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Comparison of the Interfacial Bond Strength Behaviour using Shear Key

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Abstract

Many of the existing reinforced concrete structures throughout the world are in urgent need of strengthening, repair or reconstruction because of deterioration due to various factors like corrosion, lack of detailing, failure of bonding between beam-column joints, increase in service loads, spalling, loss of strength, deflection, etc., Retrofitting techniques have changed the old scenario to construct the new structure always by demolishing the damaged one. Retrofitting is the modification of existing structures to make them more resistant to external force quantities. The objectives like higher loading requirements; damage by accidents and environmental conditions, rectification of initial design flaws, change of usage can be achieved by retrofitting. Though, retrofitting technique have many significant advantages, suffers from a limitation that sometimes can occur which is debonding and BOND SLIP. Thus in this paper, efforts have been made to identify the parameters which plays a major role for causing bond slip and solution have been tried to find out for limiting the same. In this paper efforts have been made to study the bond slip phenomenon in different variety of retrofitted specimen such as jacketed specimen without any bonding agent (Specimen _N) and jacketed specimen with SBR and shear key (Specimen _SK). After performing experiments, the bond strength was evaluated in both of the cases and has given satisfactory results.
Keyword- Bond slip, Jacketing, Retrofitting, Bond strength, Debonding, Specimen _N, Specimen _SK

I. INTRODUCTION

Up till 2016, many small and large earthquakes have occurred throughout the world which has directly or indirectly damaged the structure in minor or major way. Earthquake is uncontrollable natural calamity which can occur at any time and at any place. From the decades, earthquake has damaged lots of engineering structures and the result was loss of lives, loss of properties and building deficiencies. The building deficiencies observed in multi-storied RC buildings can be broadly classified as Local Deficiencies and Global Deficiencies. Local deficiencies lead to the failure of individual elements of the building like Beams and Beam-to-Column Joints, Slab-to-Column Connections and Structural Walls. Global deficiencies can broadly be classified as plan irregularities and vertical irregularities.

Damaged structures undergone deficiencies can be brought to its serviceable condition by adopting certain retrofitting techniques such as Jacketing, Addition of Concrete, Steel Plating, Use of FRP bars, Addition of Infill Walls and shear walls, Addition of Steel Braces, Energy Dissipation Devices and Base Isolation etc. Retrofitting techniques helps to increase the strength of damaged structure more than its strength before damaging. Retrofitting technique such as jacketing not only increases the lateral strength and stiffness of the building but also eliminates the source of weakness from structure. Jacketing is the most popularly used method for strengthening of building columns. The most common types of jackets are steel jacket, reinforced concrete jacket, fibre reinforced polymer composite jacket, jacket with high tension materials like carbon fibre, glass fibre etc.

Though, retrofitting technique have many significant advantages, it suffers from major drawback that sometimes can occur which is Debonding and Bond Slip.

A. Debonding

Debonding is simply the separation of Fibre Reinforced Polymer (FRP) from retrofitted RCC member. Separation of FRP is due to its high strength as compare to RC member. When an RC structure is strengthened with externally bonded FRP, the bond between FRP and concrete plays a crucial role in guaranteeing the effectiveness of the strengthening. Most failures of FRP strengthened RC members are caused by debonding along FRP-to-concrete interfaces. Therefore, appropriate considerations must be given to debonding failures in design.

B. Bond Slip

The slip occurring between parent column and jacketed layer due to failure of bond between them is known as bond slip. When proper friction is not available between the bonding surfaces of retrofitted specimen, resisting force cannot be generated and thus the phenomenon “Bond Slip” comes into existence.

II. OBJECTIVES AND SCOPE

The prime objective of this study is to identify the innovative technique which can be used to strengthen the parent specimen and to know the extent of bond strength gained by using the additive materials. The following are the main objectives of study:
- To strengthen the damaged specimen using innovative technique/material.
- To study the behavior of specimen after application of innovative technique/material.
- To compare the different parameters by means of obtained charts and graphs.

In this research, efforts have been made for studying and estimating the bond slip by comparing normal hand chipped jacketed specimen with jacketed specimen using styrene butadiene rubber (SBR) and shear key to increase friction between bonding surface and to prevent the failure of bond.

The scope of this study is to know the material which is giving higher bond strength and can be used on field to strengthen the parent specimen. This research provides the solution to strengthen the bond between parent specimen and jacketed layer by using jacketing technique with SBR and shear key.

