Effect Of Post-Installed Rebar Connection On Concrete Structure

Ankita S. Bhoir, Dr. Sudhir P. Patil

Abstract: With increase in demand of construction industry, man has developed various techniques of construction. Post-installed connection is one of the techniques which allows to extend or strengthen the structure without affecting the existing structure. The technology of post-installed reinforcing bars is gaining importance since these bars are being frequently used in horizontal, vertical, and overhead applications in retrofit and rehabilitation of structures. Design of post-installed rebar connection is an issue as proper design guidelines are not yet provided in IS codes. Proper design of anchorage length is important parameter in post-installed connection. Post installed rebar connections, Eurocode approach to design, post-installed reinforcement approval and design method for static loads are discussed. The main aim of the study is to design post-installed rebar connections for existing structure. We have also carried out analytical investigation using finite element method to check the effect of post-installed connections by varying anchorage length as 10d, 15d, 20d and compared the effect with actual designed anchorage length for static loads. Behavior of structure after post-installed connection under static loading is studied.

Index Terms : Anchorage Length, Ansys Workbench, Design, Post-installed, rebar, strut-tie model

1. INTRODUCTION

In most of the countries in the world, the buildings and structures are ageing and needs continuous maintenance and also a repair. Also, the majority of existing constructions have deficient in the light of current knowledge and design codes. In practice, more connections between reinforced concrete element are carried out by bonding deformed reinforcing bars with adhesive mortar in holes drilled into existing concrete problem of the structural deficiency of existing constructions is serious in seismic regions. The costs of demolition and reconstruction of structurally deficient constructions are little prohibitive; also, they comprise a substantial waste of natural resources and energy. Therefore, structural retrofitting is increasing widely throughout the world.The rise in traffic flows and increase in axle weights cause rise in impose loading on bridges which is far in excess of loads for which bridges are designed. As a result of this many bridges are subjected to strengthening schemes. So, rehabilitation works come with engineering challenge of providing monolithic connection A common application of anchoring adhesive is the installation of deformed rebar in holes drilled in concrete to imitate the behavior of cast-in-place reinforcing bars. Rebar is standing for reinforcement bar. The word rebar is used for a reinforcement bar inserted into a borehole filled with chemical adhesive in reinforced concrete structures, that also means for post-installed reinforcement. Post-installed reinforcement can be split up into different applications such as Rebar as Anchor and Rebar as structural rebar. Post-installed reinforcing bars are used to develop a monolithic connection between new and existing concrete elements or structures. Post-installed rebar can be used to build most connections on site like, walls, slabs, beams, foundations or supporting columns. Most common use of rebar connections is for extensions of existing structure. It is also used to connect new components to existing structure and to strengthen existing concrete structures.

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between new and existing concrete structure. Post installed reinforcement is a reinforcement which is installed in hardened concrete member by drilling holes and inserting bar with adhesive. Post installed reinforcement bars are used for different purposes such as attaching new concrete members to existing reinforced concrete members, enabling the flow of forces via joints or strengthening existing structure by additional straight rebars.

