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"Self-Healing of Rubberized Polymer Concrete by Partial Replacement Method"

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ABSTRACT

Study about Self-healing concrete and its strength parameters is very important criteria in recent concrete industry. The major problem in the application of concrete is crack formation which may be structural or non-structural. These cracks reduce the durability of the concrete. This is because concrete provides a convenient way to transport liquids and gases. Therefore, maintenance and repairs are inevitable. A variety of external methods can be used to repair the crack, but the solution is expensive, time consuming, and in some cases unattractive. If cracks occur in hard-to- reach places, they must be sealed without damaging the structure. Therefore, there is a need to develop concrete that can repair cracks without external maintenance. This self-healing property can be achieved in physical, chemical, or biological ways. This paper studies the strength parameters of self healing concrete by combining with super absorbent polymer (SAP). Because SAP (sodium polyacrylate) is a chemical polymer that can be used as a self- healing agent, concrete can repair cracks without manual maintenance. Rubberized concrete is a concrete in which the scrap tire rubber is used as a partial replacement of coarse aggregate. It has been estimated that nearly 1000 million tires reach the end of their useful lives every year which imposes a serious problem to dispose of this huge bulk of waste rubber creating a threat to environment. To protect the environment from this problem researchers are consistently exploring to use this rubber as a source to replace the natural resources such as stone aggregates which will also address the growing demand of natural construction material. In this paper, we have prepared a self-healing rubberized polymer concrete by partial replacement of materials and addition of SAP, fine aggregate is replaced by copper slag (20%), coarse aggregate is replaced by rubber aggregate (15%, 25%, 35%) and cement is replaced by silica fume (5%, 10%, 15%). The SAP that is being added is Sodium polyacrylate, after the mix is prepared, we have to add this polymer (0.5%, 1%) of the sodium polyacrylates, it is used as a self-curing agent of sodium polyacrylate having the formula [-CH2-CH(CO2Na)-]n. Sodium polyacrylate consists of multiple pairs of acrylic compounds with positive and anionic charges that attract and bind water molecules, making sodium polyacrylate highly absorbent.

INTRODUCTION

SELF HEALING CONCRETE Self-healing concrete is a new type of concrete. It imitates the automatic healing of body wounds by the secretion of some kind of material. To create self- healing concrete, some special materials (such as fibres or capsules), which contain some adhesive liquids, are dispensed into the concrete mix. When cracks happen, the fibres or capsules will break and the liquid contained in them will then heal the crack at once. However, self-healing concrete is only at the research stage. Its application in the concrete industry is still some way off. Self- healing concrete is mostly defined as the ability of concrete to repair its cracks autogenously or autonomously. It is also called self-repairing concrete. Cracks in concrete are a common phenomenon due to its relatively low tensile strength Durability of concrete is impaired by these cracks since they provide an easy path for the transportation of liquids and gases that potentially contain harmful substances.

Therefore, it is important to control the crack width and to heal the cracks as soon as possible. Self-healing of cracks in concrete would contribute to a longer service life of concrete structures and would make the material not only more durable but also more sustainable. Self-healing is actually an old and well-known phenomenon for concrete as it possesses some natural autogenous healing properties. Due to ongoing hydration of clinker minerals or carbonation of calcium hydroxide ($Ca(OH)_2$), cracks may heal after some time. However, autogenous healing is limited to small cracks and is only effective when water is available, thus making it difficult to control. Nonetheless, concrete may be modified to build in autonomous crack healing. Dry started to work on the autonomous self-healing concrete in 1994. In the following years, several researchers started to investigate this topic. Many self- healing approaches are proposed. They mainly include autogenous self-healing method, capsule-based self-healing method, vascular self- healing method, electrodeposition self-healing method, microbial self-healing method, self-healing method with use of a super absorbent polymer (SAP) and self-healing method through embedding shape memory alloys. The self-healing property can be achieved by any of the following methods: 1. Self-healing by physical action 2. Self-healing by biological action 3. Self-healing by chemical action Self-healing by biological action refers to the technique of adding various bacteria like Bacillus subtilis which could acted as long-term crack sealing ineffectively, this action works at the life time of concrete. These bacteria act as catalysts, converting precursor compounds into appropriate filler materials. Newly generated compounds, such as calcium carbonate-based materials, act as bio adhesives and seal newly formed cracks. Chemical self-healing refers to the technology of adding different chemical polymers and chemically reacting with concrete cement to create a calcium carbonate-based material to repair the cracks that have formed. These polymers can be encapsulated in capsules or mixed with cement before pouring concrete.

Rubberized Concrete

Traditional concrete is primarily made up of four fundamental ingredients, i.e., coarse aggregate, fine aggregate (i.e., sand), cement and water. It has been used for over a century. Concrete occupies a unique place among modern construction materials. It gives freedom to mould the structure to any shape which is not possible with other material. Rubberized Concrete is the concrete in which coarse as well as fine aggregate is replaced by scrap tyre rubber. Nowadays, large quantities of scrap tires are generated each year globally. If these waste tires are not disposed of properly, the resulting stockpiles would cause major health risks for the public and environment. This is dangerous not only due to potential environmental threat, but also from fire hazards and provide breeding grounds for rats, mice, vermin’s and mosquitoes. To protect environment from this damage, waste tyre rubber should be reused. In the last 20 years, a lot of work by using these waste materials has been done in various civil engineering projects. By using waste tyre rubber as a coarse aggregate as well as fine aggregate in concrete the natural resources can be saved and environmental pollution can be minimized. Partially replacing the coarse or fine aggregate of concrete with some quantity of small waste tire cubes can improve qualities such as low unit weight, high resistance to abrasion, absorbing the shocks and vibrations, high ductility and brittleness and so on to the concrete.

