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STUDY ON THIN RCC SLAB - BRICKWORK COMPOSITE LINTEL

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ABSTRACT

This paper throws light on the possibilities of applications of Thin RCC SLAB - Brickwork Composite Lintel (TRSBWCL). These composite lintels will consist of thin RCC slab precast or cast in situ. On the slab brick masonry will be constructed with cement mortar of ratio equal to or richer than CM 1:5. On loading, the slab and brick the brick work both joined together expected to function as a composite structure and sustain the applied external load. This paper includes the fundamental design methods of the Thin RCC SLAB - Brickwork Composite Lintel (TRSBWCL), with reference to existing literatures, which would be helpful for designers to choose and apply. These lintels generally expected to exhibit the two major possible modes of failures. Moment capacity calculations in both the failure modes are presented.

KEYWORDS: Thin RCC Slab, Mesh reinforcement, Brick masonry, Cement Mortar 1:5.

INTRODUCTION

Composite action in lintel

Lintel is an essential component in masonry constructions. It is used to support the load of the masonry above and to distribute the load to the sides of the opening safely. Even though it gets combined with sujja 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 slab or beam. 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 of the lintel.

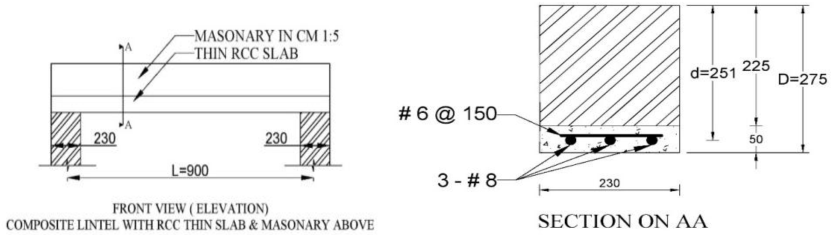

Fig. 1: Longitudinal section and Cross Section of the TRSBWCL.

Literature

Compared to conventional RCC lintels, the application of thin lintel consumes only 50% cost.[1] Cost effective techniques in wall, roof etc., when indigenously applied can reduce 20% of the overall cost of a building but ensuring safety, durability.[2] Height of the masonry above the RCC lintel distributes the load to the ends of the lintel and so, the load on the span is much relieved. This leads to the reduction of moment due to external load. There is a direct proportion of the height of masonry above the supporting lintel beam and the ultimate load of the structural component in the composite action of the RCC lintel and over lying masonry.[3] The possible failure modes of masonry wall are a) Sliding b) Rocking c) Toe crushing and d) diagonal tension. The relationship between vertical axial stress and shear stress has a square root proportion.[4] The relationship between aspect ratio and shear stress has linear proportion. Thickness is not linearly proportional to shear stress. The ultimate average shear stress of the unreinforced masonry (URM) walls is figured to be at 0.2 MPa.[5] Out of the eight beams were tested for different shear span to depth ratio, the shear capacity of the beams depends not only on the geometric and material properties but also on the type of loading and its position over the span. When the shear span to depth ratio is 1 to 1.25, the shear failure occurred. For the ratio of 1.5; shear-flexure failure, for the ratio of 1.75 to 2; flexural-shear, for the ratio from 2.25 to 2.75; that is the single point load towards centre of the span, flexural failure was noted. Higher deflections were recorded when the shear span to depth ratio was 2 to 2.75, due to higher flexural behaviour as compared to the effect of shear deformations, with the loads placed more towards the middle of the span.[6] Shear stress decreases with increasing shear span to depth ratio.[7] For the cause of diagonal failure, shear force and compressive force are important and it depends on the state of stress in the shear span. Shear span is the first and foremost for the diagonal failure rather than the reinforcements in the beams both longitudinal and the one meant as shear reinforcements.[8] In the lower ratio between shear span and effective depth, maximum deformation took place due to crushing of concrete.[9] Minute flexural cracks formed initially at mid span and slowly enlarged on increasing the load and then in the shear span diagonal cracks appeared and propagated point of application of load.[10] The results of calculations, where diagonal tension shear mechanism and tensile strength of masonry are considered as the critical parameters, are more realistic.[11] 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.[12] Minimum Compressive strength of bricks is 7.5 MPa.[13] The minimum and maximum shear stress in masonry may be taken as 0.1 MPa and 0.5 MPa respectively.[14] The allowable shear stress in the masonry may taken as (0.1+ compressive strength of brick / 6), subject to the maximum of 0.5 MPa.[15]

