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# STRENGTHENING OF REINFORCED CONCRETE SLAB USING COIR AND SISAL FIBERS

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**Abstract: Changes in the purpose of structure usage, errors in design and in construction, upgradation in codal provisions, and reduction in strength due to corrosion of steel reinforcement are conditions that often call for the strengthening of RC structures. So for the strengthening of structures is confined to the use of artificial fibres like carbon, glass or aramid fibres etc, very little work is being conducted to improve the performance of structures using natural fibres. Among the various natural fibres, coir fibres are of particular interest as these composites have high impact strength besides having moderate tensile and flexural properties compared to other lignocellulosic fibres.**

**An investigation was conducted experimentally, to study the behaviour of strengthened concrete slabs using Natural Coir Fiber Reinforced Polymers (NCFRP) and Natural Sisal Fiber Reinforced Polymers (NSFRP). Totally 9 number of scaled models of reinforced concrete (RC) slabs were cast and tested statistically under uniformly distributed load, out of which 3 slabs were control slabs, another three slabs were strengthened using NCFRP and the remaining 3 slabs were strengthened with NSFRP. The support condition was simply supported on all four sides of the slab. The focus was on the aspect of the structural behaviour of RC slabs strengthened by externally bonded fibre at the flexural zone. Studies on the load-deflection characteristics, the load-carrying capacity of all the slabs were carried out. From the experimental result, it was found that the load-carrying capacity of strengthened slabs was enhanced significantly compared to control slabs.**

***Key Words: Natural Coir Fiber, Natural Sisal Fiber, Strengthening of RCC slab.***

## I. INTRODUCTION

The current progresses in the application of composites for strengthening and rehabilitation of structures are increasing on the basis of industry involvement, definite requirements and national desires. And also, reinforced concrete structures that are designed prior to the application of seismic design codes, are the most part affected by the seismic load [1]. So, the demand in efficient strengthening techniques has resulted in research and development of natural or artificial composites for strengthening of existing buildings. The restoration or strengthening or retrofitting of concrete are rehabilitation work to the structural elements. So that these elements can perform for more years with less maintenance cost [2]. For centuries, research is going on in search of better alternatives for steels and alloys to combat the high cost of repair and maintenance of structures damaged by corrosion. Composite materials, formed by the combining two or more different materials on a microscopic scale, have gained cumulative admiration in the engineering field [3]. Natural or artificial Fiber Reinforced Polymer (FRP) is a relatively new composite material manufactured from fibers and resins. This has proven efficient and economical for the repair or retrofitting of new and deteriorated concrete or masonry structures. Application of FRPs became ideal in construction worldwide because of its mechanical properties [4]. A composite is developed by combining two materials in which one of the material is reinforcing segment, in the form of fibers, sheets, or particles, and is embedded in the other materials called the matrix segment. Composites are used because the properties of composites are superior to those of the individual components. These composites are valid for the construction of new structures as well as strengthening of existing structures [5]. Metals, natural fibers, ceramics, glasses, or polymers can be used as reinforcing fibers in composites. Due to excessive loading, change in use or in code of practice, exposure to adverse environmental conditions and/or inadequate maintenance, Strengthening of RC structures became effective and economical alternative. FRP composite reinforcement has been accepted in the construction industry as an encouraging substitute for conventional steel reinforcement in the past era.

Materials chosen for strengthening in this work, have functional efficiency and the capability of refining the several properties of the structures, by fulfilling the cause of improved quality and sustainability. These strengthening materials do not contaminate the environment and endanger bio reserves. As they are self-sustaining and stimulate self-reliance, and also help in the recycling of polluting waste into usable materials. Materials, local skills and manpower were utilised for this work. From this, local economy was benefitted by being income generating and being low in monetary cost. Thus far, artificial fibres like carbon, glass, aramid etc., are used as strengthening materials and measly naturally available materials or natural fibres are used as strengthening material. The use of composites in structures is mostly focussed on increase of the strength rather than addressing the issue of sustainability of these raw materials [6].
Alternate materials for artificial fibres, that is economical and at the same time offer equal or better properties, have to be developed. In developing countries including India, managing of solid waste generated from industrial production and agriculture activities is a challenging task. From agricultural activities sugarcane bagasse, rice husk, jute fibre, coconut husk, cotton stalk, etc. are generated as waste in larger quantities.
Converting such wastes as a sustainable construction material appears to be practical solution not only to pollution problem but also to the problem of the land-filling and high cost of building materials [7]. Abundant natural resources are available and research must be done on these, as strengthening material. By taking a step towards this, Coir and Sisal fibre are considered as a strengthening material in this work. Compared to other lingo cellulose fibres, Coir and Sisal reinforced composites have moderate flexural and tensile properties addition to impact strength, hence these materials gained specific importance in construction industry. Coir fibre was modified into Coir Fibre Reinforced Polymer (NCFRP) and sisal fibre into Sisal Fibre Reinforced Polymer as a strengthening material in this research work.

