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USING ORGANIC FIBERS AS A SUBSTITUTE TO SYNTHETIC FIBERS IN CONCERETE REINFORCEMENT

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Abstract: In an attempt to reduce the negative environmental impact caused by the disposal methods of poultry waste, an alternative solution was undertaken to employ such wastes in concrete reinforcement. An experimental investigation was initiated to determine the sustainability of using feather fibers as a substitute to synthetic fibers in concrete mix design. The process was divided into two phases; Phase 1, included the preparation of three feather fiber reinforced concrete mix designs (Chicken, Duck, Feather) to be tested against two control mix designs (Normal Concrete & Fiber Reinforced Concrete). Due to quality concerns, regarding the Chicken Feathers, they had to be eliminated during the procedure. Feather fibers and synthetic fibers were, initially, kept at a 1% volumetric ratio in the mix design. The specimens were then left for 7 days and 28 days curing, and tested for compressive strengths. The duck fiber reinforced specimen yielded the highest results, with a 2.8% strength increase over the synthetic fiber specimen at 7 days and a 4.4% increase at 28 days. The specimens were also tested for flexural strengths, chemical attacks and harsh conditions, in which all feather fiber specimens yielded the least results. For Phase 2, the feather fiber specimen that yielded the highest results (Duck Feather) was then subjected to alterations in the mix design to try and obtain higher results than Phase 1. As opposed to the initial 1% volumetric ratio, two mixes, using duck feathers, were created using 1.25 and 1.5% volumetric ratios while administering another two, to additives (Silica Fume, Super Plasticizer) and curing them for 7 and 28 days.

1 INTRODUCTION

Feather fibers are commonly described as a waste by-product contributing to environmental pollution due to the negative environmental impact caused by their disposal methods. The disposal method of feather fibers is usually done by burning or burying; in the case of burying, feathers are organic biodegradable material that will degrade in the soil and therefore have no adverse effect on the environment. On the other hand, the burning process releases toxic gases further contributing to environmental pollution. According to a study developed to investigate and research the "Mechanical properties of Chicken feather and Cow Fibre Reinforced High Density Polyethylene Composites", " the composite reinforcement application of the CFF offers much more effective way to solve environmental concerns compared to the traditional disposal methods. [IJST, 2014] Feather Fiber Reinforced Concrete offers several advantages over synthetic fibers, due to their lightweight, sustainability, low-cost and abundance, and therefore making use of such properties allows the concrete matrix to be lighter, cheaper and also stronger. Despite the many investigations done on natural and synthetic fibers, only a few have been done on keratin fibers (chicken feathers). Keratin Fibers, are usually founded on the outer skin layer of vertebrates, and are composed of hydrogen-bonded protein strands, that allow for covalent bonding thus giving the fibers their material characteristics. In our investigation we aim to research a different type of bird feathers (Duck and Turkey) and develop a comparison between these results and previous ones. These differences in results might come from the material characteristics of the types of birds due to their distinctive living environments, thus resulting in their feathers being composed of various oils and substances.

2 OBJECTIVE & SCOPE

The main objective of the undertaken experimental procedure was, to first and foremost, substitute the use of expensive synthetic fibers used in concrete reinforcement, with a greener, more sustainable polymer that provides the same mechanical characteristics, if not better. Furthermore, the use of such natural fibers resulted in a lighter, cheaper concrete mix that further encourages such an application. Extensive studies have been previously conducted on replacing synthetic fibers with naturally occurring fibers such as hemp, wool, cotton and other plant and animal based extracts, while little research has been conducted on adopting keratin fibers as an alternative. Moreover, conducted researches on keratin fibers only concentrated on one type of keratin fiber, chicken feathers. In an effort to broaden the scope of this previously conducted research, we have decided to employ three types of feathers, according to their availability, in our investigation: Chicken Feather, Duck Feathers and Turkey Feathers. Of the three, the one that yields the best results will then enter into a second phase, where it will be chemically treated and have an altered mix design, in an attempt to maximize its mechanical properties.

