International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.14, pp 49-57, 2017

Experimental Study on RC Beam Externally Bonded with Electrogalvanized Steel Plate Using Epoxy

M.Sivaranjani*, S.Pavithra, A.Venkatachalam

Department of Civil Engineering, Agni College of Technology, Chennai, Tamil Nadu India.

Abstract : Reinforced concrete (RC) is a composite material in which concrete's low tensile strength and ductility are neutralised by the inclusion of reinforcement having higher tensile strength or ductility. Plate bonding technique has gained widespread acceptance as a potential solution. The plated beams show considerable enhancement in flexural strength. An experimental study on RC beam externally bonded with electrogalvanized steel plate is carried out. The present study describes the result of testing RC beam externally bonded with electrogalvanized steel plates using epoxy by varying the thickness of steel plates. Steel plates are bonded to the tension side and side faces of reinforced concrete structure, thus supplying additional longitudinal reinforcement and shear reinforcement respectively, hence the flexural capacity shear capacity increases. This project deals with experimental and comparative study of flexural behaviour of reinforced concrete beam bonded with galvanized steel plate with control beam and to study its failure pattern by placing the plate in the bottom and side faces of the beam using suitable bonding agent such as epoxy.
Keywords : External bonding, electrogalvanized steel plate, flexural behaviour of concrete.

Introduction

Structures can be damaged due to various factors such as over-loading, earthquakes, fire, blast loading, mistakes in design calculations, corrosion of reinforcement and improper concrete mix design. Damage can be defined as the variation in structural performance, which can be seen in terms of discrete cracks or a weak zone formation. Undetected and unrepaired damage leads to structural failure which demands costly repair and huge loss of lives. It is important to study the behaviour of damaged RC members, since it involves huge expenditure to demolish and reconstruct them. In the past few years, the concrete construction industry has faced various challenges in view of the deterioration of infrastructure. A large number of bridges, buildings and other structural elements need rehabilitation and repair works. Various factors such as effect of environment, increase in both traffic volume and truck weights and design of older structures, which may have been adequate, with old codes but are not suitable with current codes that have been the factors contributing to infrastructure becoming either structurally deficient or functionally obsolete. A plenty of strengthening systems have been formulated and adopted. The choice of the strengthening system depends on the different performance requirements.

In recent days, buildings are found to be damaged because of sudden variation in the function of building, exposure to different environmental conditions and also due to use of older codal provisions.

Today deterioration of RC structure is the major problem in civil industry. This is because large number of buildings are constructed according to older design codes in different parts of the world, thus they are structurally unsafe compared to present design codes, since replacement of deteriorated structure demands plenty of money and time. Nowadays, it is necessary to find repair techniques suitable in terms of low costs and fast processing time.

Plate bonding technique

Plate bonding technique[1,2,3,4] has gained widespread acceptance as a potential solution. The plated beams show considerable enhancement in flexural strength. All the plated beams experience flexural failure and none of the externally plated beams show premature brittle failure. Also the plated beams provide the required ductility to ensure a ductile mode of failure.

Over the recent years, the plate bonding technique has been established as a simple and convenient method of repair for enhancing the flexural performance[5,7] of concrete structures particularly for bridge beams and slabs. The advantages of this technique is that the work can be done while the structure is still in use and it is economical when compared to other methods. The strengthening of structures by plate bonding is mainly adopted in order to increase the flexural capacity and shear capacity of structures. Steel plates are bonded to the tension side of reinforced concrete structure, thus supplying additional longitudinal reinforcement and hence flexural capacity[5,7] increases. Steel plates are bonded to the side faces of reinforced concrete structure, thus supplying additional shear reinforcement and hence shear capacity increases. Although the beams failed in shear, as expected, the mode of failure was ductile, controlled by the yielding and local buckling of the external plates that were bonded to the beam. The experimental study showed that this method of construction could prove to be both practical and reliable for strengthening the existing in-situ concrete beam.

Electrogalvanized steel plate

A galvanized iron (GI) steel sheet is generally coated with zinc and includes wide range of hot dip galvanized and electro-galvanized steel sheets. As zinc weathers at a very slow rate, the coating has long life. Also, zinc has greater electro-negativity than that of iron and therefore provides cathodic protection to the steel. As a result, the zinc corrodes in preference to steel if the coating is chipped or damaged to expose the base metal. Other than acting as galvanic protector; the other functions of the zinc layer are as follow:

1) It retains the steel with its full initial strength.
2) Also provides the surface more pleasing appearance.
3) Increases the life of any suitable finishing system applied over it.
4) Protects the steel from corrosive attack in various atmospheres, so that it acts as a continuous and lasting shield between steel and the atmosphere.

