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Impact of using SAP and Stone Powder in High Strength Concrete

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Abstract

In the current exploratory examination, an undertaking has been made to consider the properties of high strength concrete using the mix of stone powder and a super absorbent polymer (SAP) like sodium polyacrylate. In M60 evaluation of concrete, sand is supplanted with stone buildup and sodium polyacrylate is added while blending the constituents. Mechanical properties like compression, split tension and flexural strength have been surveyed and compared with the referral concrete. At later age, imperative upgrades in the mechanical properties of SAP intertwined concrete were taken note. SAP decreases the shrinkage in concrete and improves cement hydration which serves to increase the compressive strength. SAP retains pore solution during blending of concrete and conveys it when the relative humidity of pore framework gets diminished because of cement hydration. Expansion of SAP in concrete extends the speed of hydration of cement particles, which thusly adds to decrease in capillary porosity of the framework. Air relieving of concrete can accomplish a similar strength as that of regularly restored concrete; henceforth SAP is moreover sensible in water sparse zones.

Keywords*: - Super absorbent polymer, High strength concrete, Stone powder*

INTRODUCTION

High density concrete is of concrete with a density higher than normal 2300 to 2550 kg/m³ and is used for special purposes such as radiation shielding, counter weights, ballasts, safe walls and safe roofs. Thus the density of high density concrete is about 50% more than the density of customary concrete. However this concrete can be produced up to density of 5200

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kg/m3 using iron as both fine and coarse aggregate. The modulus of elasticity and Poisson's ratio of high density concrete and normal concrete are approximately the same. Shrinkage of high density concrete is about 1/4 to 1/3 of the normal concrete. Thermal conductivity, diffusivity etc. of high strength concrete is considerably lower than corresponding values for normal aggregate concrete. High density concrete may contain high content of cement and may exhibit increased creep and shrinkage. Due to the high density of aggregate, it has a tendency of segregation. Coarse aggregate used may be of only high density mineral aggregate, or a mixture of mineral aggregate and steel particles or only steel particles.

High strength concrete (HSC) with a low water cement ratio has become widely used in the last decades, it needs particular curing to complete hydration process so addition of super absorbent polymer (SAP) as internal curing and its effect on mechanical properties of high strength concrete is studied in this research.

If the early age shrinkage of ultra high strength concrete (UHSC) cannot be effectively controlled, the self-stress development under constraint conditions may induce cracking and impair the properties of concrete. Conventional external curing methods, such as watering and covering with wet burlap, are difficult to have obvious effects due to a relatively low surface porosity of high strength concrete. Internal curing is thought to be a very effective way to retain the internal relative humidity of concrete by releasing water of internal curing materials.

Super absorbent polymers are gradually being applied in concrete production as internal curing agents. SAP can effectively reduce early age autogenous shrinkage of concrete, alleviate the hazards caused by concrete cracking and improve its freeze–thaw resistance.

SAPs have water absorption capacity of up to 5000 times of their own mass. Internal curing by SAPs is based on the release of water from a reservoir within the SAP into the microstructure; thereby the cement matrix maintains a high relative humidity (RH) over time. Therefore, SAPs can effectively inhibit the autogenous shrinkage and the onset of cracking.

SAP can absorb hundreds milliliters (ml) of water per gram of its weight. After SAP particle absorb the external water during mixing of concrete, the water released from SAP to continue the hydration of

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cement, i.e. producing more gel particles and hence, more development in strength. The addition of SAP to concrete mix lead to decrease in compressive strength especially in early age, this reduction was associated with increase of capillary and gel porosity in the internally cured system because SAP expands after absorbing water, became a hydro-gel and acted as voids in the cementation materials.

Water curing is a very important technical measure for concrete in order to ensure the hydration process of cementitious materials in concrete. Effective water curing measures should ensure enough moisture environments inside and outside the concrete which are necessary for hydration. If the moisture is not enough, it will cause early shrinkage and even the cracking of concrete, which will adversely affect the growth of strength and durability of concrete at later age. In practical engineering, manual operation and external curing are usually adopted, which is very difficult to produce timely and adequate curing.

