Experimental Study on The Behavior of RC Corbels Reinforced with GFRP Bars

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***Abstract*— FRP bars have been adopted as internal reinforcement of concrete slabs, beams and columns increasing their service life in unfavourable conditions. FRP bars are more corrosion resistant than steel bars and shows good resistance to fatigue loads. The corbel is generally built monolithically with the column or wall. Here GFRP bars are used as the reinforcement in the corbel. The preliminary test of cement and aggregates were done. Compressive strength of concrete cube specimens was measured. Corbels projecting from the faces of reinforced concrete columns are extensively used in precast concrete construction to support the primary beam and girders. Recently, high strength concrete has been increasing used in practice. However high strength concrete is considered to be a relatively brittle material and has low ductility. The tensile strength of GFRP bar is determined. In this project the study of the behaviour of RC corbels reinforced with GFRP bars are to be done and compare it with the control specimen.**

***Keywords*— Corbel, GFRP bars, Reinforcement.**

I. INTRODUCTION

The corbel is generally built monolithically with the column or wall. The shear span-to-depth is often less than unity. Corbels projecting from the faces of reinforced concrete columns are extensively used in precast concrete construction to support the primary beam and girders. Corbels are structural members characterized by a shear span-to-depth ratio (a/d), generally lower than unity. Recently, high strength concrete has been increasing used in practice. However high strength concrete is considered to be a relatively brittle material and has low ductility.

The fibre-reinforced polymer (FRP) reinforcement is currently being used as a viable alternative to steel in new concrete structures especially those in harsh environments. The main driving force behind this effort is the superior performance of FRP in corrosive environments attributable to its noncorrodible nature. However, the FRP materials exhibit linear-elastic stress-strain characteristics up to failure with relatively low modulus of elasticity [40–60 GPa for glass (G) FRP compared to 200 GPa for steel]. Moreover, they have different bond characteristics and relatively low strength under compressive and shear stresses.

There is large horizontal force transmitted from the supported beam result from long-term shrinkage and creep deformation. Bearing failure due to large concentrated load. The cracks are usually vertical or inclined pure shear cracks mode of.

Failure of corbel are: yielding of the tension tie, failure of the end anchorage of the tension tie, failure of concrete by compression or shearing and bearing failure. Here the reinforcement of corbel is replaced with the GFRP bars. The objective of the study is to understand the behaviour of RC corbels reinforced with GFRP bars and to find out the parameters like shear strength, strain, displacement. GFRP bars are good corrosion resistant when compared to steel bars. It will increase the durability of the structure. By increasing the use of corbels we can reduce the size of the columns.

II. MATERIALS USED

A. Cement

The cement used for the work is Portland Pozzolana Cement (PPC) – 53 Grade. The details are tabulated in Table 1 below.

Table 1: Properties of Cement

Properties	**Results**
Type of cement	PPC 53 grade
Standard Consistency (%)	29
Specific gravity	2.83

B. Fine Aggregate

Manufactured Sand (M-Sand) is used for the work which is conforming to the requirements of IS 383. It is having aggregate size ranging from 4.75mm to 150microns. The details are tabulated in Table 2 below. Particle size distribution of fine aggregate is shown in Fig.1.

Table 2: Properties of Fine Aggregate

Properties	**Results**
Type of fine aggregate	M Sand
Specific gravity	2.78
Zone	II

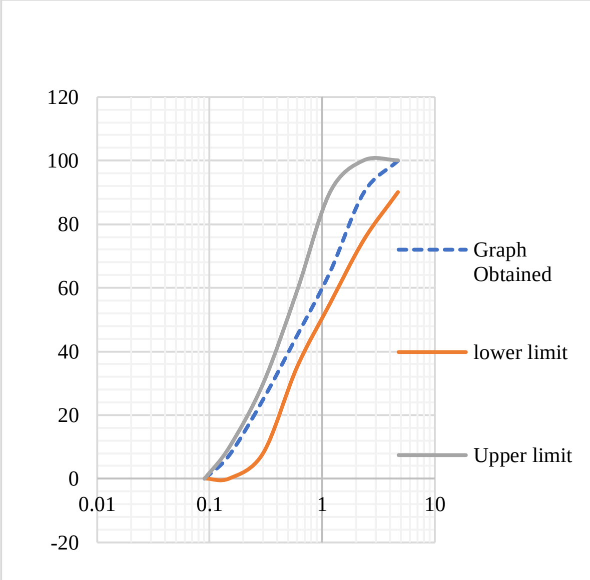

Fig. 1: Particle Size Distribution of Fine Aggregates

C. Coarse Aggregate

Coarse aggregate used for the work is conforming to the requirements of IS 383 and is having aggregate size ranging from 20 mm to 4.75 mm. The details are tabulated in Table 3 below. Particle size distribution of coarse aggregate is shown in Figure 2.

