A Study on Strength and Durability Characteristics of Concrete with Partial Replacement of Fine Aggregate by Laterite Sand

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Abstract

The upturn in prices of materials for building construction is causing a lot of concern due to more utilization of building materials such as fine aggregate, coarse aggregate for the construction of structures, creating need for research into original materials as alternatives in building and rural infrastructures. Research efforts are directed towards enhancing the use of locally and readily available material such as lateritic soils for the construction. This study presents, the results of an experimental program to study the strength and durability performance of laterized concrete. A total of 108 cubes of 150mm, 108 cylinders 150mm dia X 300mm height and 81 prisms of 100 X100 X 500 mm dimensions were casted and cured in water as well as chemical solution for 7, 28, 60, and 90 days. Laterized concrete is concrete in which some or all of the fine aggregate is from laterite. To perform this investigation, M30 grade concrete is used, mix proportions 1: 1.274: 3.126 (Cement: sand/laterite: granite) with water/cement ratio of 0.45 was used. In this investigation, percentage laterite content (0%, 10%, 20%, 30%, 40% and 50%) exposure periods of 7, 28, 60, and 90 days on the compressive, flexure and splitting tensile strength tests of laterized concrete were investigated and also the effect of varying percentages of sulphuric acid (H2SO4) concentrations 1%, 3% and 5%, exposure periods of 7, 28, 60, and 90 days on the compressive, flexure and splitting tensile strength tests of laterized concrete were investigated. Data results revealed that the laterite fines used could satisfactorily replace the sand up to 30%. By fixing the laterite content as 30% of fine aggregate, the specimens are tested for durability studies under chemical attack. The specimens are immersed in H2SO4 solution for concentrations of 1%, 3%, 5% for an exposure period of 7, 28, 60 & 90 days, and the strengths of concrete at these ages were investigated.
Keywords: Concrete, Laterite Sand, Laterized Concrete, Sulphuric Acid, Tests

I. INTRODUCTION

Concrete is the most commonly used construction factual in India and other countries also. It is tough to point out another material of construction which is as adaptable as concrete. It is the material of choice where strength, flexural structure, better workability, performance, durability, impermeability, fire resistance and abrasion resistance are required. Cement concrete is one of the outwardly simple but actually complex materials. Many of its compound behaviors are yet to be identified to employ this material advantageously and frugally.

Concrete is so closely related with every construction activity that it touches every human being in his day to day living. It is an artificial compound generally made by mixing of binding material(Cement), fine aggregates, coarse aggregates, water and admixtures in suitable proportions. Concrete does not solidify from drying after mixing and placement; the water reacts with the cement in a chemical process known as hydration. In India the annual consumption of cement is in the order of approximately 22 million tons. Concrete is a site-made material unlike other materials of construction and as such can vary to a very great extent in its quality, properties and performance due to the use of natural materials except cement. From materials of varying properties, to make concrete of stipulated qualities, an intimate knowledge of the interaction of various ingredients that go into the making of concrete is required to be known, both in the fresh and hardened conditions. This knowledge is necessary for concrete technologists as well as for site engineers. The increased demand for the usage of the huge quantity of concrete leads to increase in cost of binding material (cement) and depletion of natural sources of fine aggregate which in turn increases cost of concrete. Due to above cause alternative materials are required to partially or fully replacement for portland cement or fine aggregate or coarse aggregate in the concrete mixture to continue the construction work, without changing the previous properties of the concrete like strength, workability and durability. Laterite is a product of intense sub aerial weathering. Laterisation process involves leaching of alkalis, basis and silica with complimentary enrichment of alumina, iron and some trace elements.

II. REVIEW OF LITERATURE

Felix F. Udoeyo, Udeme H. Iron, Obasi O. Odim et all are conducted an experimental program to investigate some characteristics of concrete containing laterite as a partial or fullreplacement of sand is presented in this paper. Sand in a concrete of mix ratio 1:2:4:0.56 (cement:sand:coarse aggregate:water-cementratio) was replaced with 0%, 20%, 40%, 60%, 80%, and 100% laterite. The results show that concrete with up to 40% replacementlevel of sand by laterite attained the designed strength of 20 N/mm2, thus indicating the possibility of using laterite as a partial replacement for sand up to this level. It was also observed from the results that the workability of laterite concrete (LATCON) increases with increase in the replacement level of sand by laterite, while the compressive, split tensile, and flexural strengths and the percentage water absorption of the concrete decrease with increase in the replacement level of sand.

