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A Study on Strength and Durability Properties of Concrete with Partial Replacement of Cement with Ground Rubber

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ABSTRACT
Concrete is most widely used building material in the world, as well as the largest user of natural resources with annual consumption of 12.6 billion tons. Basically it consists of aggregates which are bonded together by cement and water. The major part of concrete with high cost material is cement. Rubber which is generated in large quantities as waste does not have useful disposal till now. But rubber is found to possess properties that are required for viable replacement of cement in concrete. Hence we in this project have aimed to study the effectiveness of rubber as substitute for cement and utilize the ground rubber tyre powder in concrete, to minimize global warming. Strength &durability properties viz.., Compressive strength, Split tensile strength, Acid attack test & Alkali attack test have to be conducted to ascertain the properties of concrete specimens were to be casted and tested for concrete mix with various percentage of replacement with proportions of 5%, 10%,15% &20% rubber powder and its viability for replacement are discussed in this project.
Keywords :- Rubber powder, Compressive strength, Split tensile strength, Acid attack test & Alkali attack test.

1. INTRODUCTION

1.1 General:

Cementitious composites are widely used as the majority of structural materials. However, cementitious composites are limited to some special projects due to inherently brittle behaviour. Most efforts have been made to modify the brittle behaviour of cementitious composites all along. As a result, fibre reinforced cementitious composites (FRCC) occurred. Normal concrete suffers brittle failure problem even in the condition of meeting its required strength. People have been trying to explore effective method to improve the brittleness of concrete. Studies reported that adding rubber powder into concrete can improve the brittle failure of concrete. Rubberized concrete (RC) takes the characteristics of rubber and cement concrete into together, its main features as fallows

(i) Light weight
(ii) Low elastic modulus
(iii) High modulus of rupture
(iv) High hardness
(v) High elongation
(vi) Anti cracking performance
(vii) Superior energy absorption
(viii) High toughness

Other features include abrasion resistance, anti-aging properties, low shrinkage coefficient, low thermal expansion coefficient so on. In addition, rubberized concrete also have superior function in heat insulation and sound insulation. Rubber particles added to concrete made from waste rubber tires, can not only improve the performance of concrete, such as shock resistance, but also solve the problem of dealing with waste rubber.

1.2 Rubberized concrete

The concrete mixed with rubber powder added in different weight or volume proportions is called rubberized concrete and is an infant technology. Partially replacing the cement of concrete with some quantity of waste rubber tyre powder can improve qualities Moreover the inclusion of rubber into concrete results in high resilience, durability and elasticity. In constructions that are subject to impact effects the use of rubberized concrete will be beneficial due to the altered state of its properties.

1.3. Objectives of the study

1. The principal objective of the study is to modify the brittle failure of concrete by adding waste rubber powder of size less than 90µm in different weight proportions to the cement.
2. To investigate the mechanical properties such as compressive strength and tensile strength of rubberized concrete.
3. To compare the normal concrete plastic deformation properties with rubberized concrete.
4. To investigate the durability properties such as Acid attack test, Alkali attack test of rubberized concrete.

II. EXPERIMENTAL PROGRAM

2.1. MATERIALS USED

The different materials used in this investigation are:

1. Cement
2. Fine Aggregates
3. Coarse Aggregates
4. Water
5. Waste tyre rubber

2.1.1 CEMENT:

Cement used in this investigation was 53 grade ordinary Portland cement confirming to IS: 12269-1987. The cement was obtained from a single consignment and of same grade and same source. Producing the cement and seeing that it was stored properly. The properties of cement are given in following table.