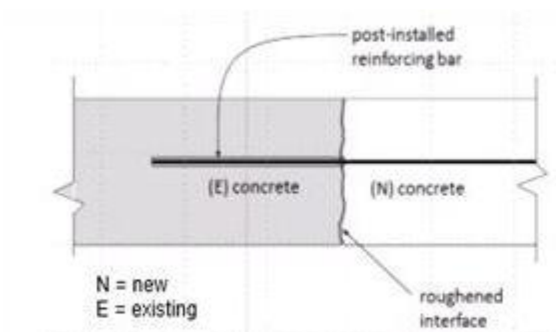

Fig. 1. *Post-installed reinforcing bar*

2 LITERATURE REVIEW

Rolf Eligehausen And Hannes Spieth (2001): Paper discusses post-installed rebar links and bond length comparison with manufacturer suggestions based on reinforced concrete codes. The bond length suggested by producers is much lower than reinforced bar bond length provided in various global reinforced concrete codes. Paper deals with tests of deformed bars mounted post and casts deformed bars in location. Results show that bar bond strength in well-cleaned holes in uncracked concrete bonded with suitable products is as large as cast-in-place bar bond strength. So, it summarizes that post installed rebar bond strength should be as long as strengthened concrete codes require anchorage or splice length. Giovacchino Genesio, Roberto Piccinin, John Silva (2017): The paper describes the comparison of guidelines for the qualification of a post-installed reinforcement bar scheme developed by EOTA and ICC-ES. The qualification procedures of a post installed systems to verify their compatibility with applicable building codes which revolves around the ideas of efficiency equivalence between installed reinforcement bars and post installed bars, conducted in the Europe under provisions established by EOTA and in the U.S using ICC-ES. Paper has explained key points such as bond strength, the viability of adhesive delivery system, corrosion resistance and response to tension loading under splitting-critical conditions where shear lag is important. The assessment process, recommendations for harmonization and improvements are also discussed. With the development of new bonding materials, systems may result with significance differences in load-displacement response, bond or splitting test to address shear lag for long embedment as per AC308 is advisable and should be added in Eurocode. However, paper concludes that product could be designed and qualified in accordance with EAD330087 as its performance in cracked concrete is potentially unconservative.Giovacchino Genesio, Roberto Piccinin, John Silva (2017): Paper compares design methods based on Eurocode 2 and ACI 318. It also discusses some case studies where post installed rebar systems are used for the moment resisting connections. Challenges and new opportunities related to post installed connections are discussed. Paper shows multiple methods which could be adopted to satisfy the design requirements of real reinforced concrete moment resisting connections. Paper highlights strong need for a unified approach capable of merging reinforcing to concrete theory.Christph Mahrenholtz, Rolf Eligehausen, Hans-Wolf Reinhardt (2015): Paper highlights the interrelationships that are required for design between material strength parameters. Paper provided the methods of rebar building as cast-in or post installed end anchorage as per EN1992-1 and as CEN / TS 1992-4 bonded anchors. The comparison of both techniques is made using an illustration of the scenario demonstrating that the design of post-installed rebars as a bonded anchor may permit a lower anchorage length than needed if intended as end anchorages for high-strength mortars. It also addressed the design and problems of the end anchorages as part of the strut and tie models.Hannes A. Spieth, Josko Ozbolt, R. Eligehausen, Jorg Appl (2001): Research paper describes research on a post-installed rebar connection system's bond behavior. Single rebar pull-out tests and splice tests are discussed. Influence of the separate bond rigidity on the finite three-dimensional component splice stimulations of diverse transverse splice length cracking was conducted for investigation purposes. Research demonstrates that the stiffness of the bond and the strength of the bond influence Splice length and crack along the seat length. Research demonstrates that the rebar instruments used after installation provide similar bond rigidity and no reduced bond strength than the rebars cast-in-place. The layout can be accomplished according to the reinforced concrete codes.Finley A. Charney, Kamalika Pal, John Silva (2013): This publication offers context to ACI 318's adhesive anchor design and growth length regulations as well as provisions available in global codes for post-installed rebars. The document has recommended the creation of a new technique for the design of post installed reinforcement bars. This study has provided practical perspective to the issue of design, acknowledging the assumptions that are significant in ACI318's provision of anchorage and duration of growth. It is found that in applying this strategy to the wide range of information connected with post-installed reinforcing bars, engineering judgement is needed.

3 OBJECTIVES

- To check static effect of rebarring on existing structure.
- Study and design of the post installed rebar connections for concrete structures using Eurocode 2 for anchorage lengths.
- Application design using Eurocode 2 Part1.
- Software-based application design: PROFIS – Rebar.
- To check the effect on column-beam joint with anchorage length 10d, 15d, 20d and calculated length as per EC2 part 1 for static loading.
- To compare total deformation, stress for static loading.

