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# MECHANICAL STUDY OF CONCRETE COLUMN WRAPPED WITH NATURAL FIBRES

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## ABSTRACT

Fibre Reinforced Polymers (FRP's) are made known into a vast field of civil engineering functions. FRP is defined as a material which is composite made of polymer matrix reinforced with fibres. Their ability involves strengthening and rehabilitation of structures. The use of FRP as an external confinement on cylindrical columns and on different wrapping patterns helps us to determine the structural behaviour and variation in confinement strength of structures. There are so many existing researches in artificial fibres for confinement of structures and this paper concentrates on wrapping of structures with Natural FRPs because of its superior endurance and environmental friendly directories. In this paper, 39 cylindrical specimens of diameter 150mm and height 300mm are cast with m40 grade of concrete in which 9 specimens are unwrapped and remaining 30 specimens are wrapped with FRPs. The wrapping pattern includes different types such as one layer full wrap, two layer full wrap, centre wrap, partial wrap and two layer wrap. Axial compressive load is applied on all specimens and their strength is compared to find an effective one. Two types of Natural fibres such as Flax and Hemp are used for confinement in which 15 specimens are wrapped with flax and remaining 15 specimens are wrapped with hemp. The percentage gain of confinement strength of wrapped specimens are compared with different patterns of wrapping and among with different fibres and also with unwrapped specimens.

**Keywords:** FRP, wrapping pattern, compressive strength, confinement strength.

## 1. INTRODUCTION

Concrete wrapped with fibre - reinforced polymers (FRP) is a technique used widely to reinforce and restore the material. Replacing synthetic fibres with natural fibres is a method of achieving sustainable construction [1]. Using both artificial and natural fibres, FRP is used extensively as external containment. FRP is a moderately new composite class produced from fibres and resins and has proven to be effective and cost - effective in the development and healing of new and deteriorating civil engineering structures [2]. The natural fibre-reinforced polymer composite is promptly growing both in terms of their industrial applications and vital research. They are renewable, cheap, completely or partially recyclable and biodegradable. These composites are having low density and reasonable mechanical properties make them an striking due to easy obtainability and renewability of raw materials [3]. When six slender RC columns wrapped with fibre reinforced polymer which are all having the slenderness ration from 4.5 to 17.5 undergone axial compression test, the load carrying capacity is more effective than the ordinary conventional columns and also another factor is that the effect of reinforcement decreases when the slenderness ratio is increased. This implies that the slenderness ratio play a significant role in increasing the capacity of the load carrier [4]. In another case, when the FRPs such as sisal and jute are wrapped along the concrete in substitute for artificial fibres where the thermally conditioned FRPs have better tensile strength and also flexural strength is enhanced by temperature conditioning which may be due to effective cross-linking, adhesion factor and dehydration, which gives sufficient applications for natural fibre[5].Observing the ultimate load of BFRP wrapping columns using different configurations and layers is higher than that of non - BFRP wrapping columns. Single layer full wrap, double layer full wrap, single layer horizontal strip, double layer horizontal strip, single layer vertical strip, double layer vertical strip wrap are 57%, 69%, 17%, 36%, 13% and 26% respectively. Increasing Ultimate Load and Ductility Index is responsible for BFRP lateral containment. The direction of confinement is an important criterion for increasing the capacity of load carrying [6]. Natural fibres are the future source of cost effective, environment friendly and recyclable one. Prior to synthetic fibres which are all having better strength, various natural fibre conditioning and applications will prove effective and non-environmental impact [7]. They can withstand maximum and minimum main stresses and resist deformation in a similar way of wrapping RC beam with Kevlar and jute fibre [8]. Therefore, better awareness and encourage must be given for using the natural fibres that are an easily available source and an attempt should be made to study the probabilities of using hemp and flax as FRP in structural column reinforcement, which attempts to improve structural properties.

