, B. Sarath Chandra Kumar

***Abstract:** Reinforced concrete deep beams are different compared to normal beam because of compression bottle shape is happen after the diagonal crack has occurred. An experimental program consists of four specimens are carried out to investigate the shear strength behavior of reinforced concrete sandwich deep beam concealed with the variation of insulation pad depth (200 mm, 300 mm and 400 mm). Constantly maintained effective length, depth, the width of the specimens, width of bearing plates, longitudinal reinforcement as 1% and vertical and horizontal reinforcement as 0.15%. The shear span to depth ratio of deep beams is 0.95. The study also aims at examining the influence of longitudinal shear reinforcement along with vertical and horizontal shear reinforcement on the shear strength, shear ductility of RC sandwich deep beams of insulation pads placed at different depths. The main outcome of these study is to compare load vs. deflection.*

***Index Terms:** Deep Beam, Shear Reinforcement, Insulation Pad, Crack Pattern, Diagonal Crack.*

I. INTRODUCTION

Deep beams are structural elements loaded as simple beams in which a significant amount of the load is carried to the supports by a compression force combining the load and the reaction. Consequently, the strain distribution is never again thought to be direct, and the shear mishappening wind up unique when contrasted with pure flexure. Reinforced concrete deep beams have helpful applications in tall structures, seaward structures, and establishments. Especially the utilization of profound shafts at the lower levels in tall structures for private and business purposes has expanded quickly in view of their accommodation and economic proficiency. Based on some experimental results variation of width of deep beam it doesn't affect the shear strength of specimen because of this only in my present study we are varying the depth of polystyrene (200, 300, 400 mm) in middle portion of the deep beam and the observe the shear strength behavior, then compare the experimental results with control specimens.

The reduction in shear strength with an increase in the height of deep beams and the experimental results indicating that evenly-distributed web reinforcement also plays an important role in mitigating size effect in deep beams [1].Development of size dependent shear strength expression of reinforced concrete deep beams using refined Strut and Tie Model [2]. The concentrated and uniformly distributed loads, were adopted to understand the influence of distribution of horizontal reinforcement along the depth of beam and the web confinement changes the mode of failure from sudden flexural splitting to diagonal shear [3]. The development of the shear strength expression is based on the shear transfer mechanism of deep beams idealized through a refined strut-and-tie model according to the modified Bezant's size effect law and a large experimental data [4]. For both strut boundary and strut geometry play an important role in controlling size effect [5]. Prove that variation of a/d ratio, will effect on shear strength of deep beam under failure load [6]. Discussion about the increases the shear strength of deep beam with alternative web reinforcement with different percentages [7].

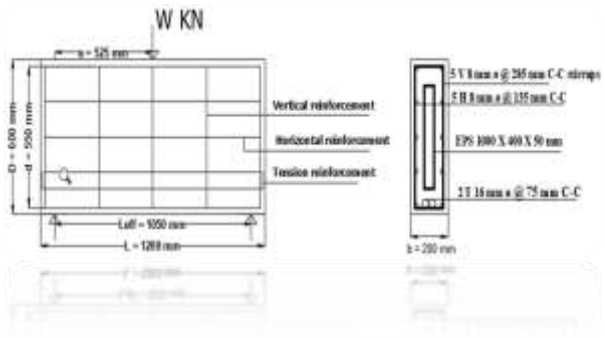

Figure 1: Details of reinforcement in sandwich deep beam

Table I: Summary of concrete

Description	Type
Characteristic cube strength	30 MPa
Cement type	OPC 53 grade
Aggregate type	Crushed granite and natural washed sand
Fine aggregate content	710kg/m^3
Cement content	420 kg/m^3
Coarse aggregate content	1127kg/m^3
Slump for concrete	100 mm
Water/cement ratio	0.45