4 METHODOLOGY

The following tasks were performed to accomplish the goals of this study:

1. Review prior studies on post-installed rebar connections and methods used.
2. Finding comparative parameters to regulations of the IS and European code.
3. Understanding the importance of assessment and approval.
4. Data collection for the study and checking of strength of the structural element to be studied using Rebound Hammer.
5. Application design using the European Code for the case study proposed.
6. Using software PROFIS-REBAR for design of rebar connection.
7. Modelling of design post installed connection in Ansys Workbench.

5 CASE STUDY

A 4 years old G+4 RCC building of 6000 sq. ft having built up area 4800 per floor slab is considered for study. For this study Column-beam connection is kept in focus where existing column will connect the new beam using post installed rebar connection.

Table 1
Schedule identified from Staad files

Column No	SIZE	MAIN BARS	RINGS
C6	(230x450) mm	4-12mm+ 2-16mm	6mm@150 mm c/c

Beam No	Size	Top	Bottom	Extra Top	Stirrups
PB1	(230x450) mm	2-12mm	2-10+2-12	2-12mm	8mm@ 150mm c/c
PB2	(230x450) mm	2-12mm	2-10+2-12	2-12mm	8mm@ 150mm c/c

Rebound Hammer Test was performed using Schmidt Hammer to measure compressive strength of the concrete column of existing building. After conducting test, the compressive strength of the concrete column was found to be 25 MPa.

6 DESIGN OF POST-INSTALLED ANCHORAGE

6.1 Design using European Standards

Post-installed beam reinforcement bar on concrete column (230*450) mm of an existing building is manually designed using European code norms as shown below:

Height(h) of existing column: 230 mm

Effective span of beam: 3.5m

Effective Depth (d) of beam: 500mm

Characteristic yield strength of Reinforcement f_{yk} = 500 N/mm^2

Partial Factor for reinforcing steel γ_s = 1.15

Design forces considered for the design:

M_{Ed} = 73.19 kN-m/m

V_{ED} = 97.6 kN/m

Anchorage length calculated from manual calculation using European codes are 340 mm, 400mm for bottom layer and upper layer respectively.

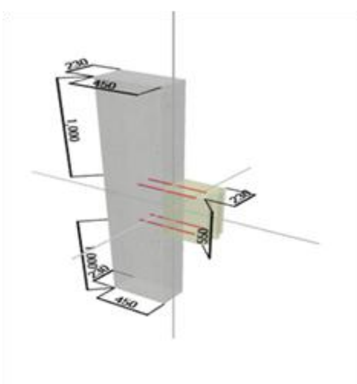

Fig. 2. *Column to beam connection*

1.2 Design using PROFIS-REBAR Software

The PROFIS Rebar software allows the post-installed reinforcement attachment to be designed quickly and securely, taking into consideration all the parameters listed in the above sections. The Region is selected as India. Eurocode based design method and standard application covering the range of application according to TR023 are selected for design of proposed study. The necessary data is defined with regard to existing and new structures.Only shear force is taken into consideration. The anchorage length from the report is found to be 227 mm for upper layer and 378 mm for lower layer. Here, the maximum anchorage length is selected for the study. The difference between manually calculated anchorage length and software-based anchorage length is 0.11%. So, for the further study and analytical modelling anchorage length calculated is taken as 378 mm.

