# Comparative Study on the Mechanical Properties of Cell filled and Whitetopped Concrete Overlay with Human Hair as Pavement Rehabilitation Method

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*Abstract*—**During the past two decades, the issue of upgrading the existing pavements has become of great importance. The use of fibre reinforced concrete in rehabilitation of pavements has become very popular. Fibre reinforced concrete is an economical method to overcome flexural failure, micro cracks etc. Human hair is a non-degradable fibre which can be used as a reinforcement material in concrete. Human hair fibre modified concrete can be used as cell filling and whitetopped concrete has pavement rehabilitation methods. In whitetopping a concrete overlay is provided over the existing deteriorated bituminous pavement. In cell filled concrete overlay a mesh of cell is provided and is filled with concrete. In this study the mechanical properties such as compressive strength, tensile strength and flexural strength of whitetopped and cell filled concrete overlays incorporated with human hair is investigated.**

***Keywords: Whitetopped concrete overlay, Cell filled concrete overlay, Human Hair Fibre reinforced concrete, Pavement Rehabilitation, Mechanical properties.***

## I. INTRODUCTION

### A. General

Road traffic is increasing steadily over the years. This is an international phenomenon. An international forecast predicts that such increase will continue in near future. Even in case of developed countries, there is a shortage of funds required for new infrastructure projects, both for constructing them and more significantly towards their maintenance and repairs. The position in the context of a developing country like India is obviously far worse. As a result, more and more roads are deteriorating and the existing pavement structure as a whole is often found to be inadequate to cope up with the present traffic. The proper strengthening and maintenance of roads is urgently required to ensure balanced regional development and alleviation of poverty as they connect the villages and other small town centers harbouring backwardness. A majority of these roads do not have traffic worthy pavement. The cost of strengthening and repair by Conventional method of this large network will need huge resources both physical and financial which are quite scarce. Most of the existing flexible pavements in the network broadly have thin bituminous layers. These bituminous pavements were get deteriorated with time. Most of our roads exhibit deficiencies like rutting, fatigue cracking, and thermo cracking.

Under the present rehabilitation programs, normally the overlays are being placed over such cracked or rutted bituminous layer without making any significant efforts to seal these cracks properly. Sometimes the cracks are so extensive and widespread that it is not even possible to fully seal them, with the result that such newly overlaid surfaces again exhibit rutting/cracks in a very short time. Reflection cracks are one example frequently encountered with such overlay repairs. Such repairs do not enhance their expected life and bring avoidable criticism from the public. Such practices of strengthening by overlaying thus need to be discarded. Any alternative method of strengthening or repairing of roads should, therefore, be based on their durability rather purely by initial cost. The cost comparison for such alternative strengthening/repair methods should be based on the concept of life-cycle cost. Alternative methods of strengthening/repairs should take care of the deficiencies of the existing bituminous layers. Rutting and cracking are overwhelmingly observed to be general nature type of distress on most of bituminous pavements. This could be remedied by milling the existing surfaces. Milling significantly de-stresses the cracked/rutted section. However, in isolated stretches, where the pavement is badly distressed due to sub-grade failure etc., full depth repair needs to be resorted to. Whitetopping and Cell filled concrete overlay were investigated as rehabilitation methods of moderately distressed bituminous concrete pavements and intersections. Now a day these have much import role for pavement preservation. Here cement concrete overlays over existing bituminous pavements have been used as a rehabilitation option for more than 80 years [1].

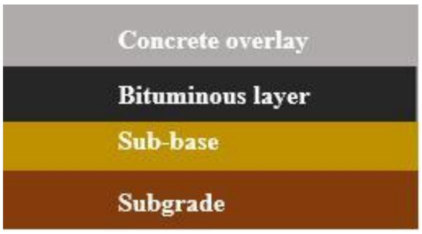


Fig 1 Cross-section of a pavement shows the concrete overlay over bituminous layer [1]

## B. Maintenance and Rehabilitation

Even the best designed and built concrete pavements will eventually wear out and require maintenance or rehabilitation. It is important to recognize that timely maintenance, or pavement preservation, can substantially extend pavement life and delay the need for rehabilitation. Rehabilitation of today's highways requires traffic management, contracting and construction techniques that are quick and efficient and that result in a pavement with superior ride ability and service life.