## 2. MATERIAL INVESTIGATION

### 2.1 CEMENT, FINE AND COARSE AGGREGATE

Ordinary Portland Cement (OPC) of grade 53 is used for concrete mixture. The physical properties of OPC are show below in table and they are calculated in accordance with IS: 12269:1987. River sand is used as fine aggregate which are available in local areas. Size of coarse aggregate used for the concrete mixture is 20mm. The physical attribute of aggregates is shown in table 1and tested in accordance with IS: 2386-1963.

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**Table-1.** Physical attributes.

| S. No. | Physical attributes | | |
|---|---|---|---|
| | Stipulation | | Pan out |
| 1 | Specific gravity | Cement | 3.12 |
| | | Fine aggregate | 2.45 |
| | | Coarse aggregate | 2.86 |
| 2 | Fineness of cement | | 8% |
| 3 | Consistency of cement | | 29% |
| 4 | Initial setting time | | 50 min |

## 2.2 CHEMICAL ADMIXTURE

Ceraplast 300 is a high grade super plasticizer based on naphthalene, highly recommended for increased workability and high early and ultimate strength of concrete. 0.3% to 1.5% by the weight of cement is the recommended dosage to be used. Maximum dosage may have to be increased to 3% of cement. The properties are given below Table-2.

**Table-2.** Properties of chemical admixture.

| Supply form | Liquid |
|---|---|
| Colour | Brown |
| Specific gravity | 1.2± 0.3 |
| Chloride elements | Nil |

## 2.3 HEMP FIBRE

Hemp is like jute, kenaf, flax, ramie, a bast fibre plant. Hemp fibers among all natural textile fibres are one of the strongest and most durable. Hemp fibres exhibit similar properties in fibre length, durability, strength, absorption, and anti - microbial properties as all natural bast fibres and excels. The processing of this fibre produces various types of decorative textile products. It also combines with other fibres and gives the fibre extra strength. It is shown in Figure-3.

**Table-3.** Hemp fibre properties.

| Tensile strength (MPa) | 900 |
|---|---|
| Water absorption (%) | 85-105 |
| Density(kg/m$^3$) | 1500 |
| Modulus of elasticity (GPa) | 34 |
| Elongation at break (%) | 1.62 |

**Figure-1.** Hemp fabric.

## 2.4 FLAX FIBRE

Flax is the strongest of cellulosic fibres in nature. It is a bast fibre extracted from the flax plant's stem's skin. It is a very strong fibre because it allows its extremely long polymers to form more hydrogen bond than cotton polymers because it is a very crystalline polymer system. Tenacity varies from 18 - 30 inches, which is shown in Figure-2 below. It has the best heat resistance and conductivity of all textile fibres commonly used. Flax properties are given below:

**Table-4.** Flax fibre properties.

| Tensile strength (MPa) | 1339±486 |
|---|---|
| Modulus of elasticity (GPa) | 58±16 |
| Density(kg/m$^3$) | 2550 |
| Elongation at break (%) | 3.27 |

**Figure-2.** Flax fabric.

## 2.5 PRIMER AND SATURANT

For better adhesion and smooth concrete surface, Nippon Primer Coat is used to fill the pores in the surface and Saturant are generally Resin and hardener which are termed as Part A and Part B. Epoxy is made of medium viscosity epoxy resin (LY 556) and hardener (HY951) which are healing together in temperature conditioning with diluent DY02.Go Green products Pvt. Ltd., Chennai supply all materials. In the ratio of 3:1, the resin and hardener are mixed. Table-5 lists the properties of the materials. Overall, the polymetric epoxy resin thermoset have good mechanical properties, corrosion and chemical resistance and the way of processing is easy.