It has been observed that the use of waste tyre as aggregate replacement improves the toughness and sound insulation properties of concrete. Rubberized concrete is specially recommended for concrete structures located in areas of severe earthquakes risk and also for applications submitted to severe dynamic actions like railway sleepers. The rubberized concrete is affordable, cost effective and withstand for more pressure, impact and temperature when compare it with conventional concrete. It is observed that the Rubber Modified Concrete (RMC) is very weak in compressive and tensile strength. But they have good water resistance with low absorption, improved acid resistance, low shrinkage, high impact resistance, and excellent sound and thermal insulation. Rubberized Concrete improves the mechanical and dynamic properties such as energy absorption, ductility and resistance. However, this may decrease compressive strength of the concrete which may be compensated by adding micro silica to the rubber containing concrete. It has been considered that rubberized concrete would be very suitable to be used in architectural applications such as nailing concrete, where high strength is not necessary, in wall panels that require low unit weight, jersey barriers in which high strength is not necessary. In recent years, much attention has been attracted towards using silica fumes in concrete to increase the strength of the concrete.

Super Absorbent Polymer

Among the sodium polyacrylates, it is used as a self-curing agent of sodium polyacrylate having the formula [-CH2-CH(CO2Na)-]n. Sodium polyacrylate consists of multiple pairs of acrylic compounds with positive and anionic charges that attract and bind water molecules, making sodium polyacrylate highly absorbent. The super absorbent polymer shown in Figure 1 is a chemical agent that inappropriately absorbs large amounts of water when added to conventional concrete. SAP after water absorption becomes an insoluble soft gel as shown in Figure 2 and its volume increases. When concrete is formed due to shrinkage or other reasons, SAP is exposed to the atmosphere. The exposed SAP absorbs moisture from the atmosphere and seals the cracks created by the swelling. The water absorbed by SAP is released after a period of time and is used to hydrate the cement. It is also widely used in agriculture.

Objectives

To determine the compressive strength and split tensile strength of the rubberized polymerconcrete.

LITERATURE REVIEW

Self-Healing Of Concrete Using Super Absorben Polymer

Authors: - Dr. A. Goplalan, E. Arundhavapriya, N. Mohanraj, S. Abirami

Study about Self-healing concrete and its strength parameters is very important criteria recent Concrete industry. The major problem in the application of concrete is crack formation which may be structural or non- structural. These cracks reduce the durability of the concrete. This in because concrete provides a convenient way to transport liquids and gases. Therefore, maintenance and repairs are inevitable. A variety of external methods can be used to repair the crack but the solution isexpensive, time consuming and in some cases unattractive. If cracks occur in hard-to-reach places, they must be sealed without damaging the structure. Therefore, there is a need to develop concrete that can repair cracks without external maintenance. This self- healing property can be achieved in physical, chemical, or biological way. This paper studies the strength parameters of self-healing concrete by combining with super absorbent polymer (SAP). Because SAP (sodium polyacrylate) is a chemical polymer that can be used as a self-healing agent, concrete can repair cracks without manual maintenance. Samples are cast with an additional 0%, 0.2596, and 0,506 and tested at the 7th and28th cures to determine the compressive, flexural, and impact strength of concrete using SAP. The results show that the strength of the concrete increases only with increasing curing period.

Study On The Properties Of Concrete By Using SuperAbsorbent Polymer" (2017)

Authors: - M Sivaranjani, K Ranjitha, S Premkumar

The use of super absorbent polymer (SAP) in concrete is confirmed to have many constructive effects on the properties of concrete in its both stage; fresh concrete and hardened concrete. This study focuses on the use of a most select amount of Sodium Polyacrylate as a super absorbent polymer in ordinary plain concrete. In the past efforts were made only to study the significant reduction of crack width in the concrete. However strength being the important factor for concrete the study focuses on the strength parameter of concrete The main focus of this study will be on the result of the SAP on the fresh concrete as the hardened concrete Several batches were prepared to determine the result of the SAP on concrete when subjected to compressive, tensile stress In the present study, the effect of admixture (super absorbent polymer) on compressive strength, split tensile strength and water absorption by varying the percentage of super absorbent polymer by weight of cement from 0% to 1.5% were studied for M20. It was found that a super absorbent polymer could help in increasing hydration process by giving super absorbent polymer by weight of cement was optimum for M20 grade concretes for achieving maximum strength without well compromising workability. In this review paper effort has been made to understand the working and efficiency of this curing method and compared with the conventional water curing method.

