iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 Issue: XI Month of publication: November 2017

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

Experimental Investigations on Properties of Concrete with Paper Sludge as Self Curing Agent

M. Sheik Mohamed Anas[1], J.Srisindhu[2]
[1, 2] Assistant Professor, Department of Civil Engineering, Rathinam Technical Campus, Coimbatore

***Abstract:** In this study, focus was made on the investigation of the viability of using paper sludge, an industrial waste generated from paper mills as self curing agent in concrete. Basically high absorptive materials, such as light weight aggregate, super absorber polymers, wood-derived fibers and powders etc., are increasingly being investigated for use as an internal curing agent in cement based materials. Every year in our country approximately more than eleven million tons of waste is produced from industries. Recently many of the solid waste materials are replaced as construction materials such as fly ash, glass powder, construction and demolition wastes, silica fume, copper slag, E-waste, quarry dust, bottom ash, rice husk ash, wood pulp, waste rubber, granite industry waste etc. The major solid wastes are by products from industries. In this present work, out of above mentioned waste materials paper sludge a low cost materials and easily available from paper mill is used as self curing agent. The pulp and paper industry generates large volume of wastes. Since it's a wood based material it has high water absorption capacity. A trail has been made with paper sludge as an internal curing agent with different sludge ratios. This project presents the paper sludge concrete (PSC) with different water sludge ratio and two different curing conduction 1) Air-dry or self curing, 2) Full water or normal laboratory curing. The mechanical properties like compressive strength, split tensile strength, flexural strength results shows that the PSC was good when compared with conventional concrete. In this study, focus was made on the investigation of the viability of using paper sludge, an industrial waste generated from paper mills as self curing agent in concrete. Basically high absorptive materials, such as light weight aggregate, super absorber polymers, wood-derived fibres and powders etc., are increasingly being investigated for use as an internal curing agent in cement based materials. Every year in our country approximately more than eleven million tonnes of waste are produced from industries. Recently many of the solid waste materials are replaced as construction materials such as fly ash, glass powder, construction and demolition wastes, silica fume, copper slag, E-waste, quarry dust, bottom ash, rice husk ash, wood pulp, waste rubber, granite industry waste etc. The major solid wastes are by products from industries. In this present work, out of above mentioned waste materials paper sludge a low cost materials and easily available from paper mill is used as self curing agent. The pulp and paper industry generates large volume of wastes. Since it‟s a wood based material it has high water absorption capacity. A trail has been made with paper sludge as an internal curing agent with different sludge ratios. This project presents the paper sludge concrete (PSC) with different water sludge ratio and two different curing conduction 1) Air-dry or self curing, 2) Full water or normal laboratory curing. The mechanical properties like compressive strength, split tensile strength, flexural strength results shows that the PSC was good when compared with conventional concrete.*

***Keywords:** PSC, self curing, waste.*

I. INTRODUCTION

A. General

In the past, most of the structures were made either in masonry, steel, or timber depending on the availability of material and the nature of work. Concrete is a homogeneous mixture of cement, sand, gravel, coarse aggregate and water. Concrete is strong in compression and weak in tension and also it is very strong in carrying flexural force. By the judicious use of available concrete materials and their proportions in the fresh and hardened stages, concrete maintains their strength and durability due to adding various admixtures and curing agents

.

B. Curing and Self Curing

Using of concrete can be compared with a baby as when concrete is born? When you place fresh concrete? Where you want it to live out its life? - It‟s like a baby; concrete is very sensitive and easily ruined. If you take good care of it, when it's young it will grow up to be a strong and reliable adult. Curing is all of the things that we do to keep our concrete wet and durable during the first week; maintain the proper temperature and dampness. I know, most babies prefer to be dry but, concrete likes being difficult. Curing is easy to skip in the instant but that will have a major impact on the quality of your finished work.

Concrete curing is one of the most important processes in achieving the desired properties of the concrete. The test cubes of any particular mix will be immersed in water till the date of testing. This is done in order to promote the hydration process of the concrete. The initial mixing water used to make concrete will not be sufficient to bring out the full performance of the concrete. However, the actual structures cannot be immersed in water. That is why the structures shall be covered with wet gunny sack or plastic sheet. The reason being that provide water from gunny sack to protect the initial water from evaporating. This is one of the main reasons why the concrete structure does not last throughout the design life. Therefore, now it is time to think of a way to cure the concrete from inside without having to cover it with gunny sack or plastic sheet. This new technology is called self-curing concrete. As it name sounds, the concrete would be able to cure on its own without having to provide additional water. This concept is also known internal curing. The basic concept of this technology is to provide water for concrete, so that it can continue the curing process on its own. This is done by embedding the water inside the materials used to make concrete. If the water just added as mixing water; this would lead to many other quality related problems, such as bleeding, segregation, and etc. Therefore, a special material shall be used; so that some of the water can be hidden into the material. This water will be released into the concrete over time after the concrete has been placed in the structure and hardened. By doing this the hardened concrete will be able to undergo continuous curing for a long time, which will promote towards a better hydration product. There are many types of material that can be used to impregnate the water. One example is by using paper sludge; which is capable of holding the water into its porous microstructure.

