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EFFECT OF STRENGTHENING SCHEMES ON PERFORMANCE OF RC BEAMS RETROFITTED WITH GFRP, CFRP AND ULTRA HIGH STRENGTH CONCRETE

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Abstract

Structural strengthening of reinforced concrete (RC) structural elements has become essential due to several reasons, namely, (i) to meet the up-gradation of existing structures due to the infrastructure development (ii) excessive deflection, cracking, inadequate ultimate strength (iii) to carry higher permissible loads (iv) design faults (v) poor construction practices (vi) poor durability etc. Sometimes, structures/components may be subjected to overloads, which will cause more cracking and reduction in stiffness/strength. There are several popular techniques, namely, externally bonded steel plates, concrete jacketing, fibre reinforced laminates or sheets, external prestressing/external bar reinforcement technique are available to address repair and retrofitting of RC structural components. Recently, cementitious based material, namely, ultra high strength concrete or ultra high performance concrete is being used as strengthening material. Each technique/retrofit material has its own merits and limitations.

Keywords:RCC**,** fibre, cracking, design fault

1. Introduction

Reinforced cement concrete (RCC) structures constructed throughout the world are often found to exhibit distress and suffer damage even before the service life is completed. The reasons could be numerous, namely faulty construction, excessive loading, improper design, change of codal provisions, aggressive environment etc. Strengthening of existing RCC structures is now a major part of construction activity in India as well as all over the world. Various types of strengthening materials namely steel plates, ferro-cement, fiber reinforced polimer, advanced UHSC materials are available to strengthen the damaged structures/components. Each strengthening materials has its own merits and limitation.

They need structural up gradation to meet new seismic design requirements. The reasons may be due to changes in loading, corrosion of reinforcement, construction errors, additional loadings or changes in configuration or accidents such as earth quakes or due to fire etc.

1.2 Types of Strengthening Materials

Three types of fibre-reinforced polymers are mainly used for strengthening of existing structures.

•Steel plate
•Glass fibre Reinforced polymer (GFRP)
•Carbon fibre Reinforced polymer (CFRP)
•Aramid fibre reinforced polymer (AFRP)
•Basalt fibre reinforced polymer (BFRP)
•Ultra High Strength Concrete (UHSC)

Although FRP composites are expensive and more susceptible to physical damage than steel, they have become an attractive substitute for steel in strengthening systems for concrete structures due to their many advantages: high strength to weight ratio, corrosion resistance, high fatigue resistance, easy and reliable surface preparation, reduced mechanical fixing, durability of strengthening system and reduced construction period.

1.2.1 Applications of CFRP

The CFRP materials increased the nominal capacity of the strengthened beams by up to 76%, however, the increase of the elastic stiffness was minimal. In a related study, the tension flange of three other steel–concrete composite beams were notched with a 1.3 mm wide notch at midspan to simulate 25, 50, and 100% loss of the area of the tension flange Tavakkolizadeh and Saadat- manesh 2003b. The repair restored the elastic stiffness and nominal capacity of the girders to levels comparable to the undamaged beams and helped in reducing the residual deflections due to over-loading conditions. Other researchers have simulated corrosion damage by removing a uniform portion of the tension flange along the entire length of the girders Al-Saidy et al. 2004. CFRP materials were subsequently used to repair the girders. The technique restored the lost strength of the damaged beams to levels higher than those of the undamaged girders. However, only 50% of the lost stiffness of the beams was recovered. Investigations on the fatigue durability of steel beams strengthened with CFRP materials have been limited.

2. Literature Review

Lokesh A. Doddamani et al (2014) studied the Strength and stiffness of RC Beams retrofitted with GFRP wrapping. The beam dimensions taken into consideration for look at are 150mmx150mmx1300mm. Fe415 grade metal and M25 grade concrete has been used for casting of beams .The underneath bolstered and over strengthened sections were retrofitted with layers of U-formed GFRP sheets on full period of the beams. The development in load carrying capacity of the bolstered beneath bolstered beam at the start crack was 49.Sixty seven% as compared to controlled beams. The development in load resonant ability of the strengthened over strengthened beam at first crack become ninety two.88% compared to managed beams. Finally the weight sporting capability of all of the bolstered beams is better while compared to the manipulate beams. The balanced and over strengthened sections retrofitted with two layers of GFRP showcase more power and stiffness than the underneath bolstered RC beams retrofitted with GFRP.