Table 3: Properties of Coarse Aggregate

Properties	**Results**
Water Absorption	0.5%
Specific gravity	2.5

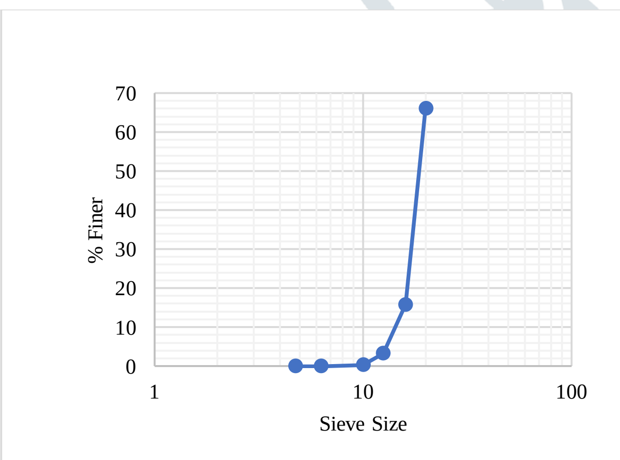

Fig. 2: Particle size distribution of coarse aggregate

D. Water

Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalies, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. It is an important ingredient of concrete as it actually participates in the chemical reaction with cement termed as hydration of cement. Since it helps to form the strength giving cement gel, the quantity and quality of water are required to be looked into very carefully. Potable water is generally considered satisfactory for mixing concrete.

III. MIX DESIGN

The selection of mix proportion is a process of choosing suitable ingredients of concrete and determining their relative quantities with the object of producing as economically as possible, the concrete of certain minimum properties, notably strength, durability and a required consistency. The key to achieving strong, durable concrete rests in the careful proportioning and mixing of the ingredients. A concrete mixture that has no enough paste to fill all the voids between the aggregates will be difficult to place and will produce rough, honeycombed surfaces and porous concrete. A mixture with an excess of cement paste will be easy to place and will produce a smooth surface, however the resulting concrete is likely to shrink more and be uneconomical. A properly designed concrete mix will possess the desired workability for the fresh concrete and the durability and strength for the hardened concrete. The mix design is shown in the table 4.

Table 4: Mix Design

Description	**Results**
Design Mix	1:1.73:3.43
Water-Cement Ratio	.0.49
Cement (kg/m ^{3})	359.73
Fine Aggregate (kg/m ^{3})	650.7
Coarse Aggregate (kg/m ^{3})	1286.36
Water(l/m ^{3})	144

IV. EXPERIMENTAL INVESTIGATIONS

A) Specimen details

Columns of size 0.3 x 0.3 x 1.4 and corbels of size 0.3 x 0.3 x 0.15 were casted monolithically. Corbels with and without GFRP bars were casted and tested. Table 5 shows the specimen details.

Table 5: Mix Design

Specimen Details	Dimensions
i. RCC column	ii. 0.3m x 0.3 x 1.4m
iii. RCC corbel	iv. 0.3m x 0.3 x 0.15m

B) Reinforcement details

The beam was designed as singly reinforced beam. The support conditions were simply supported at both ends. The reinforcement details are given in the figure 3. Reinforcement detailing was done as per IS456:2000 specification are given in below brief

- A_{st} : 4 no.s of 12mm Ø in column and 6 no.s of 12mm Ø in corbel
- 5 no.s of 8mm Ø stirrups in both column and corbel
- 25mm cover