Fig 2 Deteriorated bituminous pavement [2]

## C. Overlay Options

An overlay is a layer of suitable thickness provided on top of an existing pavement to improve its structural adequacy and riding quality. It should be distinguished from resurfacing or resealing, which are part of periodic maintenance operations and which involves thin layers intended to seal cracks, restore anti-skid property and smoothen rough riding surface. Overlays are part of what are commonly termed "rehabilitation" or "strengthening" measures. In India, resurfacing or resealing operations are financed from maintenance grant, whereas overlays are financed from capital budgets. Thus, fund for overlays comes from plan outlays.

## D. Purpose of Overlay

The principal purpose of an overlay is to restored or to increase the load-carrying capacity, or life, or both, of the existing pavement. In achieving this objective, overlays also restore the ride ability of the existing pavement which have suffered due to rutting and deformations. Besides, an overlay also rectifies other defects such as loss of textures.

## E. Whitetopped Concrete Overlay (WTC)

Whitetopping (WT) is a way of strengthening or rehabilitating deteriorated asphalt pavements by Plain Cement Concrete (PCC) overlay with or without fibers. Ultra-Thin Whitetopping (UTWT) and Thin Whitetopping (TWT) are being increasingly practiced in USA and West Europe. Demarcation between UTWT and TWT depends upon the thickness of the Plain Cement Concrete (PCC) overlay and degree to which it is bonded with the existing underneath bituminous layer. For thickness up to 100 mm, it is designated as UTWT and for thickness more than 100 mm but up to 200 mm; it is called Thin Whitetopping (TWT). Beyond 200 mm thickness, it is called Conventional Whitetopping like our ordinary PCC pavements. The governing design principles are somewhat different than those of normal concrete pavements. In case of UTWT, the bond between the existing asphalt pavement and Plain Cement Concrete (PCC) overlay is considered mandatory. However, in case of TWT the bonding is desirable but not mandatory. Another difference is that for these overlays joints are spaced close. Normal spacing of joints is at 0.6 m to 1.2 m and in some cases it is up to 1.5 m. These joints are normally not doweled. No tie roads are also provided in the longitudinal joints. The thickness of UTWT is between 75 to 100 mm. A thickness of up to 150 mm is normally provided even in case of thin whitetopping [1].

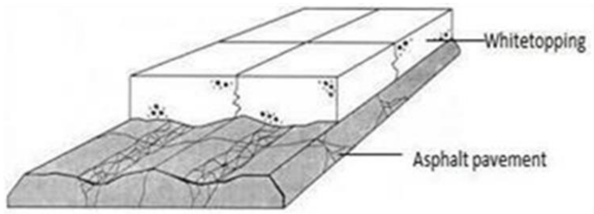


Fig 3 Pavement structure with whitetopping [1]

Fig 4 Finished whitetopped pavement

## F. Cell Filled Concrete Overlay (CFC)

As an alternative, for better structural performance and low maintenance, a new pavement technology called plastic cell filled concrete block pavement (PCCBP) was developed in South Africa. Plastic cell formwork has been successfully used for canal lining, reinforced earth treatment, etc. The cells are tensioned and spread across the foundation layer and concrete is filled and compacted into the cells. Upon compaction, the cell walls get deformed, resulting in interlocking of adjacent individual concrete blocks. Cell-filled concrete (CFC) overlay is one of cast-in-situ block pavement Deformed walls of plastic sheet behave like a hinge and the blocks can undergo limited rotation. Thus, flexibility is introduced into the cement bound (rigid) surfacing. Cell filled concrete overlay also a better choice for the rehabilitation of village roads where no need any bigger machine like which needed for Whitetopping construction [3].

Fig 5 Cell filled pavement under construction and compaction of concrete [4]

### F. *Human Hair Fibre*

Human hair is considered as a waste material in most parts of the world and is a common constituent found in municipal waste streams which cause enormous environmental problems. This particular topic has been first chosen as a method of finding the possibilities of hair rather than considering it as a non-bio degradable waste material. It is also available in abundance and at a very low cost. It reinforces the mortar and prevents the spalling of concrete. The properties like high tensile strength, unique chemical composition, thermal insulation etc. makes it suitable to be used as a reinforcing material.