III. CHARACTERIZATION OF MATERIALS

1) Ordinary Portland cement of 53 grade with specific gravity 3.15 and consistency as 31.5 %

No. of Days	*Compressive Strength (MPa)*	
	Test Results	*Standard Value*
3	*28.2*	*>27*
7	*39.93*	*>37*
28	*55.4*	*>53*

Table 1: Compressive Strength of Cement

2) Fine aggregate with Specific gravity as 2.62 and Fineness modulus as 3.1
3) Coarse aggregate with Specific gravity as 2.82 and Fineness modulus as 7.1

According to Design stipulation, characteristic compressive strength require in the field at 28 days is expected to be 20 Mpa with maximum size of aggregate 20mm(angular) and 0.9 as compacting factor with type of exposure mild. Water absorption for coarse aggregate and fine aggregate was 0.55% and 1% respectively. Coarse aggregate is confirming as per Table 2 of IS 383-1970 and fine aggregate is confirming to zone I as per Table 4 of IS 385-1970.

IV. METHODOLOGY

Steel mould available in the lab is of size 150x150x700mm. It was then made in size of 150x150x450 by us with the help of wooden plywood. Total 06 numbers of specimens of size 150 x 150 x 450 mm were casted using 0.50 as water cement ratio and proportion was kept as 1:1.5:3 for cement, sand and aggregate respectively. Application of load was undertaken with the help of Universal Testing Machine (UTM) to damage the specimen. After identification of damaged zones in a specimen, detailed assessment of the in-situ quality of the material was done. Then, repairing of damaged specimen was carried out and depending on the feasibility and suitability of experimental set-up, we adopted concrete jacketing technique. Finally, load was applied and bond slip phenomena were observed.

V. DESIGN AND CASTING OF PARENT SPECIMEN

For designing and casting of concrete specimen, IS 456: 2000 was referred. It was calculated that the 4-12mm diameter bars and stirrups of 2-6mm diameter provided @ 150mm c/c of Fe500 (TMT) bars.

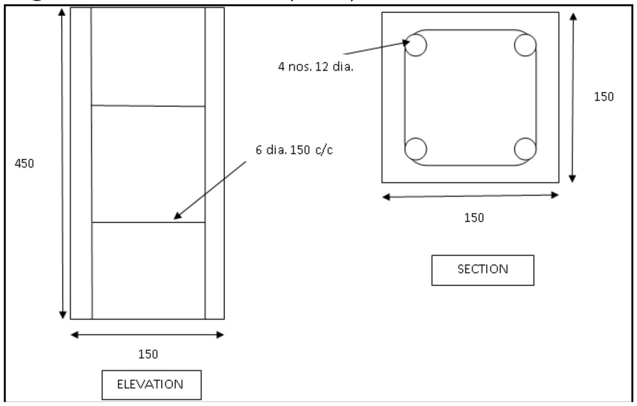


Fig. 1: Specimen Detailing

The casting was done with utmost care with M20 grade of concrete so as to achieve its good workability and proper compaction was given to eliminate the air voids in the concrete mass. Thorough curing by soaking in portable water for 28 days was genuinely provided for gaining the required strength.

A. Shear Key

Shear key was provided at parent specimen for bonding purpose. Chemical FISCHER injections - FIS V was used for anchorage of the same at room temperature. Diameter of bar used was 8mm having total length of 180mm with an anchorage of 100mm.

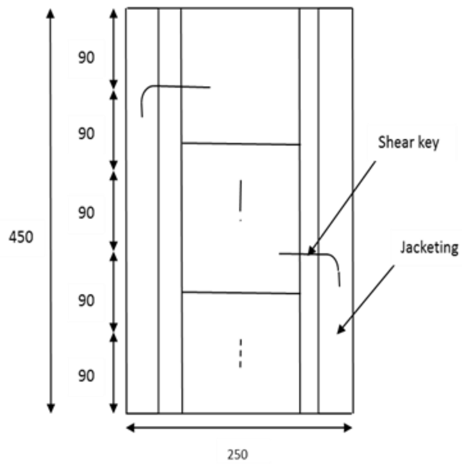


Fig. 2: Detailing of Shear Key

B. Jacketing

Wooden mould made up of waterproof plywood of thickness 16-20 mm was used as a formwork in the process of jacketing with joints properly sealed to make it water tight. In casting of jacketed layer, inner column was placed in proper alignment of wooden mould. For concreting, M20 grade of concrete with 4-12 mm diameter bars of Fe500 at corners and stirrups were provided. To remove air voids, reduce permeability and achieve good workability proper compaction was given to concrete mass.