SCOPE

- To enumerate the salient points of the literature studied, with a focus to the design approach of the TRSBWCL.
- To propose a simple design model calculation with reference to existing literature, at least for the trial selection; as is not readily available for the specific type of composite lintels, with an assumed trail section as shown in fig.1.
- Identify the intricacies of the design considerations if any; and suggest for future research.

Specific Outcome from the Literature

1. For achieving the cost effectiveness the RCC thin lintel is more advantageous.
2. The masonry with richer than CM 1:5 above the RCC lintel will incidentally act as composite structure and resist the external moment.

3. Out of the possible failure modes of masonry walls a) Sliding b) Rocking c) Toe crushing and d) diagonal tension the first one and the last one are generally applicable in the portion of masonry above lintel. That is Shear-sliding and diagonal tension.
4. For the lower range of shear span to effective depth ratio, shear failure is more pronounced.
5. For the higher range of shear span to effective depth ratio, the flexural failure is more possible.
6. Diagonal failure initiated more primarily based on shear span then only the question of longitudinal and shear reinforcements come in to play.
7. Flexural cracks initiated first in the vicinity of mid span and they got developed; then the diagonal cracks are formed at shear span and approached to the load point.
8. a_v / d ratio up to 1 develop inclined cracks joining the load and the support and the behavior from beam action to arch action. These beams have uniform tensile force by longitudinal bars at the bottom of the beam and act as tie of the tied arch finally fail by anchorage failure. b) If a_v / d ratio range from 1 to 2.5, develop inclined cracks. After some internal redistribution of forces, carry some extra loads, then fail by splitting, loss of bondage, shear tension or shear compression.

DISCUSSIONS AND PROPOSITIONS

Based on the above mentioned points, one can understand easily that for a masonry constructed just above RCC lintels, there is a composite action of the composite structure by virtue of their position. That is RCC lintel acts as tension part of the composite structure and the masonry above the RCC lintel contributes for compression zone of the flexural couple when loaded.

As found in the literature study above, many authors mention,[3] that in general, laboratory experiments, for the combination of RCC lintel carrying masonry made in suitable cement mortar on it; the shear failure is evidenced more compared to flexural failure. The main reason for this could have been that due to arch action of the masonry above the lintels, the load on the top of the masonry is spread over the ends of the span of the lintel. Also, it was noted that higher the masonry height, higher will be the ultimate load in the experiments. A little consideration will show that in 8 a) and b); both ranges, the a_v /d ratio 1 is covered. Hence, in shear failure, the a_v / d ratio almost 1, lead to behave analogous to deep beam with arch action. After some internal redistribution of forces, carry some additional loads and the failure may occur in anchorage, splitting, bond loss, shear compression and shear tension.

Hence, in the RCC thin lintel and brick masonry composite lintels, the following two are the possible major failure modes.

1. Failure due to flexural tension and / or compression.
2. Failure due to shear

From the assumed values of the longitudinal and cross section of a typical composite lintel shown in figure.1, the failure due to shear and flexural tension and compression can be calculated.

6. Calculation of Ultimate moment

Calculation of moment by failure mode in to a) Flexure and b) Shear and the calculation of Ultimate moment of resistance of the composite lintel are shown in the appendix.

7. Suggestions for future work

1. Experimental works may be carried out with local materials to verify the earlier researches.
2. Results may be validated with sophisticated Finite Element Analysis.
3. Experiments may be done to curb sliding at the interface of RCC slab and masonry, by extending upwards the RCC slab at the ends with L shape beyond bearing of lintel.

