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Substrate and Overlay of RC Beams under Static Load

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Abstract—*The newfangled concept of using concrete overlays are worldwide used for reviving or renovating surfaces of concrete infrastructure which in sequel has proved potent involuntary outcomes for a decade. Various cementitious composites has bespeak high strength and superior durability characteristics to conventional overlay material maintaining a good mechanical bond between the substrate(existing) and overlay(new). Along with further studies, comprehensive equations from codes have shown incompatible result used for predicting average crack spacing with multilayered reinforced components. Addition to this we see delay in concreting for reasons like improper casting sequence can result in cold joints and cause the executed construction joint limit the successive concrete placement and adversely affect the structure. This experiment is done to study the behavior of bond strength and evaluate properties like ability of deformation i.e. displacement coreponding to given load under four point bending between the interface of RC beam substrate and overlay and calculate the flexural strength, cracking pattern because of the influence of neutral axis depth. It illustrates how the substrate bond restraint affects the surface stress and contributes early age surface crack in bonded concrete overlays under flexure.*

CE Database subject heading*: Bonded concrete overlay, Substrate, flexure load, Cold Joint, De-bonding.*

Research significance: *It is essential to represent loading histories to quantify performance which are prevalent for performance based seismic design as an alternative to routine code design.*

1. INTRODUCTION

New concrete overlay bond to an existing substrate out-turn restraint in differential volume changes between the two composites, these restraints leads to excess tensile overlay strength which cause cracking and may compromise with the appearance of surface texture and impair with durability and strength through the ingress of harmful substances from both composite and environment. Secondly a mechanism of locked in strain energy that is released during overlay debonding leads to local delamination and spalling which is related to cracking as it is initiated at overlay boundaries at free edges and joints.Many examples of concrete overlays are found for pavements and bridge decks where overlay is an alternative for rehabilitation thus increasing the thickness, improving and restoring mechanical capacity of the structures that are susceptible to damage from exposure to severe environments, abrasion and deterioration from traffic loads. But although our subject of interest is substrate and overlay of beam, the requirements are almost similar i.e. to obtain concrete overlay the optimal strength and resistance to crack propagation but in many cases they face premature delamination and failures. Most importantly the aspects of structural performance in seismic loading is the ability of the structure to adequately dissipate energy. Plastic hinges (in elastic zones) will form in the beams rather than in the columns in designed lateral load resisting frame under severe lateral loading. Higher the strength of a member greater is the imposed load. The moments and shear to which the beams are subjected are a function of the flexural strength of the members. And for these overlaid beams situations becomes more critical when there is an influence of the cold joint on the strength of concrete which is a plane of weakness or discontinuity formed when a batch of concrete hardens before the next batch is placed against it.

Aim of this study is to find and compare the load displacement, flexural strength and separation of layers of each substrate and overlay beam under static load which may have possibility of failure in flexure under four point bending. since the deformation is influenced by the casting procedure of interface, smooth casting leads to larger deformation under peak load.

2. LITERATURE REVIEW

C.H. Hsueh *et al.* [2009] studied the closed form solution of the steady state interface energy release rate of elastic multilayered beams subjected to four point bending test. The solution is applicable to elastic multilayered systems with any number of layers and cracking at the interface. The beam is subjected to moment of Pl/2 and found for bi-layered system the normalized steady state interface energy(G) release rate increases with increasing thickness ratio. For tri-layered systems with the decreasing strain energy the normalized energy G goes for maximum and then decreases with thickness ratio.

Xudong chen *et al.*[2014] presented the strength data of cement mortar and concrete obtained by means of direct tension and bending test. A Weibull statistical model was used to analyze the results. OPC was used for casting prism and cubes. The result indicated that the direct tensile strength is lower than the flexural strength. Weibull models define that fracture mechanics are the same for both tests and that in flexure fracture is caused by the tensile stress component.

M.A.Rashid *et al.* [2005] reports that the issue of ductility in flexural members when aramid fiber reinforced polymer are used in combination, with high strength concrete and found that the load deflection response of these beams significantly differs from that of steel reinforcement beams in terms of crack, stiffness and magnitude of deflection. At any particular load level the maximum surface crack width and maximum deflection are several times larger than those in equivalent steel reinforced beams.

Xudong chen *et al.*[2013] presented a comparative analyze of direct tension and four point loading test for determining stress strain behavior of concrete under quasi-static and intermediate strain rates. The strain rate effects on the stress-strain behavior of concrete under flexure and direct tension was co-related by a combination of the highly stressed volume approach. The direct tensile strength of concrete was more sensitive to an increase in the strain rate than flexural strength specimens tested under four point exhibits higher strength.

Maher A.Adam *et al.*[2015] presented experimental numerical and analytical study of the flexural behavior of concrete beams reinforced with locally produced glass fiber reinforced polymer (GFRP) bars. The main parameters were reinforcement material type, concrete compressive strength and reinforcement ratio under static flexure and determine deflection behavior, cracking and ultimate load carrying capacity. Results of GFRP exhibit reasonable mechanical properties comparing with commercial products and good agreement between experimental and numerical results were found.

3. MATERIALS AND TEST PROCEDURE

PPC Cement is used for the whole casting of each beam. Four no's of PCC reinforced beams are casted of M20 grade having dimension 90×100×1000 mm. Mild steel bars of Fe 250 are used (Fig. 1).

4. PREPARATION OF CEMENT SLURRY

Plain PPC cement is mixed with water with a water cement ratio of fifty percent in order to prepare a thick cement paste which is used at the interface between the substrate and overlay as a bonding agent.