For the bond between two layers three specimens were casted without using anything and another three were casted using SBR chemical and shear key. SBR was applied by brush on chipped surface as usual procedure.

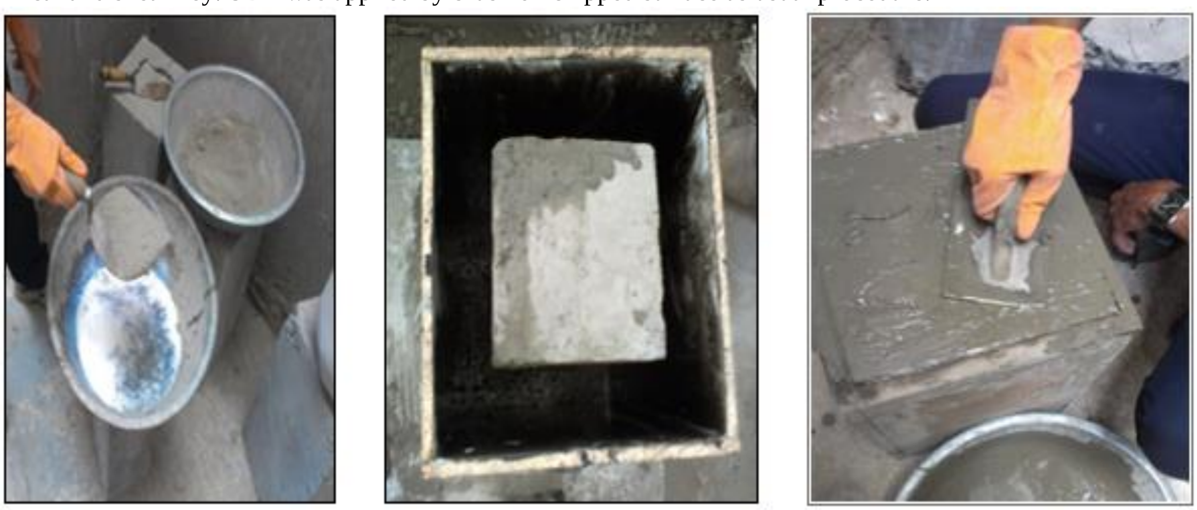


Fig. 3: Application of SBR on specimen_SK and Finishing

C. Test Setup

Hollow Mild Steel (MS) plate was first of all placed on Universal Testing Machine (UTM) base. Then, jacketed specimen was placed on hollow MS plate in such a way that it supported jacketed layer. On the top of specimen, 140 x 140 mm solid plate was placed in such a way that it rested on parent column and thus loading process was undertaken and load was applied.