7 ANALYTICAL STUDY

- Three-dimensional existing column-beam joint with dimensions (450*230) and (230*450) is modelled in ANSYS WORKBENCH.
- New beam (230* 550) mm is modelled which is to be connected to the existing structure with varying anchorage lengths i.e. 10d, 15d, 20d and calculated anchorage length=378mm.
- Material properties such as fck =25 N/mm2 , fy = 500 N/mm2 , Es =2 * 105 Mpa , Ec =25* 103 Mpa were defined
- Geometry

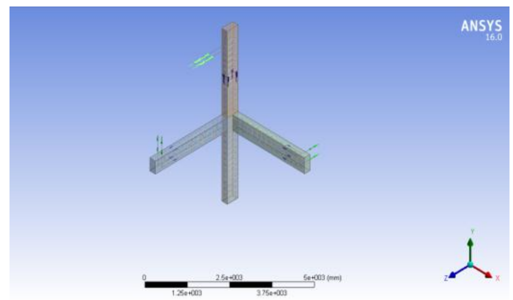

Fig. 4. *Geometry of Existing Structure*

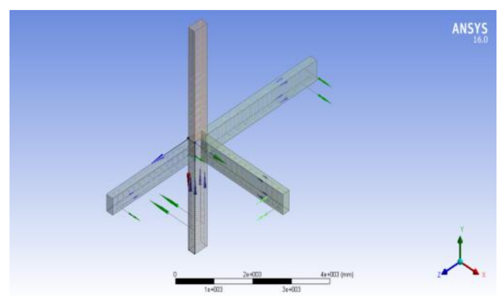

Fig. 5. *Geometry of post-installed connection to existing structure*

- Boundary Conditions and Loading

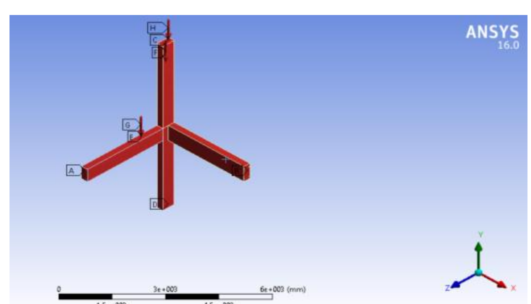

Fig. 6*. Existing structure with boundary conditions*

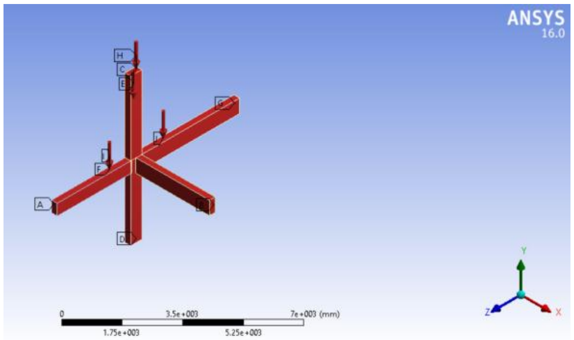