C. Paper Waste

Wastes are important from different points of view. It helps to save and sustain the natural resources which are not replenished; it decreases the pollution of the environment and it also helps to save and recycle energy in production process. The productive use of waste material represents a way of solving some problems of solid waste management. Wastes and industrial by-products could be valuable materials as alternative resources for building and construction and other applications.

The management of wastes in which environmental objectives are set, namely, the need of restricting and in a short time the volume of wastes deposit in landfill. Several studies were published on the use of waste material in pavements. These include the use of fly ash, waste pumice, glass, steel slag, tires and plastics, marble quarry waste, cement and mortars, polypropylene fibres.Following this perspective, this research describes a study developed with wastes from pulp and paper industry as follows,

The pulp and paper industry generates large volume of wastes which is technology-dependent but the estimate is around 100 tons of waste for 550 tons of pulp production. In terms of developed countries more than eleven million tonnes of waste are produced yearly by this sector. It generates, in all stages of its production process, solid wastes with different composition and moisture content.

D. Paper Sludge

The produced wastes are of organic and inorganic origin, some of them with re-use potential. Two of these wastes, named as dregs and grits, are still sent for landfill disposal. Different salts are presenting their composition coming from the pulp and paper mill process. Paper mill sludge is a major economic and environmental problem for the paper and board industry. The material is a by-product of the de-inking and re-pulping of paper. The main recycling and disposal routes for paper sludge are land-spreading as agricultural fertilizer, incineration in CHP plants at the paper mill, producing paper sludge ash, or disposal to landfill. The scope for landfill spreading is limited and is covered by an industry code of practice in functional terms. Paper sludge consists of cellulose fibres, fillers such as calcium carbonate and china clay and residual chemicals bound up with water. The moisture content is typically up to 40%. The material is viscous, sticky and hard to dry and can vary in viscosity and lumpiness.It has an energy content that makes it a useful candidate as an alternative fuel for the manufacture of Portland cement. Paper sludge is currently in use as an alternative fuel. It is classified as Class 2 (liquid alternative fuels) in the Cembureau classification of alternative fuels.

Fig 1.1 Sample of Paper Sludge of the Research

E. Objective Of The Study

The proposed work has the following objectives,

1) To implement the paper sludge as a self curing agent in concrete.
2) To determine the compressive strength of concrete by using paper sludge as a self curing agent.
3) To determine the split tensile strength of concrete by using paper sludge as a self curing agent.
4) To determine the flexural strength of concrete by using paper sludge as a self curing agent.

II. OVERVIEW ABOUT SELF CURING AGENT

A. General

Curing agent has been recognized that adequate curing is essential to obtain that desired structural and
Durability properties of concrete. Proper curing of concrete is one of the most important requirements for optimum performance in any environment or application. Historically, curing has not received the attention it deserves. It was not until the early 1950s that any significant articles devoted to
Concept of self curing is to reduce the water evaporation from concrete and hence increase the water retention capacity of the concrete compared to conventional concrete. Now a day, the availability of water is going on reducing. Also, the consciousness of the labor is also reducing. The cost involved in curing of concrete is either increasing or the concrete if left uncured, result in the formation of cracks in concrete or failure on the concrete surface, thereby reducing the strength of the concrete. Previously researches have been carried out and found that water soluble polymers, light weight aggregates can be used as self curing agents in concrete.
Curing of concrete plays a major role in developing the concrete micro structure and hence improves its durability and performance. The aim of the investigation is to evaluate the use of a vegetative material like Calotropis as self curing agent. The use of self curing admixtures is very important from the point of view that water resources are getting valuable every day. Each m3 of concrete requires about 3 m3 of water for construction most of which is used for curing. By using internal cuing admixtures like vegetative material, the design engineer will assume more of the responsibility for curing instead of leaving it to the contractor or his agent to cure the concrete, sometimes under adverse conditions.

B. Significance And Importance Of Curing

Poor curing practices adversely affect the desirable properties of high-performance concrete, just as they do any concrete. Proper curing of concrete is essential to obtain maximum durability, especially if the concrete is exposed to severe conditions where the surface will be subjected to excessive wear, aggressive solutions, or severe environmental conditions. Likewise, proper curing is necessary to assure that design strengths are attained.
Even when good quality concrete is placed on the job site, curing is necessary to ensure the concrete provides good service over the life of the structure. Good concrete can be ruined by the lack of proper curing practices. Curing is even more important today than ever before for at least three reasons (Neville 1996):
1) Today's cements gain strength earlier and allow contractors to remove formwork soon after concrete placement. This encourages discontinuing curing operations prematurely.
2) The lower water-cement ratios being used with modern concretes (like HPC) tend to cause self- desiccation. Ingress of water from proper curing is necessary to control this phenomenon.