S.No.	Properties	Results	IS: 12269-1987
1.	Specific gravity	3.13	
2.	Standard consistency	32%	
3.	Initial & final setting time	32 &280 min	Mini. Of 30 &600min
4.	Comp.strength 3 days 7 days 28 days	 30Mpa 46.8Mpa 55.5Mpa	Mini. Of 27Mpa 40Mpa 53 Mpa

Table 1 Properties of Ordinary Portland cement

2.1.2 FINE AGGREGATES: According to IS: 650-1991, the standard sand shall be obtained from Swarnamukhi river, Naidupet. The sand grains shall be angular, the shape of the grains approximating to the spherical form elongated and flattened grains being present only in very small or negligible quantities. The standard sand shall (100 percent) pass through 2-mm IS sieve and shall be (100 percent) retained on 90-micron IS Sieve with the following particle size distribution. And the sieves shall conform to IS 460 (Part: 1): 1985.

Particle Size	Grade	Percent
Smaller than 2 mm and greater than 1 mm	I	33.33
Smaller than 1 mm and greater than 500 microns	II	33.33
Below 500 microns but greater than 90 microns	III	33.33

The physical properties of sand is given by

Colour	Grayish White
Specific gravity	2.60
Absorption in24 hours	0.80%
Shape of grains	Sub angular

Table 2 Properties of Fine aggregate

2.1.3 COARSE AGGREGATES: According to IS 383: 1970, coarse aggregate may be described as crushed gravel or stone when it results from crushing of gravel or hard stone. The coarse aggregate procured from quarry was sieved through the sieved of sizes 20 mm and 10 mm respectively. The aggregate passing through 20 mm IS sieve and retained on 10 mm IS sieve was taken. Specific gravity of the coarse aggregate is 2.76.

The physical properties of gravel is given by

Colour	Grayish White
Specific gravity	2.76
Shape of grains	Angular

Table 3 Properties of Coarse aggregate

2.1.4 WATER: Portable water was used in the experimental work for both preparing and curing. The pH value of water taken is not less than 6.

2.1.5 WASTE TYRE RUBBER:

In the present study ground rubber of size 0.075-0.475mm are used for the partial replacement of cement. The powder of tyre rubber was allowed to pass through IS sieves. The particles which passed through 0.475mm sieve are taken.

Type of rubber	Ground rubber
Size	0.075 to 0.475mm
Colour	Black
Specific gravity	1.14

Table 4. Properties of Waste tyre rubber

2.2 MIX DESIGN FOR PRESENT INVESTIGATION.

In the present work the Indian Standard Method (Is METHOD) has been used to get propositions for M25 grade concrete. The concrete mix design for M25 were carried out according to Indian standard recommendation method is 10262-2009.

TABLE 5. MIX PROPORTION FOR M25

Cement	Fine aggregate	Coarse aggregate	Water
437.77 Kg/m^3	568.85 Kg/m^3	1226.02 Kg/m^3	197 Kg/m^3
1	1.3	2.8	0.45

2.3 MOULDS USED FOR CASTING:

Standard cubes moulds of 150 x 150 x 150mm made of cast iron used for the cement mortar and concrete specimens for testing of compressive strength. Cylindrical moulds of 150 mm in diameter and 300 mm height is made for concrete specimens for testing of Split tensile strength.

2.4 PREPARATION OF GROUND RUBBER FOR MIXING:

Waste tyre rubber is collected with different sizes by crushing and grinding of tyres from mills under normal temperature. The collected waste has granular texture, it is sieved to the size varies from 0.075-0.475 for mixing. The tyre rubber powder was added in required proportions to partial replacement of cement.

2.5 CASTING:

The standards moulds were fitted such that there are no gaps between the plates of the moulds. If there is any gap, they were filled with plaster of Paris. The moulds were then oiled and kept ready for casting. Concrete mixes are prepared according to required proportions for the specimens by hand mixing; it is properly placed in the moulds in 3 layers. Each layer is compacted 25 blows with 16 mm diameter bar. After the completion of the casting, the specimens were vibrated on the table vibrator for 2 minutes. At the end of vibration the top surface was made plane using trowel. After 24 hours of a casting the moulds were removed and kept for wet curing for the required number of days before testing.

Figure 1. Hand mixing of wet concrete.

Figure 2. Placing of wet concrete in moulds.