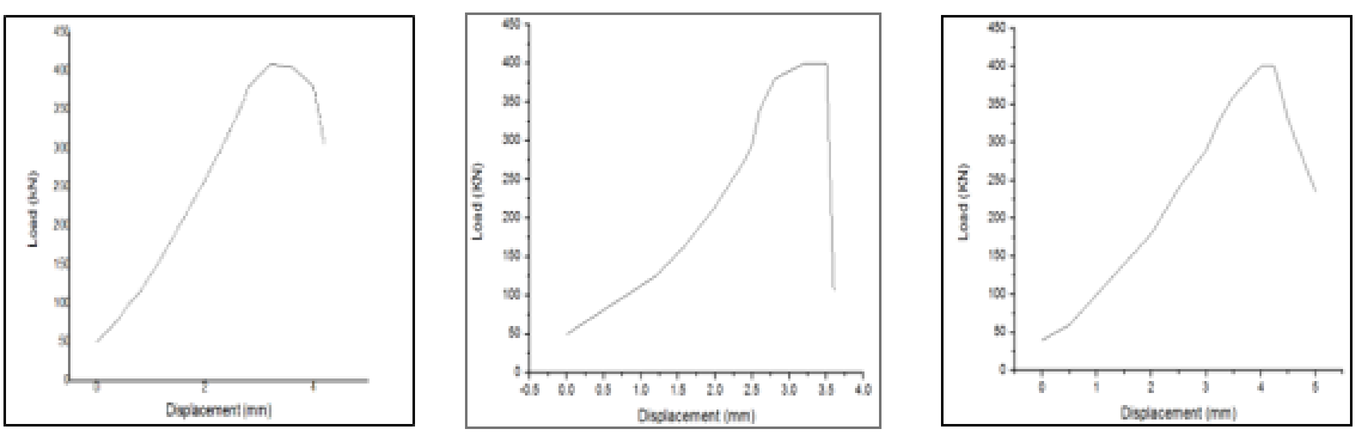
Fig. 4: Test setup

VI. RESULTS AND DISCUSSION

Based on experimental results, efforts have been made to study the bond slip phenomenon and to compare the effectiveness of jacketing techniques used in this study. Following are some of the observations of bond slip under application of load through Universal Testing Machine.

Fig. 5: Failure of specimen_SK

The results obtained from the test have been presented by graphs in the form of load vs. Settlement for normal specimen **(**without any bonding agent)



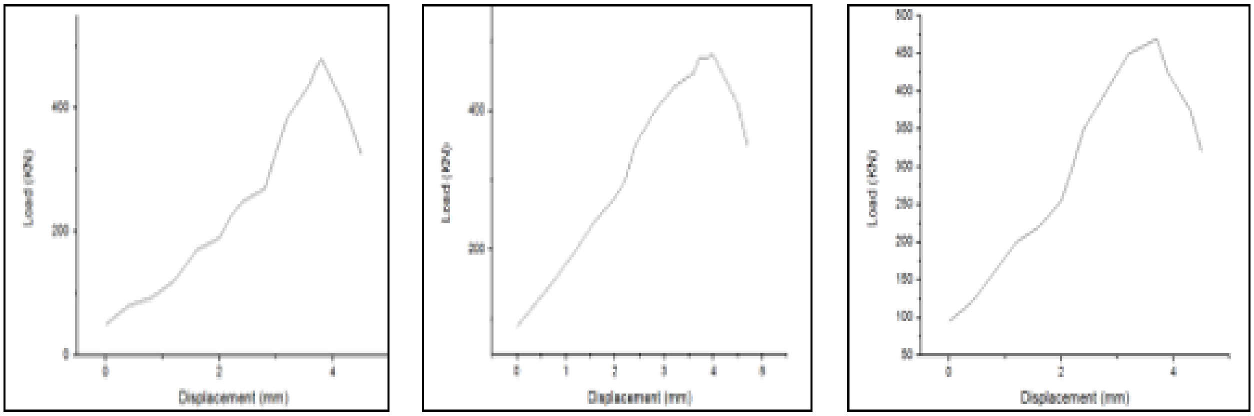
Graph 1: Specimen_N

Based on the peak load, average bond strength has been evaluated as shown in table below:

Load (N)	*Bond strength (N/mm^2)*	*Avg. Bond strength (N/mm^2)*
408.69x10^3	*1.513*	*1.499*
403.47 x10^3	*1.494*	
402.42 x10^3	*1.490*	

Table 2: Bond Strength of Specimen_N

The same results have been obtained for specimen using SBR as bonding agent:



Graph 2: Specimen_SK

Load (N)	*Bond strength (N/mm^2)*	*Avg. Bond strength (N/mm^2)*
224.94 x10^3	*0.833*	*0.955*
279.06 x10^3	*1.033*	
270.21 x 10^3	*1*	

Table 3: Bond Strength of Specimen_SK

VII. CONCLUSION

After putting rigorous efforts and performing experiment, we observed bond slip phenomenon in different variety of retrofitted specimen such as jacketed specimen without any bonding agent and jacketed specimen with SBR and Shear key. Through this research, our focus was to discover the bond strength developed between the parent specimen and jacketed layer by introducing different ways of jacketing as specified above.

In case of specimen with shear key and SBR, we observe that the bond slip did not occur but the different phenomenon took place. Previously when the shear key was not provided, there were no restrictions for the occurrence of bond slip and that's why the parent column suffered from minor damage but in case of specimen with shear key, bond slip was resisted by shear key as well as SBR. Load coming over the parent specimen was transferred to collar through shear key mechanism because of which occurrence of bond slip was resisted and expansive failure of parent specimen was observed resulting in the tearing effect of jacketed layer. This type of expansive failures may be avoided by providing higher grade concrete in the jacketed portion which will resist the quantum of force coming from parent specimen and this can be the future area of work which one can opt for.

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