Strengthening of Normal and High Strength Concrete Corbels with Horizontal and Inclined Stripes of Carbon Fiber

Danish Khan[1] Jainendra Kumar[2]
[1]PG Scholar [2] Resident Engineer
[1]RGPV, Bhopal [2]MSV International INC

Abstract— Concrete corbels prepared with normal and high strength concrete and strengthened with different types of horizontal and inclined stripes of carbon fiber are studied. Concrete corbels are architectural elements which are also used to support girders of heavy simply supported beams as well as gantry girders for indoor cranes. The CFRP strips, used for strengthening, is applied in three different orientation - horizontal and inclined at 30º and 60º.

Key words: Concrete Corbels, Carbon Fiber Reinforced Polymer Strips, High Strength Concrete, Strengthening

I. INTRODUCTION

Concrete corbels are defined as cantilever type structure which have span to depth ratio less than unity for which the design and analysis has been validated [1], [2]. The corbels have been historically used primarily for its architectural purposes (Fig. 1).

Fig. 1: Corbels are characteristic feature of Indian architecture
(Source: https://astonishingindia.net/2014/06/19/brackets-and-corbels-temples-and-forts/)

However, corbels are also used as structural elements mainly to support concentrated load. The concentrated load due to girder is usually supported on corbel. Simply supported beam girder, Fig. 2, and gantry girder, Fig. 3, are two types of structures which are supported on corbels.

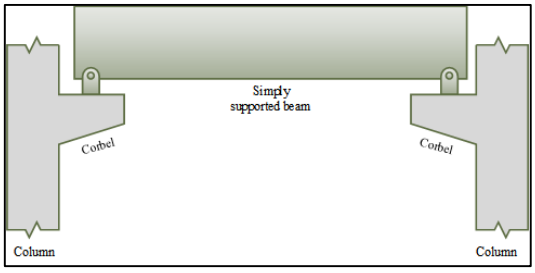

Fig. 2: Corbels used in simply supported beam girder

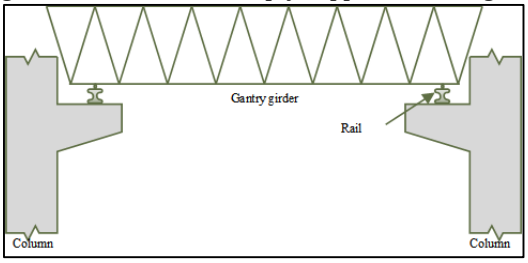

Fig. 3: Corbels used in gantry girder

Under the action of loads, corbels do not behave as flexure member rather it behaves as deep beams or simple trusses [2]. The failure of corbel, hence, is predominantly due to shearing between corbel & column or compression along inclined plane as illustrated in Fig. 4.

Since, corbels are required to support large loads on small area, the corbels are expected to undergo inelastic deformations [3].

Due to above considerations, the strengthening of corbel is mainly aimed at enhancing its shearing strength. For this purpose, CFRP laminate strips have been investigated by various researchers to enhance shear strength of corbel [3]–[8].

In present study three different cases of strengthening of corbel with CFRP stripe are studied for their effectiveness in improving performance of concrete corbels. The concrete corbels are considered both for normal strength and high strength concrete.

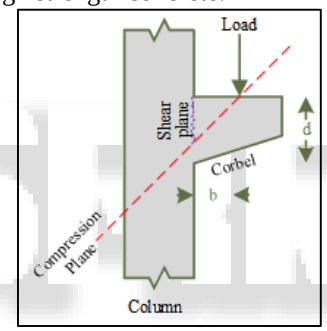

Fig. 4: Concrete corbel structural details

II. DETAILS OF CONCRETE CORBEL USED IN STUDY

The corbel attached to column is as shown in Fig. 4. The column dimension is 200×200 mm and height of column is 1000 mm. The column is designed as per IS 456:2000 [9], the longitudinal reinforcement is 4 nos. steel bars having 16 mm diameter. The steel used is of grade Fe 415 as specified in above mentioned IS code. The lateral ties of 8 mm are provided at spacing of 150 mm c/c.

The corbel dimension is 300×200 mm including the curtailed part. These are reinforced with 3 nos. of 20 mm dia. steel bars of same grade and ties are provided similar to that in columns. The detailing of reinforcement is shown in Fig. 5.

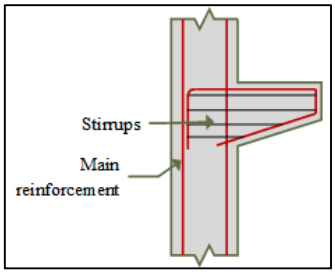

Fig. 5: Main and stirrup reinforcement details of concrete corbel

The details of various models used are given in Table 1. Two different mixes of concrete are considered in study and corbels are studied for these mixes.

Designation	Concrete mix type	CFRP Orientation
L0	M20	Horizontal
L30	M20	Inclined at 30º
L45	M20	Inclined at 60º
H0	M50	Horizontal
H30	M50	Inclined at 30º
H45	M50	Inclined at 60º

Table 1: Designation of various types of models used in study

These separate types of corbels are then strengthened with the three types of CFRP stripes. The CFRP stripes are employed in three different orientations - horizontal, inclined at 30º and inclined at 60º. Hence, in total there are six models considered.

