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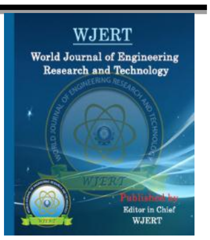

TEST ON THIN RCC SLAB - BRICKWORK COMPOSITE LINTEL

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ABSTRACT

This paper enunciates experimental findings of laboratory results of a typical composite lintel consisting of a thin RCC slab supporting brick masonry layers on it. In this paper, two Thin RCC Slab - Brick Work Composite Lintel (TRBWCL) specimens of both 900 mm clear span were cast with 50 mm thin RCC Slab. Out of them, one was over laid with one layer of brick work in CM 1:5 and the other was laid on three courses of brickwork CM 1:5. The ultimate flexural capacity of such TRBWCL were experimentally tested and reported along with its flexural behavior.

KEYWORDS: Thin RCC Slab, Mesh reinforcement, Brick masonry, Cement Mortar, Ultimate load.

1. INTRODUCTION

Composite action in lintel

Lintel is an essential component in masonry constructions. It is used to support the load of the masonry from above opening to the sides of the opening safely. Even though it gets combined with Chajja projections in facing of outer side of a wall and lofts in the inner side of walls, in many situations the lintels are confined with a width of only equal to wall thickness. Whatever the main material by which a masonry above lintel is made; in general the block masonry contributes compression zone effectively in flexural behavior of lintel and it needs essentially a system of tension zone which often made as Reinforced concrete. Where as a combined action of the said Compression zone and Tension zone together of them to form a couple called as a Resisting moment which sustains the external moment induced by both self weight and external load on the lintel.

2. LITERATURE

Comparatively, thin lintel saves as much as one half of cost of conventional RCC lintels; being precast lintels, it eliminates centering and shuttering and hence reduces construction time.[1] It is possible by adopting various techniques of cost reduction, to minimize the cost of construction without compromising on the aesthetics, durability and safety.[2] When lintel beam and masonry above combined, ultimate load capacity increased greatly as the height of masonry is increased.[3] Av / d ratio and shear stress has linear proportion, but thickness is not like that. For the unreinforced masonry (URM) walls, the ultimate average shear stress of is noted as 0.2 MPa.[4] In masonry walls, there can be four different failure modes such as a) Sliding b) Rocking c) Toe crushing and d) diagonal tension. Shear stress is equal to square root of permissible compressive stress.[5] For more realistic calculations, diagonal tension shear mechanism and tensile strength of masonry both are to be considered as critical data.[6] Minimum Compressive strength of bricks is 7.5 MPa.[7] The shear stress in masonry may be taken between 0.1 MPa and 0.5 MPa.[8] The allowable shear stress in the masonry may taken as (0.1+ Compressive strength of brick / 6), but limited to a maximum of 0.5 MPa.[9] Initially small flexural cracks near middle of span and on further increment of load, the cracks got enlarged. Thereafter, diagonal cracks were noticed at end span and they propagated and approached the load point.[10] Beams with a_v / d up to one develop inclined cracks joining the load and the support changing the behavior from beam action to arch action, and are called deep beams. These beams have uniform tensile force from end to end due to longitudinal bars at the bottom of the beam and act as tie of the tied arch. Such beams fail by anchorage failure at the ends of tension tie. If a_v /d ratio range from 1 to 2.5, develop inclined cracks. After some redistribution of forces carry some extra loads, then fail by splitting, loss of bondage, shear tension or shear compression.[11]

3. Scope

1. To cast and test sample specimens of TRBWCL and do flexure test to study the flexural beahviour.
2. To verify the feasibility of TRBWCL for further application.
3. To check the adequacy of the selected sample by simple design steps with reference to existing literature.

4. To identify possibilities of suggestions for future researchers.

4. MATERIALS

RCC M 20 Grade concrete made by using BIS cement of 53 grade, 10mm and 20 mm coarse aggregate, river sand from Karur as fine aggregate, local municipal supply water and BIS standard Fe 415 grade steel as reinforcement were used, for thin slab as tensile portion of the composite lintel. Second class ground molded burnt mud bricks made from local place Govanur which is 27 kM from Coimbatore city in northwest, was used. The ratio of cement Mortar 1:5 was used.

4.1 Technical data

The compression stress brick f_{wk} = 8 MPa, f_{ck}= 27.2 MPa, f_y = 415 MPa, Mix ratio. 1: 1.56: 3.05 W/c Ratio = 0.49.

