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Experimental Investigation of Partial Replacement of Textile Sludge by Weight of Cement in Concrete

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ABSTRACT: This experimental study investigates the feasibility of partially replacing cement with textile sludge in concrete formulations, contributing to sustainable waste management and eco-friendly construction. Textile sludge content was varied from 0% to 30% by weight of cement across M20 grade concrete mixes. Key mechanical properties including compressive strength, split tensile strength, flexural strength, and workability were evaluated at curing ages of 7, 14, and 28 days. Results indicate that 15% replacement (S3 mix) yields optimum performance, achieving a maximum compressive strength of 23.3 N/mm², representing an 11.48% gain over conventional concrete. Split tensile and flexural strengths improved by 14.47% and 16.20% respectively. RC beam testing under two-point loading confirmed enhanced crack resistance and load-carrying capacity. ANSYS finite element analysis closely corroborates experimental findings. The study establishes that textile sludge can effectively replace cement up to 15% without compromising structural performance, supporting sustainable construction practices.

KEYWORDS: Textile sludge, concrete, partial replacement, compressive strength, split tensile strength, flexural strength, sustainable construction, ANSYS

I. INTRODUCTION

The demand for construction materials is increasing rapidly with growing infrastructure requirements worldwide. Concrete is the most widely used building material, produced at approximately 12 billion tonnes globally each year. It relies heavily on cement, whose production depletes natural resources and contributes significantly to greenhouse gas emissions.

Industrial wastes, if efficiently utilized as supplementary cementitious materials, can help conserve natural resources, reduce carbon emissions, and address waste management challenges. Textile effluent sludge (TES) is one such by-product generated in large quantities – approximately 70 to 80 million tonnes annually – from effluent treatment plants of textile industries. TES is characterized by high moisture content and complex composition comprising fibres, dyes, and chemicals, posing serious environmental disposal challenges.

This study investigates the partial replacement of cement with dried textile sludge in M20 grade concrete. The research evaluates the mechanical performance of concrete mixes at replacement levels of 5%, 10%, 15%, 20%, 25%, 30%, and 35% by weight of cement. In addition to experimental testing, ANSYS finite element analysis is used to validate the structural behaviour of reinforced concrete beams made with the optimum textile sludge mix.

SCOPE

M20 grade concrete. To study the strength properties of concrete through compressive, split tensile, and flexural strength tests. To identify the optimum percentage of textile sludge for better concrete performance. To analyze the behaviour of RC beams using experimental testing and ANSYS software to promote sustainable construction through effective utilization of textile wasteTo partially replace cement with textile sludge in.

METHODOLOGY

M20 grade concrete was designed per IS 10262-2009 with a water-cement ratio of 0.5. Cement was partially replaced with dried textile sludge at 0%, 5%, 10%, 15%, 20%, 25%, 30%, and 35% by weight. Materials included 43-gradeOPC, natural river sand (Zone II), M-sand, and textile sludge dried under sunlight.

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II. MATERIALCOLLECTION

CEMENT

Acementisabinder,achemicalsubstanceusedforconstructionthatsets, hardens,andadherestoother materials to bind themtogether.Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. The most common, called ordinary Portland cement (OPC), is grey, but white Portlandcement is also available..

TEXTILESLUDGE

Textile sludge, a by-product of the textile industry encompasses variouswastematerials,generatedduringthemanufacturingprocessesoftextiles and garments. This residue consists of fibres, dyes, chemicals, and other substances used in the production of fabrics. Often characterized by its high moisture content and complex composition, textile sludge poses environmental

MATERIALTEST

ConstructionMaterialsTesting(CMT)primarilyinvolvestestingstructural materials used to build new projects from the ground up, materials and components used to construct new additions or new components being added to an existing facility.

SPECIFICGRAVITYTEST OF TEXTILE SLUDGE

The specific gravity (Gs) of a material is the ratio

DETERMINATION OF SPECIFIC GRAVITY OF TEXTILE SLUDGE

Definition

Textile sludge specific gravity is defined as the ratio of the density of textile sludge to the density of water at a standard temperature. It indicates how heavy the sludge particles are when compared to water. The specific gravity of textile sludge is an

the mass of a unit volume of soil solids at a specific temperature to be mass of an equal volume of gas-free distilled water at the same temperature. The specific gravity of soil is usually reported at 20˚C.

SieveAnalysis

Sieves can be used for testing chemicals, powders, oils and other fluids These tests yield information about contaminants, byproducts, defects and particledensity. Sieve analysisisthe traditional method for determining particle size distribution.

important property used in the design and analysis of construction materials, especially when textile sludge is used as a partial replacement material in concrete or bricks.

