NON-LINEAR FE ANALYSIS OF REINFORCED CONCRETE CORBELS RETROFITTED WITH CFRP

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1. INTRODUCTION

Reinforced concrete corbel is a common structural member, basically used in precast structures and sometimes to facilitate expansion joint. Extensive researches have been carried out to simplify its design philosophy and to improve the effectiveness. While very few of the researchers are focused on retrofitting of them. In this study, non-linear three dimensional finite element analyses are carried out on typical corbel in existence which doesn't fully obey design guidelines. And effectiveness of different structural strengthening measures is presented.

According to design codes (BS 8110-1: 1997), the bearing portion used to transfer load from supported member to the corbel should not extend beyond the straight portion of main flexural reinforcement. In a case study, several RC corbels having bearing pad extended to the edge is found to have anchorage splitting and bearing failure as shown in Fig. 1, require urgent retrofitting. To recover the desired load carrying capacity, retrofitting by addition of RC is quite obvious. But epoxy-based external FRP wrap would be easier and cheaper alternative. Among few past studies, it is found that external wrapping of FRP is efficient to replace transverse reinforcement of corbel to reduce reinforcement congestion problem, Campione et al (2005). In such studies, FRP is proposed to wrap all around the corbel, which isn't applicable for corbel in beam-column junction having beam in both way and hence application of FRP should be terminated at the column face. This paper shows the current progress in simulation of RC corbels with above mentioned retrofitting measures and improvements they bring.

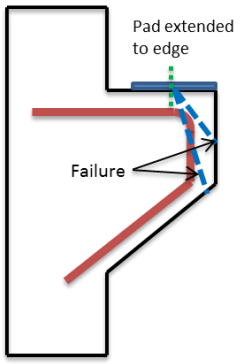


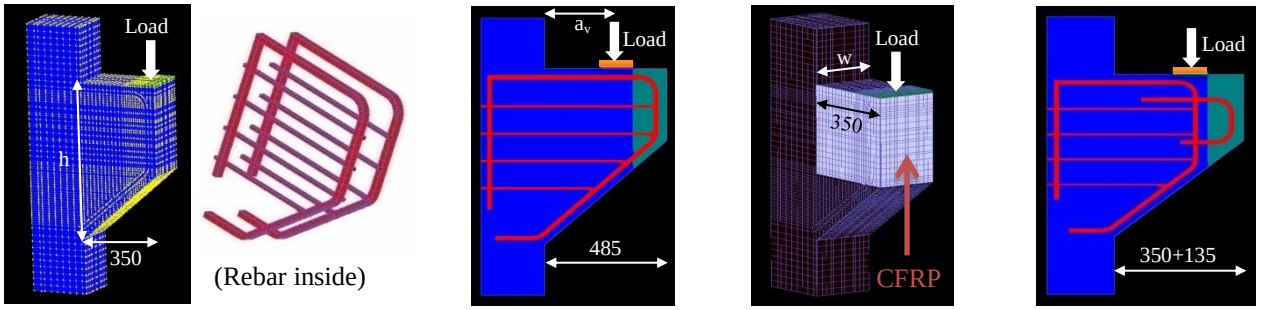
Fig.1 Failure case

2. ANALYSIS MODEL

A three dimensional FE mesh is created for full size corbel using simulation program; *COM3D*. Details of models are shown in Table 1, along with visual details in Fig. 2. Rebar (f_y= 400 MPa) is modeled as rectangular steel element having same area as circular section and all concrete element as plain concrete (f'_c=32MPa). The bond between FRP to concrete is assumed to be perfect and the interface of old concrete and new concrete in RC retrofitting is assumed to be ideally monolithic. It's been suggested that the column load doesn't affect the behavior of corbel, Fattuhi et al (1990). But some portion of column is considered in model so that shearing across column-corbel interface won't be affected. Each model is subjected to displacement controlled vertical line load at the center of bearing pad throughout the width of corbel.

Table 1 Specimen details

Sr. No.	Designation	a_v (mm)	h (mm)	w (mm)	Rebar Details	Retrofitting Measures	Bearing Pad (mm)
1	Existing corbel (EC)	287.5	700	200	2-T20 main+ T10 @100mm Transverse bar (with 25 mm clear cover)	-	125
2	Correctly designed corbel (CDC)	287.5	700	200		-	125
3	Corbel retrofitted with CFRP (CRC)	287.5	700	200		2-layer 0.5mm(70/30) CFRP wrap	125
4	Corbel retrofitted with RC (RRC)	287.5	700	200		135 mm Concrete with 1-T20 bar	125



(a) EC (b) CDC (c) CRC (d) RRC

Fig. 2 Analysis models

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3. ANALYSIS RESULTS

The load carrying capacity and corresponding displacement is extracted from the analysis for each model. And the overall load bearing capacity for vertical loading is compared for all four models as shown in Fig. 3. The load-displacement curve shows that due to fault in design of RC corbel, the load capacity is reduced by 29% of its desired capacity. On further retrofitting the capacity is recovered up to 75-83% of its desired capacity. Load displacement behavior shows that the RC retrofitting is effective than the CFRP wrap. In RC retrofitting case, RC member is added to extend as long as the designed corbel length, but the capacity isn't fully recovered. This is due to lack of rebar area as compared to correctly designed one. The width of corbel is 200mm only. Therefore, in RRC, single bar is proposed at the center of corbel so that practically it could be possible to insert it without any adverse effect to existing structure.