The property of CFRP stripes are modelled as provided in technical data sheets provided by suppliers.

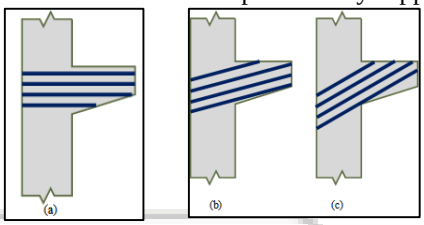

Fig. 6: Orientation of CFRP strips for concrete corbels used in study, (a) horizontal, (b) inclined to 30º and (c) inclined to 45º

III. Results and Discussions

The various types of corbels as specified in previous sections are studied for their behavior under application of load. The concentrated load is applied in small increments to investigate the load deformation characteristic. The ultimate load at failure is used as basis to compare various strengthening schemes.

The load displacement curve for normal strength concrete corbel strengthened with different stripes is shown in Fig. 7 and for high strength concrete is shown in Fig. 8. From these, results it is observed that inclined stripes show improvement in load resistance of corbels.

It is also observed that, corbels undergo large inelastic deformation as inferred from nonlinear portion of load displacement curves. The nonlinear characteristic of corbel, if incorporated in design, would lead to safer and economic design and construction of corbels in concrete structures.

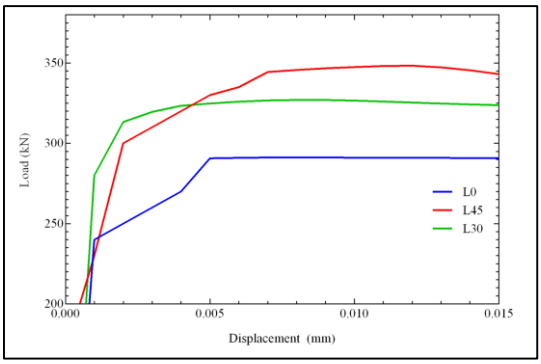

Fig. 7: Load displacement relation for normal strength concrete corbel

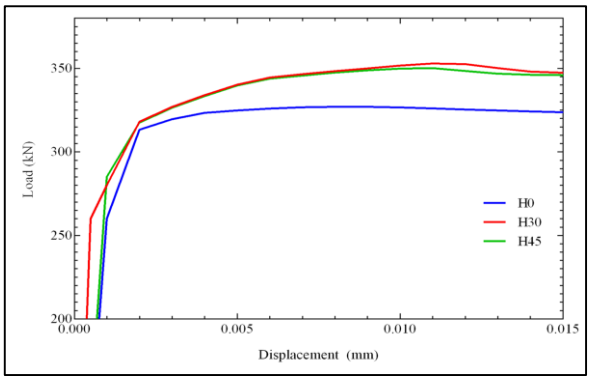

Fig. 8: Load displacement relation for high strength concrete corbel

IV. Conclusions

The corbels have historical significance as architectural elements. The concrete corbels are also widely used to support concentrated loads occurring due to girders with static and dynamic load. Due to large loads involved in girders, the corbels undergo significant inelastic deformations and damage. CFRP stripes are a viable option of strengthening of concrete corbel which enhances its shear strength. In present study, different orientations of CFRP stripes are used on concrete corbels and its effectiveness in enhancing load carrying capacity is obtained analytically. The results show that inclined stripes provide better load carrying capacity to corbels compared to horizontal stripes. The compression failure plane is at an angle other than horizontal as a result inclined stripes bear both shear and compression stresses.

References

[1] ACI 318M-05, "Building code requirement for structural concrete and commentary," 2005.
[2] ACI 318M-14, "Building code requirement for structural concrete and commentary," American Concrete Institude (ACI) Committee 318, 2015.
[3] L. A. G. Yassin, E. K. Sayhood, and Q. A. M. Hasan, "Reinforced Concrete Corbels – State of the Art," Journal of Materials and Engineering Structures, vol. 2, no. 1, pp. 180–204, 2015.
[4] A. N. Abbas and W. A. A. Al-kareem, "Strengthening of normal and high strength concrete corbels with horizontal and inclined stripes of carbon fiber," International Journal of Civil Engineering and Technology (IJCIET), vol. 7, no. 3, pp. 271–282, 2016.
[5] M. A. Elgwady, M. Rabie, and M. T. Mostafa, "Strengthening of corbels using CFRP - An experimental program," pp. 1–9, 1976.
[6] I. Ivanova and J. Assih, "Experimental study of local behavior of strengthened reinforced concrete short corbel by bonding carbon fiber fabrics," Int. J. Struct. & Civil Engg. Res., vol. 4, no. 1, pp. 148–158, 2015.
[7] K. K. Shadhan and M. M. M. Kadhim, "Use of CFRP laminates for strengthening of reinforced," International Journal of Civil Engineering and Technology (IJCIET), vol. 6, no. 11, pp. 11–20, 2015.
[8] S. B. Tobeia, "Behavior of corbels strengthened with carbon fiber reinforced polymers (CFRP) – Numerical

Study," Eng. & Tech.Journal, vol. 32, no. 10, pp. 2394–2407, 2014.

[9] Bureau of Indian Standards, "IS 456:2000, Indian standard code of practice for plain and reinforced concrete," New Delhi, 2000.