2.6 CURING:

The test specimens are stored in place free from vibration; specimens are removed from moulds after 24 ± half an hour time of addition of water to dry ingredients. After this period, the specimens are marked and removed from the moulds and unless required for test within 24 hours immediately submerged in clean fresh water and kept there until taken out just prior to test. The water in which the specimens are submerged, are renewed every seven days and are maintained at temperature of 27°±2°C.The specimens are not allowed to become dry at any time until they have been testing. The specimens were put under curing for 28 days.

Figure 3. Curing of concrete cubes & cylinders.

2.7 TEST SETUP& TESTING PROCEDURE:

2.7.1 PREPARATION OF TEST SPECIMENS

A day before test, the cured specimens were removed from the curing tank, allowed to dry properly and were cleaned off from any surface dust and kept ready for testing.

Figure 4 Concrete cubes & cylinders after curing.

2.8 TESTS FOR PROPERTIES OF CONCRETE:

2.8.1 WORKABILITY TEST:

The workability of concrete was found by using slump cone test. The slump apparatus consists of a conical shape frustum of top diameter 10cm and bottom diameter 20cm with a height 30cm. The concrete mix is placed in slump cone in three equal layers. Each layer was tampered by given 25 blows with a bullet end tamping rod. After completion of last layer excess concrete was removed and level. Immediately the slump cone was raised upwards, this allows the concrete subside. The subsidence of concrete was known as SLUMP. The slump value can be measured by taking the difference between height of subside concrete and mould height. The following table gives a clear image about slump values for different workabilities.

Degree of Workability	Slump Value
Very low	___
Low	25-75
Medium	50-100
High	100-150
Very high	_____

Table 6 Slump values of Concrete with 20mm or 40mm maximum size of aggregate.

2.8.2 COMPRESSIVE STRENGTH OF CONCRETE:

Compressive strength was found out as per IS 516-1959. The compressive strength test was conducted after 28 days of curing. Standard cast iron moulds of dimensions 150 x 150 x 150 mm were used to cast the specimen.

To find the strength of the concrete specimen is tested as follows:

1) The bearing surface of the machine is cleaned.
2) Place it under a compressive load using a hydraulic compression machine.
3) Place the specimen such that the load is applied on the opposite faces.
4) Align the specimen centrally on the base plate of the machine.

The machine would increase the load onto the concrete cylinder until failure was reached.

Figure 5 Compression testing machine

2.8.3 SPLIT TUBE TENSILE STRENGTH OF CONCRETE :

This is also sometimes referred as “Brazilian test”. This test is carried out by placing a cylindrical specimen of dimensions 150mm diameter and 300mm length horizontally between the loading surfaces of a compression testing machine and load is applied until failure of the cylinder along the vertical diameter. When load is applied along the generatix, an element on the vertical diameter of the cylinder is subjected to a vertical compressive stress of $\frac{2P}{\rho LD}\left[\frac{D^2}{r(D-r)} - 1\right]$ and a horizontal stress of $\frac{2P}{\rho LD}$ where P= compressive load on cylinder, L= length of cylinder, D= diameter of cylinder and r and $(D-r)$ are the distances of the element from the two loads respectively.

The loading condition produces a high compressive stress immediately below the two generators to which the load is applied. But the larger portion corresponding to depth is subjected to a uniform tensile stress acting horizontally. It is estimated that the compressive stress is acting for about 1/6 depth and the remaining 5/6 depth is subjected to tension.

The main advantage of this method is that the same type of specimen and the same testing machines as are used for the compression test can be employed for this test.Strength determined in the splitting test is believed to be closer to the true tensile strength of concrete, than the modulus rupture. Splitting strength gives about 5 to 12% higher value than the direct tensile strength.