III. EXPERIMENTAL INVESTIGATIONS

Concrete is a mixture of binding material, fine aggregate, coarse aggregate and water. Before performing this investigation, to know properties of materials such as fineness, normal consistency, initial setting time, final setting time, specific gravity, etc of cement, fineness modulus, bulk density, bulking, specific gravity of fine aggregate and fineness modulus, bulk density, specific gravity of coarse aggregate which are used in the concrete are essential.

A. Materials:

1) Cement

Cement is a binding material that has cohesive and adhesive properties in the presence of water. It is of Silicates and Aluminates of Lime obtained from Limestone and Clay. The cement combines chemically with water to form a hardened mass. The hydraulic cement is usually known as Portland Cement because of its resemblance upon hardening to the Portland stone found near dourest England.

a) Tests on Cement

1) Fineness of Cement
   The fineness of cement test is done according to IS: 269-1989 & IS: 4031-1988 is 5%.
2) Normal Consistency of Cement
   The standard consistency test of a cement is done by according to IS: 269 - 1989 & IS: 4031 – 1988, Part – 4 is 32%.
3) Initial & Final Setting Times of Cement
   Initial setting time for the given sample of cement = 3 Hrs = 180 min
   Final setting time for the given sample of cement = 4 Hrs = 240 min
4) Compressive Strength of Cement
   The compressive strength of cement mortars is IS: 269-1989, IS: 8112-1989, IS: 12269 -1987, IS: 4031-1988, Part - 4 & IS: 4031-1988. Compressive strength of the given cement
   at 3 days = 25.6 N/mm^2
   at 7 days = 30.5 N/mm^2
   at 28 days = 52.9 N/mm^2

2) Aggregates (Fine & Coarse)

The aggregate like sand, stone are inert materials. The behavior of concrete since they occupy about 70 to 75% of the total volume of the concrete. It is logical to use maximum of aggregate, since they provide bulk to the concrete, are less expensive than cement and are freely available in nature.

a) Tests on Fine Aggregate Coarse Aggregate

1) Fineness Modulus Of Fine Aggregate
   The fineness modulus of given conventional sand = 3.27
   The fineness modulus of given laterite sand = 3.25
2) Specific Gravity Of Fine Aggregate
   The specific gravity test of fine aggregate is done according to IS: 2386 -1963, Part -3.
   For Conventional Sand = 2.56.
   For Conventional Sand = 2.44.
3) Bulk Density Of Sand
   Bulk density of Conventional Sand = 1.08 Kg/ m^3
   Bulk density of Laterite Sand = 1.01 Kg/ m^3
4) Bulking Of Sand
   The maximum bulking of the given normal sand is 820 ml at 4% of moisture content.

The maximum bulking of the given laterite sand is 860 ml at 6% of moisture content.

5) Fineness Modulus Of Coarse Aggregate
   The fineness modulus of given coarse aggregate = 2.86
6) Specific Gravity Of Coarse Aggregate
   The specific gravity of coarse aggregate is done according to IS: 2386 -1963, Part – 3 is 2.72.
7) Bulk Density Of Coarse Aggregate
   Bulk density or unit weight is done according to relevant IS code is 0.94 Kg/ m^3.

3) Water

For proper chemical action, the amount of water required is about 25% of the weight of cement used, however, more water is used for proper workability of concrete. The water used for both mixing and curing should be free from injurious amount of oils, acids, alkalis, salts, organic materials or other substances that may be harmful to concrete. According to IS 456 – 2000, the pH value of the water shall not be less than 6. In the Present study, The pH value of water used in the concrete mix is 5.5.