Fig 6 Human hair fibre

## II. OBJECTIVE

The main objectives of the study is:

- To study the mechanical properties of Cell Filled Concrete (CFC) and Whitetopped Concrete (WTC) overlays with human hair as reinforcing material in concrete in the laboratory

## III. METHODOLOGY

### A. *Procurement of materials*

The different materials that were collected are,

- Cement: Portland pozzolano cement
- Manufactured sand as fine aggregate
- Coarse aggregate
- Water
- Plastic Sheet

### B. *Testing of materials*

(a) Cement: Properties of cement such as consistency, initial setting time, final setting time and Specific gravity of cement tested as per IS 1489 (Part 1): 1991, IS 4031(Part 4): 1988, IS 4031 (Part 5): 1988 and IS 4031 (Part 11): 1988.

(b) Fine aggregate: Properties such as fineness modulus, Specific gravity, Water absorption, and bulk density as per IS 383-1970 and IS 2386 (Part III) – 1963.

(c) Coarse aggregate: Properties such as fineness modulus, Specific gravity, Water absorption, and bulk density as per IS 383-1970and IS 2386 (Part III) – 1963

(d) Hair fibre: The hair needed for the project work was collected from salons and beauty parlour. It needs treatment before to be added in the concrete specimens. It is carried out as in the following steps:

- Separating hair from other waste. Depending on the source, the collected hair may contain waste. This was to be removed.
- Washing*:* After sorting, the hair is washed to remove impurities
- Drying: The hair is then dried under sun or in oven. After drying, the hair can be stored without any concern for decay or odor.
- Sorting*:* The hair is then sorted according to length, color, and quality. The hair fibres are checked at random for its length and diameter

### C. *Specimens Details*

- Cube -150mm×150mm×150mm
- Prism-100mm×100mm×500mm
- Cylinder-150 diameter and 300mm length

## IV. EXPERIMENTAL PROGRAMME

The concrete used is M40. The mix was designed using IS 10262:2009. Water cement ratio was fixed as 0.4. The fresh properties of the mix were evaluated by measuring the slump according to IS 1199-1959 and the hardened properties were evaluated according to IS 516-1959.The hardened properties of concrete such as compressive strength, flexural strength, splitting tensile strength, cylinder compressive strength and modulus of elasticity were found. The tests were conducted after 28 days of curing.

*A. Development of mix with hair fibre addition*

To study the effect of human hair on plain cement concrete on the basis of compressive, crushing, flexural strength and cracking control to economize concrete and to reduce environmental problems. Concrete cubes with various percentages of human hair fibre that is, 0, 1, 1.5, 2 2.5, and 3% by weight of cement and found out an optimum dosage.

*B. Mix Proportion for M40*

Table 1 Trial mix for M40 mix

| Mix | Cement content/ $m^3$ (kg) | FA /$m^3$ (kg) | CA /$m^3$ (kg) | W/C ratio | Comp. strength 28th day ($N/mm^2$) |
|---|---|---|---|---|---|
| TM1 | 380 | 775.8 | 1308 | 0.4 | 37.67 |
| TM2 | 390 | 769.3 | 1288 | 0.4 | 38.3 |
| TM3 | 400 | 761.4 | 1272 | 0.4 | 45.2 |
| TM4 | 410 | 755 | 1269 | 0.4 | 47.3 |
| TM5 | 420 | 747.8 | 1256 | 0.4 | 49.2 |
| TM6 | 430 | 740.2 | 1243 | 0.4 | 52.4 |

From the above data adopted a trial mix 5 that is cement content at 420 (kg/$m^3$)

*C. M40 Mix with Hair Fibre*

Varying percentage dosage of Human Hair Fibre (HHF) were added in M40 mix as shown below