## II. EXPERIMENTAL PROGRAMME

Totally nine slabs of dimension 1050mm x 1050mm x 100mm were cast. Out of nine slabs, three elements were considered as control slabs. The remaining six slabs were strengthened by natural fibre reinforced polymers. All concrete slabs were designed according to IS 456 specification [8], and tested under static loading condition. 8 mm diameter steel bars of characteristic strength 415 MPa were provided along both sides at a spacing of 170 mm for all slabs.

### 2.1 Casting of reinforced concrete beam specimens

The M20 grade concrete was prepared using concrete mixer in the laboratory and placed in the wooden moulds where the reinforcement cage was placed. The Concrete was compacted and the top concrete layer of the slab was properly finished using a trowel. Slabs were de-moulded after 24 hrs and kept for curing for 28 days.

### 2.2 Chemical treatment of Coir fibres and Sisal fibres

An important properties of the good fiber reinforcement is the bond strength between polymer matrix and natural fiber. Natural fibers absorb high moisture content and have poor compatibility between fiber and matrix. Weak interfacial bonding will be developed between fibers and the hydrophobic polymers due to presence of hydroxyl and other polar groups in the natural fibers. The presence of water in the composite, leads to failure by delamination. To overcome this disadvantage, chemical treatment is provided, so that surface properties are altered [9]. By this chemical treatment, moisture absorption can be decreased and also, both physical and mechanical properties of the fiber can be altered [10].
In this experimental work, Coir fibers discarded as waste brought to the laboratory and cut into small pieces of length 30mm. These fibers immersed in 4% of NaOH solution at room temperature. After 2 hours, fibers were removed from the alkali solution and washed for several times with fresh water to remove any NaOH sticking to the fiber surface, by this the slippery nature was removed. Later these loose fibers were neutralized with dilute acetic acid, and then these fibers were washed again with distilled water, final pH of 7 was maintained by verifying using pH paper. The loose fibers were then dried at room temperature for 48 Hrs followed by oven drying at 60°C for 24 Hrs. Once the loose fibers have completely dried, then the fibers were used for developing composites. The above said chemical treatment procedure was adopted for sisal fibers also.

### 2.3 Preparation of Coir and Sisal Fibre composites

Based on the strengthening requirements, composite of natural fiber reinforced polymer was developed. The volume fraction of the fiber and polymer was calculated after the chemical treatment for coir and also for sisal. To develop the composite 25% of fiber by volume was taken along with epoxy resin and hardner. Here epoxy resin, Araldite LY556 and hardner, Aradur HY951 taken in the ratio of 100:10. Both resin and hardner stirred well and poured into a mould coated with silicon grease. Only about 40% of mixture was poured and spread uniformly into the mould. Over this layer, chemical treated natural fibers added and squashed to get wet in the polymer as shown in figure 1. Afer the squashing the rest of the polymer was added and a glass plate coated with silicon grease was placed and pressed uniformly. Later the glass plate was removed and an insulating paper coated with silicon grease was placed over the composite, and pressure was applied evenly.

Fig.1: Preparation of Coir Fibre Composite

### 2.4 Elongation test on Coir and Sisal Fibre composites

By using the Universal Testing Machine, percentage elongation and ultimate tensile strength carried by NSFRP and NCFRP composites were determined. Totally four Specimens of size 290 mm x 65 mm x 10 mm considered for the elongation test. The grip length of the specimen was 30mm on each side and gauge length was 230mm. A dial gauge of range 0.001 -10 mm was used to measure elongation of specimen. The test setup in a UTM was as shown in figure 2. The results obtained from the elongation test was tabulated in table1.