**Table-5.** Property of Part A and Part B (Resin and hardener).

| Ingredients | Trade name | Chemical name | Density(g/cm$^3$) |
|---|---|---|---|
| Epoxy resin | LY556 | Diglycidal Ether of bisphenol A (DGEBA) | 1.16 |
| Hardener | HY 95 | Triethylenetetramine (TETA) | 0.95 |

## 3. EXPERIMENTAL SETUP

### 3.1 MIX PROPORTION

Grade of concrete for this is mix is M40.The mix ratio is 1:1.74:3.32. As per IS10262:2009 code, mix is designed. Totally 39 cylindrical specimens are made. Amount of volume required are given below in Table-6.

**Table-6.** Volume requirements of concrete mix.

| Material | Volume(kg/m$^3$) |
|---|---|
| Cement | 383.2 |
| Fine aggregate | 667.341 |
| Coarse aggregate | 1271.03 |
| Chemical admixture | 7.66 |

### 3.2 FABRIC LAYOUT USING EPOXY RESIN

All the concrete specimens are cured for 28 days. After curing, primer coat is applied on the surface for levelling and filling up the pores on the surface and allowed to dry for four hours. After primer coating, the surface is saturated with epoxy resin and the fabric is also saturated with the same and it is mounted on the surface using hand. While applying the fabric, constant pull is maintained to avoid air gaps between the surface and the FRP material. It is then left for 48 hrs. Depending upon the pattern of wrapping, fabric is sealed onto the concrete surface.

**Figure-3.** a) fabric saturated with epoxy3 b)wrapping around the surface.

### 3.3 TYPES OF WRAPPING PATTERN (BOTH HEMP AND FLAX)

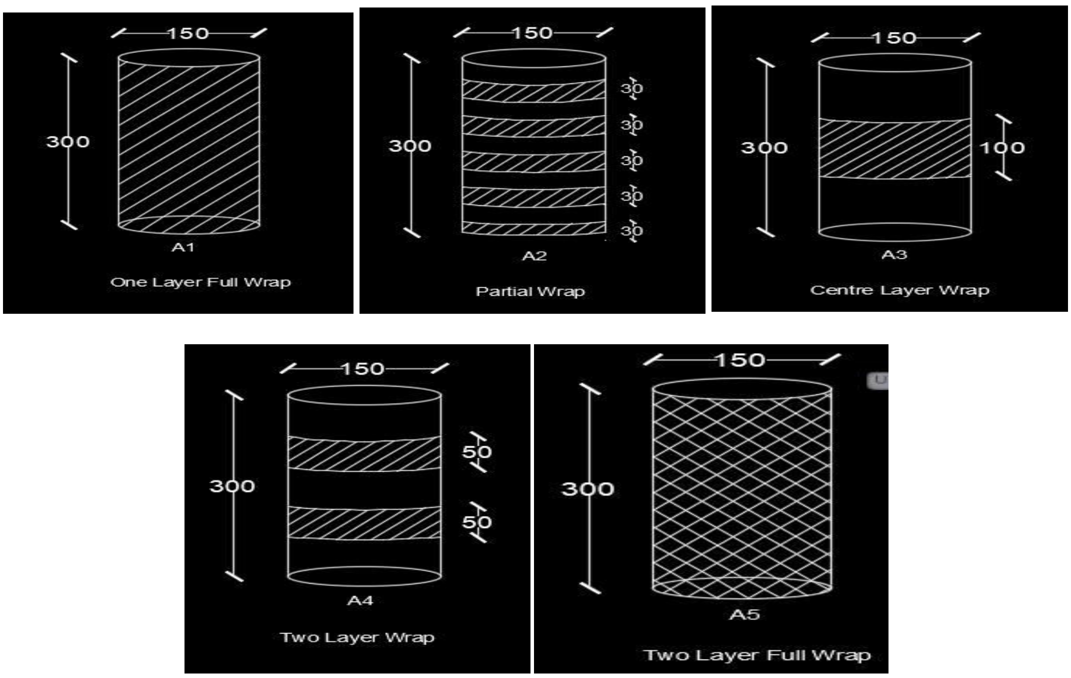


**Figure-4.** CAD diagram of different wrapping patterns and its dimensions.

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**Table-7.** Patterns of wrapping

| | |
|---|---|
| A1 | One layer full wrap |
| A2 | Partial wrap |
| A3 | Centre layer wrap |
| A4 | Two layer wrap |
| A5 | Two layer Full wrap |

The above diagrams reveal the patterns of wrapping and the dimensions for every pattern and they are denoted by the following terms. All dimensions are in mm.