Experimental

Collection of Materials

A. Cement

Ordinary Portland cement was used in casting the specimens. The Specific Gravity, Fineness, Initial setting time and Consistency of the cement were tested[11,12].

B. Coarse aggregate

Hard granite broken stones which is less than 20mm size has been used as coarse aggregate. The Specific Gravity, Fineness modulus, Water absorption and Bulk density of the coarse aggregate were tested in laboratory.

C. Fine aggregate

River sand which consists of size less than 4.75 mm size was used as fine aggregate.

The Specific Gravity, Fineness modulus, Water absorption and bulk density of the fine aggregate were tested in laboratory.

D. Water

Potable water that is available in laboratory with pH value of not less than 6 and conforming to the requirement of IS 456-2000 has been used for mixing concrete and curing the specimen as per the requirement.

E. Electrogalvanized steel plate

Electrogalvanized plates of thickness 1.5mm and 2mm are used in this experimental investigation.

F. Epoxy adhesive

Epoxies are produced by polymerizing a mixture which consists of two starting compounds, the resin and the hardener. When resin is mixed with a specified catalyst, curing is initiated. Curing is the process of molecular chains reaction at chemically active sites, which result in an exothermic reaction. Epoxy adhesives provide good adhesion to a wide variety of materials and whose properties are dependent upon the specific chemistry of the system and the nature of the cross-linking available. The characteristics are better moisture resistance, low shrinkage and good adhesion

Mix design

Mix design[9] is the process in which suitable ingredients of concrete are selected and their relative proportion are determined with the object of producing concrete of certain minimum strength and durability as economically as possible. The mix design is carried out to achieve specified age, workability of fresh concrete and durability requirements by using IS 10262-1982. The following data are required for mix proportioning of a particular grade of concrete.

1)	**Grade designation**	**:**	**25 N/mm^2**
2)	Type of cement	:	OPC53
3)	Maximum nominal size of aggregate	:	20 mm
4)	Specific gravity of fine aggregate	:	2.61
5)	Specific gravity of coarse aggregate	:	2.8
6)	Degree of workability	:	0.9
7)	Maximum water-cement ratio	:	0.55
8)	Exposure conditions	:	mild
9)	Type of aggregate	:	Crushed angular

Experimental investigation

A. Workability of Fresh Concrete by Slump Test

Slump test is used to find out the workability of fresh concrete. Slump test as per IS: 1199 – 1959 is followed. Fresh concrete was tested for its workability using slump cone test. Slump of 95 mm was observed for the concrete mix.

B. Compressive Strength

Concrete cubes of 150×150×150mm were casted. 9 nos of cubes were casted and cured in water tank after 20 hours of casting. Hardened concrete cubes were tested for their compressive strength using compression testing machine.

Specimen description

A. Casting of beam

In this experimental investigation, reinforced concrete beam was designed as doubly reinforced section using M25 grade concrete and Fe 415 grade steel , having a cross section of 100mm x 100 mm by limit state method. The tension reinforcement of 2nos-12mm dia bar, compression reinforcement of 2nos-12mm dia bar and stirupps having a dia of 6mm at 150mm spacing was designed by using limit state method. The clear span of the beam was 1000mm. A total of 6 beams were casted and cured for 28 days.

B. Bonding of external plate

The electrogalvanized plates that were used in bonding in this experimental investigation consists of a thickness of 1.5mm and 2mm respectively. The steel plates were bonded on the tensile, compressive and side faces of the beam. The width of the plate was 100mm and the length of the plate was 1000mm. The bonding faces of the steel plates and the beam surface were roughened and cleaned thoroughly.

The epoxy adhesive (Bostik EP bond) was mixed in accordance with the manufacturer’s instructions. Epoxy was uniformly spread all over the roughened surface of the beam and the steel plates to a thickness of 1mm. After the application of epoxy gets over, the plates were bonded to the beams. The beams are then left undisturbed for 24 hours.

Testing arrangements

The span length of the beam in loading test was 1000mm and a two point loading test was conducted. The configuration for test specimen and loading arrangement is represented.