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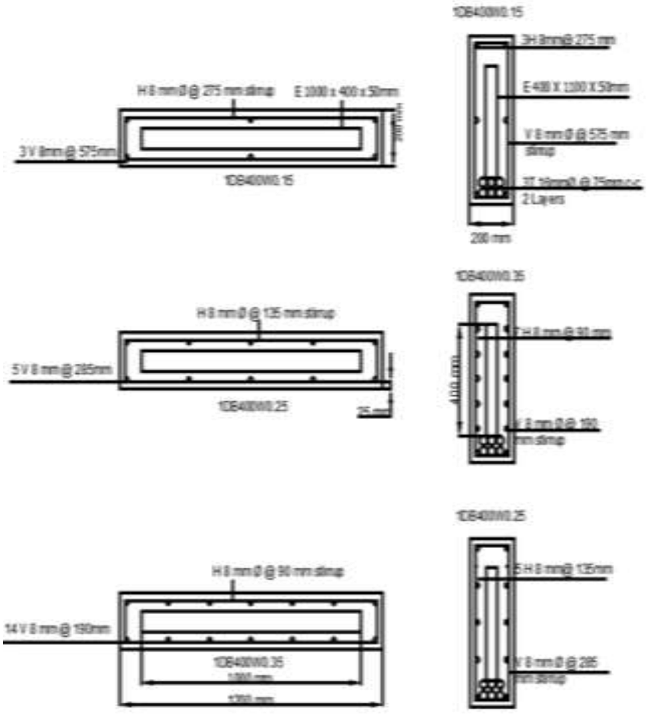

Figure 2: Beam cross section

II. RESEARCH SIGNIFICANCE

This work expects to give experimental evidence on the shear behavior of Reinforced concrete deep beams to allow a superior comprehension of the impacts of fluctuating the depth of the sandwich sheet. The issues will likewise permit an estimation of the present code arrangements and help distinguish their controls.

III. EXPERIMENTAL PROGRAM

Specimen details: The test specimens consisted of four simply supported beams 600 mm deep and 200 mm wide and effective span $Leff$ of 1035 mm. The beams had a tension steel area As = 300 mm^2, providing ρ = 0.25 percent. All the beams have the same shear span by depth ratio (a/d = 0.875) and effective length by depth ratio ($Leff/d$ = 1.725) and varies the depth of polystyrene (dp) at different depths of 200 mm, 300 mm, 400 mmof length (Lp) 1000 mm and width (Wp) of 50 mm placed at the middle of the cage. At locations of loading or support point, a local reinforcement cage was provided to prevent premature crushing or bearingfailure. One variation is introduced, viz., depth of sandwich depth 200 mm, 300 mm, 400 mm and their cross-sections are shown in Figure 3 to 6. The cube and cylinder compressive strengthfcu and $f'c$ are additionally given in Table II, while the concrete mix design is given in Table I. The estimations of fcu and $f'c$ were acquired from control examples restored under indistinguishable conditions from the test beams and were the mean estimations of three $150\ mm\ X\ 150\ mm\ X\ 150\ mm$ cubes and three $150\ mm\ X\ 150\ mm\ X\ 300\ mm$ cylinder, separately. They were tried on an indistinguishable day from the beam example to assess the age effect on the concrete strength. To get a similar main reinforcement proportion for allbeams, two bar sizes were utilized as the longitudinal steel that is ϕ16 mm hot-rolled bars, with normally estimated yield qualities of 502 MPa and 554 MPa, separately. The web support comprised of ϕ8mm hot-rolled bar of yield quality 511 MPa as flat steel and ϕ8mm round bar with 250 MPa as vertical steel.

Table II: Details of specimens

S. No	Beam Designation	L □ B □ D	a/d	ρ_s %	ρ_h&ρ_v %	A_{hst}	A_{vst}	n_s	n_h	n_v	S_v	S_h	f_{cu}	f_c’
1	DBW0.15	1200 x 200 x 600	0.95	1	0.15	202	302	6	2	3	575	550	920	1007
2	DB200W0.15	1200 x 200 x 600	0.95	1	0.15	202	302	6	2	3	575	550	960	1054
3	DB300W0.15	1200 x 200 x 600	0.95	1	0.15	202	302	6	2	3	575	550	940	1030
4	DB400W0.15	1200 x 200 x 600	0.95	1	0.15	202	302	6	2	3	575	550	935	1024

Note: a/d - shear span to depth ratio, B - width of specimen in mm, D - depth of specimen in mm, $\rho_v$andρ_h - percentage of vertical and horizontal web reinforcement, A_{hst} and A_{vst}- area of vertical and horizontal shear reinforcement in mm2, $n_h$and n_v - number of stirrups in vertical and horizontal, S_v and $S_h$center to center spacing between vertical and horizontal shear reinforcement in mm, f_{cu} - compressive strength of cube @ same day of beam test in N/mm^2, fc’ - cylinder compressive strength in N/mm^2. All the beams maintain 6 bars of 16mm diameter steel bars @95mm from base of the beam in tension zone in two layers c-c distance of 75mm andA_{st} 1206.37mm^2 for all control and sandwich specimens.