## 4. EXPERIMENTAL RESULTS

### 4.1 COMPRESSIVE AND SPLIT TENSILE STRENGTH OF CONVENTIONAL CONCRETE

In CTM, all cylindrical specimens undergone compressive axial load. The testing machine is loaded at 200N / minute with a loading capacity of 3000kN. The ASTM C39 is used to test the cylindrical specimens as a standard method.

The below Table-8 shows the compressive and split tensile strength in which the specimens are cured at 7, 14 and 28 days.

**Table-8.** Compressive and split tensile strength of concrete specimens.

| Testing | 7 days ($N/mm^2$) | 14 days ($N/mm^2$) | 28days ($N/mm^2$) |
|---|---|---|---|
| Cube(Compressive strength) | 38.16 | 45.56 | 49.97 |
| Cylinder(split-tensile strength) | 3.05 | 3.48 | 3.99 |

The trail and error method for testing the specimens of grade m40 to attain its target strength in both cube and cylindrical specimens.

### 4.2 TESTING RESULTS OF COLUMNS WRAPPED WITH FLAX FABRIC (BI-DIRECTIONAL)

**Table-9.** Compressive strength of unwrapped and wrapped specimens of flax fabric.

| S. No. | Wrapping Type (ht-300mm, dia 150mm) | Ultimate load (kN) | Compressive strength ($N/mm^2$) | Average Compressive strength ($N/mm^2$) |
|---|---|---|---|---|
| 1 | Conventional | 750 | 42.42 | |
| | | 730 | 41.29 | 42.23 |
| | | 760 | 42.98 | |
| 2 | One layer full wrap(A1) | 940 | 53.17 | 53.17 |
| | | 960 | 54.30 | |
| | | 920 | 52.04 | |
| 3 | Partial wrap(A2) | 870 | 49.21 | 49.39 |
| | | 890 | 50.34 | |
| | | 860 | 48.64 | |
| 4 | Centre layer wrap(100mm)(A3) | 900 | 50.90 | 50.90 |
| | | 920 | 52.04 | |
| | | 880 | 49.77 | |
| 5 | Two layer wrap(50mm each)(A4) | 790 | 44.68 | 46.38 |
| | | 850 | 48.08 | |
| | | 820 | 46.38 | |
| 6 | Two layer full wrap(A5) | 1160 | 65.61 | 66.74 |
| | | 1180 | 66.74 | |
| | | 1200 | 67.87 | |

The above Table shows the confinement strength of different wrapping patterns in which the two layer full wrap has percentage gain of 57.33 % when compared with the unconfined specimen followed by one layer full wrap, Centre layer wrap, Partial wrap and two layer wrap which is 25%, 20%, 16.45% and 9.33% respectively. But there is no much difference in percentage gain between A1 and A3 wrapping which is 5% and also between A2 and A3 wrapping which is 3.55%. The fact that the maximum load of the unwrapped specimen was attained when the cracks developed and propagated but the wrapped specimens resist load beyond the failure of specimen as the FRP

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provide the lateral support. Depending upon the type of wrapping, the confinement strength varies with A5 wrap exhibiting higher strength in which they failed in an explosive manner with greater sound as FRP wrapping experienced excessive tension in the hoop direction. After failure of specimens also, the concrete is bonded to the FRPs which shows the better adhesion character of it. The major fact is that the A3 wrap has very much less difference of confinement strength when compared with A1 wrap.