Farhat A. Farhat et al (2015), premeditated the comportment of RC beams retrofitted with CARDIFRC after thermal pedaling. This take a look at examines the consequence of thermal cycling at the overall enactment of concrete beams retrofitted with CARDIFRC, a brand innovative class of high enactment fiber-strengthened cement-based totally material that is like minded with concrete. The outcomes of these exams are accessible and in comparison to analytical prophecies. The estimates show properly association with the untried consequences. This look at examines the consequence of thermal biking at the overall enactment of concrete beams retrofitted with CARDIFRC, a brand new elegance of high overall enactment fiber-bolstered cement-based cloth this is companionable with concrete. 24 beams had been endangered to 24 h thermal cycles among 25 and 90° C. One third of the beams have been bolstered whichever in flexure best or in flexure and shear with traditional metal reinforcement and used as manipulate varieties. The residual 16 beams have been retrofitted with CARDIFRC strips to offer outside flexural and/or shear establishment. All beams have been uncovered to a numerous wide variety of 24 h thermal cycles starting from zero to ninety and had been verified in four-point bending at room temperature. The checks specified that the retrofitted members have been more potent and firmer than manage beams, and greater significantly, that their botch originated in flexure with none symptoms of interfacial delamination outrageously. The outcomes of these assessments are provided and in comparison to investigative estimates. The estimates display appropriate connection with the tentative consequences.

Deepak Kumar et al (2015), studied the use of GFRP for strengthening of structures. E- glass fibre is the most collective type of fibre use for GFRP wrapping. And concluded that structures like bridges built completely of FRPs proves exceptional stability and effective resistance to effects of environmental contacts. Most commonly used roving has 4000 filaments having diameter of 24fm (93x10 -3in).

Nachimuthu et al (2015) scrutinized on strengthening of corroded RC beam using Hybrid FRP wrapping technique and concluded that the Provision providing in the ACI code may be used as recommendations for use of FRP in reparation and convalescence of structures. All the beams furnished with GFRP strips attained the energy for which they're designed. The load resounding capability of the retrofitted beams had been discovered to be greater than of controlled beams, as a consequence the outwardly bonded FRP’s had been able to take more loads. The control bolstered beams, oxidized beams, corroded reinforced beams and retrofitted beams has the burden carrying capability of 163%, seventy nine%, 177% and 202% respectively.

Sarita R.Khot et al (2015) conducted investigation on repair of damaged RC beams superficially bonded with glass fibre strengthened polymer leaves and concluded that the load wearing capability for zero% harm diploma beams is increased after strengthening with unmarried and double layer of one hundred mm width of GFRP sheets to 34% and forty two% and five% and 17% respectively compared with regard beam. The 80% damage beams increases load wearing potential by 4.Forty five% when reinforced with 100mm width of GFRP plate in double layer as compared in regards beam.

Subramani et al (2015) conducted analytical exploration of bonded glass fibre reinforced polymer expanses with reinforced concrete beam using Ansys and concluded that rehabilitation by GFRP has proven itself to be a better feasible option than other methods. GFRP pasted beams performs better than the RCC beams. The experimental and analytical results are coinciding with each other.

Hema Shangari et al (2016) Studied analytical, arithmetical and tentative investigations on glass fibre sheet wrapped reinforced concrete beams. A predetermined element strengthened concrete model has been analysed by means of the usage of ANSYS finite detail software for both unstrengthen and reinforced RC beams. In analytical research six beams had been analysed using theoretical formulae. In experimental exploration six beams were casted and analysed underneath factor loading machine in a loading frame. The retrofitting is conquered with the adhesion of GFRP sheet to the entire volume of the beams. In this thesis absolutely six beams of size a hundred and fifty x 200mm2 with a span of 1200mm are modeled on the premise of 3 parameter which include beneath reinforced, balanced and over strengthened beams. The remaining failure load, deflection, crack pattern, percent of increase in strength of GFRP reinforced RC beams are associated with those of their counterpart specimen of manipulate organization to assess the efficiency of consolidation. From the arithmetical analytical and tentative research it's far determined that the remaining load resounding ability of RC beam wrapped with GFRP sheet is higher when associated to the unwrapped beams.