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Figure 3: Reinforcement details of 0.15% Control deep beam

Figure 4: Reinforcement details of 0.15% - 200 mm deep beam

Figure 5: Reinforcement details of 0.15% - 300 mm deep beam

Figure 6: Reinforcement details of 0.15% - 400 mm deep beam

IV. STUDY OF DEEP BEAMS

The beam specimens were tested under three-point loading in a loading frame of the capacity of 2000 kN. The point of the testing was to identify the shear behavior of beams with varying percentage of shear reinforcement respective sandwich depth. All the beam specimens were analyzed at 28 days under gradually advancing load. The individuals are loaded utilizing a 2000kN hydraulic jack which has a load cell to monitor the load. Deflections of the beams at the mid span are checked to appropriate LVDT. The load at the initial diagonal or midspan split and a definitive shear crack were recorded. The crack pattern is set apart on the beam

V. RESULTS AND DISCUSSION

A. Deflections

Figure 7 shows the behavior of the control specimen (DBW0.15) under the initial and ultimate loading condition at 490 kN and 773 kN load. It shows deflection of 1.66 mm at an initial diagonal crack load of 490 kN and 2.53 mm at the ultimate diagonal crack load 773 kN. Table IV show the experimental load values. Figure 8 shows the behavior of DB200W0.15 under initial and ultimate loading condition at 359 kN and 639.1 kN load. It shows deflection of 0.915 mm at the initial diagonal crack load of 359 kN and 2.153 mm at ultimate diagonal crack load 639.1 kN.

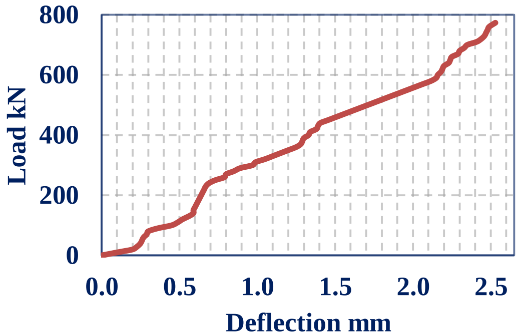

Figure 7: Shear strength of 0.15% control specimen of deep beam

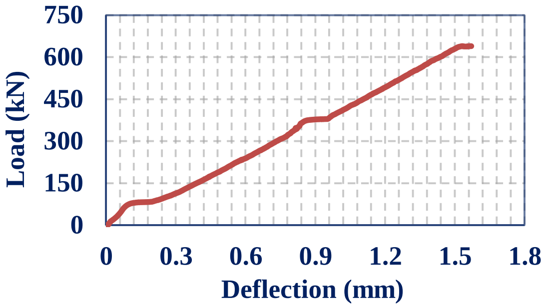

Figure 8: Shear strength of 0.15% - 200 mm deep beam

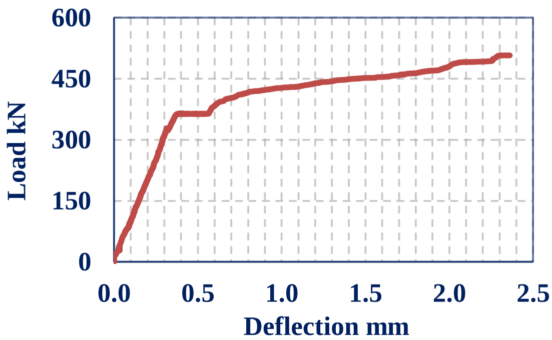

Figure 9: Shear strength of 0.15% - 300 mm deep beam

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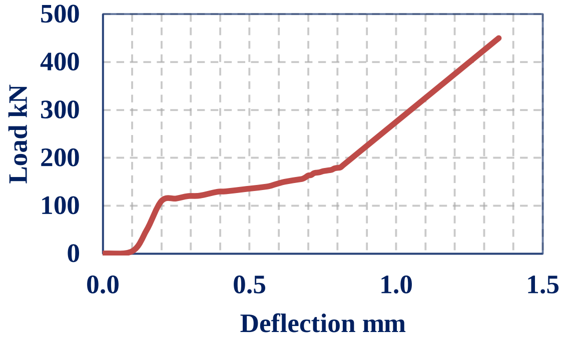