Test results

The beams were tested for their ultimate strength under two point loading system. In case of control beam (without plate), the failure occurs as soon as the first critical shear crack forms. Initial crack occurred at 18 kN near the support. The ultimate load was found to be 32 kN. The deflection at ultimate load was found to be 11.5mm. The failure pattern and the load-deflection diagram for control are given below.

In case of beams strengthened with 1.5mm thick plate, the beam takes additional load compared to the control beam and also shows good ductility. The failure occurred due to debonding of plates just before the ultimate load. Initial crack occurred at midspan (after debonding) at 40 kN, whereas the debonding of side plates occurred at 38 kN and the

ultimate capacity was found as 62 kN. The maximum deflection occurred at ultimate load was found to be 26.75mm.The failure pattern and load- deflection diagram of strengthened beam is shown below.

In case of beam strengthened with 2mm thick plate which took an additional load compared to 1.5mm thick plate and shows less ductility when compared to 1.5mm thick plate. Initial crack occurred at midspan (after debonding) was 52 kN, whereas the debonding of side plates occurred at 50 kN and the ultimate capacity was found as 68 kN. The maximum deflection occurred at ultimate load was found to be 6.9 mm.

Table 1.Properties of Cement

S.No	Description	Result
1	Specific gravity	3.12
2	Fineness (by sieve analysis)	2%
3	Consistency	32%
4	Initial setting time	52 minutes
5	Final setting time	420 minutes

Table 2.Properties of coarse aggregate

S.NO	Description	Values
1	Specific gravity	2.8
2	Water absorption	1%
3	Fineness modulus	4.67
4	Bulk density	1648.73 Kg/m^3

Table 3.Properties of fine aggregate

S.NO	Description	Values
1	Specific gravity	2.61
2	Water absorption	1%
3	Fineness modulus	2.72
4	Bulk density	1632.19 Kg/m^3

Table 4.Mix Proportion

Water	Cement	Fine Aggregates	Coarse Aggregates
188.8	503.00	673.27	1250.27
0.44	1	1.338	2.48

Table 5.Results of Compressive test on cubes

Day	S No	Compressive load (KN)	Compressive strength (MPa)
7^{th} day	1	394	17.5
	2	400.5	17.8
	3	391.5	17.4
	Average		17.6
14^{th} day	1	535.5	23.8
	2	513	22.8
	3	544.5	24.2
	Average		23.6
28^{th} day	1	622.5	27.6
	2	656.5	29.2
	3	644.5	28.6
	Average		28.5

TABLE 6
COMPARISON OF CONTROL BEAM AND STRENGTHENED BEAM

SPECIMEN	ULTIMATE LOAD (KN)	PERCENTAGE INCREASE IN STRENGTH (%)	MAXIMUM DISPLACEMENT (MM)
CONTROL BEAM	32	-	11.5
BEAM STRENGTHENED WITH 1.5 MM THICK PLATE	62	93.75	26.75
BEAM STRENGTHENED WITH 2 MM THICK PLATE	68	118	6.9