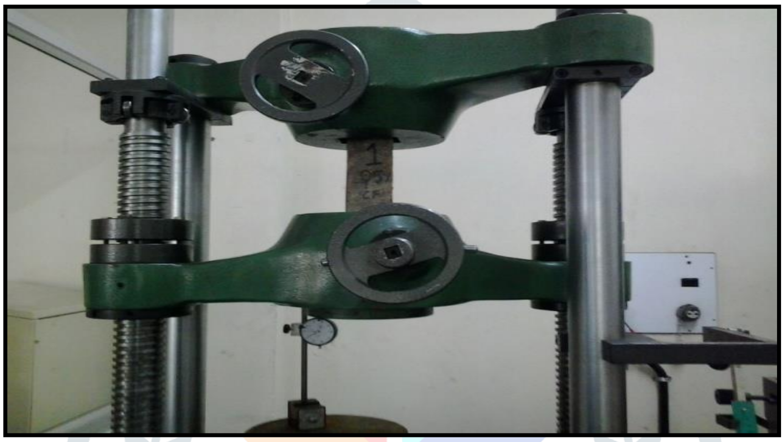

Fig 2: Setup under UTM for elongation test

Table 2.1: Summary of results obtained from elongation test.

| Type of Specimen | Gauge length of specimen (mm) | Final elongation of the specimen (mm) | Percentage of elongation (%) | Ultimate load (N) | Ultimate tensile strength (MPa) | Average tensile strength (MPa) |
|---|---|---|---|---|---|---|
| NCFRP | 230 | 3.32 | 1.4434 | 1119.32 | 1.722 | 1.845 |
| | 230 | 3.75 | 1.6304 | 1279.22 | 1.968 | |
| NSFRP | 230 | 10.23 | 4.4478 | 2078.74 | 3.198 | 3.075 |
| | 230 | 9.85 | 4.2826 | 1918.84 | 2.952 | |

### 2.5 Strengthening of slabs with composites of Coir fibre:

Strengthening process was started for concrete slab after curing for 28 days. Slabs were strengthened at flexure zone using NCFRP composite sheets. Strengthening by wrapping was executed by hand lay-up method and later these slabs were allowed to dry in room temperature for 7 days. The bond between the concrete surface and the strengthening material plays very important role on performance of strengthened structural elements. When strengthening is done on tensile face of concrete element the normal stress changes at this level [11]. Before wrapping of composites, the slab surface was cleaned using air blower to remove dust and debris.

The Nitowrap 30 primer contains two components, they are the base and a hardener. These components were mixed thoroughly and applied on the clean concrete surface of the slab. To maintain a thin layer of the epoxy primer as shown in figure 3, paint brush was used. This was allowed to cure for 24 hours before placing of the fibre sheet as per the guidelines of the manufacturer. The first coat of Nitowrap 410 was applied on primer and pre-cut NCFRP fabric for the desired dimension was placed as shown in figure 4. NCFRP fabric was pressed uniformly to remove voids between concrete surface and strengthening material. A Second layer of Nitowrap 410 was applied over the fabric to permeate the strengthening material. Later, strengthened specimens were kept at room temperature for about 7 days for air curing. The above said procedure was also followed for the application of NSFRP to strengthen the slab as shown in figure 5.

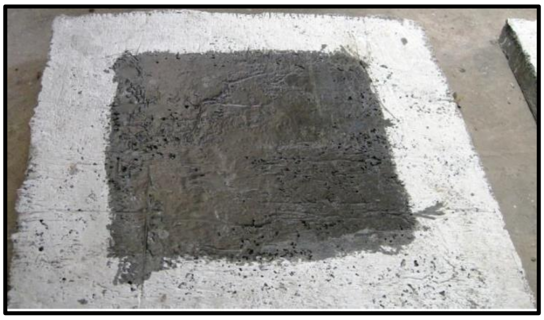

Fig. 3: Slab after the application of primer

Fig. 4: Slabs after strengthening by NCFRP

Fig. 5: Slabs after strengthening by NSFRP

### 2.6 Static tests on controlled and strengthened slabs

All slabs were subjected to a flexural test under static loading condition. The procedure of testing was the same for both controlled as well as strengthened slabs. The slabs were white washed thoroughly, in order to note the development of crack pattern in the specimen easily. The experiment was carried out with a 25 ton loading frame and a Loading Jack was fixed on top of the slab to apply static load. The loading channels were arranged such that, when the load is applied at the centre on one channel, then the load will be transferred to the slab by equally placed channels to give the effect of uniformly distributed load as shown in figure 6. The dial gauge was fixed at the bottom of the slab to measure the deflection at the centre. At an increment of 2 kN, the load was applied and the corresponding deflection was noted on the dial gauge.