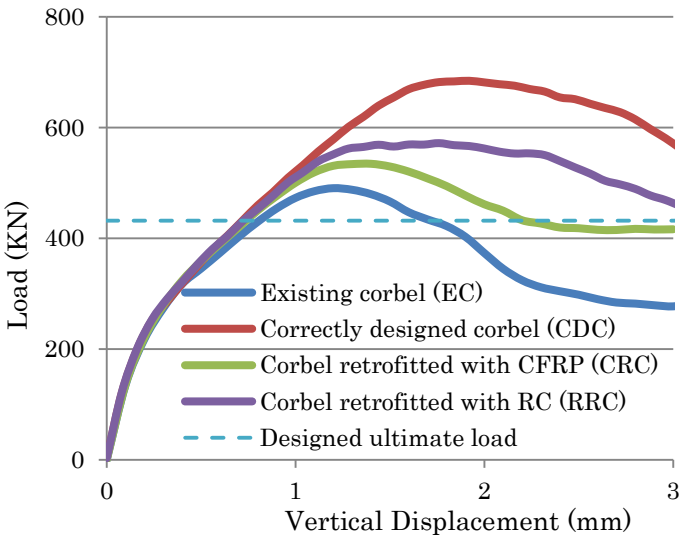
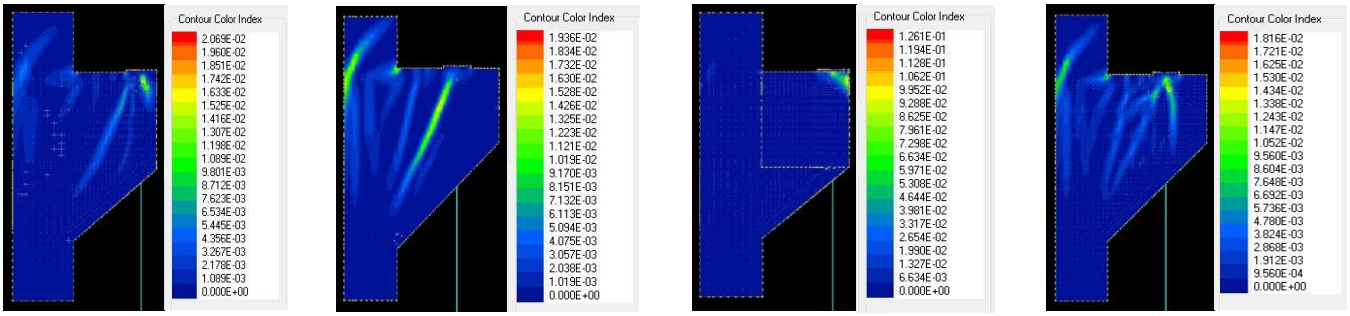


Fig. 3 Vertical Load vs Displacement

The principal strain contour is plotted for each model as shown in Fig 4. The observed field damage of existing corbel characterized by misplacement of bearing pad is modeled well by the numerical simulation as shown in Fig. 4(a).

Failure of retrofitted corbels is propagated through almost same position as the defective one. In RRC case, the failure is localized near the interface of old and new concrete. This is due to the absence of transverse reinforcement and insufficient flexural reinforcement in added concrete. Similarly, in CFRP retrofitting case, strain inside concrete section is found to be localized at the similar position as EC. In actual case, the debonding of CFRP prior to its rupture may occur. But based on the assumptions made for this typical case, adequate mechanical anchorage may prevent premature failure; obtained result represents the behavior of CFRP retrofitting in RC corbel.



(a) EC (b) CDC (c) CRC (d) RRC

Fig. 4 Principal strain contour

3. CONCLUSIONS

Numerical model is successfully established to analyze retrofitted and non-retrofitted RC corbel. Analyses show that the proposed retrofitting concept can recover up to 75 to 83% of desired load capacity. Comparative study among retrofitting of RC corbel using traditional method by adding RC member and applying CFRP wrap shows that the former one is more effective. Further research on precise modeling of FRP in such application considering premature failure along with the experimental verification is going on.

4. REFERENCES

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