Fig. 1. Electrogalvanized plate

Figure 2.Compressive strength of cube

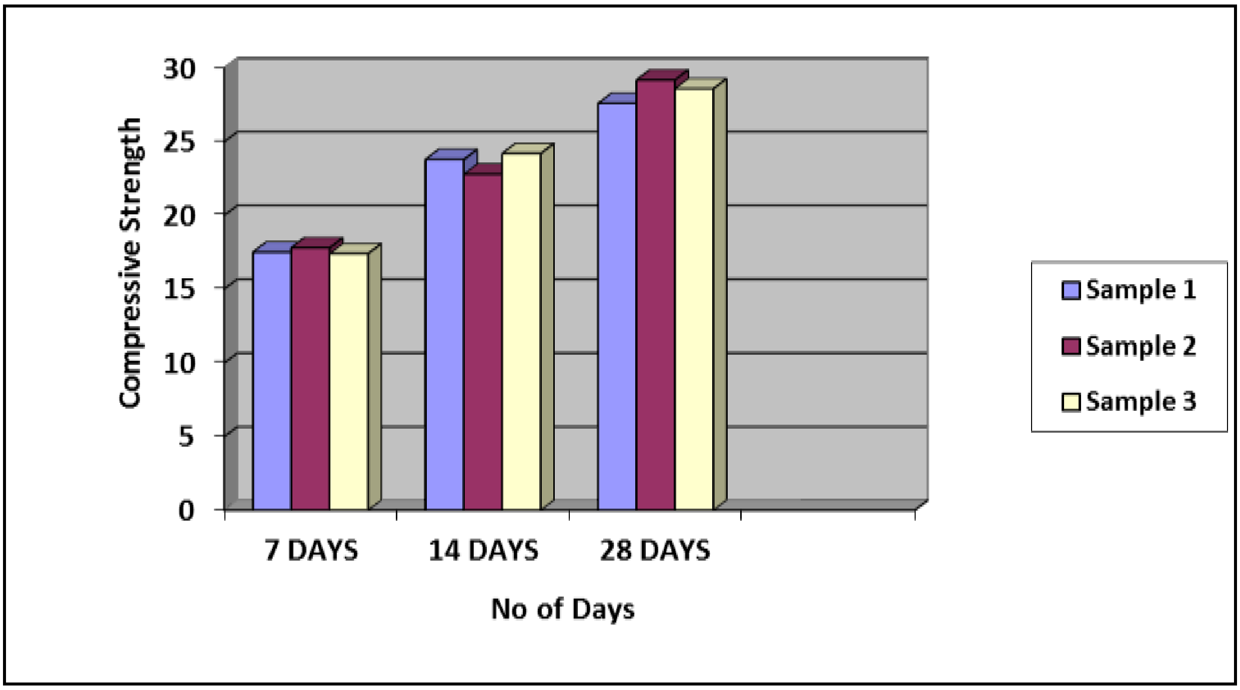

Figure 3.Compressive strength graph

Figure 4.Casting of beam

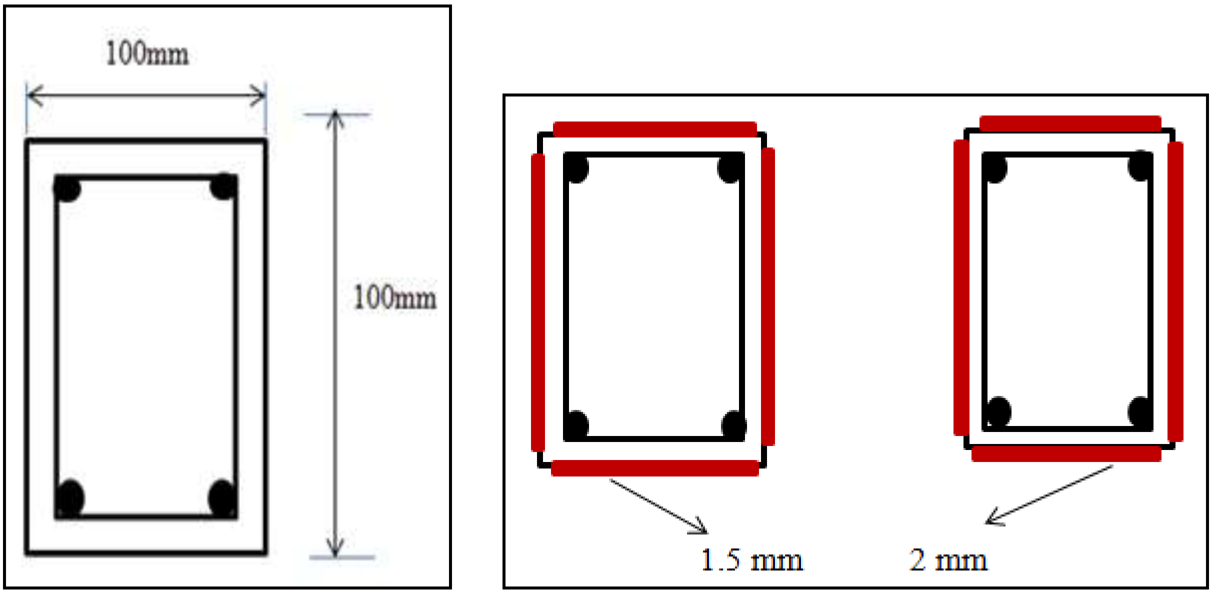