### 4.3 TESTING RESULTS OF COLUMNS WRAPPED WITH HEMP FABRIC (UNI-DIRECTIONAL)

**Table-10.** Compressive strength of unwrapped and wrapped specimens of hemp fabric.

| S. No. | Wrapping Type (ht-300mm, dia 150mm) | Ultimate load (kN) | Compressive strength (N/mm$^2$) | Average Compressive Strength (N/mm$^2$) |
|---|---|---|---|---|
| 1 | Conventional | 750 | 42.42 | 42.23 |
| | | 730 | 41.29 | |
| | | 760 | 42.98 | |
| 2 | One layer full wrap(A1) | 830 | 46.96 | 48.10 |
| | | 870 | 49.23 | |
| | | 850 | 48.10 | |
| 3 | Partial wrap(A2) | 780 | 44.14 | 45.08 |
| | | 790 | 44.70 | |
| | | 820 | 45.08 | |
| 4 | Centre layer wrap(100mm)(A3) | 800 | 45.27 | 46.78 |
| | | 850 | 48.10 | |
| | | 830 | 46.96 | |
| 5 | Two layer wrap(50mm each)(A4) | 770 | 43.51 | 44.47 |
| | | 800 | 45.27 | |
| | | 790 | 44.70 | |
| 6 | Two layer full wrap(A5) | 1002 | 56.70 | 58.37 |
| | | 980 | 55.45 | |
| | | 1110 | 62.81 | |

Similar to Flax fabric results, A5 wrap exhibits higher percentage gain of 37.48% than the unconfined specimen and order-wise decrease in percentage gain of wrapping patterns is same as flax which is 13.98%, 10.49%, 6.27% and 4.83% respectively. Comparing two FRPs, Flax has higher confinement strength due to its high modulus of elasticity, tensile strength, adhesion characteristics. The testing of wrapped specimens in CTM is shown in below Figure-5.

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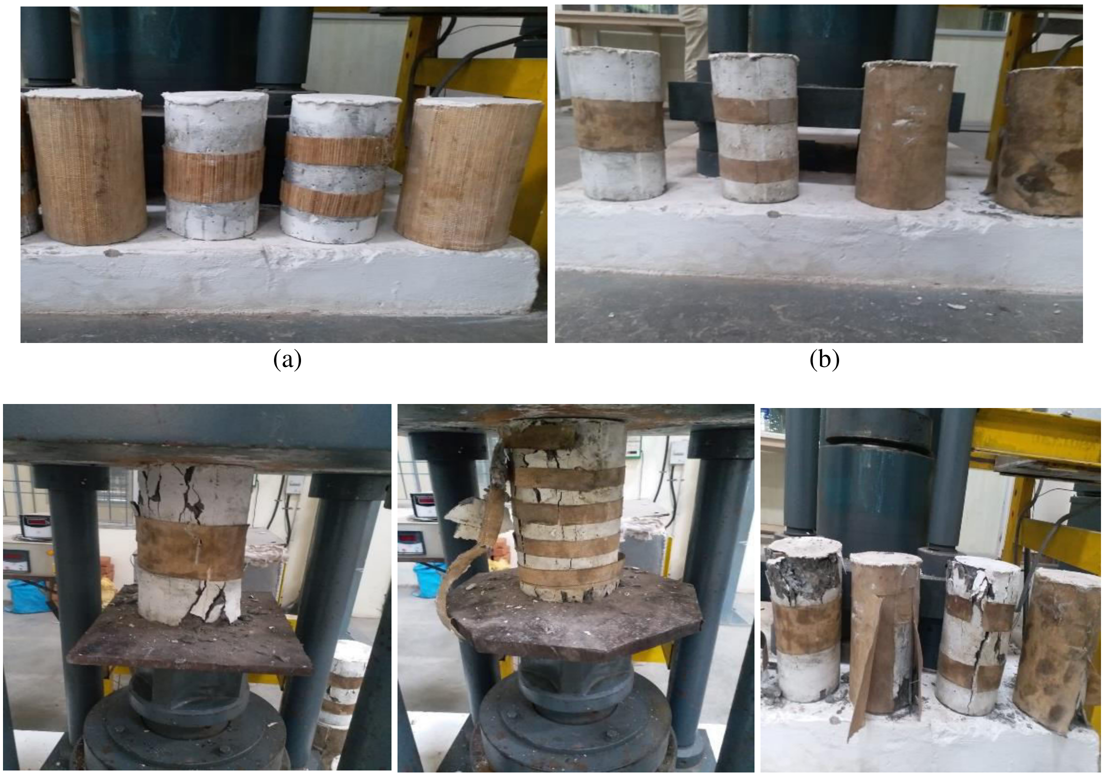