5. METHODS

5.1 Casting of Specimens

Figure 1 shows the Preparation of Thin RCC Slab and Laying Brickwork. To avoid concrete sticking on floor and to avoid wastage of cement slurry, news papers were spread. Pair of temporary moulds was formed by arranging bricks. Three numbers of 8 mm dia. longitudinal main bars and 6 mm dia. distributors at 150 mm c/c were laid perpendicular to the longitudinal bars and tied and placed in position. For necessary clear cover, selective coarse aggregates were placed below the reinforcing bars at suitable intervals. For M 20 mix the ratio, cement, aggregates were carefully measured by weight and mixed by electrically operated batch mixer machine. The concrete was laid carefully in two layers and compaction is done for each layer. Figure 2 shows the finished RCC thin slab and after laying one course of brick masonry.

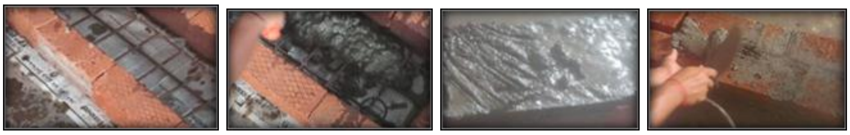

Fig. 1: Preparation of Thin RCC Slab and Laying Brickwork.

Fig. 2: Finished RCC thin slab and after laying one course of brick masonry.

To ensure the recommended grade of concrete, simultaneously three cubes were cast and after one day they were immersed in water. Gradually, the fresh concrete was laid in the mould. Thus the required thin slabs of 1000 mm length were prepared. On the slabs, after one hour, brick work in CM 1:5 were laid. Curing was done for 21 days. Figure 3 shows the Longitudinal section / Elevation of the TRBWCL and figure 4 shows the typical Cross Sections TRBWCL1- 1 layer brickwork & TRBWCL2 – 3 layers brickwork.

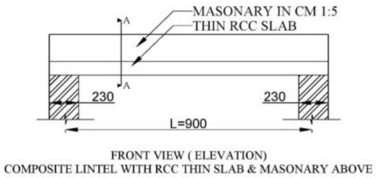

Fig. 3: Longitudinal section / Elevation of the TRBWCL.

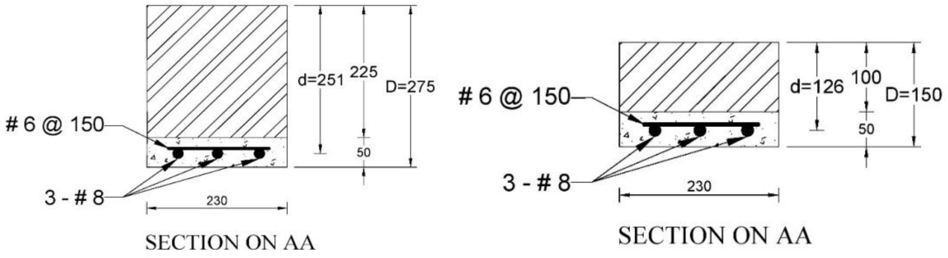

Fig. 4: Typical Cross Sections - TRBWCL1- 1 layer BW & TRBWCL2 – 3 Layers BW

5.2 Four Point Loading.

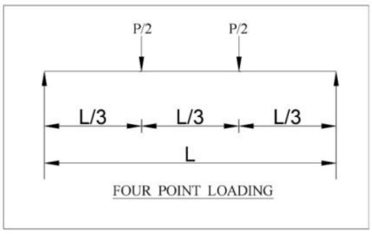

Fig. 5: Schematic Diagram of Four Point Loading.

Figure 5 shows the schematic diagram of the four loading of the test set up.

5.3 Flexural Test

Figure 6 shows specimens in loading frame. Test specimen was placed in 30 kN capacity loading frame, over simply supported span of 900 mm. Loads were placed at 300mm spacing and such that 300mm spacing was maintained from each load towards each of the support. Linear Variable Data Transformer (LVDT) was placed at mid span to digitally measure the central vertical deflection. Load was applied in the increment of 1 kN through load cell. Each load was observed for around 2 minutes. The first crack load and its propagation were observed by visual examination and noted then and there.

Fig. 6: Specimens in Loading frame.

When the further increment of load was not possible, that load was noted as the ultimate load. The entire test for each specimen took around 45 minutes.

5.4 Failure Modes and Flexural behaviour

The figure 7 and 8 show the failure in tested samples in front and rear views.

Crack in Concrete 7 kN

Crack near load point

Fig. 7: Failure in TRBWCL1 - Front and Rear view.

No Crack in this L/2

Parallel Diagonal Crack

Fig. 8: Failure in TRBWCL2 - Front and Rear view.