8. CONCLUSIONS

Within the scope of studies of this paper and the foregoing information presented here, the following points can be concluded.

1. Compared to conventional RCC lintel, the RCC Thin slab supporting reasonably good brick work can be designed and constructed to exploit the advances of composite action between the two materials, which lead to sizable materials savings.
2. For carrying experimental works, preliminary calculations and sample design may done using the moment calculations by flexure failure mode and shear failure mode shown in appendix.
3. Application of TRSBWCL can be adopted for triangular loading conditions over the openings recommended for the design calculations. However, for other cases more experiments may be necessary.

Appendix

A1 Moment of Resistance of the TRSBWCL –lintel, assuming failure mode by flexure.

Ultimate Moment of Resistance can be calculated with reference to [16],

A1.1. Guidelines for a balanced section of TRSBWCL- lintels and the selection of either d based on A_{st}, or A_{st} based on d;

Assuming, Equating Compressive force by Brick masonry and Tensile force by the steel in RCC slab, we have, C = T

i.e. $0.429f_{wk}bX_u = 0.87fyA_{st}$

Assuming M 20, Fe 415 grades for Concrete and Steel and breadth of brick work as 230mm, The above equation reduces to,

$0.429x8x230x0.5d = 0.87x415xA_{st}$

$394.68d = 361.05\ A_{st}$ ……(1)

So, $d = 0.915\ A_{st}$

From fig.1, using 3 nos. 8mm dia. bars as reinforcement,

d' minimum required = 0.915x3x (3.14x8x8)/4 = 137.98 mm

Hence, d used = 225mm > 137.98.50 mm safe.

NOTE: from (1), for the section to be balanced, the Max. A_{st} = 251 / 0.915 = 274.3 mm^2

A1.2. Moment of Resistance of the Trial Section (fig.1)

Compressive force due to brickwork = 394.68 d = 394.68 x 225 = 88,803 N

Lever arm = 0.8 d = 0.8 x 251/2 =200 mm

MR_{cb} = C. Z = 88803 x 200 = 17.66 x10^6 Nmm. – (2)

MR_{ts} = T.Z = 361.05 x A_{st} x Z = 361.05 x 150.7 x 200

= 10.88 x 10^6 Nmm.- (3)

Out of (2) and (3), the least value is M_{us} = 10.88 x 10^6 Nmm (for Moment failure case)

For accomplishing this moment of 10.88 kNm, the experimental shear force in the shearing force in the span of 0.9m as in fig.1, the possible reaction in each support can be as follows,

For two point loading status, P/2 = 10.88 / 0.3 = 36.27 kN – (4)

A2 Moment of Resistance of the TRSBWCL –lintel, assuming failure mode by Shear.

The shear capacity of the composite lintel may be calculated as follows.

A2.1 Considering the shear resistance of the composite lintel by material effect.

The shear may be calculated as follows.

The vertical section of the composite lintel is (b x d). Selecting an intermediate value of allowable permissible shear in the masonry as per [13]- Section 5.4.3,

$$T_{vm} = 0.3 \text{ MPa},$$

Shear resistance of the Fig.1 assumed section P_v = 0.3 x b x db

= 0.3 x 230 x 225 = 15.53 kN- (5) (*)

Inference: Out of the shear values shown in (4) and (5), the least will govern the failure mode. That is; if, (4) is lesser, the mode of failure will be by flexure, or else the shear failure will occur.

NOTE (*) Here, care should be taken to see that in the shear resisting section; the depth of brickwork (db) is only taken, not the effective depth (d); because of the following two reasons. 1) Over the depth d, the Reinforced concrete slab is in tension,[17] either by simple flexure theory or by arch action under the Deep beam theory, as a tie extending between the two ends. 2) There is no shear connector introduced between the RC Slab and the masonry; hence, the possibility of separation at the interface of them is assumed to be taking place on safer side.

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