MATERIALS REQUIRED

The following materials are required:

1. Ordinary Portland Cement
2. Fine Aggregate
3. Coarse Aggregate
4. Copper Slag
5. Silica Fume
6. Sodium Polyacrylate

Properties Of The Materials

Ordinary Portland Cement

The chief chemical components of ordinary Portland cement are Calcium, Silica, Alumina andIron. Approximate oxide composition limits are:

Table 1 Ordinary Portland Cement

CaO	60-67%
SiO2	17-25%
Al2O3	3-8%
Fe2O3	0.5-6.0%
Alkalis	0.3-1.2%
SO3	2.0-3.5%
MgO	0.5-4.0%

Fig 1 Ordinary Portland Cement

Coarse Aggregate

Construction aggregate, or simply aggregate, is a broad category of course- to medium-grained particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Due to the relatively high hydraulic conductivity value as compared to most soils, aggregates are widely used in drainage applications such as foundation and French drains, septic drain fields, retaining wall drains, and roadside edge drains. Aggregates are alsoused as base material under foundations, roads, and railroads. In other words, aggregates are used asa stable foundation or road/rail base with predictable, uniform properties (e.g., to help prevent differential settling under the road or building), or as a low-cost extender that binds with more expensive cement or asphalt to form concrete.

Fig 2 Coarse Aggregate

Fine Aggregate

Fine aggregate is the essential ingredient in concrete that consists of natural sand or crushed stone. The quality and fine aggregate density strongly influence the hardened properties of the concrete. The concrete or mortar mixture can be made more durable, stronger and cheaper if you madethe selection of fine aggregate on basis of grading zone, particle shape and surface texture, abrasion,skid resistance, absorption and soil moisture. Aggregate is the granular material used to produceconcrete or mortar and when the particles of the granular material are so fine that they pass through a 4.75mm sieve, it is called fine aggregate. It is widely used in the construction industry to increase the volume of concrete; thus, it is a cost saving material and you should know everything about the fine aggregate size, its density and grading zone to find the best material.

Fig 3 Fine Aggregate

Rubber Aggregate

Rubber is produced excessively worldwide every year. It cannot be discharge off easily in the environment as its decomposition takes much time and also produces environmental pollution. In such a case the reuse of rubber would be a better choice. In order to reuse rubber wastes, it was added to concrete as coarse aggregate and its different properties like compressive strength, Tensile strength, ductility etc. were investigated and compared with ordinary concrete. As a result, it was found that rubberized concrete is durable, less ductile, has greater crack resistance but has a low compressive strength when compared with ordinary concrete. The compressive strength of rubberized concrete can be increased by adding some amount of silica to it.

Fig 4 Rubber Aggregate

Silica Fume

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the mostbeneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it isa very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable. Silica fume, also known as micro silica, is an amorphous polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloyproduction and consists of spherical particles with an average particle diameter of 150 nm.

Fig 5 Silica fume

COPPER SLAG

Copper slag is a by-product of copper extraction by smelting. During smelting, impurities become slag which floats on the molten metal. Slag that is quenched in water produces angular granuleswhich are disposed of as waste or utilized as discussed below.

Fig 6 Copper slag

Sodium Polyacrylate

Sodium polyacrylate, also known as water lock, is a sodium salt of polyacrylic acid with the chemical formula [−CH₂−CH−] and has broad applications in consumer products. This super- absorbent polymer has the ability to absorb 100 to 1000 times its mass in water. Sodium polyacrylate is an anionic polyelectrolyte with negatively charged carboxylic groups in the main chain. Sodium polyacrylate is a chemical polymer made up of chains of acrylate compounds. It contains sodium, which gives it the ability to absorb large amounts of water. Sodium polyacrylate is also classified as an anionic polyelectrolyte. When dissolved in water, it forms a thick and transparent solution due to the ionic interactions of the molecules. Sodium polyacrylate has many favorable mechanical properties. Some of these advantages include good mechanical stability, high heat resistance, and strong hydration. It has been used as an additive for food products including bread, juice, and ice cream.

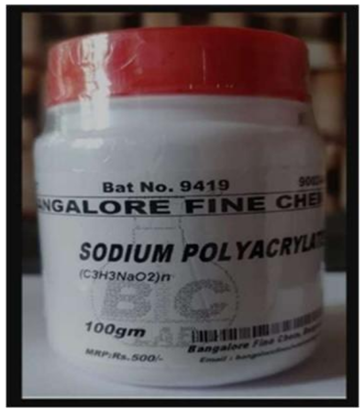
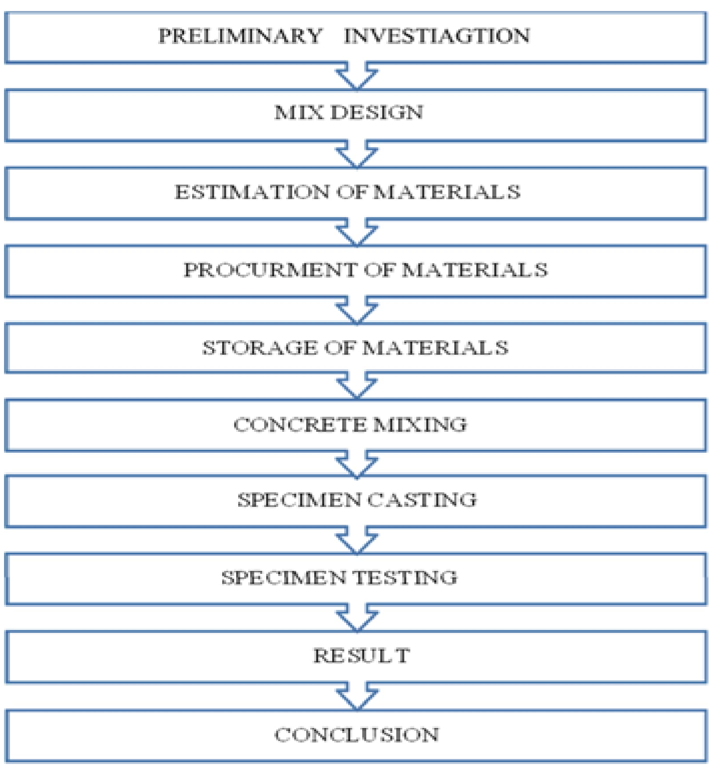