Failure mode in both the specimens was due to shear. Crack initially started at bottom concrete around 7 kN earlier stage of loading in between the two load points. Then, it gradually propagated at one upward in diagonal direction on each increment of the load and then reached the load point at top. In the TRBWCL1, the first masonry crack at 8 kN load occurred one end. At the end the shear failure and dislocation of brick work took place on the other side of the mid span also. Almost the entire one course of brickwork got separated at the interface of RCC part and brickwork. In TRBWCL2, almost all visible cracks took place from one of the load points towards the end of the same side only. First masonry crack occurred at 34 kN load and on further loading, it propagated diagonally. On further loading, a vertical downward crack developed directly below one of the load points, at mid depth of the specimen TRBWCL2. Almost near the peak load, separation at the interface of RCC and masonry took place along with further lateral movement in upper courses of brick work. Simultaneously, from the first diagonal crack at a distance of one brick length, a second parallel diagonal shear crack over the entire depth of brickwork was occurred. This is visible in the rear side of the specimen in figure 8. On the rear side of the TRBWCL2, during ultimate load the concrete splitting and anchorage failure occurred as a result, a portion of RCC slab fell down. There is no other visible crack on the other half span of the specimen.

5.5 Load Deflection Curve

The figure 9 shows the plots of the Load - deflection curves of specimens TRBWCL1 and TRBWCL2.

The Load deflection curve indicates the flexural behavior of the composite lintel as a whole. The curve for TRBWCL1 followed with lower stiffness as it looks like a concave curve. In TRBWCL2, the curve followed with slightly larger stiffness, as it rises upward and in all, it looks like a curve with major convex curve.

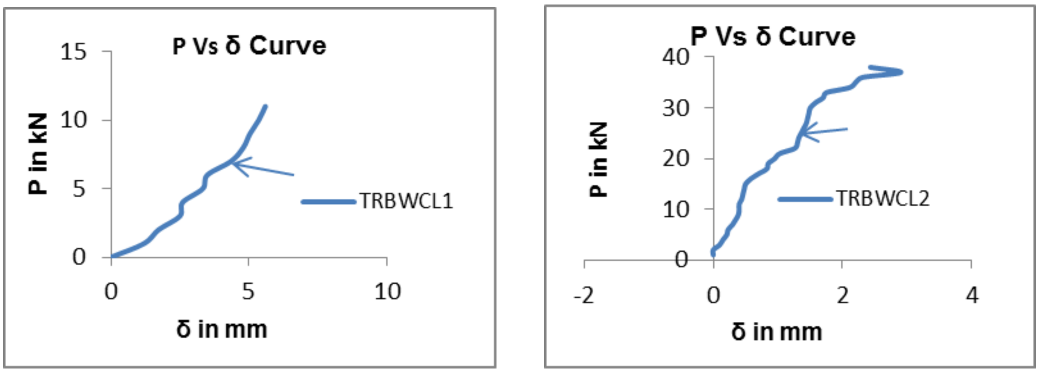

Fig. 9: Load Vs Deflection Curve of TRBWCL1and TRBWCL2

For both specimens there are tri-linear response noted. In TRBWCL2 exhibited the tri-linear response clearly just before approaching ultimate load. The arrow marks in both the plots of figure 9 are representing the point of start of full composite action of the TRBWCL specimens.

6. RESULTS AND DISCUSSIONS

Compared to TRBWCL1 and TRBWCL2, the later one was found to have larger stiffness. First crack in First crack formation in masonry was noticed in TRBWCL1 and TRBWC2 at 73% and 89% of the ultimate load respectively. This proves that both a) the more the number of masonry rows, the higher will be service load and b) the composite action between the RCC thin slab and brickwork is more in TRBWCL2. As far the ratio of the span / maximum deflection is concerned, it was 160 and 340 for the specimens TRBWCL1 and TRBWCL2 respectively. Hence, compared to both the specimens, the deflection ratio was found to be 2.125. Being the failure mode is shear, shear connector from concrete slab to masonry and masonry lower courses to higher courses if provided, may contribute for higher ultimate loads. In TRBWCL2, it is evident that crack did not occur in the middle third span. Hence, composite action is well pronounced in flexure zone of TRBWCL2 rather than TRBWCL1. In TRBWCL2, because of the arch action of the masonry, major portion of the applied load could have got distributed on the end of the span. The cause of failure being shear and in brittle nature, it is noted as sudden failure without sufficient caution. So, a designer can take the load 36 kN at which first masonry crack as a design load. So that the zone from first masonry crack to the peak load may be treated as safety zone.

7. Ultimate Moment capacity

The Ultimate moment capacity of TRBWCL2, worked out as follows.