(a) (b) (c) (d) (e)

**Figure-5.** (a) & (b) before testing of Wrapped specimens (Hemp & Flax) (c) Failure of centre layer wrapped specimen (d) Failure of partially confined specimen (e) After testing of specimen

### 4.4 DATA COMPARISON AND PERCENTAGE GAIN OF SPECIMENS

**Table-11.** Percentage gain of different pattern of specimens of flax fabric.

| Description of strength (Flax fibre) | Conventional | One layer full wrap | Two layer full wrap | Centre layer wrap | Two layer wrap | Partial wrap |
|---|---|---|---|---|---|---|
| Confined Strength (MPa) | 42.42 | 53.17 | 66.74 | 50.90 | 46.38 | 49.4 |
| % Gain | | 25 | 57.33 | 20 | 9.33 | 16.45 |

**Table-12.** Percentage gain of different pattern of specimens of hemp fibre.

| Description of strength (Hemp fibre) | Conventional | One layer full wrap | Two layer full wrap | Centre layer wrap | Two layer wrap | Partial wrap |
|---|---|---|---|---|---|---|
| Confined Strength(MPa) | 42.42 | 48.10 | 58.32 | 46.8 | 44.47 | 45.08 |
| % Gain | | 13.98 | 37.48 | 10.49 | 4.83 | 6.27 |

The below Figure-6 shows the comparison graph of confinement strength of different wrapping patterns with conventional specimen

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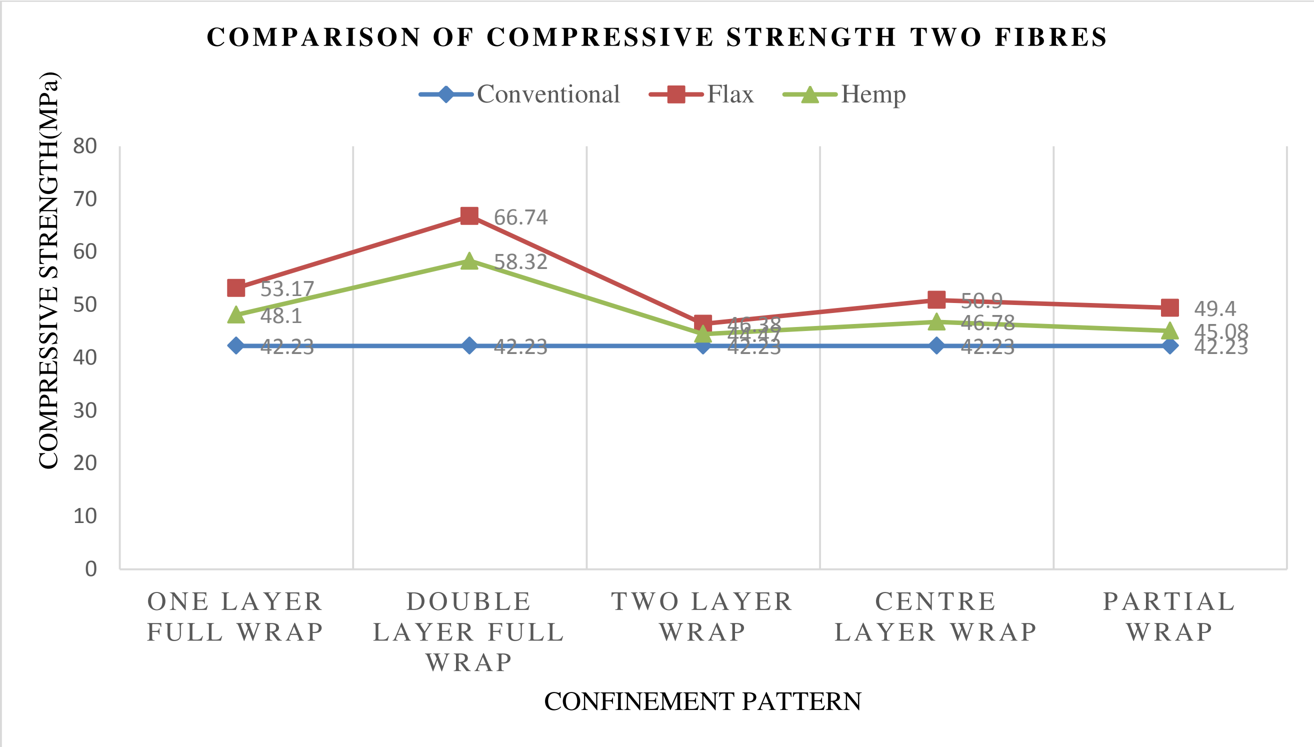