Fig 3.2.7 Sodium Polyacrylate

METHODOLOGY

Steps Involved (Flow Chart)



MIX DESIGN OF RUBBERIZED POLYMER CONCRETE

MATERIAL	QUANTITY
Cement	328 kg/m3
Silica fume	123 kg/m3
Fine aggregate	600 kg/m3
Copper Slag	150 kg/m3
Coarse aggregate	720 kg/m3
Rubber aggregate	580 kg/m3
Super absorbent polymer (SAP)	1.885 kg/m3
Water	192 kg/m3
Water Cement ratio	0.47
Ratio	1:0.42:1.89:0.47:2.27:1.83 (Cement: S.F: F.A: C.S: C.A: R.A)

AS PER IS 10262:2016

Estimation of Materials Required

Based on the requirement of experimental work to be conducted the materials required for the casting of specimens (cubes and cylinders) is calculated. The dimensions of the cubes and cylindersto be prepared are 150x150x150mm cubes and cylinders of diameter 150mm and height 300mm. in the present study the materials used are cement, coarse aggregate 10mm down size, river sand, fly- ash, super-Plasticizer, bacterial solution, calcium lactate and the chemicals required for culturing of bacteria. Weight batching method will be adopted for material proportioning.

Procurement of Material

Based on the calculations of quantities of material required considering the losses and other parameters the materials will be procured based on the quality of materials required and availability of the material locally. The material procurement will be done at the initial stage so as to maintain the same quality throughout the project work and to avoid the preliminary investigations of materials multiple times.

Storage Of Material

The materials procured will be stored properly such as cement will be stored in such a manner that it does not come in contact with water and similarly other materials will be stored in controlled environmental conditions to avoid the degradation of quality of materials.

Mixing And Casting Procedure

- All the materials are weight batched using weighing balance.
- The materials are weighed according to the proportions and mix design.
- The coarse aggregate is taken first during mixing procedure.
- The fine aggregates are then thoroughly mixed with coarse aggregate.
- Cement is added to the mixture of coarse aggregate, rubber, fine aggregate and copper slag.
- Silica fume is added as a partial replacement of cement in dry state only.
- Sodium polyacrylate added to the concrete dry mix as per mix design.

- The measured quantity of water taken in a container and added to the mix.
- After adding mix, it is thoroughly mixed till a uniform paste is obtained.
- Standard mould of cubes of size generally 150 x 150 x 150mm will be used
- And cylinders of diameter 150mm and height 300mm will be used.
-