Experimental Ultimate load was 38 kN, because brittle mode of failure took place; without sufficient early warning, considering the first crack load took place at 89% of Ultimate load,

First crack load = 0.89x38=33.82 kN,

P / 2 = 16.91 kN, Since, L / 3 = 0.3m,

Hence, Safe Moment capacity = 16.91x0.3 = 5.07 kNm. (*)

NOTE (*) An additional factor of safety of around 11% is allowed from experimental load, considering sudden failure. Calculation of moment by failure mode in a) Flexure and b) Shear and the calculation of Ultimate moment of resistance of the composite lintel are shown in the appendix.

7.1 Adequacy of TRBWCL.

Referring to,[14] the design moment of conventional RCC lintel cum sunshade with 600 mm Chajja, is 3.87 kNm < 5.07 kNm. The safety ratio of Moment capacity and Moment required is, 5.07 / 3.87 = 1.31, Hence, this TRBWCL2 is found adequate in all regards up to 1.5 m span with triangular masonry load for simply supported end condition.

8. Verification of Experimental Load

The failure of the composite lintel can be either by flexure mode, or shearing mode. In both the specimens, the shearing failure occurred prior to the yielding of steel by flexure. The following is the calculation of failure load due predominant shear.

Let the permissible shear stress of brick work be.[8] = 0.35 MPa.

The shearing force under any one of the two points loading will be equal to,

Shear force V= Shear resisting area x shear stress = 0.35 x b x db (*)

On substitution, we get the shear resistance V = 0.35 x 230 x 225 = 18.11 kN – (1)

For failure, the applied load from load cell was = P = 38 kN

Therefore the one of the two point loads was = P / 2 = 19 kN – (2)

Since 19 kN > 18.11 kN, the failure occurred by shear.

NOTE(*) = Here, db = depth of brickwork only considered, assuming RCC part is in tension and fully cracked, neglected,[13] and,[15] and the shear effect of longitudinal bars also neglected, as there is no hangers to hold them and being subjected to end anchorage due to deep beam action of tie.[11]

9. Suggestions for future work

An optimum relation between masonry height above Thin RCC lintel and the span may be arrived at. Tests may be made with different masonry using Stabilized mud block, stone-concrete block, concrete blocks with fibres and AAC blocks. An effective shear connector may be identified, to maximize composite action. The behavior similar composite lintel for continuous beam can be studied. Experimental works may be validated with Finite Element Analysis.

10. CONCLUSIONS

Within the scope of this paper, the following conclusions may be drawn.

TRBWCL specimens cast and tested for flexure. The TRBWCL can be applied up to 1.5 m span with a minimum of five courses of brickwork in CM 1:5 on thin RCC lintel, in residential projects where the triangular masonry loading is only expected on lintel. Adequacy of the TRBWCL2 section is checked with the conventional lintel design for moment capacity and found satisfactory. For a comparable moment capacity, TRBWCL2, when compared to conventional RCC Lintel with top and bottom reinforcements at four corners and this Composite lintel with a thin slab of mesh reinforcement without conventional ring and masonry above it, proves using substantially lesser reinforcements. Hence, the TRBWCL is cheaper in cost without reduction in structural response.

Appendix

A1.Guidelines for a balanced section of TRBWC lintels and the selection of either d based on A_{st}, or A_{st} based on d;[12]

Assuming, C = T

i.e. $0.429 f_w k b X_u = 0.87 f_y A_{st}$

For M 20, Fe 415 grades and the standard breadth of brick work as 230mm,

The above equation reduces to,

$$0.429 \times 8 \times 230 \times 0.5d = 0.87 \times 415 \times A_{st}$$

$$394.68d = 361.05\ A_{st} \quad – (3)$$

$$\text{So, } d = 0.92\ A_{st}$$

For the present case, using 3 nos. 8mm dia. bars,

$$d \text{ min required} = 0.92 \times 3 \times (3.14 \times 8 \times 8)/4 = 138.66 \text{ mm}$$

$$\text{Hence, } d \text{ used} = 251 > 220.50 \text{ mm safe.}$$

A2. Moment of Resistance of a TRBWCL

Compressive force as in equation (3),

$$C = 394.68d \quad = 394.68 \times 251 = 99064 \text{ N}$$

Lever arm (z) $= 0.8\ d = 0.8 \times 251 = 200.8$ mm

Moment in Compression $= C.\ Z = 99064 \times 200.8 = 19.9 \times 10^{6}$ Nmm. –(4)

Moment in Tension $= T.Z = 361.05 \times A_{st} \times Z = 361.05 \times 150.7 \times 200.8$

$= 12 \times 10^{6}$ Nmm.- (5)

Out of (4) and (5), the least value is $= 12 \times 10^{6}$ Nmm is the Moment of Resistance

A3. Experimental ultimate load possible in flexural failure mode, when shear failure not initiated

Assume the MRts = 12 kNm

For a span L=900 mm, a = L/3 = 300mm

So, P/2 = M / a = 12 / 0.3 = 40.00 kN

Load from load cell expected = P/2 x 2 = 40 kN x 2 = 80 kN.