Figure 6 Split tube tensile test apparatus

2.8.4 ACID ATTACK TEST :

The concrete cube specimens of various concrete mixtures of size 150 mm were cast and after 28 days of water curing, the specimens were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. The acid attack test on concrete cube was conducted by immersing the cubes in the acid water for 90 days after 28 days of curing. Sulphuric Acid with pH of about 2 at 5% weight of water was added to water in which the concrete cubes were stored. The pH was maintained throughout the period of 90 days. After 90 days of immersion, the concrete cubes were taken out of acid water. Then, the specimens were tested for compressive strength. The resistance of concrete to acid attack was found by the % loss of weight of specimen and the % loss of compressive strength on immersing concrete cubes in acid water.

Figure7. Sulphuric acid

2.8.5 ALKALINE ATTACK TEST:

To determine the resistance of various concrete mixtures to alkaline attack, the residual compressive strength of concrete mixtures of cubes immersed in alkaline water having 5% of sodium hydroxide (NaOH) by weight of water was found. The concrete cubes which were cured in water for 28 days were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. Then the cubes were immersed in alkaline water continuously for 90 days. The alkalinity of water was maintained same throughout the test period. After 90 days of immersion, the concrete cubes were taken out of alkaline water.

Figure 8 Sodium Hydroxide.

Then, the specimens were tested for compressive strength. The resistance of concrete to alkaline attack was found by the % loss of weight of specimen and the % loss of compressive strength on immersion of concrete cubes in alkaline water.

III. RESULTS AND DISCUSSIONS

3.1. WORKABILTY RESULTS

Results obtained from slump cone test showing that the workability of concrete with the increasing percentage of rubber powder to cement in different volume ratios decrease the workability drastically.

Replacement of ground rubber(%)	Slump values(mm)
0	52
5	50
10	48
15	43
20	37

Table 7 Slump values for Concrete M $_{25}$ grade with varying % of rubber powder.

Figure 9 Slump cone test

From Table7, it can be concluded that the workability of concrete with increasing percentages of ground rubber in cement and corresponding slump values decreases. This is because the bond between rubber powder and concrete is increased and due to this the friction developed between rubber and concrete increases. This results in decrease in workability of concrete with surface treatment of rubber powder.

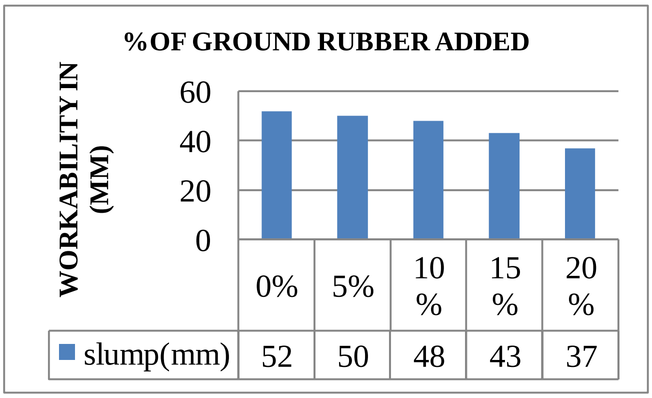

Figure10 Workability variation of concrete M $_{25}$ grade with varying % of rubber powder.

3.2 COMPRESSIVE BEHAVIOUR

The 28-days cube strength of both normal concrete and rubberized concrete were evaluated. The compressive strength of rubberized concrete is observed to be lower than that of normal concrete. The strength reduction observed in rubberized concrete when the rubber content is increased may be attributed to two reasons, the first reason is that the rubber particle are much softer (elastically deformable) than the surrounding cement paste and cracks are initiated quickly around the rubber particles in the mix, which accelerates the failure of the rubber-cement matrix. The other one is that soft rubber particles behave as voids in the concrete matrix due to the lack of adhesion between the rubber particles and the concrete. The lack of adhesion results in a void between the concrete and rubber particles. These voids decrease the strength of concrete

Figure 11 Comp. Strength test of concrete cubes

3.2.1 COMPRESSIVE STRENGTH FOR 7 DAYS & 28 DAYS CURING:

% of rubber added	Cement replacement			
	Load (Average in KN)	Comp. strength of cube after 7days (N/mm^2)	Load (Average in KN)	Comp. strength of cube after 28days (N/mm^2)
0%	714	31.75	916	40.71
5%	446	19.78	571	25.36
10%	338	15.03	434	19.27
15%	204	9.09	262	11.65
20%	183	8.14	235	10.44