Specificgravityoffineaggregate
=(W2-W1)/((W2-W1)-(W3-W4))
= (1600-650)/(1600-650)-(2140-1520)
= 2.87
= 2.87

SAMPLE	CEMENTKG	FINEAGGRIGATE KG	TEXTILE SLUDGE KG	WATER RATIO
S1(0%)	0.603	2.010	0	0.3
S2(5%)	0.572	2.010	0.03	0.3
S3(10%)	0.542	2.010	0.06	0.3

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S4(20%)	0.513	2.010	0.09	0.3
S5(25%)	0.480	2.010	0.12	0.3
S6(30%)	0.450	2.010	0.15	0.3
S7(35%)	0.420	2.010	0.18	0.3

SELCTION OF COMBINATIONS

CUBE, CYLINDER, BEAM SPECIME

SPLIT TENSILE STRENGTH TEST

This is an indirect test to determine the tensile strength of cylindrical specimens. Splitting tensile strength test is carried out at the age of 28 days for the concrete cylinder specimen of size 150mm diameter and 300mm length using universal testing machine. The load is applied gradually till the specimen split and the readings are noted. The splitting tensile strength has been estimated using the relationship

$$f = 2P/\pi dl$$

Where,
f = Splitting tensile strength of concrete inMPa.
P = Load at failure in Newton
d = Diameter of cylinder = 150mm
l = Length of cylinder = 300mm

% Mix	7 Days N/mm^2	14 DaysN/mm^2	28 Days N/mm^2
Conv(0%)	2.33	2.69	3.11
S1 (5%)	2.47	2.83	3.28
S2 (10%)	2.62	2.97	3.42
S3 (15%)	2.76	3.11	3.56
S4 (20%)	2.66	3.00	3.45
S5 (25%)	2.55	2.90	3.34
S6 (30%)	2.43	2.80	3.22
S7 (35%)	2.38	2.72	3.14

SPLIT TENSILE TEST RESULTS OF 7TH, 14TH AND 28TH DAY

FLEXURAL STRENGTH TEST

In order to determine the lateral load resistance, the prisms are tested for flexure. As illustrated. the prism (100mm x 100mm x500mm)were placed horizontally and tested for flexural strength according to third point loading. The initial failure location was observed and found that the failure location of all prism was within the middle third. The third point loading was used to determine the stress.

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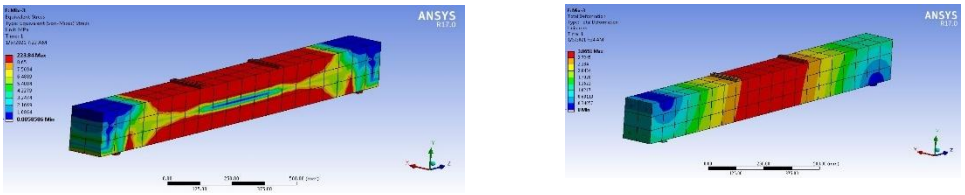
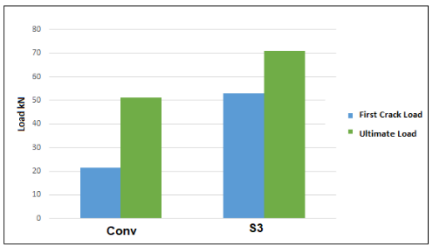
FLEXTURAL TEST RESULTSOF 7TH, 14TH AND 28TH DAY

Sl. No	Properties	Gain Over Normal Concrete
1.	Compressive Strength	+11.48%
2.	Split Tensile Strength	+14.47%
3.	Flexural Strength	+16.20%



percentage Increase in Strength over conventional mix

Checking for equivalent stress and deformation



Comparisons of First Crack Load and Ultimate Load

III. CONCLUSION

Textile sludge can be effectively utilized as a partial replacement of cement in concrete without compromising strength up to a certain limit. The utilization of textile sludge helps in reducing environmental pollution and supports sustainable waste management in the textile industry. Replacement of cement with textile sludge reduces the overall cement consumption, thereby lowering carbon emissions associated with cement production. The strength of concrete increases with curing age (7, 14, and 28 days) for all mixes due to continuous hydration and strength gain. The rate of strength gain is higher during the initial curing period and gradually stabilizes at later ages. Compressive strength increases up to the optimum replacement level (S3 mix) (15%) and

then decreases with further increase in textile sludge content. The maximum compressive strength achieved is 23.3N/mm², showing an increase of +11.48%compared to conventional concrete. The improvement is attributed to the filler effect, improved particle packing, and densification of the concrete matrix. Beyond the optimum level, the reduction in strength is due to lower cementitious properties and dilution of binding material. Split tensile strength increases up to S3(15%) mix, indicating better resistance to cracking. The maximum tensile strength obtained is 3.56 N/mm², which is +14.47% higher than conventional concrete. The increase in tensile strength reflects improved internal bonding and cohesion of the concrete matrix. At higher replacement levels, tensile strength decreases due to insufficient cement paste for proper bonding. Flexural strength shows significant improvement up to S3(15%) mix, indicating enhanced performance under bending loads. The maximum flexural strength achieved is 3.56 N/mm², representing an increase of +16.20%over conventional concrete. This improvement indicates better load distribution, crack resistance, and stiffness of the concrete. Beyond the optimum level, flexural strength decreases due to weakening of the matrix and reduced binding capacity. The optimum replacement level varies depending on the type of strength: S3 for compressive strength S5 for tensile and flexural strength The results indicate that textile sludge acts as a micro-filler material, improving the pore structure and reducing voids in concrete. Workability may slightly decrease with higher replacement levels due to the fine nature of textile sludge, which may require proper mix design adjustments. The failure pattern of concrete remains similar to conventional concrete, but improved strength indicates better structural performance. The use of textile sludge does not adversely affect the short-term mechanical properties of concrete. From an economic perspective, the use of textile sludge can reduce material cost and waste disposal expenses. From an environmental perspective, it contributes to resource conservation and eco-friendly construction practices.

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