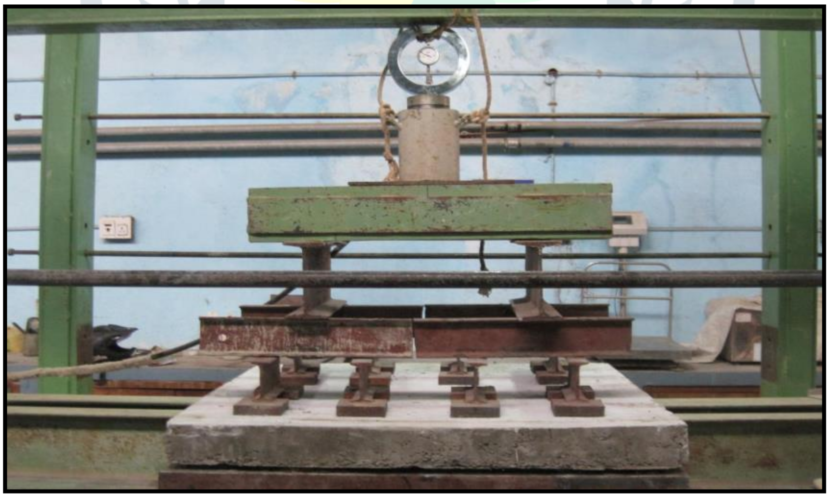

Fig. 6: Experimental set up for testing of slab under static loading.

## III. RESULTS AND DISCUSSION

### 3.1 Computation of the performance for the strengthened slabs

For the analysis of the performance of the slab, deflections were recorded using the digital dial gauges. As a measure of the stiffness of the slab, the deflection at the centre was recorded. The stiffness of the slab is inversely proportional to the deflection [12]. The performance of the strengthened RCC slabs by NCFRP and NSFRP was predicted by a load versus deformation relationship. Load versus deflection curves were developed for each specimen from the experimental work as shown in figure 7. The limit state of serviceability and limit state of collapse are two important criteria for design of any structural elements. To study the performance of any structural element deformation is considered up to service load, beyond this limit state of collapse is taken into account. The ultimate load gives the overall load carrying capacity of the specimen. The crack pattern of the control slab is as shown in figure 8. There was no de-bonding of the natural fibre composite sheet from the surface of the concrete slab till the failure of the specimen in both coir and sisal strengthened slabs. The failure pattern of the NCFRP and NSFRP was as shown in figures 9 and 10, respectively.

The first crack that appears on the bottom surface of the slab when the load is applied is taken as a cracking load ($P_{cr}$). And the corresponding deflection at this level of loading was taken as deflection at first crack ($\Delta_{cr}$). The load at which slab failed functionally was recorded as ultimate load ($P_u$) corresponding deflection as ultimate deflection ($\Delta_u$). The value obtained by dividing ultimate load by 1.5 was taken as working load ($P_w$) and the corresponding deflection ($\Delta_w$) was obtained from the load deflection graph. This procedure was followed for both control and strengthened slabs. The results obtained from experimental work are tabulated in table 2.