Table 8 Comp. Strength of Concrete M $_{25}$ grade with varying % of rubber powder after 7days & 28days

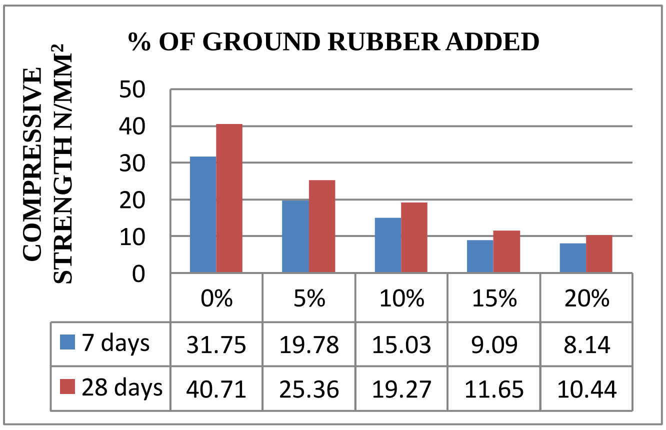

Figure 12 Compressive Strength variation of Concrete M $_{25}$ grade with varying % of rubber powder after 7days & 28days.

From above table8, it can be concluded that as the percentage of rubber content increases, compressive strength of concrete mix decreases. This is an important point to keep in mind because rubber particles when added to concrete results in drastic decrease of compressive strength.

3.3 SPLIT TENSILE BEHAVIOUR

The 28-day split tensile strength of both normal concrete and rubberized concrete were evaluated. The split tensile strength of concrete is observed to be lower than that of normal concrete. The reasons for decrement in split tensile strength are same as that of compressive strength as explained above.

3.3.1 TENSILE STRENGTH FOR 7 & 28 DAYS

Table 9 Tensile Strength of Concrete M $_{25}$ grade with varying % of rubber powder after 7days & 28days

% of rubber added	Cement replacement			
	Load (Average in KN)	Split tensile strength of cylinder after 7days (N/mm^2)	Load (Average in KN)	Split tensile strength of cylinder after 28days (N/mm^2)
0%	112.22	6.34	174.35	9.85
5%	133.81	7.56	207.79	11.74
10%	109.92	6.21	170.81	9.65
15%	87.08	4.92	135.23	7.64
20%	74.34	4.2	115.58	6.53

Figure 13 Split tensile Strength test of concrete cylinders

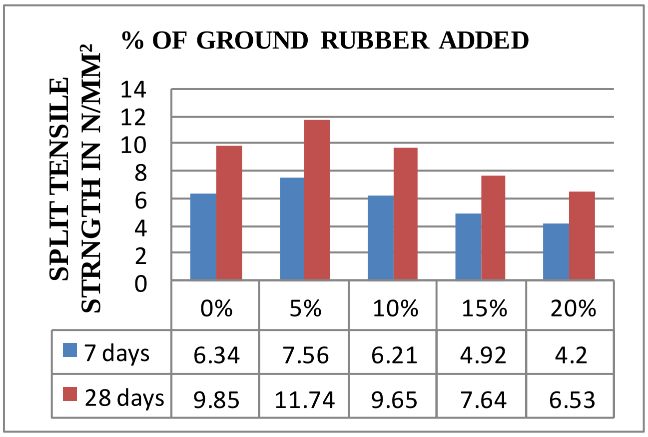

Figure 14 Split Tensile Strength variation of Concrete M $_{25}$ grade with varying % of rubber powder after 7 & 28days

From the table 9, it can be observed the as the percentage of rubber added increase tensile strength decreases. As percentage rubber increases, that resulted in reduction of tensile strength of concrete without surface treatment of rubber particles. This is because rubber particles are soft in nature, and bonding between rubber particles and cement matrix is weak. Hence when load applied on the specimen crack starts on the circumference of rubber particle and extends. When compared with reduction in compressive strength, tensile strength reduction is moderate.