Prabhat Ranjan Prem et al (2016), Studied the Acoustic emission and flexural behavior of RC beams bolstered with UHPC overlap. Reinforced concrete beams with reinforcement ratios of zero.Fifty seven%, 0.89% and 1.30% are forged and after endangering to flexural impairment bolstered with extremely excessive performance concrete (UHPC) overlays of thickness of 10, 15 and 20 mm. The compound retrofitted beams acted monolithically underneath circuitous without debonding. The dented beams have been capable of recuperate its foundation flexural ability with 10 mm overlay. The growth in load wearing capability of beams with 15 mm and 20 mm overlay is 24% and 35% for beams with reinforcement ratio of 0.57%, 11.Fifty seven% and 18.Forty five% for 0.89% reinforcement ratio and 10.60% and 15.12% for beams with 1.Three% reinforcement ratio. During mechanical trying out, auditory emission (AE) parameters are examined for five stages of damage, which might be construction of hair line crack, observable crack in UHPC overlap, yielding of fundamental bars and finally devastating of composite beams. From parametric studies among upward push mind-set and commonplace frequency, it's miles observed that AE evaluation can be correctly used to decide crack motion and classify damage level of retrofitted beams.

Gnanapoongothai et al (2016), Carried an investigation on Pre-damaged RC beams reinforced with an overlay made from extremely excessive electricity UHSC algal merged (UHSCAC). The ultra high strength UHSC algal combined (UHSCAC) overlay become cast with 2% metallic integrity and 20% of paste alternative with the useful resource of algal precipitous. In this study 3 rays were examined by the usage of four- aspect twisting load. The control beam was tested till failure and closing 2 beams had been preloaded with ninety% final load of manage beam. These 2 beams had been tested after retrofitting with 5 mm and 10 mm viscosity of extraordinarily high electricity UHSC algal composite overlay (UHSCAC) respectively. These overlays were bonded at the anxiety face of the beam the use of epoxy bonding agent. All specimens have been subjected to a 4 factor check below load control in which load deflection values had been recorded. An experimental study is offered in which the retrofit capability of the extremely immoderate strong suit UHSC algal composite (UHSCAC) is implemented to Strengthen the pre-broken RC beams. The mode of failure, more power, crack sample and the burden deflection behavior of the examined beams are mentioned. The consequences verify the appropriateness of UHSCAC intersection to decorate the moment transport functionality without slow down the ductility of RC beam. The algal precipitate inside the connection complements the CS-H formation and boom the flexural functionality of combined beam.

Anju Mary Martin (2016), studied the impact of CFRP, GFRP and AFRP on retrofitting and to discover the best covering procedure the diverse 9 models of each FRP. Also, to look at the impact of wideness of FRP sheet and to test the overall show of the beam at the same time as FRP offer in layers. Also to check the aggregate of CFRP, GFRP and AFRP over a single beam. From the effects of the current study, the following decisions have been made: RC beam retrofitted with FRP has additional capacity wearing capability than manipulate beam. When RC beam is enveloped with carbon fibre reinforced polymer (CFRP), load sporting ability is extended via the use of 10% even as wrapped with GFRP, load carrying capability is multiplied by way of five%, three.15% growth in load sporting capacity when warped with AFRP, CFRP with 6mm thickness takes supreme load. FRP layer with ninety° fibre direction is more advanced & its load sporting capability is increases by using eleven. Fifty 4%. The aggregate of CFRP, GFRP and AFRP warped along a beam increases the load carrying functionality by using way of thirteen% however it's miles tons less than the boost whilst CFRP supplied in layers. Crack width and crack promulgation get reduced for reinforced beam and it's been concluded that the electricity of the RC beam is extended with the resource of retrofitting with fibre reinforced polymers.

Al-Azzawi and Karihaloo (2017), studied the presentation of reinforced concrete (RC) beams retrofitted with a self-compacting ultra-excessive-standard performance fibre- bolstered concrete (UHPFRC) below three-issue bend repeated loading. It is discovered that retrofitting the RC beams with a skinny UHPFRC strip at the anxiety face will growth their staying power restrict under a non-zero suggest stress cyclic loading from almost 40% to about 60% of their static 3-factor flexural energy. Moreover, the retrofitted beams behave as a composite form, without a delamination of the retrofit strip being observed in any of the lethargy checks.

Garyfalia et al (2017), Investigated the structural enactment of beams with blemished steel bars at low or medium level, after their patch repair and CFRP-EBR or NSM strengthening. All strengthened beams presented increased load carrying capacity with respect to the non corroded beam, even at medium corrosion level for the tensile reinforcement. Both EBR and NSM techniques may repair efficiently RC structures with corroded steel bars provided that the damaged concrete cover is replaced with suitable mortar patch. Developed 3D FE models were used to reproduce the experimental performance. For non-corroded beam and for reference corroded beams the P-d results and the flexural failure mode by squashy of the tensile reinforcement followed by devastating of the concrete in solidity zone were captured well from the FE models. The good performance of the numerical analysis is also demonstrated by comparing the experimentally and analytically predicted ultimate flexural capacity for all strengthened corroded beams. The prevailing failure modes of de-bonding of CFRP laminate and de- bonding at the epoxy-CFRP strips interface of the beams at maximum load were predicted well by the analysis in most of the cases.