Figure 5.Test Specimen and Different configurations of beam

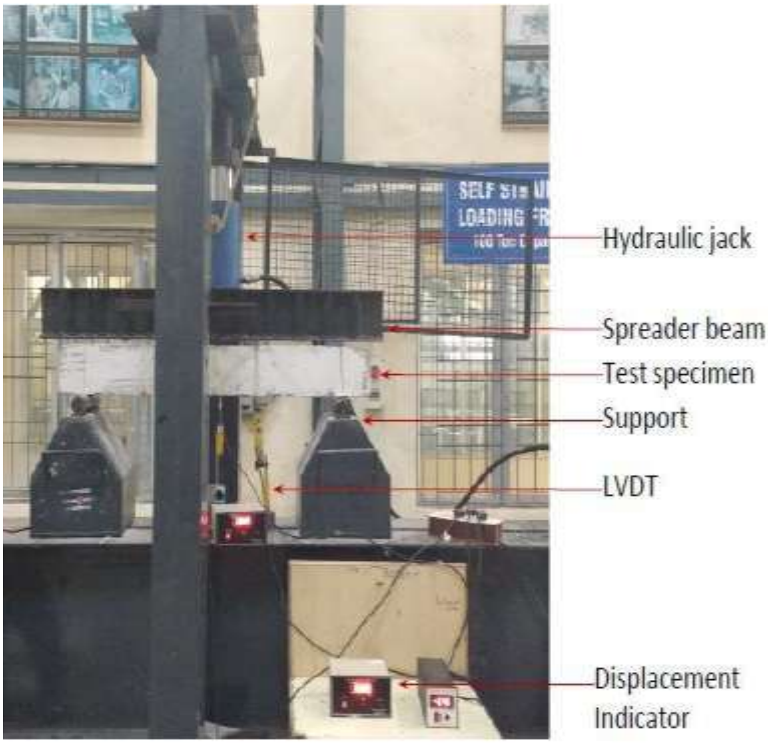

Figure 6.Two point loading test setup

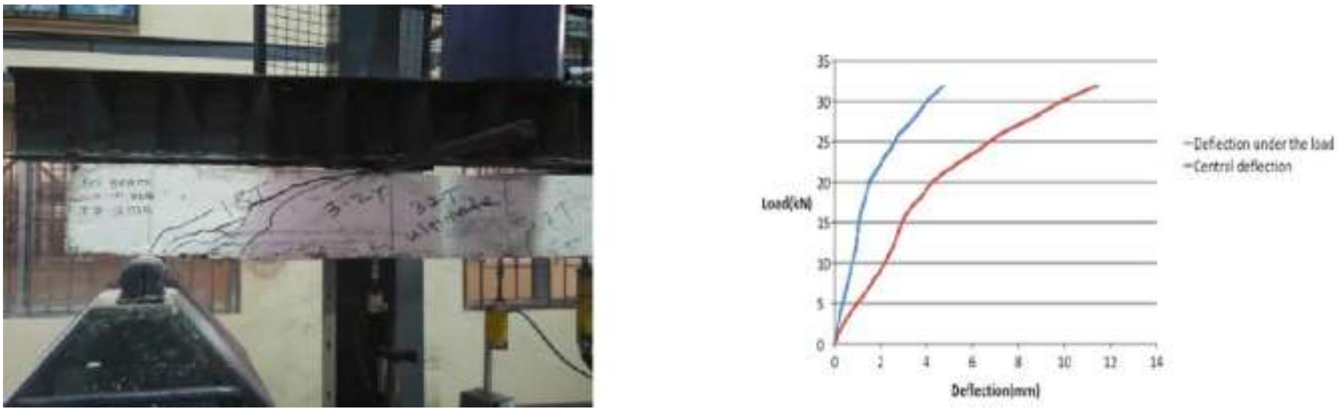

Figure 7. Failure pattern of RC control beam and Load-deflection curve of RC control beam