3.4 ACID ATTACK TEST:

3.4.1 %LOSS OF WEIGHT REDUCTION OF CUBES AFTER 28DAYS ACID CURING:

Table 10 % loss of weight reduction of cubes in acid curing after 28 days

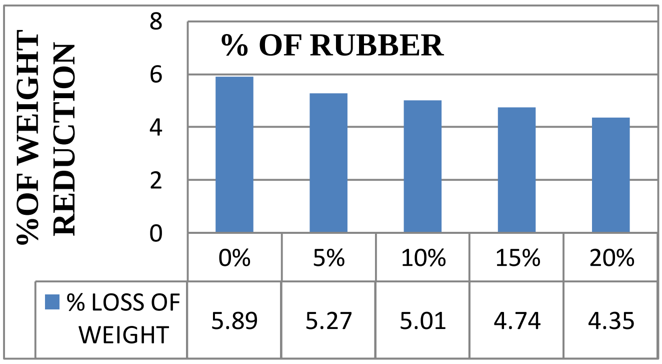

Figure 15 % loss of weight reduction of cubes in acid curing after 28 days

From above table 10, we can observe that the percentage loss of weight reduction in acid curing decreases with the increase of rubber content.

% of rubber added	Cement replacement		
	Initial weight	Final weight	%loss in weight
0%	7.97	7.5	5.89
5%	8.15	7.72	5.27
10%	7.97	7.57	5.01
15%	7.79	7.42	4.74
20%	7.57	7.24	4.35

Figure 16 Placing of concrete cubes in acid curing.

3.4.2 %LOSS OF COMPRESSIVE STRENGTH REDUCTION OF CUBES AFTER 28DAYS ACID CURING:

% of rubber added	Cement replacement		
	Comp. strength with water curing	Comp. strength after acid curing	% loss in comp. strength
0%	40.71	36.51	10.31
5%	25.36	22.86	9.85
10%	19.27	17.54	8.92
15%	11.65	10.70	8.15
20%	10.44	9.80	6.13

Table 11 % loss of compressive strength reduction of cubes in acid curing after 28 days

Figure 17 Weighing of concrete cube after 28 days acid curing.

From table11, we can observe that the percentage loss of compressive strength reduction in acid curing decreases with the increase of rubber content. The % loss in compressive strength reduction in acid curing is low with 20% of rubber content without surface treatment.

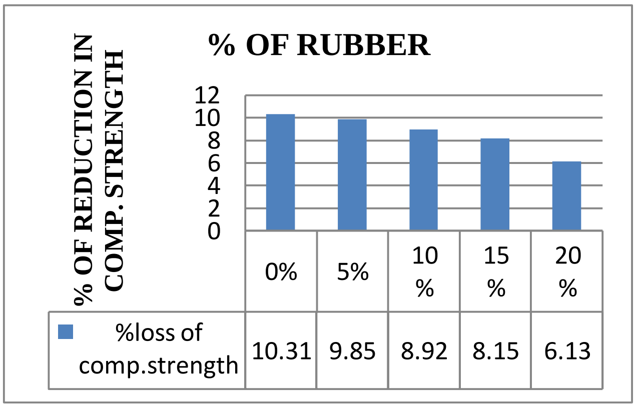

Figure 18 % loss of compressive strength reduction of cubes in acid curing after 28 days

3.5 ALKALI ATTACK TEST:

3.5.1 %LOSS OF WEIGHT REDUCTION OF CUBES AFTER 28DAYS ALKALI CURING:

% of rubber added	Cement replacement		
	Initial weight	Final weight	%loss in weight
0%	7.90	7.22	8.60
5%	8.02	7.62	4.90
10%	8.00	7.71	3.62
15%	7.92	7.82	1.26
20%	7.61	7.52	1.18

Table 12 % loss of weight reduction of cubes in alkali curing after 28 days

From table 12, we can observe that the percentage loss of weight reduction in alkali curing decreases with the increase of rubber content.