***Fig. 7**. Post-installed connection with boundary conditions*

- Deformations after analysis

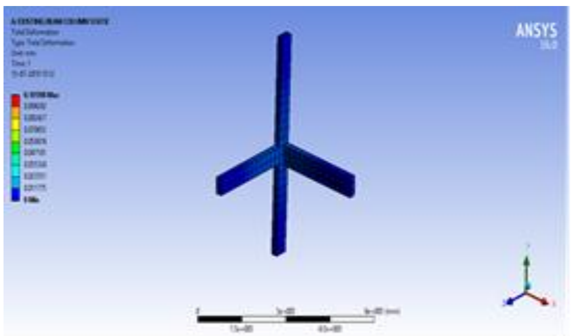

***Fig. 8.** Deformation of existing structure*

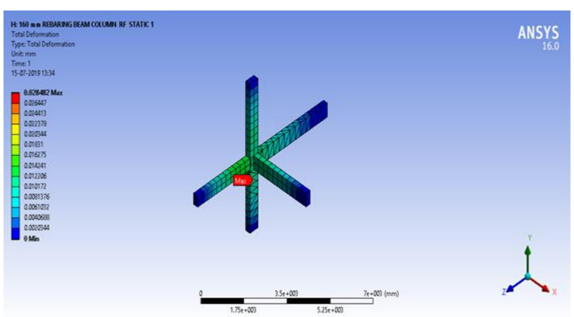

***Fig. 9.** Deformation of structure with 10d=160 mm anchorage*

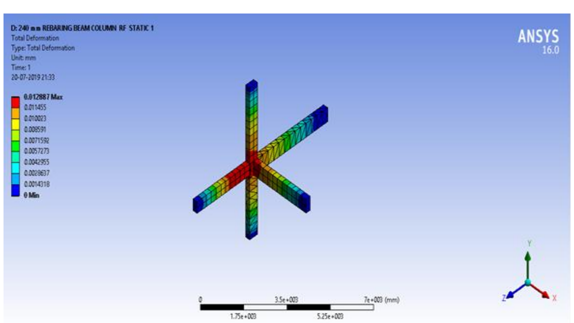

***Fig. 10.** Deformation of structure with 15d=240 mm anchorage*

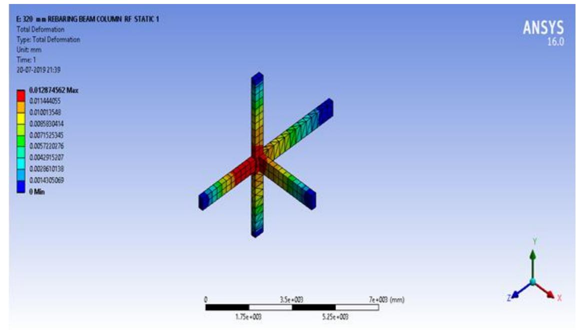

***Fig..11.** Deformation of structure with 20d=320 mm anchorage*

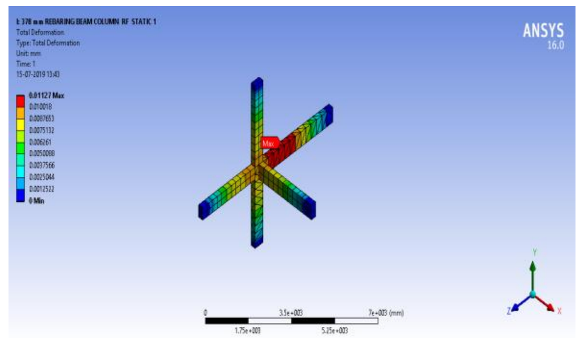

***Fig.12.** Deformation of structure with 378 mm anchorage*

- Equivalent Stresses

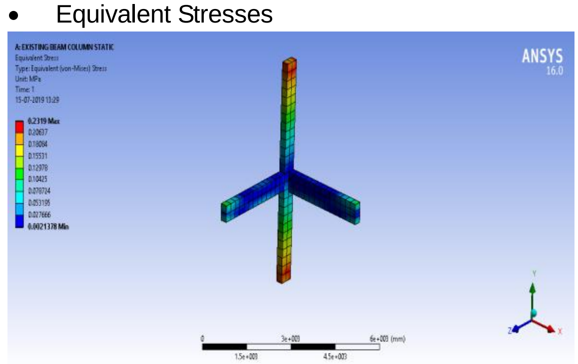

***Fig.13.** Equivalent stresses developed in structure with 378 mm anchorage*

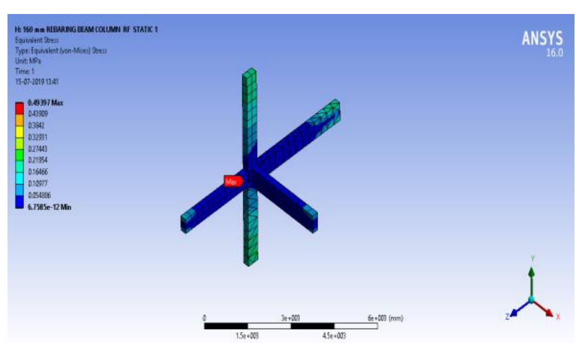