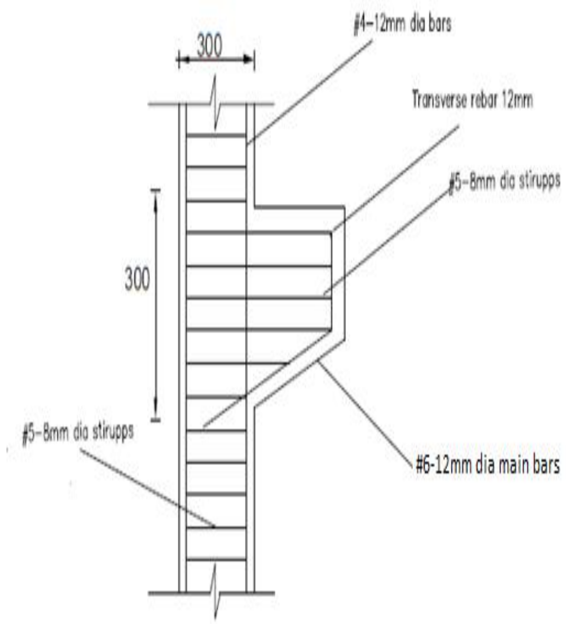

Fig .3: Reinforcement detail

Fig .4: Test Setup

C) Testing of Specimens

Two ends were fixed. Dial gauges with 10mm capacity is used. Strain measuring buds were fitted to measure the strain. For every 2T the deflection and strain are noted down. The specimens were loaded till failure. The development of initial crack and propagation of cracks are observed.

V. RESULTS AND DISCUSSION

The specimen was tested on loading frame, load vs displacement and load vs strain graphs has obtained for various loads of the control specimen

A. Load vs Deflection Characteristics

The load versus displacement curve was plotted taking the displacement along the X axis and the load along Y axis. The graphs were compared with different specimens as deflection near support and deflection at centre. It was observed that the displacement increases as the load increased that is the load and deflection were directly proportional. In the comparison it shows that the deflections is proportional to load applied during the initial loading stage and after which there is a sudden increase in deflection. This shows the deflection increases after the forming of crack. The load versus displacement of the control specimen without GFRP bars and specimen with GFRP bars are shown in figure 5 and 6 respectively.

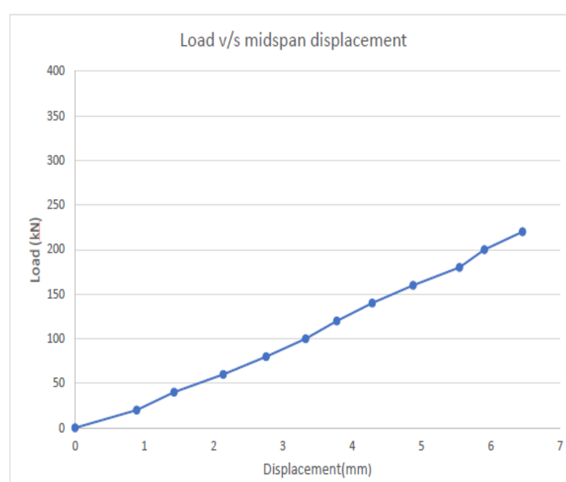

Fig 5: Load vs Displacement graph of control specimen

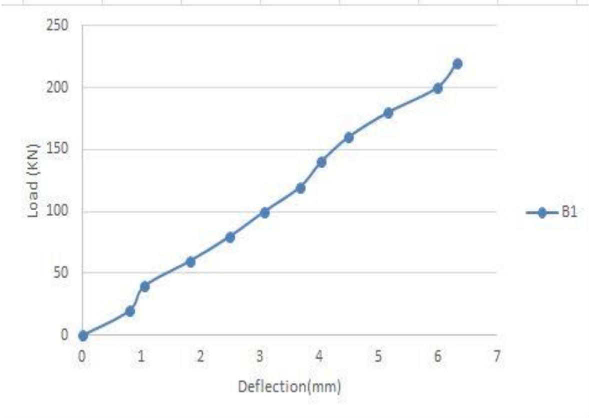

Fig 6: Load vs Displacement graph of specimen with GFRP bars

B. Cracks

Crack formation on control specimen is shown in figure 7 and crack formation on specimen with GFRP bars is shown in figure 8.

Fig .7: Crack on Control Specimen

Fig .8: Crack on Specimen with GFRP Bars

VI. CONCLUSION

The control specimen and specimen eth GFRP bars were tested. Based on the investigation the following conclusions were made,

- Load carrying capacity of specimen with GFRP bars are more than control specimen
- Control specimen have more crack than specimen with GFRP bars
- Bending of GFRP bars are difficult.

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