4) Laterite Soil

The chemical composition of laterite soil / gravel varies widely based on genesis, climatic conditions, age of laterization. Some lateritic soil contain more than 60% Fe_2O_3 and little of Al_2O_3 and where as some contain more than 60% SiO_2 and little of Al_2O_3 and Fe_2O_3. Iyer & Williams studied the laterite soil of green swamp Australia and reported the chemical compositions as Fe_2O_3 (16%), SiO_2 (66%) and Al_2O_3 (10%). The chemical analysis of Indian soils shows that these soils are rich in iron and aluminum but poor in nitrogen, potash, potassium, lime and organic matter.

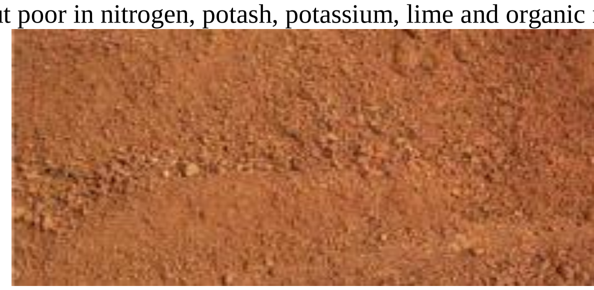


Fig. 3.1: Before Wet Sieve Analysis Of Laterite Soil

Fig. 3.2: After Wet Sieve Analysis Of Laterite Soil

The all properties of the Laterite soil are mentioned above.

5) Workability Tests

a) Slump Cone Test

In the present study, Slump Cone Test values are as follows

- For conventional concrete = 40mm
- Average value For laterite concrete = 35mm

b) Compacting Factor Test

In the present study, Compaction Test values are as follows

- For conventional concrete = 0.91
- Average value For laterite concrete = 0.89

c) Flow Table Test

In the present study, Flow Table Test values are as follows

- For conventional concrete = 27.36mm
- Average value For laterite concrete = 22.75mm

d) Vee Bee Consistometer Test

In the present study, VB Test values are as follows

- For conventional concrete = 38 VB sec
- Average value For laterite concrete = 41 VB Sec

IV. RESULTS

A. Compressive Strength

A total of 108 cube specimens of size 150 mm were tested for compression test. The test results are summarized in Tables below. Each value is the mean of a three test result.

Compressive Strength = Max. Load/Area = (W/A)

Where, W = Maximum Load on cube

A = Effected area

Fig. 4.1: Compression Testing Machine

B. Split Tensile Strength

Split Tensile Strength

A total of 108 standard concrete cylinders of sizes 150 mm diameter and 300 mm height were tested for the indirect tensile strength. The test results are shown in below Tables.

$$\text{Split tesile strength } (f_s) = (2W)/(\pi LD)$$

Where, W = Maximum Load on Cylinder
L = Length of the Cylinder
D = Diameter of the Cylinder

C. Flexural Strength

A total of 81 beams of size 150 x 150 x 500 mm were tested for flexural strength. In all the tested specimen fracture occurred within the central one-third of the beam

$$\text{Flexure strength } (f_b) = (WL) / (bd^2)$$

Where, W = Maximum Load on Prism
L = Length of the Prism
b = Width of the prism
d = Depth of the Prism

Table - 4.28
Compressive strength of cube at all percentages of laterite sand when immersion in water.

% of LS	*0%*	*10%*	*20%*	*30%*	*40%*	*50%*
Days	*Compressive strength (N/mm^2)*	*Compressive strength (N/mm^2)*	*Compressive strength (N/mm^2)*	*Compressive strength (N/mm^2)*	*Compressive strength (N/mm^2)*	*Compressive strength (N/mm^2)*
7	*35.16*	*35.14*	*35.12*	*35.11*	*24.53*	*20.53*
28	*40.67*	*40.65*	*40.63*	*40.62*	*36.93*	*31.56*
60	*51.02*	*51.01*	*51.00*	*50.97*	*45.33*	*40.44*
90	*61.42*	*61.41*	*61.40*	*61.36*	*53.78*	*45.20*

D. Bar Chart 4.11:

Compressive Strength of Cube at the rate of 7, 28, 60 & 90 days at different laterite percentages 0%, 10%, 20%, 30%, 40% & 50%.