***Fig.14.** Equivalent stresses developed in structure with 378 mm anchorage*

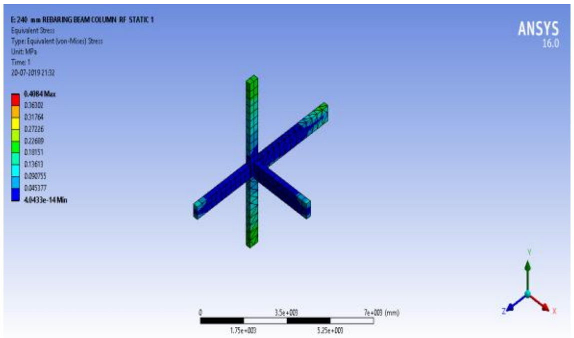

Fig.15. *Equivalent stresses developed in structure with 378 mm anchorage*

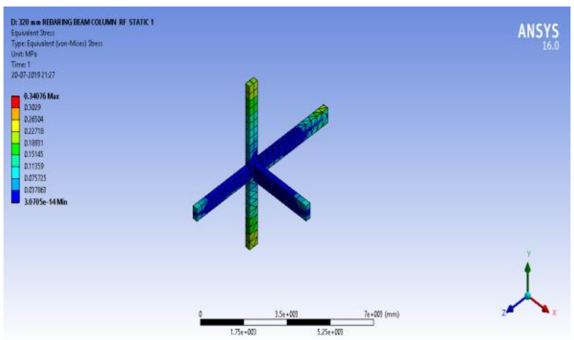

Fig.16. *Equivalent stresses developed in structure with 378 mm anchorage*

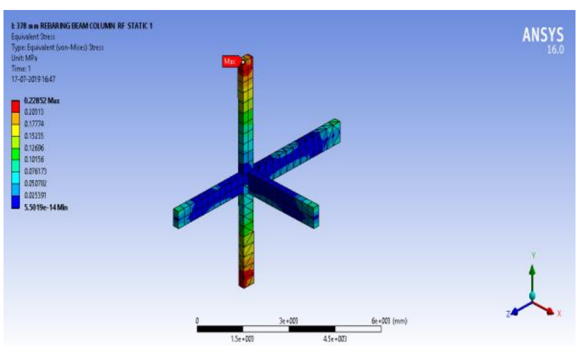

Fig.17. *Equivalent stresses developed in structure with 378 mm anchorage*

8 RESULTS

Table 2

Total Deformation (mm)

Existing Structure (mm)	160mm Rebar (mm)	240mm Rebar (mm)	320mm Rebar (mm)	378mm Rebar (mm)
0.10598	0.028482	0.012887	0.012874	0.0112

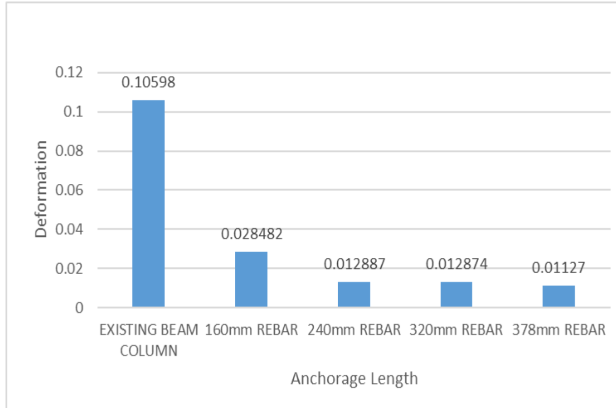

Fig.15. *Anchorage length V/S Deformation*

Table 3

Equivalent Stresses (MPa)

Existing Structure	160mm REBAR	240mm REBAR	320mm REBAR	378mm REBAR
0.2319	0.49397	0.4084	0.34076	0.22852