Fig. Specimen casting

Fig. Preparation of mould

Fig. Curing of mould

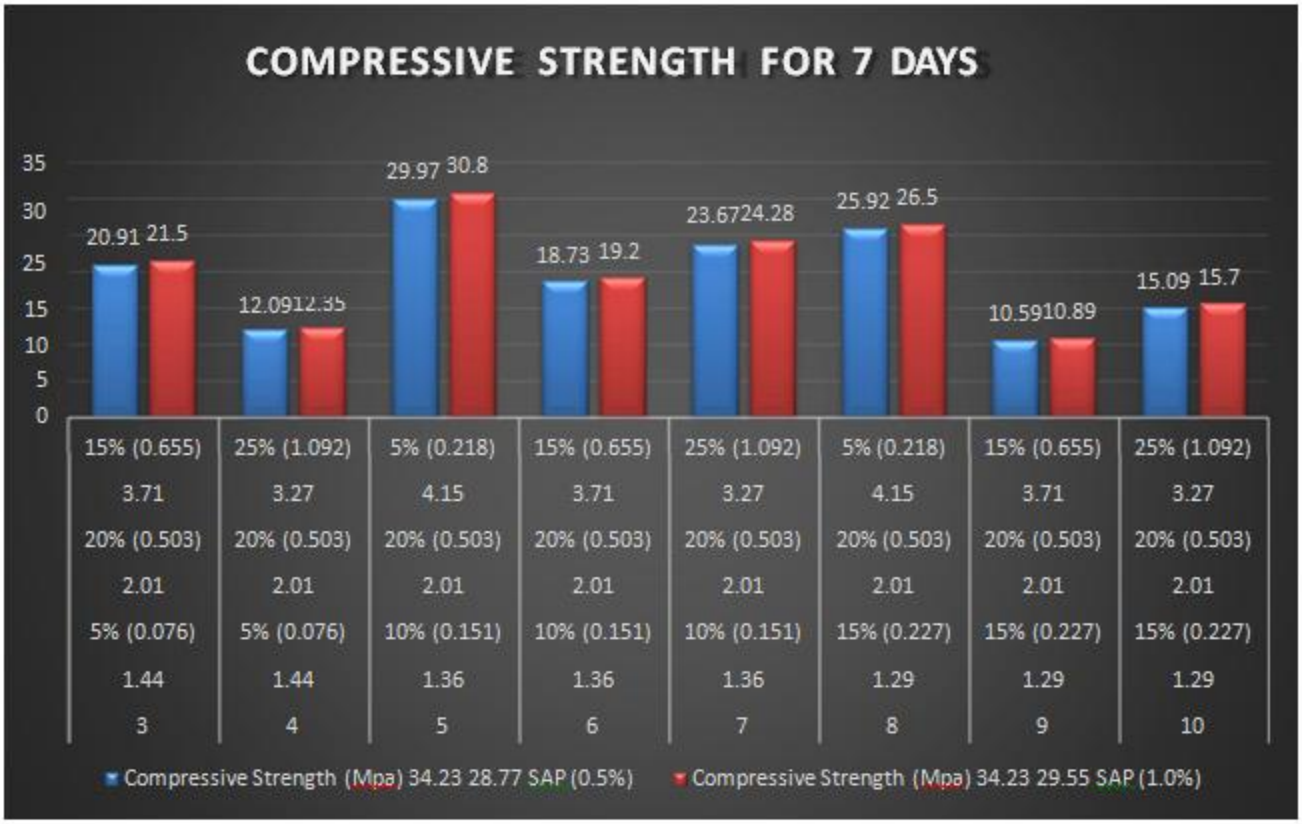
TESTING

The specimens will be subjected to the following tests:
1.Compressive strength test
2.Split tensile strength test

COMPRESSIVE STRENGTH FOR 7 DAYS

Sl. No.	Cement(kg)	Silica fume	F.A (kg)	Copper slag (kg)	C.A (kg)	Rubber Aggregates (kg)	Compressive Strength (Mpa)	
1	1.51		2.52	-	4.37	-	34.23	
2	1.44	5% (0.076)	2.01	20% (0.503)	4.15	5% (0.218)	28.77 SAP (0.5%)	29.55 SAP (1.0%)
3	1.44	5% (0.076)	2.01	20% (0.503)	3.71	15% (0.655)	20.91	21.5
4	1.44	5% (0.076)	2.01	20% (0.503)	3.27	25% (1.092)	12.09	12.35
5	1.36	10% (0.151)	2.01	20% (0.503)	4.15	5% (0.218)	29.97	30.8
6	1.36	10% (0.151)	2.01	20% (0.503)	3.71	15% (0.655)	18.73	19.2
7	1.36	10% (0.151)	2.01	20% (0.503)	3.27	25% (1.092)	23.67	24.28
8	1.29	15% (0.227)	2.01	20% (0.503)	4.15	5% (0.218)	25.92	26.5
9	1.29	15% (0.227)	2.01	20% (0.503)	3.71	15% (0.655)	10.59	10.89
10	1.29	15% (0.227)	2.01	20% (0.503)	3.27	25% (1.092)	15.09	15.7

COMPRESSIVE STRENGTH FOR 7 DAYS



SL. NO.	Cement (kg)	Silica fume	F.A (kg)	Copper slag (kg)	C.A (kg)	Rubber Aggregates (kg)	Compressive Strength (Mpa)	
1	1.51	-	2.52	-	4.37	-	45.64	
2	1.44	5% (0.076)	2.01	20% (0.503)	4.15	5% (0.218)	38.37 SAP (0.5 %)	39.3 SAP (1.0 %)
3	1.44	5% (0.076)	2.01	20% (0.503)	3.71	15% (0.655)	27.89	28.7
4	1.44	5% (0.076)	2.01	20% (0.503)	3.27	25% (1.092)	16.12	16.9
5	1.36	10% (0.151)	2.01	20% (0.503)	4.15	5% (0.218)	39.96	41.1
6	1.36	10% (0.151)	2.01	20% (0.503)	3.71	15% (0.655)	24.98	25.84
7	1.36	10% (0.151)	2.01	20% (0.503)	3.27	25% (1.092)	31.56	32.4
8	1.29	15% (0.227)	2.01	20% (0.503)	4.15	5% (0.218)	34.56	35.4

9	**1.29**	**15% (0.227)**	**2.01**	**20% (0.503)**	**3.71**	**15% (0.655)**	**14.12**	**14.8**
10	**1.29**	**15% (0.227)**	**2.01**	**20% (0.503)**	**3.27**	**25% (1.092)**	**20.12**	**20.96**