Ramachandra Murthy et al (2018), Studied the flexural behavior of RC beams retrofitted with extremely-high power concrete. The enactment of (RC) beams retrofitted with a skinny ultra-excessive strength concrete (UHSC) strip turned into tested. It is located that the broken RC beams may be correctly reinforced and renewed by using the usage of a thin precast UHSC strip adhesively merged to the prepared tensile floor of broken beams. A finite element version became advanced to expect the miscarriage load and load– deflection behavior of the retrofitted RC beams. The version debts for the (i) degree of pre-damage, (ii) fracture conduct of concrete and UHSC through their respective specific fracture energy and pressure-crack opening relation, and (iii) elasto-plastic behavior of the reinforcing metallic. The version calculations are in exact promise with the test effects. It is determined that UHSC is an exquisite forthcoming applicant for the restore and analysis of broken RC flexural elements.

3. Materials and Methods

3.1 Properties of Cement

Cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Cement is the most widely used material in existence and is only behind water as the planet's most-consumed resource. In the present work, Ordinary Portland Cement of 53 grade conforming to IS 12269-1987 was used. Physical properties of Cement should be within the codal specified range of Value. The physical properties of cement are to be tested in accordance with IS 4031-1968 to know its suitability. Cement is the major raw material used in any construction. Therefore quality of cement must be checked before using it as a building material.

Table 3.1: Properties of Fine Aggregate

S.No.	Name of Test	Result
1	Specific Gravity	2.64
2	Water Absorption	1.20%
3	Sieve Analysis	Zone II
4	Fineness Modulus	2.9

3.1.1 Properties of Ultra High Strength Concrete

UHSC concept is based on the principle that a material with a minimum of defects such as micro cracks and inside voids will be able to realize greater load carrying capacity and greater durability.
The reinforcement involved in UHSC technology makes it possible to create more homogeneous cement based material by reducing the differences between cement and aggregate. The experimental research program is generally carried out with the application of the following basic principles.

- Enhancement of homogeneity by elimination of coarse aggregates.
- Enhancement of compacted density by optimization of the granular mixture, and application of pressure before and during setting.
- Enhancement of ductility by incorporating small sized steel fibres.
- Maintaining mixing and casting procedures as close as possible to existing practice.

The inclusion of fibres improves the tensile strength significantly and also makes it possible to obtain the required level of ductility. Measures relating to composition (homogeneity and granular compacted density) are the basis of UHSC concept and are applied in all cases.

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3.1.2 Concrete Damage Plasticity

Concrete damaged plasticity is capable of modeling all structural types of reinforced or unreinforced concrete or other quasi-brittle materials subjected to monotonic, cyclic or dynamic loads. This model is based on a coupled damage plasticity theory and the multi- axial behavior of concrete in damaged plasticity model governs by a yield surface which proposed by Lubliner et al. and was modified.

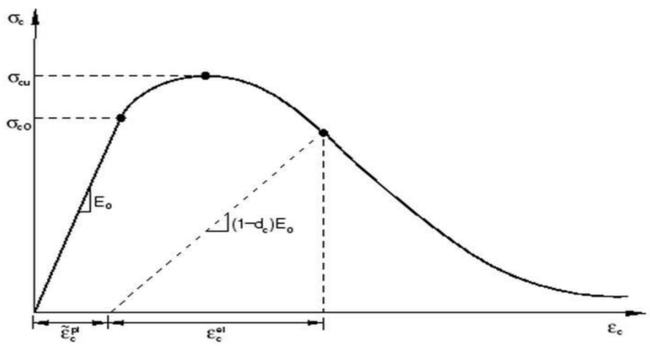

Figure 3.2: Response of normal strength

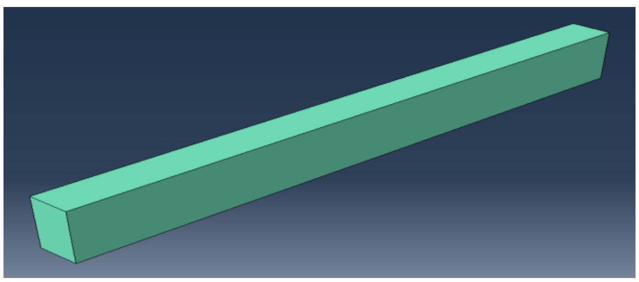

Figure 3.3: Concrete beam in Abaqus

The damage parameters are calculated by considering the first tangent modulus of elasticity in stress-strain curve obtained from the experimental test carried out in the laboratory. The input parameters required for the defining concrete material model.