3 EXPERIMENTAL PROCEDURE

3.1 Tests to be conducted

Testing was divided into two phases: Phase I and Phase II.
Phase I: Included the preparation of **4 mix designs** and testing them for the following:
Compressive Strength at 7 days.
Compressive Strength at 28 days.
Flexural Strength
Harsh Conditions (i.e. 600°C for 4 hours)
Chemical Attack (H_2SO_4, Na_2SO_4)
Phase II: Included the preparation of **4 mix designs** and testing them for the following:
Compressive Strength at 7 days.
Compressive Strength at 28 days.
Flexural Strength
Harsh Conditions (i.e. 600°C for 4 hours)

3.2 Feather Samples Used

Initially, the work scope included the use of three types of feather fibers to be investigated: Chicken Feather, Duck Feathers and Turkey Feathers. As quantities of feathers were acquired to begin the experimental procedure, the chicken feathers collected were deemed impractical due to the state they were in. The chicken feathers came in clusters stuck to each other, making them improbable for our application; the fibers were weak, the feather sizes were small, and the remaining feathers were comprised mainly of rachis and had no barbs to be used. Therefore, the chicken feather mix was eliminated.

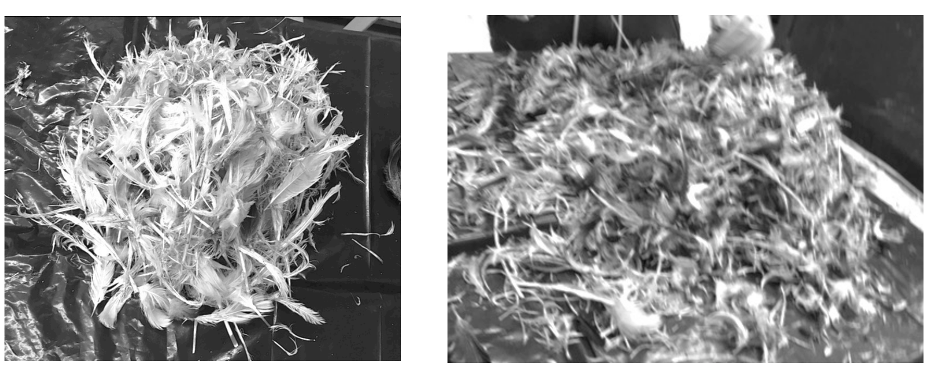


Figure 1: Chicken Feather Samples

Contrary to the Chicken Feathers, the Duck & Turkey Feather specimen's acquired, came in a variety of sizes with long rachis and strong barbules, making them ideal for application. Visual comparison between the two remaining specimens, showed that the Turkey Feathers, with the longest barbules were the most practical, and ideally should yield the best results; while, the duck feathers came second due to their shorter barbules.

Figure 2: Duck Feather Samples

Figure 3: Turkey Feather Samples

3.3 Phase I: Procedure

Sterilization:
Prior to the beginning of the testing phase, all feather specimens were to be sterilized as a safety precaution.
Acquired feathers were placed in autoclave bags, and split according to their type.
The autoclave bags were then placed in an autoclave partially filled with water, and left to be sterilized for 20 minutes at 120°C.
After sterilization in the autoclave was complete, the samples were then left to dry in the sun for a few days.
Cutting the feathers:
After the completion of the sterilization phase, the feathers were categorized according to their type into groups. The cutting technique was as follows:
Cutting the barbs from the rachis at their naturally occurring sizes.
Cut the rachis of the specimens into equal 1cm increments, whilst neglecting the last hollow section (*due its different aspect ratio).*
Notes:
The cutting technique was adjusted for maximum practicality and productivity, the use of the rachis was considered to maximize the use of the poultry wastes.
Acquire Synthetic Fibers:
As the scope of this works suggests, the feather fiber reinforced mixes should at least acquire same strength characteristics of synthetic fibers or better, for this investigation to be considered as a success.
Due to the high price of carbon fibers, a cheaper yet similar alternative was adopted in our mixes. SIKA FIBER – A polypropylene material
Sika Fibers specifications: Fibre Length=12 mm, Low Thermal Conductivity, Density=0.91 kg/lt, 160°C Softening Point, Fibre Diameter=18 micron, 100% Alkali Resistance
Preparing Mix Designs:
Necessary mix design calculations were made in order to determine the amounts to be used in our mixes.
Volumetric ratio of feathers in Phase 1 = 1%
The components of the mix design (*Sand, Water, Cement, Coarse Aggregates, Fine Aggregates, Feather Fibers & Sika Fiber*) where weighed and collected according to prior calculations.
4 mixes were prepared: Normal Concrete Mix, Sika Fiber Mix, Duck Feather Fiber Mix and Turkey Fiber Mix.
Curing & Testing:

After the mix designs, have been prepared, they are placed in the curing room.
The samples are left to cure for 7 and 28 days. After curing, the samples are tested for several characteristics such as: Compressive Strength, Flexural Strength and Compressive strengths after being subjected to high temperatures and chemical attacks.

3.4 Phase II: Procedure

Same sterilization and cutting technique as previous phase.
Acquire Additives:
For this phase the mix designs are subjected to additives that improve their characteristics.
Additives used are: Silica Fume, Super Plasticizer.
2 mix designs of the 4 to be prepared are subjected to these additives.
Preparing Mix Designs:
Necessary mix design calculations were made in order to determine the amounts to be used in our mixes.
Mix Design 1: Volumetric ratio of feathers in Phase II = **1.25%**
Mix Design 2: Volumetric ratio of feathers in Phase II = **1.5%**
The components of the mix design (Sand, Water, Cement, Coarse Aggregates, Fine Aggregates, **Duck Fibers,** Silica Fume, Super Plasticizer) where weighed and collected according to prior calculations.
4 mixes were prepared:
Normal Concrete + Silica Fume + Super Plasticizer, **Duck Feather (1.25%**), **Duck Feather (1.5%), Duck Feather (1%)** + Silica Fume + Super Plasticizer
Curing & Testing:
After the mix designs, have been prepared, they are placed in the curing room.
The samples are left to cure for 7 and 28 days. After curing, the samples are tested for several characteristics such as: Compressive Strength, Flexural Strength and Compressive strengths after being subjected to high temperatures and chemical attacks.