SAP is a common water absorbent material with excellent water absorption and desorption capacity. In recent years, relevant research work on SAP concrete has been carried out internationally, and the influence of SAP on the construction performance, strength and durability of concrete has been studied [1, 2].

The research conducted by Dudziak and Mechtcherine [3] indicated that because the SAP in concrete absorbed moisture in the mixture and reduces the slump of the concrete, additional internal curing water absorbed by the SAP was needed to compensate for the moisture in concrete. Snoeck and Schaubroeck [4] compared the performance of concrete with different kinds of SAP. The results showed that if the particle size was small, the water absorption rate and the volume of SAP had a negative impact on the performance of concrete. When internal curing water was absorbed by SAP, the reduction of workability could be compensated to a certain extent [5]. However, SAP will leave pores when water is released.

Studies [6–9] have also shown that although the swelling of SAP affects the development of early pore structures, the water absorbed by the SAP will gradually release when the relative humidity of the concrete decreases. It will effectively alleviate the autogenous shrinkage and promote hydration of cementitious materials. Therefore, the strength of concrete may be enhanced.

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The use of superabsorbent polymers in cementitious materials has seen an increased interest in the past decade due to its efficiency in mitigating autogenous shrinkage [10, 11]. Studies have shown that the concrete micro structure must be sufficiently permeable to allow any retained water within the hydro-gel to refill as many voids as possible and aid in hydration, without increasing capillary porosity. Also, micro-structural properties directly affect the strength of the cementitious material [12]. The amount of retained water in hydro-gels governs the size of voids in the microstructure and thus plays an important role in mechanical properties [13, 14].

Researchers have applied SAP as an internal curing agent in Portland cement concrete (PCC), which could greatly reduce the self-shrinkage of PCC and prevent early cracking. Also, improved impermeability, low-temperature cracking resistance, and workability were found by adding SAP [15–17]. Dang et al. [18] found that the incorporation of pre-absorbed SAP in concrete has a significant effect on the early self-shrinkage of high-strength concrete [19]. Kim et al. used the non-metallic mineral polymer water-absorbent composite material to internally maintain the concrete, which greatly improved the self-shrinkage and drying shrinkage of the concrete and improved its cracking resistance [20, 21]. Lura et al. [22] and Zhu et al. [23] concluded that SAP could significantly reduce the plastic shrinkage of concrete and particle size of SAP has a certain influence on the curing effect. The effect of reducing plastic shrinkage increases with particle size, and ～50% decrease can be observed in the reference concrete at its maximum effect.

EXPERIMENTAL PROGRAM

A. Materials

Cement: Ordinary Portland cement (OPC) conforming to Grade 53, is used in the proposed work. Cement utilized conforms to IS: 8812 IS: 12269-1987 respectively.

Stone powder: Among the numerous materials researched, crushed stone powder has all the earmarks of being the most reasonable on the grounds that it is accessible in huge amounts in many pieces of the world. The properties of concrete made with halfway supplanting with stone dust are comparable with the results of natural sand.

Fine aggregate: It is the aggregate most of which passes through a 4.75 mm IS sieve and contains only that much coarser

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material as is permitted by specifications. The sand used in this investigation is ordinary river sand obtained from the banks of Tungabhadra River. The sand is free from clayey matter, silt and organic impurities etc. The sands are commonly isolated into various zones as indicated by the rates passing the IS: 600 micron strainer. IS: 383-1970 groups four zones, I, II, III and IV with the goal that the scope of rate passing the 600 micron sifter in each zone doesn't cover. The sand utilized for the current examination falls in zone-II.

Coarse aggregate: The aggregates most of which are held on 4.75 mm IS sifter and contain only that much of fine material as permitted by the specifications are termed as coarse aggregates. 20 mm nominal size of coarse aggregate was utilized in the experimentation. Since the aggregates are formed due to natural disintegration of rocks or by the artificial crushing of gravel, they derive many of the properties from the parent rocks. The physical properties have been determined in accordance with the guidelines mentioned in IS: 2386-1963.The coarse aggregate was free from clayey matter, silt and organic impurities etc. The specific gravity of the coarse aggregate was 2.71 and fineness modulus was 3.79.