3) Many modern concrete mixtures contain mineral admixtures, such as fly ash and ground granulated blast furnace slag that have slower reaction rates. Curing over longer periods of time is needed for proper development of the properties of these mixtures. Curing has a major impact on the permeability .by increased permeability due to poor curing. The importance of adequate curing is very evident in its effect on the permeability of the "skin" (surface) of the concrete. In the United States and other countries, contractors tend to either short cut curing requirements in the field or ignore them almost completely One survey conducted in the United States in 1979 estimated that 24 % of concrete used in nonresidential construction was not cured at all, and only 26 % was cured in accordance with project specifications (Senbetta and Malchow 1987). It is doubtful that the situation has improved very much since then. The concrete industry must do a better job of educating contractors, engineers, superintendents, and quality control personnel of the importance of good curing practices in the field. This is especially true for high- performance concrete since it has been found to be even more sensitive to curing conditions than ordinary concrete, particularly at early ages. It has been suggested that one way to highlight the importance of curing is to make it a separately billed item in the schedule of prices for the project (Cather 1994). Contract specifications usually contain curing requirements; however, they are rarely adhered to in the field (Neville 1996). Similar to the batching and mixing operation for concrete, curing needs to be closely supervised and controlled. As a construction project progresses, it is extremely difficult to prove whether proper curing has been applied. Although specifications may be adequate and complete, one of the biggest obstacles to ensuring proper curing in the field is the lack of standard methods to verify curing adequacy. Various penetrability methods have been proposed (Kropp and Hillsboro 1995), but none has yet to be standardized for use. Without approved testing methods, it will continue to be difficult to verify desired levels of curing in the field. The curing of high-performance concrete has been identified as one of the critical areas in which more information and research are needed in order to realize the full potential of this class of concrete (Carino and Clifton 1990). Current national curing specifications in the United States do not include specific requirements for high- performance concrete even though its use is becoming more widespread. Existing curing criteria are based on information from ordinary concrete, and may not be appropriate for the high-performance concrete mixtures being used today. Current standards are also deficient in that they do not address proper curing for durability.

Historically, curing requirements have been based primarily on obtaining adequate strength. Some of the most recent research on high-performance concrete has focused on how curing affects the surface layer and thus, the durability of the concrete. Finally, current curing requirements in the United States do not take into account the actual rate of hydration or strength development, both of which may be affected by in-place temperature and whether chemical and mineral admixtures are used.

C. Monitoring Of Self – Curing In Concrete

Monitoring of self curing can be done by the following ways:

1) Measuring weight-los
2) X-Ray powder diffraction
3) X-Ray micro chromatography
4) Thermo gravimetric (TGA) measurements
5) Initial surface absorption tests (ISAT)
6) Compressive strength
7) Water permeability
8) NMR spectroscopy

a) Advantages of Self Curing

i) Internal curing (IC) is a method to provide the water: to hydrate all the cement, accomplishing what the mixing water alone cannot do. In low w/c ratio mixes (under 0.43 and increasingly those below 0.40) absorptive lightweight aggregate, replacing some of the sand, provides water that is desorbed into the mortar fraction (paste) to be used as additional curing water. The cement, not hydrated by low amount of mixing water, will have more water available to it

ii) IC provides water to keep the relative humidity (RH) high, keeping self-desiccation from occurring.

iii) IC eliminates largely autogenously shrinkage.

iv) IC maintains the strengths of mortar/concrete at the early age (12 to 72 hrs.) above the level where internally & externally induced strains can cause cracking.

v) IC can make up for some of the deficiencies of external curing, both human related (critical period when curing is required is the first 12 to 72 hours) and hydration related (because hydration products clog the passageways needed for the fluid curing water to travel to the cement particles thirsting for water).

b) Following factors establish the dynamics of water movement to the anhydrate cement particles:

i) hirst for water by the hydrating cement particles is very intense.
ii) Capillary action of the pores in the concrete is very strong
iii) Water in the properly distributed particles of LWA (fine) is very fluid.

c) Improvements in Concrete due to Self Curing

i) Reduces autogenous cracking, largely eliminates autogenous shrinkage,
ii) Reduces permeability,
iii) Protects reinforcing steel,
iv) Increases mortar strength,
v) Increases early age strength sufficient to withstand strain,
vi) Provides greater durability,
vii) Higher early age (say 3 day) flexural strength
viii) Higher early age (say 3 day) compressive strength,
ix) Lower turnaround time,
x) Improved theology
xi) Greater utilization of cement,
xii) Lower maintenance,
xiii) Use of higher levels of fly ash
xiv) Higher modulus of elasticity, or
xv) Through mixture designs, lower modulus
xvi) Tharper edges,
xvii) Greater curing predictability,
xviii) Higher performance,
xix) Improves contact zone,
xx) Does not adversely affect finish ability,
xxi) Does not adversely affect pump ability.