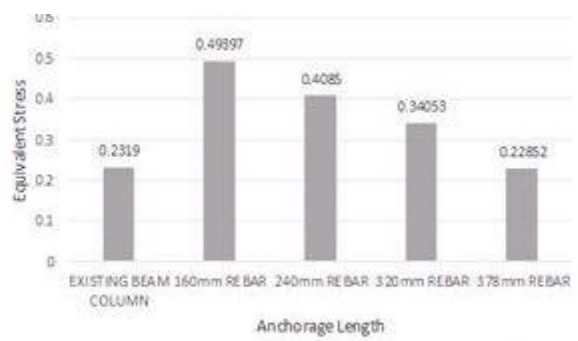

Fig.16. *Anchorage length V/S Stress*

9 CONCLUSION

The following conclusions could be made using present study.

- After applying load, the deflection observed in Post-installed structure is 70-80% lower than existing structure.
- The deflection observed in post-installed connection with 378 mm anchorage length is lower than connection with 10d, 15d,20d anchorage length.
- Stresses observed in connection with 10d=160mm anchorage length are almost double of the stresses observed in existing structure.
- Post-installed rebar technique can be used for strengthening and extension purpose.
- It is better to opt for the proper design procedure to calculate anchorage length than taking randomly anchorage distance such as 10d, 15d or 20d.
- Software design is easy and user friendly. Hence PROFIS- Rebar is effective tool for rebar design

reducing tedious calculations and saves tons of your time.

- Anchorage length varies as load conditions, boundary conditions vary. So, it is recommended to follow codal provisions and specifications and installation parameters for safety of structure.

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REFERENCES

[1]. European Technical Assessment ETA- 16/0143
[2]. EN 1992-1-1: Eurocode 2: Design of Concrete Structures-Part 1- 1: General rules and rules for buildings, 2001 IS456:2000
[3]. European Organisation for Technical approvals (EOTA) TR023
[4]. R Eligehausen, H Spieth: Post Installed Rebar Connections, International Symposium on Connections between Steel and Concrete, Rilem,29-41,2001.
[5]. Giovacchino Genesio, Roberto Piccinin, John Silva: Qualification of a System for Post-Installed Reinforcing Bars under the Rules Established by EOTA and ICC-ES, 3rd International Symposium on Connections between Steel and Concrete, Stuttgart, Germany, 2017.
[6]. Christph Mahrenholtz, Rolf Eligehausen, Hans-Wolf Reinhardt: Design of Post-Installed Reinforcing Bars as End Anchorage or as Bonded Anchor, Engineering Structures, University of Stuttgart, 645-655, 2015.
[7]. Christph Mahrenholtz, Rolf Eligehausen, Hans-Wolf Reinhardt: Design of Post-Installed Reinforcing Bars as End Anchorage or as Bonded Anchor, Engineering Structures, University of Stuttgart, 645-655, 2015.
[8]. HA Spieth, J Ozbolt, R Eligehausen, J Appl: Numerical and Experimental Analysis of Post-Installed Rebars spliced with Cast-in-Place Rebars, International Symposium on Connections between Steel and Concrete, 889,2001.
[9]. Charney F.A., Pal K., Silva J.: Recommended Procedures for Development and Splicing of post-Installed Bonded Reinforcing Bars in Concrete Structure, ACI Structural Journal, V.110, No.3, pp.437-447, May-June 2013.
[10]. C. Nuti, S. Santini: Fastening technique in seismic areas: A critical review, Tailor Made Concrete Structures – Walraven & Stoelhorst, Taylor & Francis Group, London, ISBN 978-0-415-47535-8,2008.
[11]. Yue Zhang Qun Xie and Ming-Qiang Lin.: The effect of embedment depth on the steel-to-concrete post-installed joint under cyclic loading, International Conference on Civil and Hydraulic Engineering, IOP Conf. Ser.: Earth Environ. Sci. 189 032021,2018.
[12]. www.hilti.com
[13]. www.hilti.in