Water: Potable water free from suspended solids and organic materials was used. The water utilized for both blending and curing of concrete was free from polluting influences, damaging measures of acids, antacids, oils, salts, natural issue or different substances that might be malicious to cement or steel. The presence of chlorides and sulfates are injurious to reinforcing bars as they may be corroded. The general requirements of water for blending and curing of concrete shall be as per guidelines of IS 456- 2000.

Super Absorbent Polymer: SAPs are cross-linked poly-electrolytes which swell upon contact with water or aqueous solutions and result in the formation of hydro-gel. They include acryl amide/acrylic acid copolymer and poly acrylic acid. The main driving force for the swelling of SAPs is the osmotic pressure that is proportional to the concentration of ions in the aqueous solution. Thus, the absorption capacity of SAPs is strictly dependent on the concentration of ions in the solution medium. Sodium Polyacrylate is used as an internal curing agent in the current investigation.

B. Mix Proportions

Three distinctive mix proportions were prepared. The first blend was prepared

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from 100% stream sand and cement content to deliver conventional concrete. The second mix was prepared using 50% stone powder, 50% sand and 100% cement. The third mix was produced using 50% stone powder, 50% natural sand, 100% cement and varying percentages of sodium polyacrylate. The water cement ratio for all the blends was fixed at 0.3, by weight.

Table-I: Mix proportions - M60 grade of concrete

Cement	449 kg/m^3	1
SCM	112 kg/m^3	0.25
Fine aggregate	664.52 kg/m^3	1.48
Coarse aggregate	20 mm – 808.3 kg/m^3 12.5 mm – 202 kg/m^3	2.21
Water	153 kg/m^3	0.3
SP	62 kg.m^3	0.14

This exploration was led in the laboratory to decide the conduct of the concrete in terms of mechanical properties. The extent of work covers the mechanical and physical properties with 50% stone powder as fine aggregate and addition of super absorbent polymer to the dry constituents of concrete. The mechanical properties of solidified concrete were attempted through the compressive strength test with cubes 150mm × 150mm × 150mm shape. The cube specimens were tested at the ages of 28 and 90 days after the wet curing process at the restoring tank agreement to strategies of IS 9013: (1978).

The split tensile strength was carried out on the standard test cylinder of concrete specimen of 150 mm diameter and 300 mm height. This test was carried out as per IS: 5816-1970. The fresh properties of the green concrete are resolved through the slump test for the best workability, it is done as per IS 1199-1959 for sampling at site and at the lab. The chemical admixture utilized in this examination was SP 430 Conplast super plasticizer.

Modification was being made to guarantee the best usefulness acquired with best flow slump without endangering the concrete quality. It is utilized at a measurement rate, 2% of the cementitious materials were mixed for 4 to 5 minutes in a mechanical blender at a speed of 80 rpm to ensure homogeneous mix. Water was then included and mixed with all the supplementary cementitious materials for 5 minutes, followed by 2 minutes resting period to scratch off any unmixed powders from the paddle sides of the blender and including them into the mixing bowl. The mixing was continued for an additional time of 5 minutes before placing the fresh concrete in 3D shaped molds. After complete mixing, the fresh paste was

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placed into 150 mm cube moulds and vibrated for 1 minute to expel air bubbles. Immediately after casting the moulds were covered with a polyethylene sheet to dodge any evaporating of water from the surface of the samples.

Flexural strength is an indirect measure of the tensile strength of concrete. It is a measure of the maximum stress on the tension face of an unreinforced concrete beam or slab at the point of failure in bending. It is measured by loading 150 x 150-mm (or (100 x 100-mm) concrete beams with a span length at least three times the depth.

The flexural strength is expressed as Modulus of Rupture (MR) in MPa and is determined by standard test methods ASTM C78 (third-point loading) or ASTM C293 (center-point loading). The specimen size and type of loading does impact the measured flexural strength and comparisons or requirements should be based on the same beam size and loading configuration. The MR measured by third-point loading (ASTM C78) is lower than that determined by center-point loading (ASTM C293), sometimes by as much as 15 percent. It is also observed that a lower flexural strength will be measured with larger beam specimens.