Figure 10: Shear strength of 0.15% - 400 mm deep beam

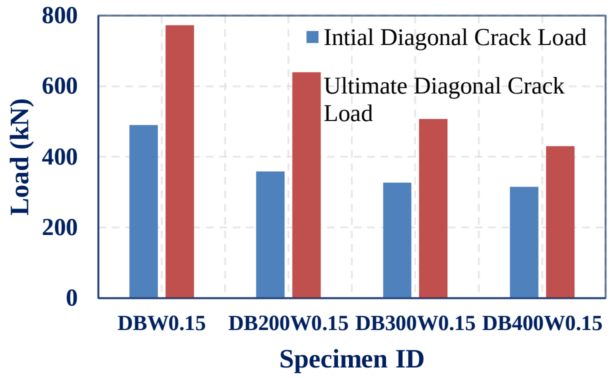

Figure 11: Shear strength comparison of 0.15% deep beam

Figure 9 shows the behavior of DB300W0.15 under initial and ultimate loading condition at 327 kN and 507.1 kN load. It shows deflection of 0.329 mm at the initial diagonal crack load of 327 kN and 2.01 mm at ultimate diagonal crack load 507.1 kN.

Figure10 shows the behavior of DB400W0.15 under initial and ultimate loading condition at 315 kN and 430 kN load. It shows deflection of 0.3 mm at an initial diagonal crack load of 315 kN and 1.35 mm at ultimate diagonal crack load 507.1 kN.Figure11 shows the shear strength comparison of 0.15% control specimen along with varying insulation pad depths of 200 mm, 300 mm, 400mm specimens shows that 1DBW0.15 specimen gives better results compare other specimens. And DB200W0.15 shear strength results are nearly equal to control specimen remaining will fail at 327 kN, 315 kN. When increasing the depth of core material decreases the shear strength of specimens.

Figure 11 show that shear strength of 0.15% control specimen's shows better results compare to DB200W0.15, DB300W0.25, and DB400W0.35 deep beam specimens.

A. Crack patterns, failure modes and crack widths

Figures13 to 17 shows the crack patterns of control specimen, DBW0.15, DB200W0.15, DB300W0.15, and DB400W0.35 shows crack forms diagonally, out of four specimens with different depths of insulation pad won't show ant flexural failure or flexural cracks.At failure together with the corresponding ultimate loads at which each crack was first observed, and it maintains greater than 25^o proves that perfect diagonal cracks under loading, and the extent of the diagonal crack at that ultimate load too. All the four specimens shows 0.01, 0.02, 0.03, 0.1, 0.2mm crack width respectively at first diagonal crack. At ultimate load point, the diagonal crack extent to 0.5 to 0.9 mm crack width through diagonally.Figure13 shows the crack pattern and crack distribution of 0.15% control specimen obtain 0.01 mm, 0.03 mm crack width at initial loading point of 490kN and 0.1 mm, 0.2 mm crack width at final loading point of 773 kN. The specimen consists of 200 mm depth insulation gives shear strength values nearly equal to control specimen.

Table III: Experimental Data

Beam Designation	L mm X B mm X D mm	Initial Diagonal Crack Load (V_d)	Ultimate Diagonal Crack Load (V_u)	Initial Deflection (Δ_i)	Final Deflection (Δ_u)	Initial Crack Width (W_i)	Ultimate Crack Width (W_u)	Mode of Failure
DBW0.15	1200 x 200 x 600	490	773	1.6	2.53	0.01, 0.03	0.1, 0.2	Diagonal Shear Failure
DB200W0.15	1200 x 200 x 600	359	639.1	0.915	2.153	0.02, 0.03	0.2, 0.4	Diagonal Shear Failure