The beams are casted in four different ways-

Control beam - PPC cement was used for making the concrete as per the design mix having w/c ratio of 0.55. And then was cured for 28 days in curing tank.

CP-(A)- First this beam is casted for sixty percent for a height of 60 mm which we termed as substrate and then is allowed to cure for 28 days. Curing is done by wet rags, after completion of 28 days the beam was surface dried and was brushed to make the surface rough for next layer casting. Cement paste was applied above the substrate so that it becomes a bonding agent at the interface of the overlay beam (Fig. 2). After applying the cement paste for a very minimal thickness the next layer of forty percent i.e. 40 mm from top, concrete is placed over the substrate. Vibration table was used for proper casting in both phases. The beam is again allowed to cure in the curing tank after 24 hrs for 28 days in curing tank.

CP-(B) - This beam is casted for eighty percent i.e. for a height of 80 mm which we termed as substrate(Fig. 3) and then allowed to cure for 28 days. Curing is done by wet rags, after completion of 28 days the beam was surface dried and was brushed to make the surface rough for next layer casting. Cement paste was applied above the substrate so that it becomes a bonding agent at the interface of the overlay beam. After applying the cement paste for a very minimal thickness the next layer of twenty percent i.e. 20 mm from top, concrete is placed over the substrate. The beam is again allowed to cure in the curing tank after 24 hrs for 28 days in curing tank.

NC-(A) – This process of beam casting is similar to beam CP-(A). The beam after curing for 28 days of the substrate is allowed to surface dry and brushed to prepare for next layer of casting. PCC concrete was prepared and 40 mm from top is casted over the substrate. Note that no bonding agent is used at the interface. And after casting the beam was allowed to cure for the next 28 days.

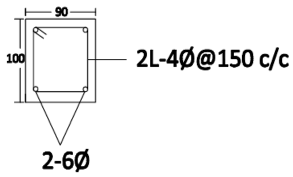

Fig. 1

5. DETAIL OF CROSS SECTION OF BEAM

Fig. 2

6. CEMENT PASTE AT THE INTERFACE

Fig. 3

7. CASTING OVER SUBSTRATE

The flexural strength test of the reinforced substrate and overlay concrete beam of case-2 are carried out as per the procedure mentioned in IS: 516-1959 in the 1000 kN capacity UTM. The specimens are taken out of the curing tank on 28th day and surface dried. On 40th day the specimens are placed in the UTM and tested till failure to ascertain the flexural strength from the ultimate load applied for each of the beam. To ensure failure due to pure bending, four point loading condition was adopted.

8. RESULTS AND DISCUSSION

The graph plotted (Fig. 4) are load vs. displacement. The control beam attained the highest load (flexural strength) before failure. Beam specimen CP-(A) also attains value near the control specimen which is decreased by 13 % compared to flexural strength of control specimen. Beam CP-(B) decreased by 18.2 % and beam NC-(A) decreased by 23.18 %. Results drawn from plotted graph shows that it is evident that use of cement paste as the bonding agent at the interface is advantageous as it provides values near to the flexural strength of control specimen. With the interface at 60 % of the beam, stress is less as it is near the neutral axis depth compared to the beam interface at 80%, which is the reason of failure at interface (Fig. 5). Specimen without bonding agent comparatively showed little less strength because of the influence of cold joint. But overall it was seen that the failure of beam was due to pure bending and not because of overlay separation (fig -6).

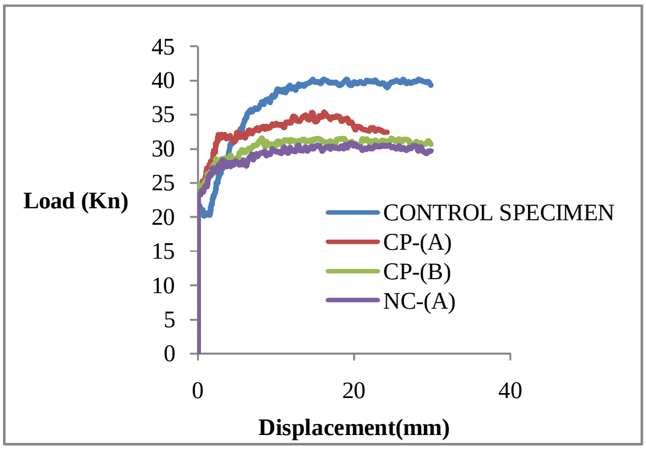

Fig. 4

Load displacement graph

9. FLEXURAL STRENGTH FOR EACH SPECIMEN UNDER FOUR POINT BENDING:

The flexural load for each specimen is calculated in Table-1.

$$\sigma\ f = \frac{Fl}{bh2}$$

where **σ f** is the flexural strength(MPa),**F** is the peak load(kn), **l** is the span(mm), **b** and **h** are the cross section

Table 1

Sl No	Beam Name	Peak Load(KN)	σ f (MPa)
1	CONTROL BEAM	40.1	44.56
2	BEAM CP-A(S)	34.9	38.78
3	BEAM NC-A(S)	30.8	34.23
4	BEAM CP-B(S)	32.8	36.45

Fig. 5

Fig. 6

10. CONCLUSION

Conclusions drawn on interpretation of the results are as follows-

1. Between the substrate and overlay at the interface there forms a weak plane called cold joint. A cold joint is usually characterized by poor bond unless remedial measures are taken before placing concrete against a previously hardened batch.
2. Use of cement paste at the interface was effectively good as it exhibited results nearer to the control beam.
3. Thickness of the casting of both substrate and overlay influences the de-bonding of layers
4. Failure result under pure bending and not because of failure due to slip of shear plane.

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