D. Need For Self–Curing

When the mineral admixtures react completely in a
Blended cement system, their demand for curing water (external or internal) can be much greater than that in a conventional ordinary Portland cement concrete. When this water is not readily available, due to depreciation of the capillary porosity, for example, significant autogenously deformation and (early-age) cracking may result. Due to the chemical shrinkage occurring during cement hydration, empty pores are created within the cement paste, leading to a reduction in its internal relative humidity and also to shrinkage which may cause early-age cracking. This situation is intensified in HPC (compared to conventional concrete) due to its generally higher cement content, reduced water/cement (w/ c) ratio and the pozzolanic mineral admixtures (fly ash, silica fume). The empty pores created during self-desiccation induce shrinkage stresses and also influence the kinetics of cement hydration process, limiting the final degree of hydration. The strength achieved by IC could be more than that possible under saturated curing conditions.

E. Potential Materials for Self- curing

The following materials can provide internal water reservoirs:
1) Lightweight Aggregate (natural and synthetic, expanded shale),
2) LWS Sand (Water absorption =17 %)
3) LWA 19mm Coarse (Water absorption = 20%)
4) Super-absorbent Polymers (SAP) (60-300 mm size
5) SRA (Shrinkage Reducing Admixture) (propylene glycol type i.e. polyethylene-glycol
6) Wood powder

F. Chemicals to Achieve Self–curing

Some specific water-soluble chemicals added during the mixing can reduce water evaporation from and within the set concrete, making it „self-curing.‟ The chemicals should have abilities to reduce evaporation from solution and to improve water retention in ordinary Portland cement matrix.

G. Super-absorbent Polymer (SAP) as self-curing

The common SAPs are added at rate of 0–0.6 wt %of cement. The SAPs are covalently cross-linked. They are Acryl amide/acrylic acid copolymers. One type of SAPs are suspension polymerized, spherical particles with an average particle size of approximately 200 mm; another type of SAP is solution polymerized and then crushed and sieved to particle sizes in the range of 125–250 mm. The size of the swollen SAP particles in the cement pastes and mortars is about three times larger due to pore fluid absorption. The swelling time depends especially on the particle size distribution of the SAP. It is seen that more than 50% swelling occurs within the first 5 min after water addition. The water content in SAP at reduced RH (relative humidity) is indicated by the sorption isotherm.

H. Water Available from LWA for Self–curing

It is estimated by measuring desorption of the LWA in SSD condition after exposed to a salt solution of potassium nitrate (equilibrium RH of 93%). The total absorption capacity of the LWA can be measured by drying a Saturated Surface Dry (SSD) sample in desiccators

I. Mineral Admixtures

1) Silica fume: (SF) is probably the most common addition to concrete mixtures to produce high-performance concrete. This material, also called *condensed silica fume* or *micro silica*, is a finely-powdered amorphous silica that is highly pozzolanic (develops cementing properties in the presence of water and calcium hydroxide). Its use is becoming so common around the world that many consider high- performance concrete to be synonymous with silica fume- concrete. Silica fume is a by-product from electric arc furnaces used in the manufacture of elemental silicon or Ferro-silicon alloys. Silica fume contains large amounts of silicon dioxide (Between 85 % and 98 %) and consists of extremely fine particles. It is collected by filtering the escaping furnace gases2. The average size of these spherical particles is less than 0.1 mm which is approximately one hundred times finer than cement. The small particle sizes lead to important benefits when SF is used in concrete. For example, the extremely fine particles can fill spaces between cement particles, which results in a more refined microstructure and a more dense cement paste. As the pores within the paste become finer and more dispersed, the permeability is reduced considerably. The beneficial effects of silica fume result from its highly reactive pozzolanic characteristics. The high reactivity can be attributed to its very high silicon dioxide content, small particle size, and large specific surface area. Because of the very high specific surface area, the use of silica fume leads to increased water demand. For this reason, it is necessary to use high-range water-reducing admixtures (Superplasticisers) with silica fume to produce workable concrete. Since the early 1980s, silica fume has been used to improve concrete properties such as compressive strength, abrasion resistance, and durability. It is frequently used as a replacement for a portion of the Portland cement in a mixture. Silica fume-concrete has become quite common throughout the United States when high compressive strength is required. Other performance improvements from silica fume replacement (about 10 % by mass appears to be optimum) include higher resistances to sulfate attack, alkali- aggregate reaction, and freezing and thawing (Hooton 1993). Studies have shown (Gjorv 1991) that silica fume can be very effective in producing highly impermeable concretes for use in harsh environments. In fact, the benefits of silica fume on reducing permeability of concrete may be more important than its benefits in improving strength. One of the concerns that must be addressed with the use of silica fume is the high potential for plastic shrinkage cracking. This is the most common complaint from users of SF (Holland 1989). Silica fume-concretes normally have low water-cement ratios and experience little bleeding .The surface of silica fume-concrete tends to dry quickly, subsequently causing shrinkage and cracking prior to final setting. This is one reason why early-age moist curing of silica fume-concr After placement, steps must be taken to prevent drying of the surface (Ozyildirim 1991).