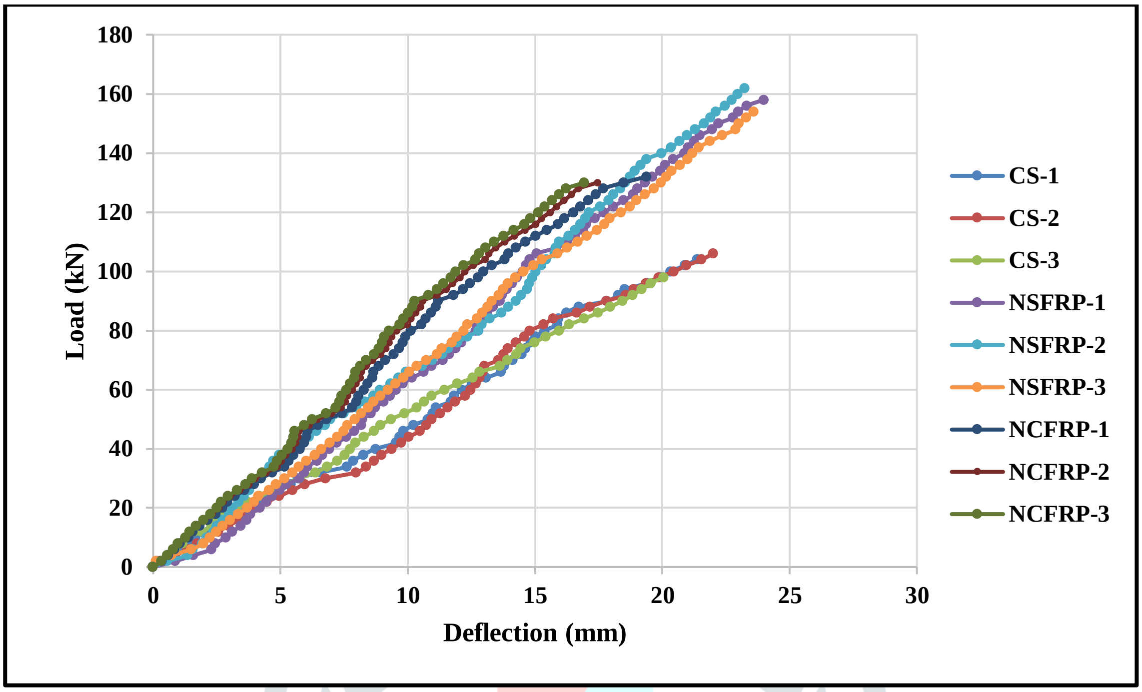


Fig. 7: Load versus deflection curves of CS, NCFRP and NSFRP strengthened slab

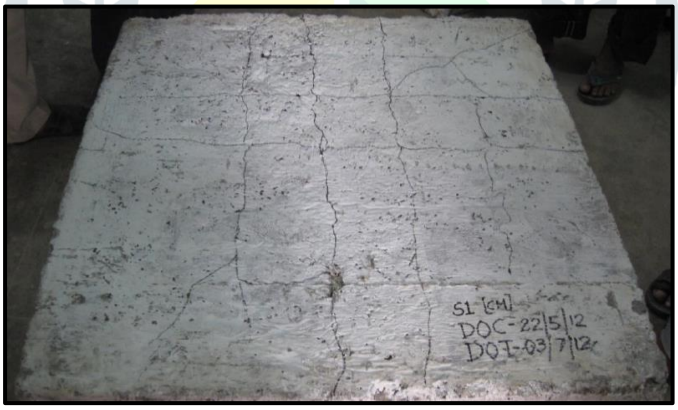


Fig. 8: Development of Cracks on control slab at bottom

Fig. 9: Development of Cracks on slab strengthened with NSFRP

Fig. 10: Crack Pattern of slab strengthened with NCFRP

Table 3.1 : Summary of results obtained from experimental investigation.

| ***Slab*** | ***$P_{cr}$ (kN)*** | ***$\Delta_{cr}$ (mm)*** | ***$P_w$ (kN)*** | ***$\Delta_w$ (mm)*** | ***$P_u$ (kN)*** | ***$\Delta_u$ (mm)*** |
|---|---|---|---|---|---|---|
| CS-1 | 54 | 11.119 | 69 | 13.791 | 104 | 21.367 |
| CS-2 | 58 | 12.262 | 70 | 13.572 | 106 | 21.997 |
| CS-3 | 52 | 9.874 | 64 | 12.562 | 98 | 20.05 |
| NCFRP-1 | 66 | 8.671 | 88 | 11.114 | 132 | 19.380 |
| NCFRP-2 | 68 | 8.378 | 86 | 10.319 | 130 | 17.455 |
| NCFRP-3 | 64 | 7.905 | 86 | 10.015 | 130 | 16.941 |
| NSFRP-1 | 60 | 9.546 | 104 | 14.807 | 158 | 23.894 |
| NSFRP-2 | 66 | 9.938 | 108 | 15.823 | 162 | 23.241 |
| NSFRP-3 | 58 | 8.932 | 102 | 14.945 | 154 | 23.591 |

## IV. CONCLUSIONS

From the load versus deflection graph along with the crack pattern developed on both control and strengthened slab, following conclusions were drawn.

a) The Reinforced concrete slabs strengthened by both coir and sisal fiber composite carry more load compared to that of un-strengthened control slabs.

b) From the elongation test, it was observed that the sisal fiber composite is more ductile compared to the coir fiber composite.

c) Load v/s deflection curves prove that, there is an increase in the stiffness of slabs strengthened by NCFRP composite compared to that of slabs strengthened by NSFRP and control slabs.

d) There was an enhancement in ductility and load carrying capacity of slabs strengthened by NSFRP composites compared to slabs strengthened by NCFRP.

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