Flexural tests are extremely sensitive to specimen preparation, handling, and curing procedure. Beam specimens are very heavy, and allowing a beam to dry will yield lower strengths. Beams must be cured in a standard manner, and tested while wet. A short period of drying can produce a sharp drop in flexural strength. Flexure can be used for design purposes, but the corresponding compressive strength should be used to and accept the concrete. Any time trial batches are made, both flexural and compressive tests should be made so that a correlation can be developed for field control.

TEST RESULTS

The compression test shows the best possible strength concrete can achieve in perfect conditions. The compression test measures concrete strength in the hardened state. This test method consists of applying a compressive axial load to cubes at a rate which is within the prescribed range until failure occurs. The compressive strength of the specimen is calculated by dividing the maximum load attained during the test with the cross-sectional area of the specimen. This strength is commonly specified as a characteristic strength of concrete measured at 28 days after mixing.

One of the important properties of

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concrete is “tensile strength” as structural loads make concrete vulnerable to tensile cracking. Tensile strength of concrete is much lower than its compressive strength (that’s why steel is used to carry the tension forces). It has been estimated that tensile strength of concrete equals roughly about 10% of compressive strength. To determine the tensile strength, indirect methods are applied due to the difficulty of the direct method. Noting that the values obtained of these methods are higher than those got from the uni-axial tensile test. These indirect techniques are: 1- split cylinder test and 2- flexural test The sample size is cylinder of diameter 15 cm and height of 30 cm. The mould used is metal with mean internal diameter of the mould is 15 cm ± 0.2 mm and the height is 30 +/- 0.1 cm. The mould should be coated with a thin film of mould oil before use to prevent adhesion of concrete. The splitting tensile strength, $Tsp = 2P / \pi DL$

Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending. The results of flexural test on concrete expressed as a modulus of rupture which denotes as (MR) in MPa. The Flexural Strength or Modulus of Rupture (fb) is given by

$fb = Pl/bd^2$

Table-II: Test Results

Mix	**Configuration**	**Compression MPa**		**Split tensile strength MPa**		**Flexural strength MPa**	
		28 D	**90 D**	**28 D**	**90 D**	**28 D**	**90 D**
M1	Conventional mix	61.23	63.46	4.59	5.03	4.91	5.23
M2	50% sand and stone dust	60.56	62.34	4.62	5.25	4.88	5.46
M3	50% sand+50% stoned dust + 100% cement + 0.3% sodium polyacrylate	63.21	65.36	4.52	5.96	5.22	6.11

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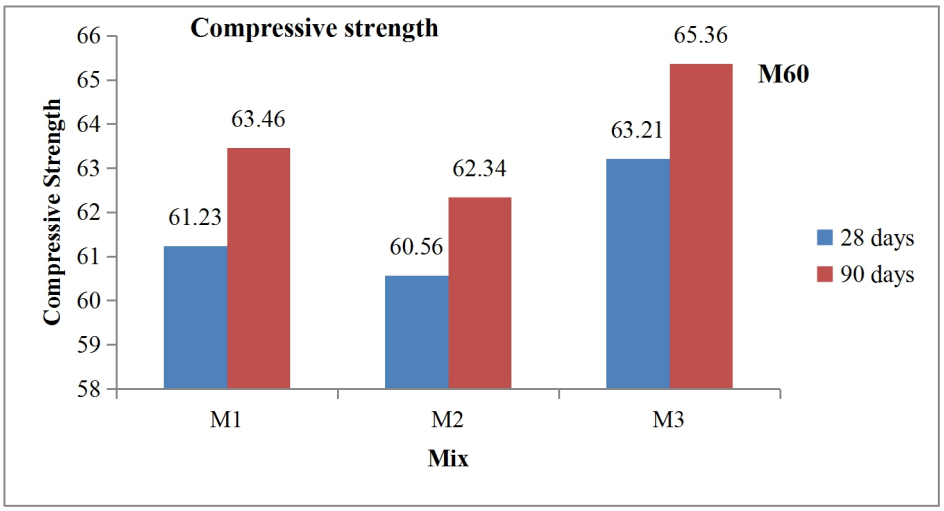