4. RESULT AND DISCUSSION

The typical assembling of the different parts is done as shown in Fig. 5.9. To simulate the best possible numerical behavior as like experiment the two steel loading plates are modeled at the location of two loading points. The tie constraint is defined between the loading plate and the top surface of beam. The loading plate is also constrained as rigid body. The allocation of reinforcement is made in such a way that an effective cover of 20 mm at tension face and 20mm at compression face of the beam is assured. The interaction between the concrete beam and reinforcing steel is defined as "embedded region" constraint. The embedded element technique is used to specify that an element or groups of elements are embedded in host elements. ABAQUS searches for the geometric relationships between nodes of the embedded elements and the host elements. If a node of an embedded element lies within a host element, the translational degrees of freedom at the node are eliminated and the node becomes an "embedded node".

4.1Shock Wave Propagation

The assembled RC beams are then meshed with the specified seed size as per requirement. The well accepted fact on the FE analysis is that the preciseness of analysis is always superior with refined mesh at the same time it takes more time in convergence. Based on the experience and nature of problem the size of element is considered. To maintain the mesh uniformity the size length of the seed is taken as 10mm for concrete beam brick element and truss element of rebars. shows the typical meshing of modeled beam.

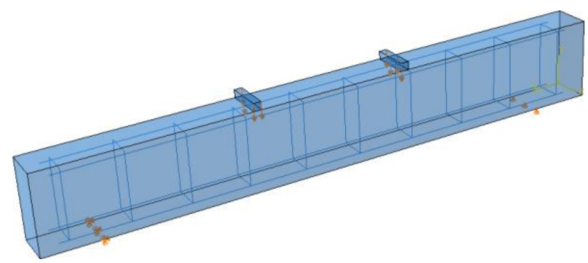

Figure 4.1: Assembling of the RC beam

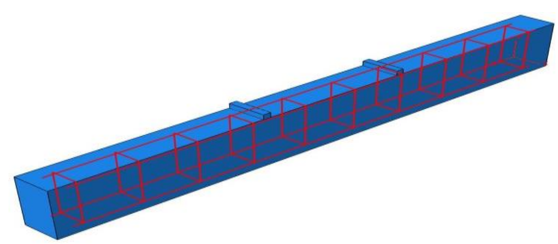

Figure 4.2: Load and Boundary condition

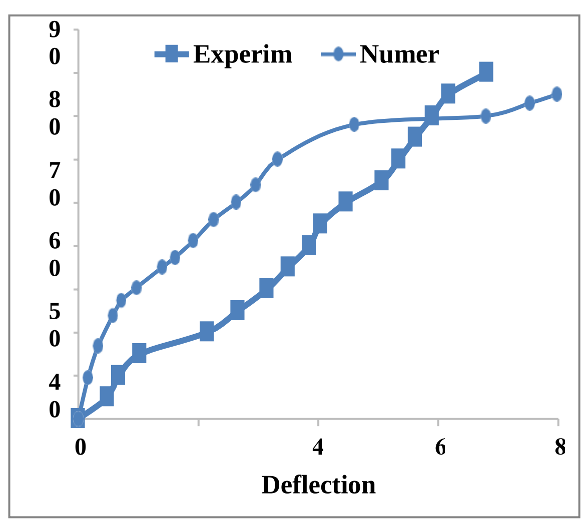

Figure 4.3: Load and deflection

5. Conclusions

Nonlinear finite element analysis (FE) has been carried out on selective RC members with and without strengthening. The non linear properties of concrete and steel are considered for simulation. The general purpose of finite element software, ABAQUS has been employed for FE modeling and analysis. The widely used concrete damage model available in ABAQUS has been employed to represent the nonlinear behavior of concrete. The integrity of all the elements i.e concrete and steel has been ensured by applying the appropriate constraint conditions. Static nonlinear analysis has been conducted and the responses such as peak load and the deformations are compared with the corresponding experimental observations. It is observed that the responses obtained from FE analysis are in close agreement with the corresponding experimental Value indicating that the developed FE models are robust and reliable.

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