J. Fly ash

Fly ash is the finely divided residue resulting from the combustion of ground or powdered coal and is transported by flue gases (ASTM C 125). This waste byproduct is used extensively in the production of high- performance concrete. Due to its outstanding pozzolanic and cementations properties, fly ash is used to improve durability and enhance strength gain. As concrete containing fly ash is cured, the products of the pozzolanic reaction fill in the spaces around cement particles. This results in a paste of lower permeability and greater resistance to chemical attack. Because the pozzolanic reaction is slower than the hydration of Portland cement, fly ash is often used to control the amount of early heat generation and the detrimental effects of early temperature rise commonly experienced in massive concrete structures.

K. Ground granulated blast-furnace slag

This is a glassy material that is formed when blast- furnace slag is rapidly cooled, such as by immersion in water (ACI C 125). It is composed essentially of silicates and alumina silicates of calcium. When it is ground to cement fineness, it is referred to as ground granulated blast-furnace slag (GGBFS), and it is commonly used in HPC mixtures. The use of GGBFS reduces the permeability of the mature Concrete. It is believed that this improvement is a result of the reaction of the GGBFS with the calcium hydroxide and alkalis released during hydration of the Portland cement (ACI 233.1R).The reaction products fill pore spaces in the paste and result in a denser Microstructure. In addition to reducing the permeability of concrete, GGBFS also improves resistance to sulfate attack because of the low calcium hydroxide content (Neville 1996).Like fly ash, GGBFS is also used to reduce temperature rise in mass concrete. Ground granulated blast- furnace slag also improves the workability of fresh concrete. It is believed that the smooth, dense surfaces of the slag particles result in very little water absorption during the mixing process. Also, cement pastes containing GGBFS have exhibited better particle dispersion and higher fluidity leading to improved workability (ACI 233.1R).

III. LITERATURE REVIEW

A. General

Concrete with self curing agents is an innovative one in recent years. Attempt was made to collect the available literature on concrete with various self curing agents. A brief review of the same is presented in this chapter.

B. Studies On Concrete With Various Self Curing Agents K.

Kevlar et al (1999) in there experiment a statistical approach was employed to develop formulation which could adequately describe the relations between splitting tensile strength and the concrete composition, when cured in two different regimes: water curing at 20^{0}C and sealed curing at 30^{0}C autogenously shrinkage was induced in the second type of curing but was largely eliminated in the first one. The relations were presented as monograms which could be used as a basis for mix design. The ratio between tensile and compressive strength varied over a large range of to 0.12. As a result, the relations developed here for tensile strength are quite different in nature than those for compressive strength tensile strength is sensitive to effects which induce autogenously shrinkage to a much greater extent than compressive strength, range of 0.25 to 0.35 and additions of 5 to 15% of silica fume by weight of cement. Additional study is required to clarify the influences suggested in the previous conclusion to determine independently the extent of damage that may be induced in conditions resulting in the development of autogenously shrinkage in high strength concretes with low w/b ratio and silica fume.

B.Persson (2000) an experimental and analytical expression study on the consequence of cement constituents, mix composition and curing conditions as regards self- desiccation in concrete. For this purpose nine concretes with three values of w/c (0.32, 0.38 and 0.50), based on two types of Portland cement, were manufactured. Five percent silica fume was used in one third of the concretes as calculated on the basis of the cement content. The measurements were done at 1 and 6 months age. The results indicated high influence of w/c, age and cement type on self-desiccation. The curing conditions only influenced internal relative humidity and strength. Self-desiccation of concrete was mainly dependent on the w/c and the age of the concrete. RH at self-desiccation was fairly independent of moderate variations in the curing temperature. Very small variations of temperature at the time of measurement (±0.50C) did not affect the measured RH, provided that the dew-point meter was calibrated at the same temperature. The maximum standard deviation of the measurements was 1.5% RH given a small shift of temperature during the time of measurement (±0.50C) The average standard deviation was 0.7% RH .The recommendation is to maintain + 20C during the curing time of the concrete but (±0.50C) during the time of measurement of RH (22h) and also during the time of calibration of dew- point meters (22h). The same requirements probably apply for other types of probes. The strength was reduced when the curing temperature was increased from 180C to 230C Concrete with normal-alkali cement had a 5% lower RH than concrete with low-alkali cement. RH in concrete with normal-alkali cement was not significantly affect by 5% silica fume. Concrete with normal-alkali cement, with and with-out silica fume, displayed other small differences in the mix composition that probably not effected the development of RH. The chemical composition of the cement had a substantial influence on the measured self-desiccation mainly due to the so-called alkali-effect. Roberto Troli et.al (2005) in this invitation the practice of using expansive