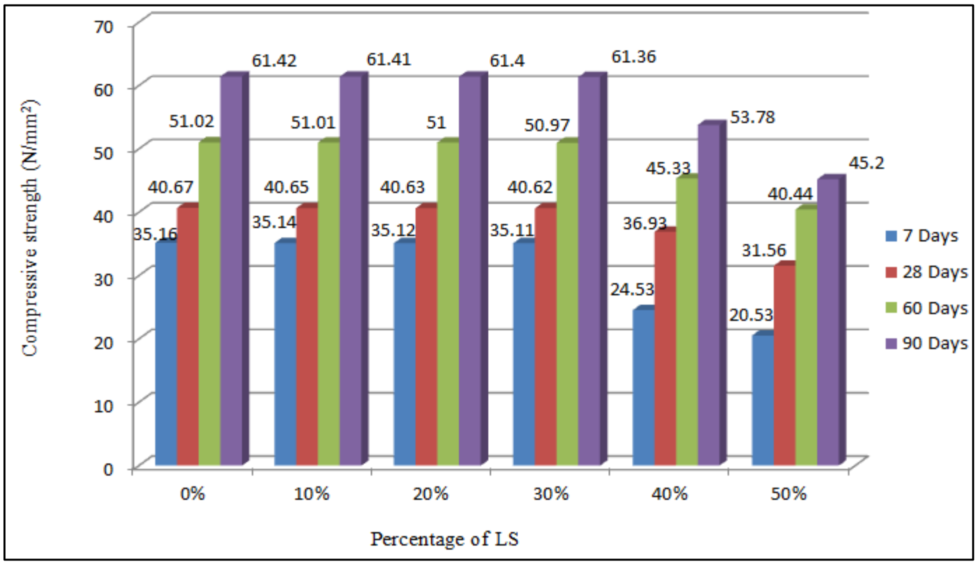


Table - 4.29

Split tensile strength of cylinder at all percentages of laterite sand when immersion in water.

% of LS	*0%*	10%	*20%*	*30%*	*40%*	*50%*
Days	*Split Tensile Strength (N/mm²)*	*Split Tensile Strength (N/mm²)*	*Split Tensile Strength (N/mm²)*	*Split Tensile Strength (N/mm²)*	*Split Tensile Strength (N/mm²)*	*Split Tensile Strength (N/mm²)*
7	2.12	2.12	2.12	2.11	1.42	0.71
28	3.12	3.12	3.11	3.10	2.56	1.42
60	4.44	4.44	4.43	4.43	3.68	2.69
90	5.87	5.87	5.87	5.86	4.39	3.55

E. Bar Chart 4.22:

Split tensile Strength of Cylinder at the rate of 7, 28, 60 & 90 days at different laterite percentages 0%, 10%, 20%, 30%, 40% & 50%.