COMPRESSIVE STRENGTH FOR 28 DAYS

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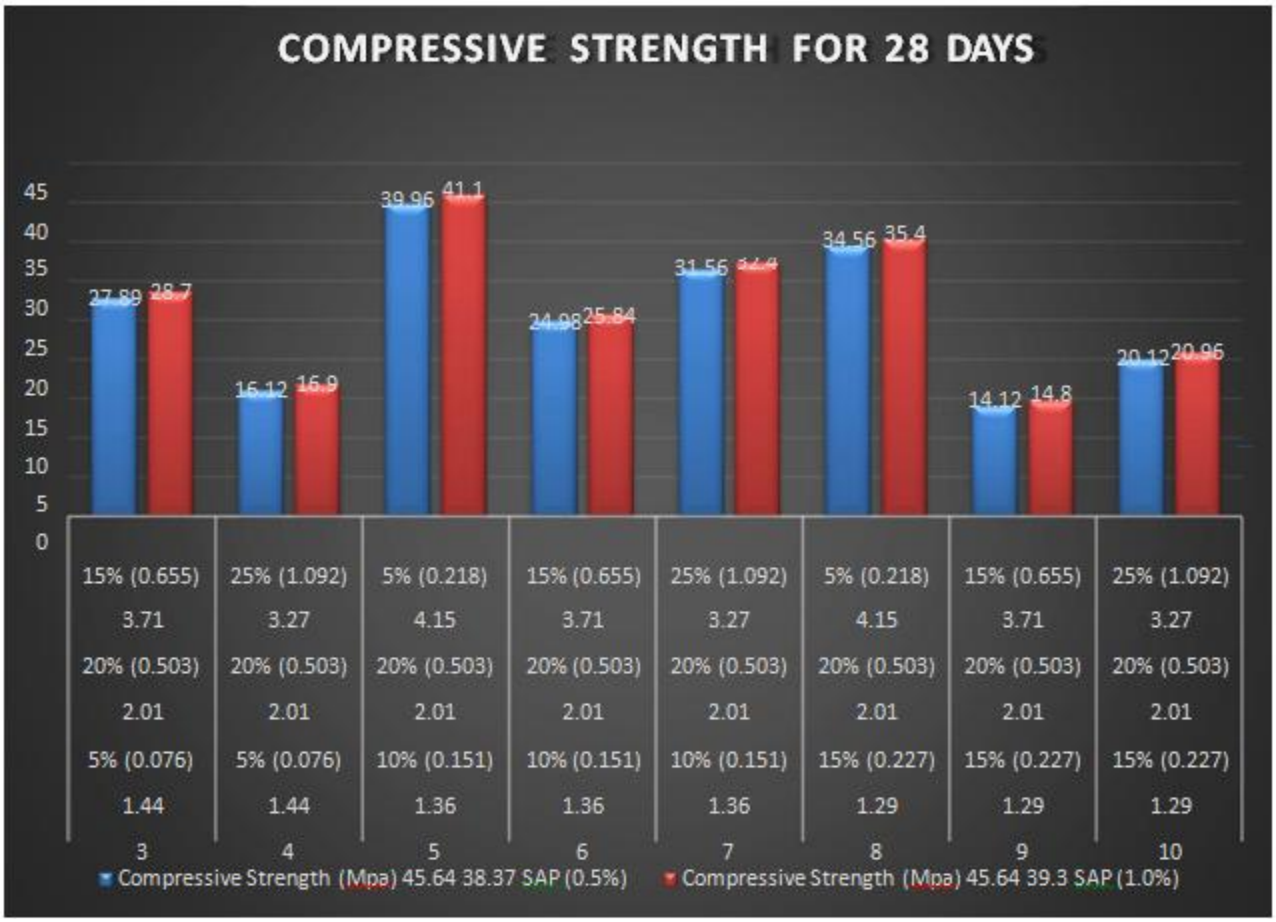
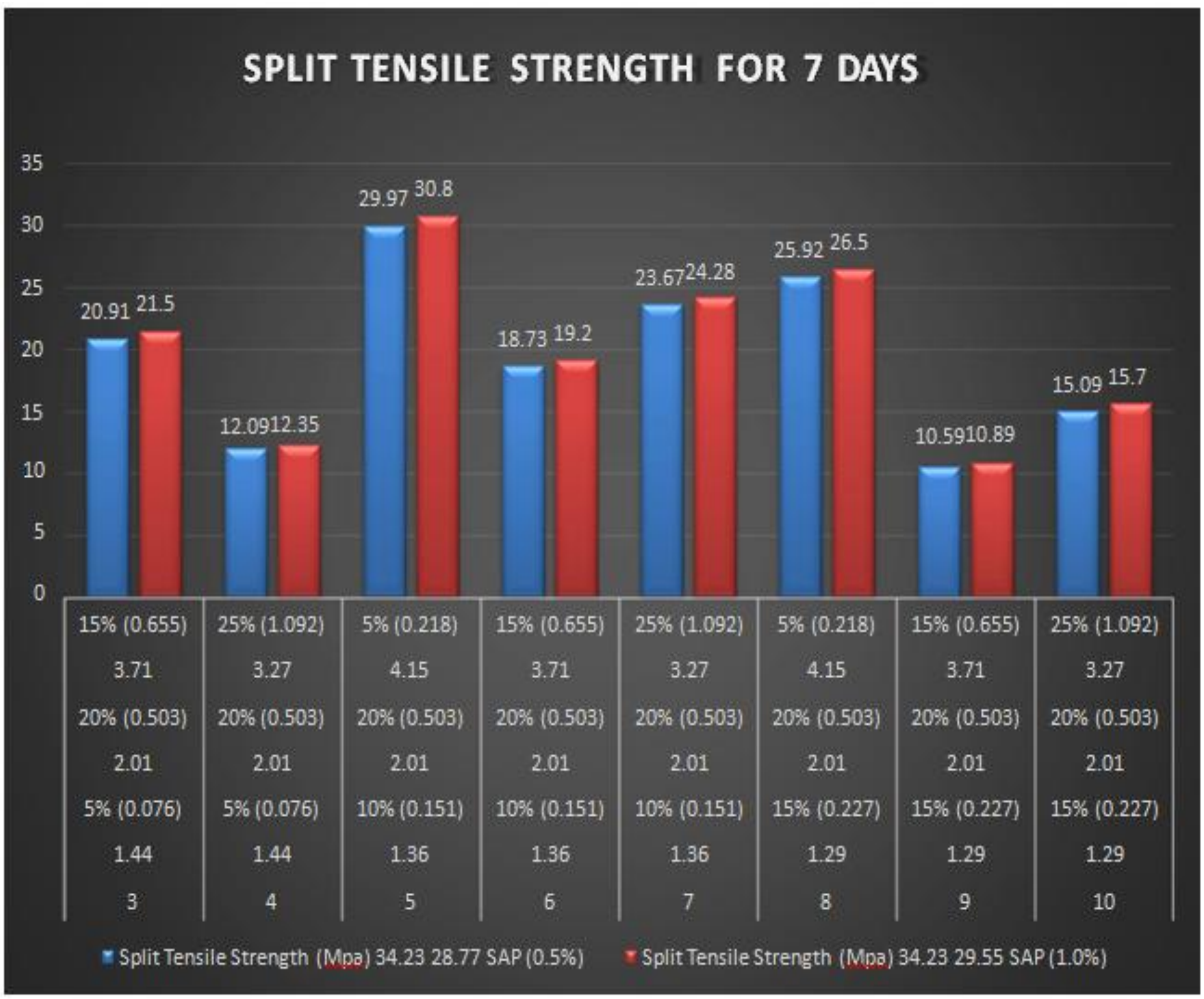