agents has been recommended to manufacture shrinkage compensating concrete provided that an adequate wet curing is carried out. On the other hand,
Shrinkage-reducing admixture (SRA), based on the use of poly-glycol products in the concrete mixes, has been more
Recently suggested to reduce the risk of cracking in concrete
Structures caused by drying shrinkage. This technology can reduce the drying shrinkage but it is not able to completely remove it. Use of CaO-based expansive agents and SRA. "*3* times self": self-compacting, self-curing and self- compressing concrete. The type of CaO based expansive agent has been adapted in order to produce an effective expansion mainly after the cement hardening process is started, so that the expansion loss which occurs in concrete in the fresh or plastic state is reduced and the useful expansion in the hardened state is advantageously increased. There is a synergistic effect in the combined use of SRA and a CaO- based expansive agent in terms of more effective expansion in the absence of wet curing. There is a lower shrinkage after removing the polyethylene sheet used to simulate the protection from drying before demoulding. However, a change in the cement with a higher strength at very early ages Alternative ways can be adopted to produce Self- Compacting Concrete which is also a Self-Compressing and Self-Curing concrete (“3-time self”): to use a super plasticizer with a reduced retarding effete or to use an expansive agent based on CaO produced at higher temperature (>1100°C) so that the restrained expansion occurs later and then in a hardened concrete.
Ole Mejlhede Jensen and Pietro Lura (2006) in this paper the different techniques for incorporation of internal curing water in concrete. And the importance of internal curing water present in normal aggregate is also discussed. Internal water curing can be used to mitigate self-desiccation and self-desiccation shrinkage. Some concretes may need 50 kg/m3 of internal curing water for this purpose. Such internal curing water can mitigate self-desiccation and self- desiccation shrinkage in high-performance concrete. The water store can function based on different physical or chemical principles, each with its different possibilities. Calculations show that concrete in extreme may need up to 50 kg/m^3 of internal curing water to offset self-desiccation and self-desiccation shrinkage. The price of the internal curing water is in the approximate range 0.1–1 e/kg
YE Jiajun et al (2006) in this research indicate that the gradient of internal relative humidity (IRH) decreases rapidly within 7-day curing age in HPC. The amount of water imported by pre-wetted light-weight aggregate can regulate IRH of concrete. By importing a proper amount of water, the process of the decline of IRH can be delayed and the autogenous shrinkage can be reduced. The relationship among the amount of water imported by pre- wetted light-
weight aggregate, IRH and AS was established. The result provides a new method of reducing early AS and enhancing early cracking resistance of HPC. IRH of concrete declines in company with the curing age, the gradient of 1-7 day IRH is especially greater. The addition of pre-wetted lightweight delays the decline process of IRH and increases IRH of concrete at different curing ages. At the same curing age, IRH of concrete and water brought in by lightweight aggregate shows a linear relationship. With the replacement of pre-wetted light weight aggregate, AS decreases under the condition of the same curing age, and the more the water brought in, the lower AS of concrete. The slope K of the line declines in company with the increase of water brought in by pre-wetted lightweight aggregate. Quantitative relationships among IRH of concrete, water carried by lightweight aggregate and AS were established. The IRH could be regulated and the AS could be controlled through controlling the water brought in by lightweight aggregate. Pietro Lura, Ole Mejlhede Jensen et.al (2007) in this invitation they deals with internal water curing of concrete and its experimental methods to study them. Internal water curing agents, e.g. lightweight aggregates, LWA, and super absorbent polymers, SAP are used. It is believed that a more quantitative foundation of the internal water curing concept should be pursued through the application of scientifically- sound investigation techniques. This will promote the acceptance and spread the use of internal water curing in concrete practice.
M.S. Ravikumar et.al (2009) in their experiment the materials like kiln ash, silica fume, rock dust are used as natural aggregate. Chemical admixtures like Conplast SP 430 was used as Superplasticisers and Structuro 485 was used as viscosity modifying agent and Concure was used as self curing admixture from the experimental investigation; it was observed that both admixtures affected the workability of SCC adversely. A maximum of 14% of kiln ash with silica fume, 25% of quarry dust and 20% of steel fibres was able to be used as a mineral admixture without affecting the self- compact ability. Silica fume was observed to improve the mechanical properties of SCC, while kiln ash along with quarry dust affected mechanical properties of SCC adversely.
N.A. Johansen et al (2009) in this invitation accurate assessment of absorption capacity (k) of internal curing agents is necessary to properly proportion cement-based mixtures and to measure their effectiveness in mitigating autogenously shrinkage. It is demonstrated that the absorption capacity of internal curing materials may be determined from early age heat evolution data

measured through isothermal calorimetry. An example application, using pulp fibres as internal curing agents, is used to demonstrate the utility of the method. A novel method, relying upon heat evolution with time curves generated during isothermal calorimetry, was proposed for the determination of absorption capacity of .finely divided materials which may be used for internal curing in cement- based materials. Here, the proposed method showed that the absorption capacity of a Kraft pulp fibre, suitable for internal curing, was twice the anticipated value.