4 RESULTS & CONCLUSION

4.1 Phase I

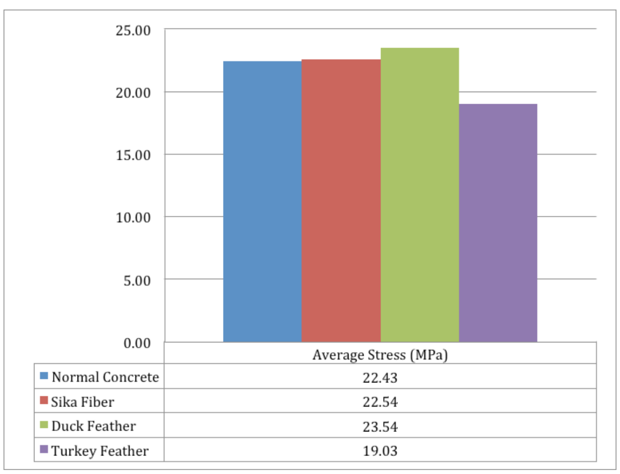


Figure 4: Compressive Strength at 28 days

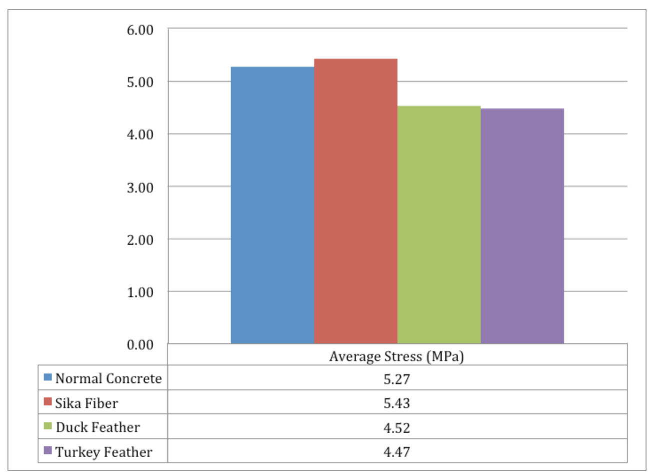
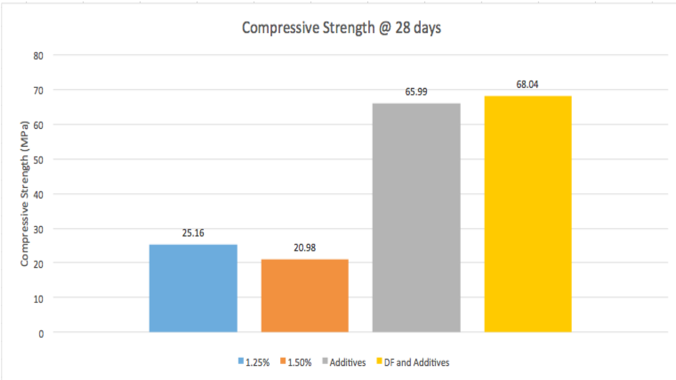


Figure 5: Flexural Strength at 28 days

4.2 Phase II

Note:
The following abbreviations, N.C, S.F, D.F, T.F represent the type of mix (i.e.: Normal Concrete, Sika Fiber Concrete, Duck Fiber Concrete & Turkey Fiber,) while the percentage represents the volumetric ratio of the fibers.



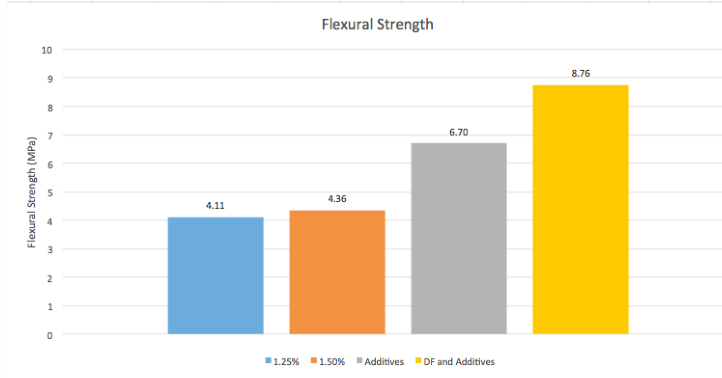


Figure 6: Compressive Strength at 28 days

Figure 7: Flexural Strength at 28 days

4.3 Harsh Conditions & Chemical Attack

Harsh Conditions:

The following results of harsh conditions are only given with respect to using Duck Fibers, it being the most predominant of the feather fibers. The full paper report will include all the graphs and tables regarding each fiber.

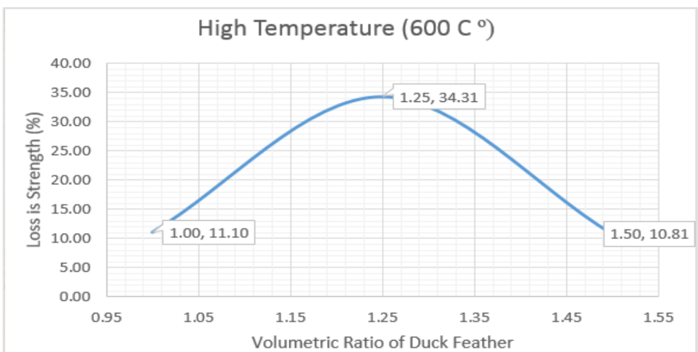


Figure 8: Loss In Strength due to harsh conditions, at different duck feather volumetric ratios.