SPLIT TENSILE STRENGTH FOR 7 DAYS

SL. NO.	Cement (kg)	Silica fume	F.A (kg)	Copper slag (kg)	C.A (kg)	Rubber Aggregates(kg)	Split Tensile Strength (Mpa)	
1	**1.51**	**-**	**2.52**	**-**	**4.37**	**-**	**34.23**	
2	**1.44**	**5% (0.076)**	**2.01**	**20% (0.503)**	**4.15**	**5% (0.218)**	**28.77 SAP (0.5 %)**	**29.55 SAP (1.0 %)**
3	**1.44**	**5% (0.076)**	**2.01**	**20% (0.503)**	**3.71**	**15% (0.655)**	**20.91**	**21.5**

4	**1.44**	**5% (0.076)**	**2.01**	**20% (0.503)**	**3.27**	**25% (1.092)**	**12.09**	**12.35**
5	**1.36**	**10% (0.151)**	**2.01**	**20% (0.503)**	**4.15**	**5% (0.218)**	**29.97**	**30.8**
6	**1.36**	**10% (0.151)**	**2.01**	**20% (0.503)**	**3.71**	**15% (0.655)**	**18.73**	**19.2**
7	**1.36**	**10% (0.151)**	**2.01**	**20% (0.503)**	**3.27**	**25% (1.092)**	**23.67**	**24.28**
8	**1.29**	**15% (0.227)**	**2.01**	**20% (0.503)**	**4.15**	**5% (0.218)**	**25.92**	**26.5**
9	**1.29**	**15% (0.227)**	**2.01**	**20% (0.503)**	**3.71**	**15% (0.655)**	**10.59**	**10.89**
10	**1.29**	**15% (0.227)**	**2.01**	**20% (0.503)**	**3.27**	**25% (1.092)**	**15.09**	**15.7**