D.C.L.Teo et.al (2010) in this study the use of waste materials and by products from different industries for building construction has been gaining increased attention due to the rapid depletion of natural resources. It has been found that oil palm shell (OPS), which is a waste from the agricultural sector, can be used as coarse aggregate for the manufacture of structural lightweight concrete. However, for OPS concrete to be used in practical applications, its durability needs to be investigated. Therefore, this paper

presents the durability performance of OPS concrete fewer than four curing regimes. The durability properties investigated include the volume of permeable voids (VPVs), sorptivity, water permeability, chloride diffusion coefficient and time to corrosion initiation from the 90-day salt pounding test, and Rapid Chloride Penetrability Test (RCPT). Results showed that the durability properties of OPS concrete were comparable to that of other conventional. The results obtained from this investigation offer valuable information on the durability of lightweight concrete produced from OPS. It was observed that with OPS concrete, the cementations hydration is enhanced during the early ages due to the process of internal curing from the internal reservoir of water absorbed by the lightweight aggregate. However, proper curing is still essential for OPS concrete to achieve better durability at the later ages. In general, the durability properties of OPS concrete, namely VPV, sorptivity, water permeability and RCPT compare reasonably well with other lightweight concretes. The durability properties of OPS concrete are summarized as follows:-

1) The VPV at 28 days was found to be in the range of 20.1–21.2% respectively.

2) The sorptivity of OPS concrete at an age of 28 days was about 0.06–0.14 mm/min0.5. This relatively low sorptivity could have been attributed to the high quality cement paste which was produced with a low w/c ratio of 0.38 and also the adequate compaction adopted during the casting of the OPS concrete.

3) At the age of 28 days, the permeability coefficient ranged from 6.4 9 10-12 to 57.5 9 10-12 m/s.

4) The chloride diffusion coefficients range from 5.86 9 10-8 to 12.02 9 10-8 cm2/s.

5) The time to corrosion initiation can be enhanced when adequate cover and proper curing is adopted.

6) The RCPT values ranged from about 3,581 to 4,549 Coulombs at 28 days, indicating moderate to high chloride penetrability. Nevertheless, the decrease ithe charge passed with concrete age shows the there is improvement of the pore structure in the OPS concrete matrix due to the continual process of hydration cement products Proper curing is required for OPS concrete to achieve better durability, especially at the later ages. OPS concrete performed best under Site- 2 and full water curing condition (CS2 and CC curing). Therefore, for OPS concrete, it is recommended that the minimum duration of moist curing should be carried out continuously for at least 7 days.

IV.METHODOLOGY

A. General

This chapter investigates the details of the materials,

properties of materials, various experiments and methods conducted in the paper sludge concrete. The materials such as, course aggregate, fine aggregate, ordinary Portland cement and paper sludge were used in the manufacture of paper sludge were used in the manufacture of paper sludge concrete. The following flow chart shows the experimental investigations of paper sludge concrete:-

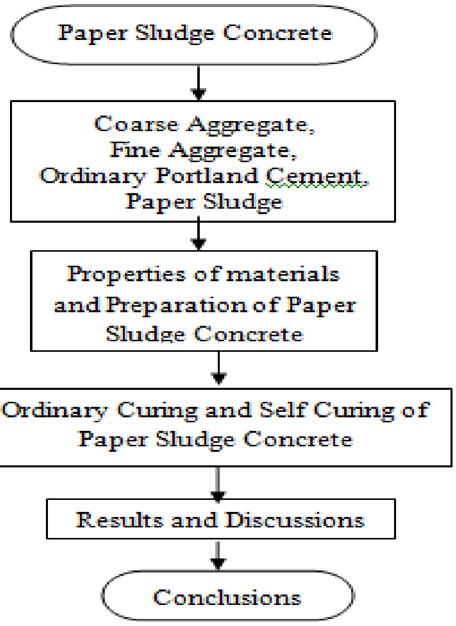


Fig 4.1 Flow chart representation of paper sludge concrete

Table 4.4 Physical Properties of Fine Aggregate

Test conducted	Observed values
Specific gravity	2.65
Grade of sand	Zone II
Water absorption	2.9%
Moisture Content	3%
Bulk density	1.86g/cc
Fineness modulus	3.05