Figure 19 placing of concrete cubes in alkali curing.

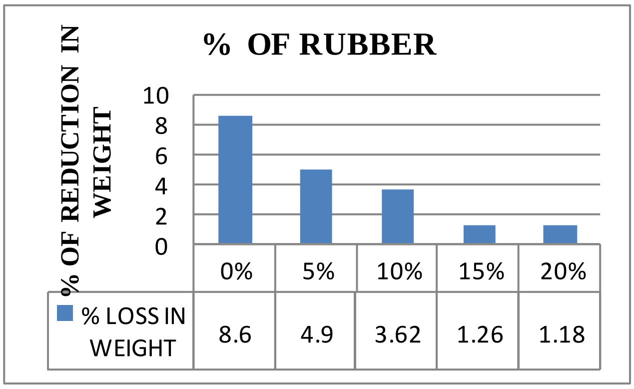

Figure 20 % loss of weight reduction of cubes in alkali curing after 28 days

3.5.2 %LOSS OF COMPRESSIVE STRENGTH REDUCTION OF CUBES AFTER 28DAYS ALKALI CURING:

% of rubber added	Cement replacement		
	compressive strength with water curing	compressive strength after alkali curing	% loss in compressive strength
0%	40.71	37.2	8.62
5%	25.36	23.46	7.49
10%	19.27	17.87	7.26
15%	11.65	10.9	6.43
20%	10.44	9.89	5.26

Table 13 % loss of compressive strength reduction of cubes in alkali curing after 28 days

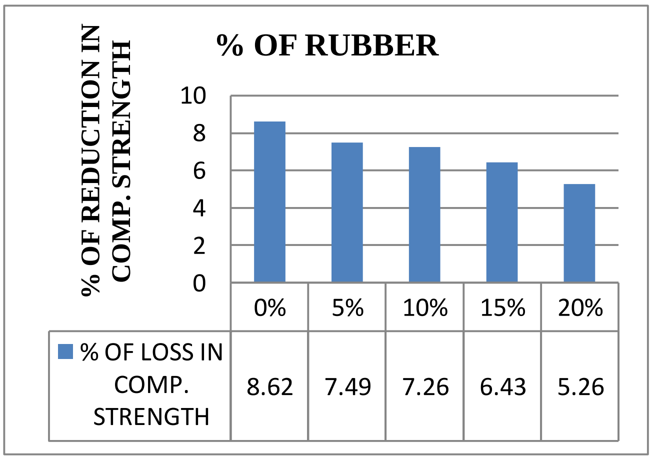

Figure 21 % loss of compressive strength reduction of cubes in alkali curing after 28 days.

From table 13, we can observe that the percentage loss of compressive strength reduction in alkali curing decreases with the increase of rubber content. The % loss in compressive strength reduction in acid curing is low with 20% of rubber content without surface treatment.

IV. CONCLUSIONS

- The addition of rubber powder to the concrete mix resulted in decrease in percentage of slump value drawn from slump cone test. As the percentage of rubber particles added increases, the percentage of slump value decreases. Hence when dealing with rubberized concrete there is a necessity of suitable super plasticiser to achieve sound workability.
- The addition of rubber powder to the concrete in different volume proportions of coarse aggregates (5%,10%,15% and 20%) resulted in a reduction of 28 days compression strength, split tensile strength of concrete mix. The decrease in strength was dependent on percentage of rubber particles added.
- This is because there is lack of proper bond between rubber particles and concrete matrix. Hence to improve the bond between rubber and concrete matrix there is need of coupling agent.
- From the alkali curing test results, We can observe that the percentage loss of weight and compressive strength reduction in alkali curing decreases with the increase of rubber content.
- From the acid curing test results, We can observe that the percentage loss of weight and compressive strength reduction in acid curing decreases with the increase of rubber content.

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