**Figure-6.** Comparison graph of confinement strength

Comparing the two FRPs of percentage gain, Flax has higher percentage gain of 57.33% in A5 wrapping whereas in hemp it has 37.48%. Similarly when we compare each pattern of wrapping, for A1 wrapping flax has8.02% greater than hemp fabric and has 9.52%, 4.5%, 10.18% difference of percentage gain for A3, A4, A2 wrapping respectively.

## 5 DISCUSSION AND CONCLUSIONS

### 5.1 DISCUSSIONS

From the results obtained above, the following conclusions have been made:

a) Following are the location of specimen failure in wrapped specimens:

| | |
|---|---|
| (i) Two layer full wrap | -Middle half region of concrete surface |
| (ii) One layer full wrap | -Middle half region of concrete surface |
| (iii) Centre layer wrap | -Top and bottom surface of concrete |
| (iv) Two layer wrap | -Throughout the concrete surface |
| (v) Partial wrap | -Throughout the concrete surface |

b) Among all wrapping patterns, two layer full wrap exhibits higher percentage gain of confinement strength which is 57.33% and 37.49% in flax and hemp FRP.

c) Failure of wrapped specimens actually occurred in middle part for fully wrapped specimens whereas on top and bottom and also throughout the concrete surfaces for partially wrapped which includes centre and two layer wrapped. Loss in compressive strength is more with centre part of crack than the others.

d) Comparing one layer full wrap and centre layer wrap, only 5% is the percentage difference between the former and latter in flax FRP and 3.48% in hemp FRP. Economic wise, Centre layer wrap is considered.

e) Two layer wrapping exhibits the least percentage gain of 9.33% and 4.83% in flax and hemp.

f) Comparing both Flax and Hemp FRP, flax exhibits higher percentage gain in all wrapping patterns than hemp which is due to its high tensile strength and modulus of elasticity.

g) For ultimate result, full layer wrapping is considered and with increase in no of layers gives better enhancement. But the centre layer wrapping is preferred economical over one full layer wrapping.

h) In general, both flax and hemp FRP exhibits good confinement strength and their use in engineering field would make a better impact for making a sustainable environment rather than using the synthetic fibres.

## 5.2 CONCLUSIONS

a) Increase in confinement strength greatly depends upon the maximum confining pressure that FRP can apply.

b) The load carrying capacity increases with varying wrapping patterns than the conventional specimens.

c) On the economic point of view and confinement strength basis, centre layer wrap is preferred to be used.

d) The utilization of these natural fibres makes a greater impact on environment rather than using synthetic fibres and it is to be encouraged in all spheres of structural applications.

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