Chemical Attack:

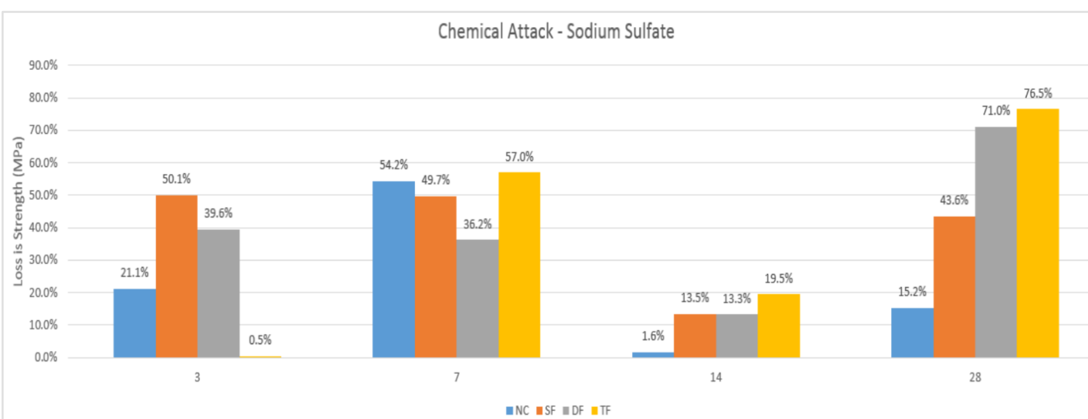


Figure 9: Loss In Strength due to Sodium Sulfate chemical attack of different mixes.

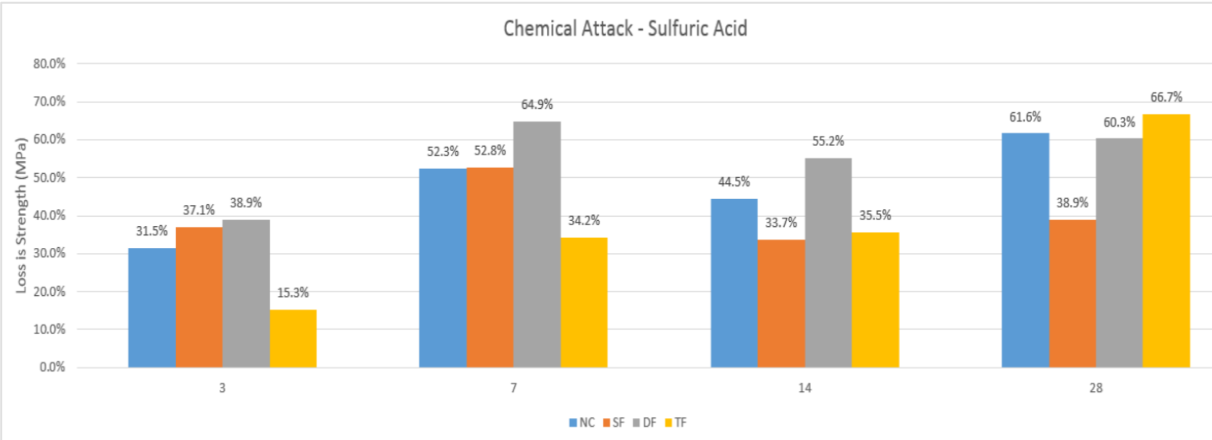


Figure 10: Loss In Strength due to Sulfuric Acid chemical attack of different mixes.

4.4 Conclusion

Duck Feather Fiber achieved the highest compressive strength after 7 and 28 days curing, while Turkey Feather Fiber was the least.
Duck Feather Fiber is the most competitive type to the synthetic fiber among all other types of feathers.
Sika Fiber showed a greater achievement in the flexural strength, followed by Normal concrete mix.
Sika Fiber had the highest percentage loss in strength when exposed to harsh condition of high temperature. However, Turkey Feather Fiber was surprisingly showed its ability to resist harsh condition.
Change in Volumetric Ratio of Duck Feather Fiber:
Volumetric Ratio of 1.25 % Duck Feather Fiber resulted in the highest compressive strength but the least in flexural.
Volumetric Ratio of 1.5% Duck Feather Fiber had the least compressive strength, but the most resistant to high temperature condition.
Turkey Feather Fiber was the most mix design affected when exposed to chemical attack solution [Sulfuric Acid Solution – H_2SO_4].
Duck Feather Fiber was mostly affected when exposed to chemical attack solution [Sodium Sulfate Solution – $NaSO_4$].

4.5 Acknowledgements

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4.6 References:

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