Table 2 M40 mix with varying HHF

| M40 Mix | Cement content (kg/$m^3$) | FA (kg/$m^3$) | CA (kg/$m^3$) | % of fibre | Comp. strength 28th day ($N/mm^2$) |
|---|---|---|---|---|---|
| TM1 | 420 | 747.8 | 1256 | 0 | 48.6 |
| TM2 | 420 | 747.8 | 1256 | 1 | 49.5 |
| TM3 | 420 | 747.8 | 1256 | 1.5 | 52.7 |
| TM4 | 420 | 747.8 | 1256 | 2 | 49.3 |
| TM5 | 420 | 747.8 | 1256 | 2.5 | 48.6 |
| TM5 | 420 | 747.8 | 1256 | 3 | 47.8 |

From the above table 2 it is adopted that a mix with 1.5 % addition of HHF

A. *Test on Fresh Concrete*

(a)Slump test: The fresh properties were evaluated by measuring slump test. Since the slump was observed to be 13 mm. These types are suitable for road constructions.

Fig 7 Slump test

B. *Test on Hardened Concrete*

(a) Cube compressive strength test

The cube strength was evaluated according to IS 516-1959.The test was conducted on a 2000 kN compression testing machine. The test setup is shown in Fig 5.2 The ultimate load divided by the area gives the cube strength.

(b) Split tensile strength test

Cylinder strength was evaluated according to IS 516-1999 [12]. The test was conducted in a 2000 kN compression testing machine. The splitting tensile strength is calculated using the below equation

$$f_{ct} = \frac{2P}{\pi dl} \quad (1)$$

Where,

fct = Splitting tensile Strength in N/mm2
P = Maximum Load in N
d = Diameter of the specimen in mm
l = Length of the specimen in mm

(c) Flexural strength test

The flexural strength was evaluated according to IS 516-1959. The test is conducted on a 100 kN flexure testing machine. Modulus of rupture is calculated by equation below.

$$f_b = \frac{Pl}{bd^2} \quad \text{(when a>13.3cm)} \quad (2)$$

$$f_b = \frac{3Pa}{bd^2}\text{l} \quad \text{(when a<13.1cm but>11.0cm)} \quad (3)$$

Where,

$F_b$ = Modulus of rupture
P = Maximum Load
d = Depth of the specimen
l = Length of the specimen between supports
b = Width of the specimen
a = Distance between the line of fracture and the nearer support, measured on the center line of the tensile side of the specimen

## IV. RESULTS AND DISCUSSIONS

(a) Cube compressive strength test results

The compressive strength results are shown in table 3

Table 3 Compressive strength of CFC and WTC

| Specimen | Compressive strength 28th day N/mm$^2$ | | | |
|---|---|---|---|---|
| | CFC | Average | WTC | Average |
| 1 | 48.5 | 48.46 | 49.6 | 49.7 |
| 2 | 48.2 | | 49.5 | |
| 3 | 48.7 | | 50 | |

Table 4 Compressive strength of CFC and WTC with HHF

| SL.NO | Compressive strength 28th day N/mm$^2$ | | |
|---|---|---|---|
| | Percentage of HHF | CFC with HHF | WTC with HHF |
| 1 | 0 | 48.46 | 49.7 |
| 2 | 1 | 49.5 | 53.2 |
| 3 | 1.5 | 52.7 | 56.8 |
| 4 | 2 | 49.3 | 50.2 |
| 5 | 2.5 | 48.6 | 49.6 |
| 6 | 3 | 47.8 | 48.3 |

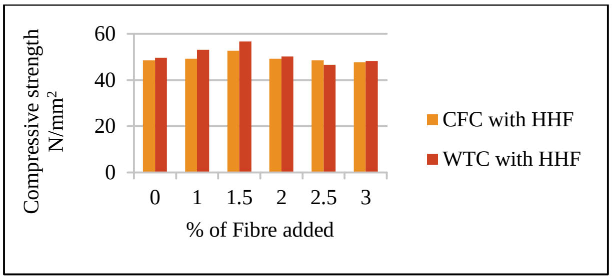


Fig 8 Compressive strength VS. % addition of HHF on CFC and WTC with HHF

From the above table 3 and 4 it is obtained that WTC specimens achieved higher compressive strength than CFC specimens