Fig. 1 - Variation of Compressive strength



Fig. 2 - Cubes and cylindrical specimens



Fig. 3 - Testing of cube sample

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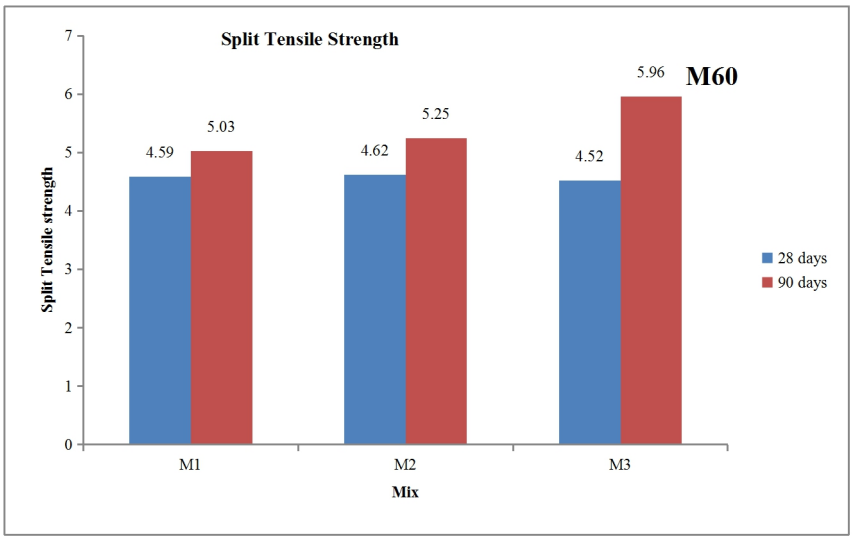


Fig. 4 - Variation of Split tensile strength



Fig. 5 - Testing of cylindrical sample

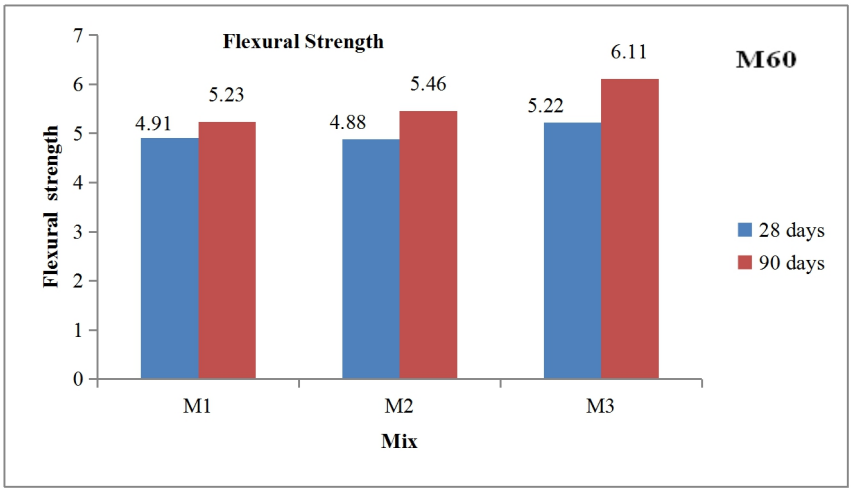


Fig. 6 - Variation of Flexural strength

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CONCLUSIONS

Addition of SAP leads to a significant increase of Compressive, tensile and flexure strengths. The self-cured concrete using SAP was more economical than conventional cured concrete. Self-curing concrete is reducing the improper curing problems. The use of super absorbent polymers (SAP) in concrete has many positive effects on various properties of concrete. Due to water entraining property of SAP, the concrete is cured internally as well as externally. As hydration progresses, SAP releases water as a result of under pressure in the surrounding matrix. This water supply counteracts two mechanisms which are likely to be responsible for the development of shrinkage deformations due to self desiccation:

1) a decrease in the disjoining pressure between the particles of the C–S–H gel, and

2) a decrease in the menisci radii of the pore water, which bespeaks an increase in tension both within the pore water and at its surface.

Hence it can be concluded that, by using 0.3% SAP in concreting and just by air curing the concrete can achieve the same strength as that of traditionally cured concrete, hence suitable where water is insufficient.

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