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DB300W0.15	1200 x 200 x 600	327	507.1	0.329	2.01	0.03, 0.05	0.3,0.4	Diagonal Shear Failure
DB400W0.15	1200 x 200 x 600	315	430	0.3	1.35	0.02, 0.03	0.2,0.3	Diagonal Shear Failure

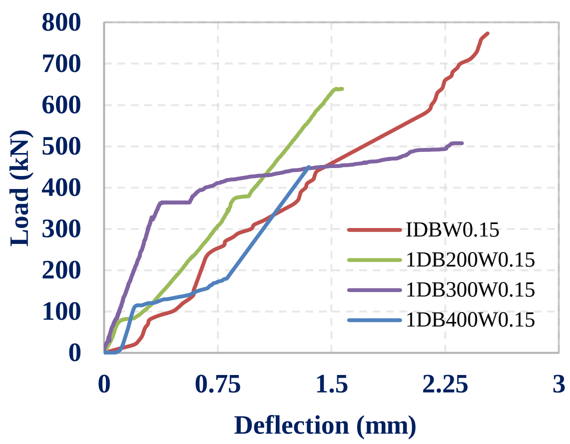

Figure 12: Shear Strength of 0.15% deep beam

Figure 13: 0.15% CS at Ultimate loading condition

Figure 14 shows a crack pattern of 0.15% 200 mm specimen of 0.02 mm, 0.03 mm at initial loading point of 359 kN and 0.2 mm, 0.4 mm crack width at 639.1 kN. Figure 15 shows a crack pattern of 0.15% 300 mm specimen of 0.02 mm, 0.035 mm at initial loading point of 327 kN and 0.2 mm, 0.4 mm crack width at 507 kN. Figure 16 shows a crack pattern of 0.15% 400 mm specimen of 0.02 mm, 0.03 mm at initial loading point of 315 kN and 0.2 mm, 0.4 mm crack width at 430 kN. At ultimate point load, the specimen shows crack at sides also as shown Figure 17 have a crack width of 0.05 to 0.08 mm.

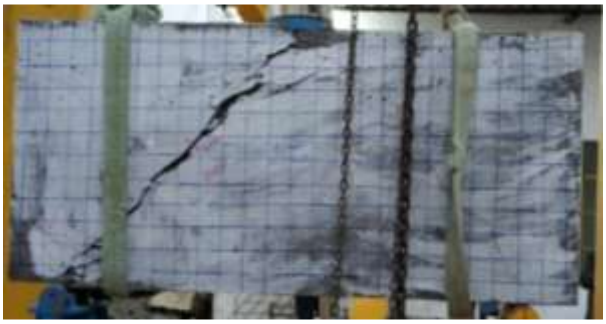

Figure 14: Ultimate loading condition 0.15% 200 mm deep beam

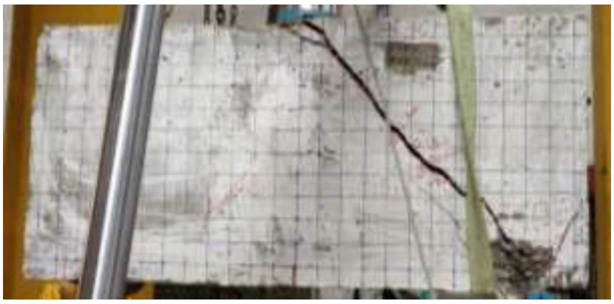

Figure 15: Ultimate loading condition 0.15% 300 mm deep beam

Figure 16: Ultimate loading condition 0.15% 400 mm deep beam

Figure 17: Ultimate loading condition 0.15% 400 mm deep beam silde view

VI. CONCLUSION

The paper presents the findings of an experimental program devised to investigate the variation of insulation

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pad depths in the center of the deep beams. The width of a deep beam is negligible on shear behavior for a/d ratio 0.95. At the initial and ultimate stage of loading diagonal crack dominates the flexural crack.

1. All the four specimens show diagonal crack only.
2. Cracks maintain greater than 25^0 from loading point as shown in Figures 13, 14, 15, 16.
3. 1DB400W0.15 show cracks at sides with a width of 0.05 mm, 0.06 mm and 0.07 mm due to increase of core depth at center portion.
4. Kern portion of the sandwich deep beam of 1DB200W0.15 show better results compare to others.
5. If the depth of the core material exceeds the kern portion, it will show uncertainty results.

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