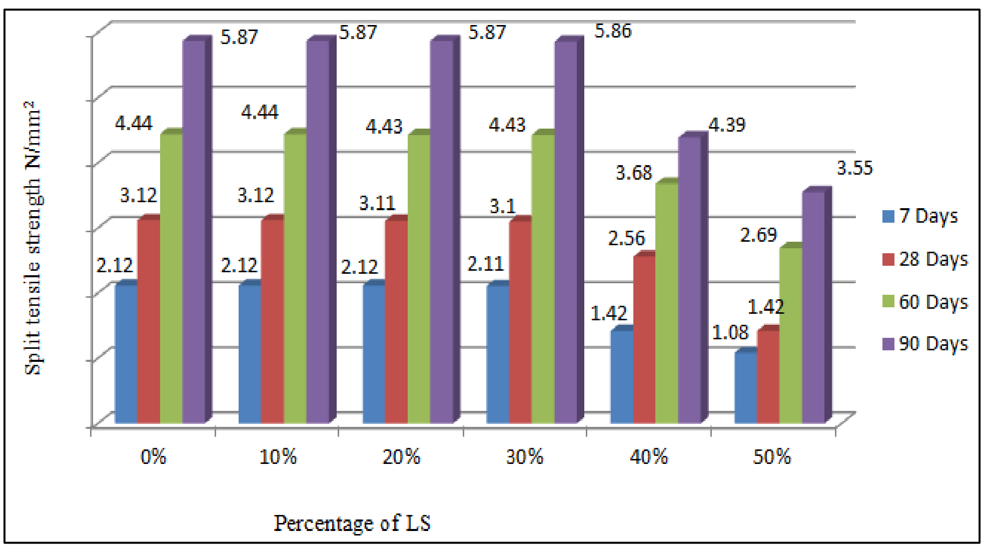


Table - 4.30

Flexure strength of prism at all percentages of laterite sand when immersion in water

% of LS	*0%*	*10%*	*20%*	*30%*	*40%*	*50%*
Days	*Flexure Strength (N/mm²)*	*Flexure Strength (N/mm²)*	*Flexure Strength (N/mm²)*	*Flexure Strength (N/mm²)*	*Flexure Strength (N/mm²)*	*Flexure Strength (N/mm²)*
28	*10.27*	*10.24*	*9.63*	*6.33*	*4.08*	*2.68*
60	*17.76*	*17.68*	*17.13*	*15.08*	*10.83*	*9.13*
90	*25.17*	*25.01*	*24.68*	*20.06*	*17.63*	*15.13*

F. Bar Chart 4.32:

Flexure Strength of prism at the rate of 7, 28, 60 & 90 days at different laterite percentages 0%, 10%, 20%, 30%, 40% & 50%

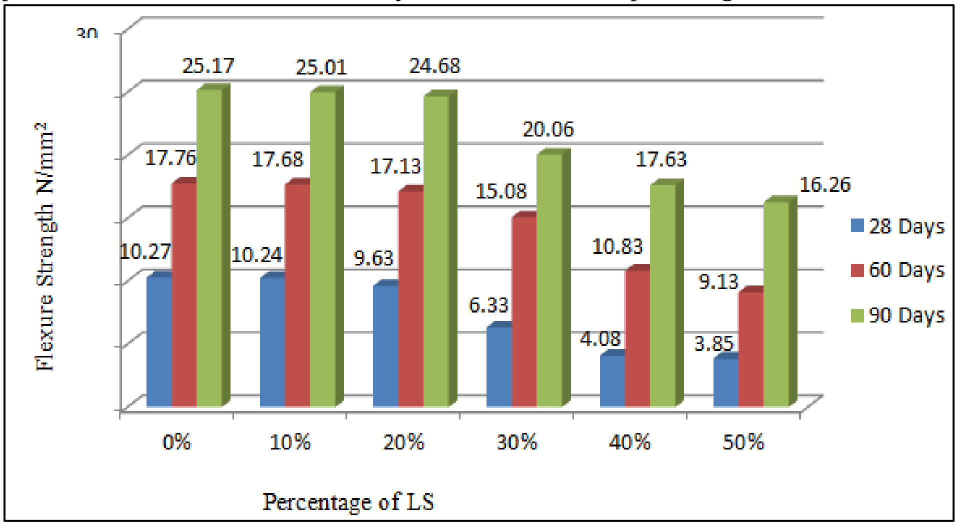


Table - 4.31
Compressive strength of cube at 30% optimum laterite sand when immersion in H2SO4 solution

Optimum Laterite Sand (OLS)	*30%*			
Percentage of H_2SO_4	*1%*	*3%*	*5%*	*0%*
Days	*Compressive strength (N/mm^2)*	*Compressive strength (N/mm^2)*	*Compressive strength (N/mm^2)*	*Compressive strength (N/mm^2)*
7	*35.13*	*35.10*	*34.99*	*35.11*
28	*40.58*	*40.50*	*40.35*	*40.62*
60	*50.87*	*50.73*	*50.47*	*50.97*
90	*61.15*	*60.88*	*60.45*	*61.36*

G. Bar Chart 4.33:

Compressive Strength of Cube at the rate of 7, 28, 60 & 90 days when the cubes immersed in 1%, 3% & 5% H_2SO_4 solution.