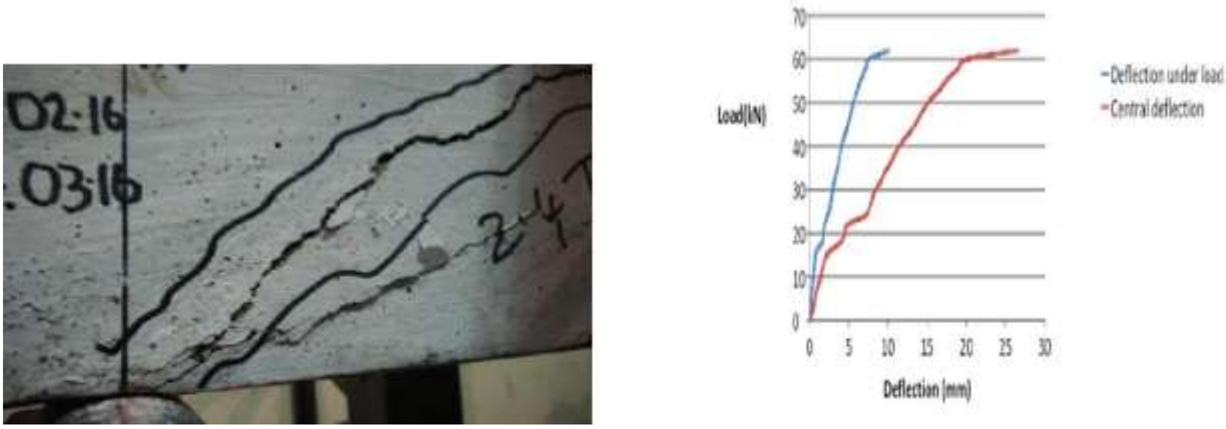

Figure 8. Failure pattern and Load-deflection curve of RC beam strengthened with 1.5 mm plate

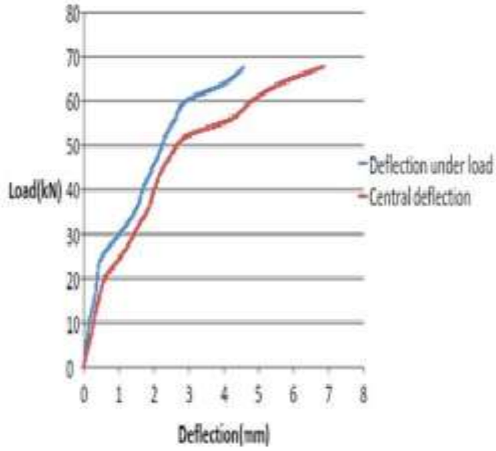

Figure 10. Failure pattern and Load-deflection curve of RC beam strengthened with 2mm thick plate

Conclusion

The Experimental investigation suggests that the strengthened beams[4,5] exhibited more strength[1,2,3] and ductility when compared to control beam. It is also inferred from the observation that lesser the thickness of plate used, greater is the ductility and lesser is the stiffness. Also, marked improvements in strength are observed when the thickness of steel plate is increased. More investigations have to be carried out in the future to address the problem of debonding in relation to the bonding surface and epoxy thickness.

References

1. Ashraf A.Alfeehan. Strengthening Of R.C. Beams by External Steel Plate Using Mechanical Connection Technique. Journal of Engineering and Development 2014;3:202-215.
2. Akinropo Musiliu olajumoke, Morgan Dundu. Flexural failure modes of steel plate strengthened reinforced concrete elements. Construction Materials and Structures 2014;1074-1079.
3. Awadh E.Ajeel, Rana Hashim Ghedan, Dina Mukheef Hamza. Replacing of Internal Tension Bars External Bonded Plate. Journal of Engineering and Development 2011;15:90-103
3. Barnes R.A, BaglinP.S, Mays G.C, Subedi N.K. External steel plate systems for the shear strengthening of reinforced concrete beams. Elsevier Engineering Structures 2000;23:1162-76.
4. Javad Vaseghi amiri, Morteza Hosseinalibegie. Determination Of Ultimate Flexural Capacity Of Strengthened Beams With Steel Plates And GFRP. 13th world conference on earthquake engineering 2004;2:3242.
5. Mohammed A, Al-Hassani H. M, Al-Ta'an S. A. Behaviour of Damaged Reinforced Concrete Beams Strengthened with Externally Bonded Steel Plate. Tikrit Journal of Engineering Sciences 2013;20:48-5.
7. Sallama.H.E.M, Badawy.A.A.M, Saba.A.M, Mikhail.F.A. Flexural behaviour of strengthened steel concrete composite beams by various plating methods. Elsvier Engineering Structures 2010;66:1081-87.
6. Code of specification for concrete mix design. IS 10262:2009.
7. Specification for coarse and fine aggregates from natural sources of concrete. IS 383: 1970.
8. Code of practice for Methods of tests for strength of concrete. IS 516-1959.
9. Code of practice for Methods of tests for splitting tensile strength of concrete cylinders. IS 5816-1970.

*****