(b) Splitting tensile strength test

Table 5 Split tensile strength of CFC and WTC

| Specimen | Split tensile strength 28th day N/mm$^2$ | | | |
|---|---|---|---|---|
| | CFC | Avg | WTC | Avg |
| 1 | 4.3 | 4.46 | 4.6 | 4.67 |
| 2 | 4.5 | | 4.8 | |
| 3 | 4.6 | | 4.6 | |

Table 6 Split tensile strength of CFC and WTC with HHF

| SL.NO | Split tensile strength 28th day N/mm$^2$ | | |
|---|---|---|---|
| | Percentage of HHF | CFC with HHF | WTC with HHF |
| 1 | 0 | 4.46 | 4.67 |
| 2 | 1 | 4.63 | 5.11 |
| 3 | 1.5 | 4.83 | 5.23 |
| 4 | 2 | 5.22 | 5.45 |
| 5 | 2.5 | 4.51 | 4.9 |
| 6 | 3 | 4.21 | 4.4 |

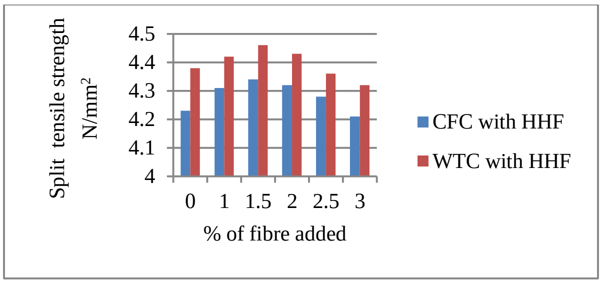


**Fig. 9. Split tensile strength of CFC and WTC with HHF**

Fibre content with 1.5 % obtained optimum where us WT acquires higher strength than CFC.

(c) Flexural tensile strength test

Flexural strength results of CFC and WTC are shown in below table

Table 7 Flexural strength of CFC and WTC with HHF

| Specimen | Flexural strength 28th day N/mm$^2$ | |
|---|---|---|
| | CFC | WTC |
| 1 | 4.51 | 4.67 |
| 2 | 4.52 | 4.65 |
| 3 | 4.50 | 4.69 |

Table 8 Flexural tensile strength of CFC and WTC with HHF

| SL.NO | Split tensile strength 28th day N/mm$^2$ | | |
|---|---|---|---|
| | Percentage of HHF | CFC with HHF | WTC with HHF |
| 1 | 0 | 4.51 | 4.67 |
| 2 | 1 | 4.63 | 5.11 |
| 3 | 1.5 | 4.83 | 5.23 |
| 4 | 2 | 5.22 | 5.45 |
| 5 | 2.5 | 4.51 | 4.9 |
| 6 | 3 | 4.21 | 4.4 |

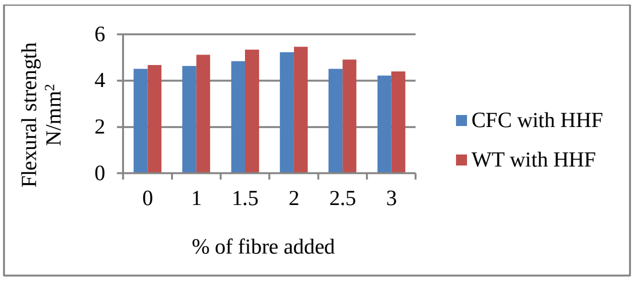


Fig 10 Flexural strength Vs % addition of HHF on CFC and WTC with HHF

From the above table 8 it's obtained that 2% of HHF addition shows a better flexural value and WTC obtained best valve than the other.

## V. CONCLUSIONS

From the study the following conclusions were obtained

- Cell filled and Whitetopped overlays represent a new rehabilitation choice to address pavements with surface distress problems
- Addition of 1.5 percentage dosage of human Hair fibre gained an optimum value in the

compressive property for CFC and WT concrete overlays

- Addition of 1.5 percentage of hair fibre in concrete achieves an characteristic strength more than 50N/mm$^2$
- Whitetopping concrete overlays shows a superior mechanical performance than that of Cell Filled concrete overlays
- Human Hair fibre can reduce the risk of Spalling of concrete

## ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the Principal and Department of Civil Engineering, MBCET, Thiruvananthapuram, Kerala for the support and facilities provided for completion of this work.

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