A4. Minimum height of masonry required

With the forgoing shear force calculations in equation (2), and for full moment capacity of the section of the composite lintel, is 12 kNm i.e to lead to flexural failure before shear failure occurs, the shear resistance required is, P/2 = V = 40 kN

From equation (1) db (*) required = V / (0.35 x b) = 40×10^3 / (0.35 x 225) = 507.93 mm say 510 mm.

So, minimum height of masonry required is = 510 mm, for inducing flexural failure before shear occurs.

Table 1 presents Design values for TRBWCL with varying reinforcing bars and Table 2 presents Design values for TRBWCL with varying fwk values.

Table 1: Design values for TRBWCL with varying reinforcing bars.

Fwk (MPa)	Fy (MPa)	B (mm)	No.of Reinf.bars	Dia. of Reinf. bars(mm)	Ast (Sq.mm)	dmin-Required (mm)
5	415	230	3	8	150.72	220.50
5	415	230	2	8	100.48	147.00
5	415	230	2	10	157	229.69
5	415	230	3	10	235.5	344.54
5	415	230	2	12	226.08	330.76

Table 2: Design values for TRWBCL with varying fwk values.

CC	fwk	b	fy	Ratio (d/A_{st})
0.429	5	230	415	1.464
0.429	7	230	415	1.045
0.429	9	230	415	0.751
0.429	5	150	415	2.44
0.429	7	150	415	1.603
0.429	9	150	415	1.151
0.429	5	115	415	2.927
0.429	7	115	415	2.091
.429	9	115	415	1.501

Where cc is the coefficient of compressive force.

NOTE: For intermediate values of f_{wk}, interpolation can be done for the ratio (d/A_{st})

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REFERENCES

1. Rinku Taur and Vidya Devi T, "Low Cost Housing", ACSGE-, Oct 25-27, BITS Pilani, India, 2009.
2. Nilanjan Sengupta Use of cost-effective construction technologies in India to mitigate climate change 2008, Current Science, 2008; 94(1): 4.
3. Praveena Rao and Dr.B.Jena, Composite Action in RCC and Brick Masonry, International Journal of Scientific & Engineering Research, Jan 2016; 7(1): 297-305.
4. Waon-Ho Yi1 et al., Shear Capacity Assessment of Unreinforced Masonry Wall, 13 World Conference on Earthquake Engineering, Vancouver , B.C. Canada, Aug 2004; 1698-675-692.
5. S. Churilov and E. Dumova-Jovanoska, In-plane shear behaviour of unreinforced masonry walls, proceedings of, 14 ECEE-549.
6. Miha Tomazevic, Shear resistance of masonry walls and Eurocode 6: Shear versus tensile strength of masonry Materials and Structures. August, 2009. DOI 10.1617/s11527-008-9430-6.
7. IS 3495 (Parts 1 to 4): " Indian Standard Methods of Tests of Burnt Clay Building Bricks", Bureau of Indian Standards, New Delhi, 1992.
8. SP 20:, "Handbook on masonry construction and design", Bureau of Indian Standards, New Delhi, 1991.
9. IS 1905: "Code of Practice For Structural Use of Unreinforced Masonry", Bureau of Indian Standards, New Delhi, 1987.
10. Abd EI Raman Magahid et al., Effect of shear span to depth ratio on the statical beahviour of HSCB subjected to transverse loading, Journal of Engineering sciences, Assiut Univ, Jan 2016; 44(1).
11. K Subramanian, Design of reinforced Concrete Structures, Oxford Unviersity Press, 2016.
12. P Dayaratnam, Bricks and Reinforced Brick Structures, CBS publishers and Distributors.
13. IS 456: "Indian Standard Plain and Reinforced Concrete- Code of Practice", Bureau of Indian Standards, New Delhi, 2000.
14. A P Arulmanickkam, Structural Engineering, Pradeepa Publishers 8th Edition, 2013.

15. Balasubramani N., et al., Study on Thin RCC Slab - Brickwork Composite Lintel, WJERT Vol 6, Issue 2, March 2020, PP 621-628.