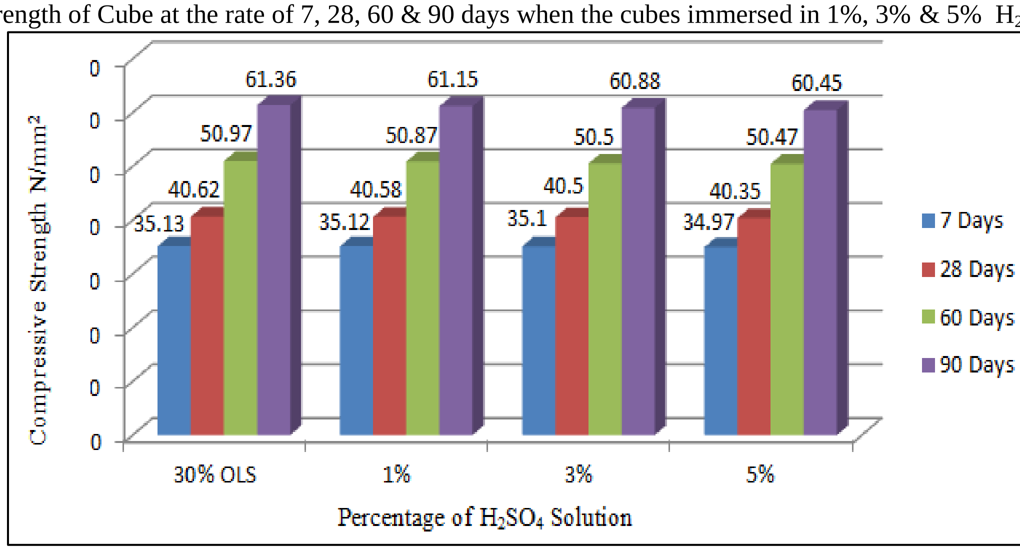


Table - 4.32
Split tensile strength of cylinder at 30% optimum laterite sand when immersion in H2SO4 solution.

Optimum Laterite Sand (OLS)	*30%*			
Percentage of H_2SO_4	*1%*	*3%*	*5%*	*0%*
Days	*Split Tensile Strength (N/mm^2)*	*Split Tensile Strength (N/mm^2)*	*Split Tensile Strength (N/mm^2)*	*Split Tensile Strength (N/mm^2)*
7	*2.11*	*2.09*	*2.07*	*2.11*
28	*3.08*	*3.07*	*3.06*	*3.10*
60	*4.41*	*4.39*	*4.37*	*4.43*
90	*5.84*	*5.81*	*5.77*	*5.86*

H. Bar Chart 4.34:

Split tensile Strength of Cylinder at the rate of 7, 28, 60 & 90 days when the cylinders immersed in 1%, 3% & 5% H_2SO_4 solution.