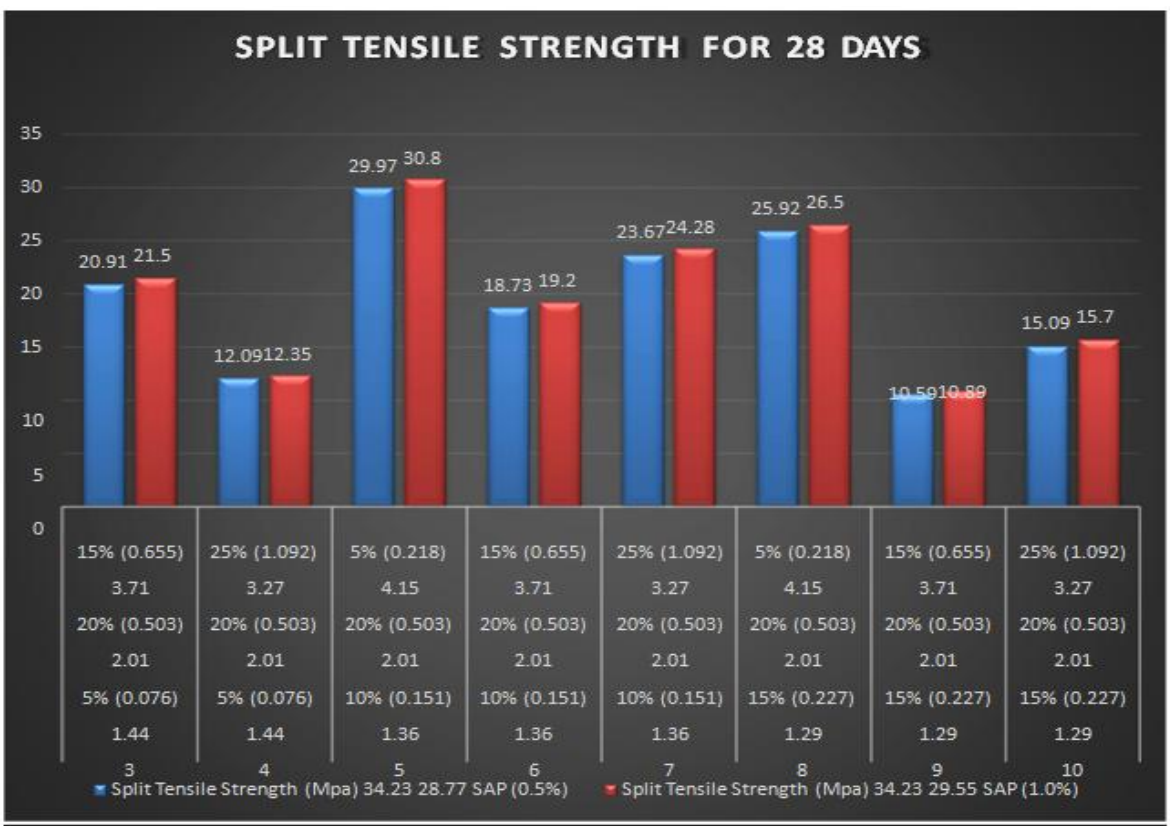
SPLIT TENSILE STRENGTH FOR 7 DAYS



SPLIT TENSILE STRENGTH FOR 28 DAYS

SL. NO.	Cement (kg)	Silica fume	F.A (kg)	Copperslag (kg)	C.A (kg)	Rubber Aggregates (kg)	Split Tensile Strength (Mpa)	
1	1.51	-	2.52	-	4.37	-	1.53	
2	1.44	5% (0.076)	2.01	20% (0.503)	4.15	5% (0.218)	1.74 SAP (0.5%)	1.77 SAP (1.0%)
3	1.44	5% (0.076)	2.01	20% (0.503)	3.71	15% (0.655)	1.67	1.69
4	1.44	5% (0.076)	2.01	20% (0.503)	3.27	25% (1.092)	1.57	1.59
5	1.36	10% (0.151)	2.01	20% (0.503)	4.15	5% (0.218)	1.68	1.7
6	1.36	10% (0.151)	2.01	20% (0.503)	3.71	15% (0.655)	1.80	1.84
7	1.36	10% (0.151)	2.01	20% (0.503)	3.27	25% (1.092)	1.68	1.7
8	1.29	15% (0.227)	2.01	20% (0.503)	4.15	5% (0.218)	1.65	1.67
9	1.29	15% (0.227)	2.01	20% (0.503)	3.71	15% (0.655)	1.56	1.58
10	1.29	15% (0.227)	2.01	20% (0.503)	3.27	25% (1.092)	1.5	1.52

SPLIT TENSILE STRENGTH FOR 28 DAYS



RESULT

1. The optimum percentage of polymer is 1% at which higher strength is achieved.

2. The Compressive Strength of the Rubberized Polymer Concrete made by replacement of materialsadding SAP (0.5%) is 40% lower than the Conventional Concrete.

3. The Split Tensile Strength of the Rubberized Polymer Concrete made by replacement of materialand adding SAP (0.5%) is 30% higher than conventional concrete.

4. It was found that the added SAP does not impact the tensile strength of concrete.

REFERENCES

[1]. Dr. A. Goplalan, E. Arundhavapriya, N. Mohanraj, S. Abirami, International Journal of Disaster Recovery and Buisness Continuity, Volume 11, No. 1 (2020), pp. 328-334.

[2]. K.Durga Bhavani, J.Naga Durga Sai, "An Experimental Study on High Strength Bacterial Concrete with Partial Replacement of Coarse aggregate As Recycled Aggregates", International Research JOURNAL of Engineering and Technology,Volume:06 issue:05 | May 2019 p- ISSN:2395-0072.

[3]. K.Satishkumar, K.Anitha, International Journal of Pure and Applied Mathematics, Volume 116 No.14 2017, 25-30 , ISSN: 1311-8080.

[4]. M. Sivaranjani, K. Ranjitha, S. Premkumar, "Study on the Properties of Concrete by using Super Absorbent Polymer", International Journal for Research in Applied Science and Engineering Technology, Volume 5 Issue 111, March 2017, ISSN: 2321-9653.

[5]. H. X. D. Lee, H. S. Wong, N. R. Buenfeld, "Self-sealing of cracks in concrete using superabsorbent polymers "Cement & Concrete Research (2016), 79, 194-208

[6]. Arn Mignona.B, Didier Snoecka, "David Schaubroeckc, Nathalie Luickxd, Peter Dubruelb, Sandra Van Vlierbergheb, Nele De Beliee" (2015) pH-responsive superabsorbent polymers: a pathway to self-healing of mortar, Vol.3, pp. 1381-5148.

[7]. Ghandhimathi, A1, Suji, D2, Elayarajah, B "Bacterial concrete; Development of concrete to increase the split tensile and compressive strength using Bacillus sphaericus", International Journal of Applied Engineering Research, ISSN 0973- 4562 Volume 10, Number 3 (2015) pp. 7125-7132.

[8]. Parul Mangal, "An experimental Study on Rubberized Concrete by Using Waste Material with the Addition of Human Hair as Fiber", International Journal for Research in Applied Science and Engineering Technology, Volume 3 Issue IX, September 2015, ISSN: 2321-9653

[9]. Didier Snoeck1, Kim Van Tittelboom1, Stijn Steuperaert2, Peter Dubrue and Nele De Belie1, "Self- healing cementitious materials by the combination of microfibers and super absorbent polymers" Journal of Intelligent Material Systems and Structures 2014, Vol 25(1) 13–24 The Author(s) 2012.