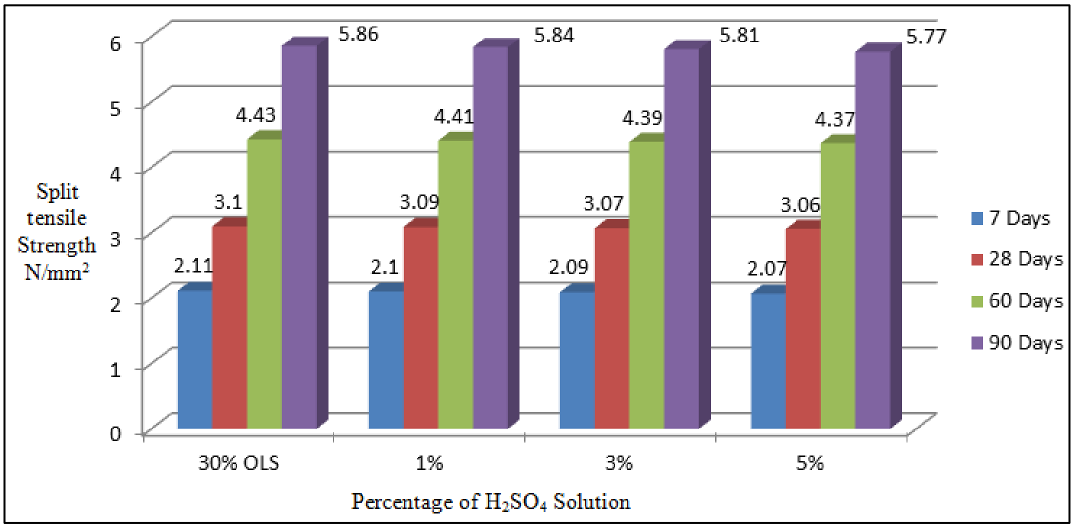
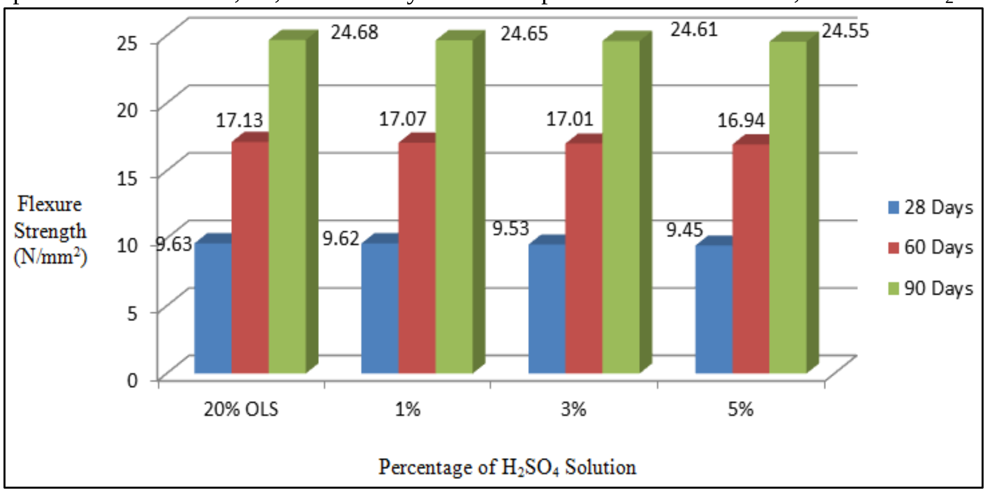


Table - 4.33
Flexure strength of prism at 20% optimum laterite sand when immersion in H2SO4 solution.

Optimum Laterite Sand (OLS)	*20%*			
Percentage of H_2SO_4	*1%*	*3%*	*5%*	*0%*
Days	*Flexure Strength (N/mm^2)*	*Flexure Strength (N/mm^2)*	*Flexure Strength (N/mm^2)*	*Flexure Strength (N/mm^2)*
28	*9.62*	*9.53*	*9.45*	*9.63*
60	*17.07*	*17.01*	*16.94*	*17.13*
90	*24.65*	*24.61*	*24.55*	*24.68*

I. Bar Chart 4.35:

Flexure Strength of prism at the rate of 7, 28, 60 & 90 days when the prisms immersed in 1%, 3% & 5% H_2SO_4 solution.



V. CONCLUSIONS

The following conclusions are drawn from the result of the investigations

1) The compressive strength of all laterite concrete specimens increased with age but decreased with increase in the replacement level of sand.
2) The specimens immersed in water did not show any visible sign of deterioration after the 90-day immersion period but rather show continuous improvement in compressive strength.
3) The compressive strength of laterized concrete cubes at the rate of all Days was optimized at 30% Laterite sand.
4) The split tensile strength of laterized concrete cylinders at the rate of all Days was optimized at 30% Laterite sand.
5) The flexure strength of laterized concrete prisms at the rate of all Days was optimized at 20% Laterite sand.
6) The strengths of laterized concrete specimens decreased with increasing acid concentration, immersion period.

- The compressive strength of laterized concrete are decreasing from 0.03% to 1.48% at 7, 28, 60 & 90 days.
- The split tensile strength of laterized concrete are decreasing from 0.47% to 1.54% at 7, 28, 60 & 90 days.
- The flexure strength of laterized concrete are decreasing from 0.10% to 1.87% at 28, 60 & 90 days.

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