Table 4.5 Chemical Properties of Fine Aggregate

Test conducted	**Observed values**
Silica	18.91%
Potassium	0.43%
Calcium	1.66%
Magnesium	2.055%
Iron	0.93%
Sodium	3.68%
Aluminium	6.33%

B. Material Used

The ingredients used for manufacturing the concrete by using paper sludge as a self curing agent are as follows,

1) Cement: Ordinary Portland cement of OPC53 grade (Priya Cement) was used to manufacture the concrete. The physical and chemical properties is as follows,

Table 4.1 Chemical Properties of Cement

Test conducted	Observed values
Calcium oxide	62.68%
Silica	20.36%
Alumina	6.87%
Iron oxide	3.67%
Magnesia	1.77%
Sulphuric anhydride	2.24%
Tri calcium silicate	42.57%
Di calcium silicate	26.33%
Tri calcium aluminate	12%
Tetra calcium aluminoferrite	2.24%

2) Paper Sludge: Paper sludge which has high water absorption capacity with potable water was used to manufacture the concrete as a self curing agent. The physical and chemical properties is as follows,

Table 4.6 Physical Properties of Paper Sludge

Test conducted	Observed values
Specific Gravity	1.57
Absorption	22.35%
Moisture Content	25.77
pH value	6.8

Table 4.2 Physical Properties of Cement

Test conducted	Observed values
Specific gravity of cement	3.15
Consistency	35%
Initial setting time	28 min
Final setting time	60min

3) Coarse Aggregate: Coarse aggregate of hard blue granite of size 20mm aggregates were used to manufacture the concrete. The aggregates are in angular shape. The physical and chemical properties is as follows,

Table 4.3 Physical Properties of Coarse Aggregate

Test conducted	Observed values
Specific gravity	2.75
Water absorption	0.9%
Moisture Content	10%
Bulk density	1.66g/cc
Fineness modulus	7.4

4) Fine Aggregate

Fine aggregate of locally available natural river sand was used to manufacture the concrete. The physical and chemical properties is as follows,

Table 4.7 Chemical Properties of Paper Sludge

Test conducted	Observed values
Silica	-
Potassium	0.03%
Calcium	0.74%
Magnesium	0.21%
Iron	0.43%
Sodium	-

C. Experimental Investigations Of Paper Sludge Concrete

Consistency test was carried out with potable water.

The consistency for different paper sludge ratio has been carried out to describe the required amount of paper sludge. The dry paper sludge has been taken by oven dried for 24 hours when it‟s used for the ratio the mass should retain constant before and after oven dried. The water which is used is ordinary potable water. With this we have made four different water sludge ratio,

1) part of dry sludge with 7 part of water
2) 1 part of dry sludge with 9 part of water
3) 1 part of dry sludge with 11 part of water
4) 1 part of dry sludge with 15 part of water
5) From this we had determine the consistency, initial setting time, final setting time and compression strength.

The mix design has been prepared by IS10262-1982 for M_{20} grade of concrete. Instead of normal water the paper sludge is mixed as water cement ratio (w/c) with the above water sludge ratio. The testes were carried out for 3days, 7days and 28days.

The tests for consistency, initial and final setting time were carried out with different paper sludge ratios are as follows;

Cement with water (nominal mix)

Initial setting time = 28min Final setting time = 60min Consistency = 35%

Cement with paper sludge (1 part of dry sludge mixed with 7 part of water)

nitial setting time = 3 hours Final setting time = 5-7 hours Consistency = 50%

Cement with paper sludge (1 part of dry sludge mixed with 9 part of water)

Initial setting time = 2 hours Final setting time = 4-5 hours Consistency = 42 %

Cement with paper sludge (1 part of dry sludge mixed with11part of water)

Initial setting time = 2.5 hours Final setting time = 3-4 hours Consistency = 37%

Cement with paper sludge (1 part of dry sludge mixed with15 part of water)

Initial setting time = 80min Final setting time = 130min Consistency = 35%

The mix design is prepared as per IS10262-1982 for M_{20} grade of concrete the mix design is made for potable water in Table 4.8. The design mix has been carried out for the four different water sludge ratio in that the water cement ratio has been changed to cement sludge ratio by the consistency of the sludge. Table 4.9 shows the amount of sludge required for each water sludge ratio.

Table 4.8 Mix design for M_{20} grade of Concrete

Cement	Fine aggregate	Coarse aggregate	Water\Cement ratio
1	1.425	3.2	0.35
383kg/m^3	564kg/m^3	1188kg/m^3	134kg/m^3

Table 4.9 Required Amount of Sludge as per Consistency

$$\text{ompressive strength in N/mm}^2 = \frac{P}{A}$$

Where,

P= Maximum load at failure in N,

A= Average net area under compression in mm^2.

D. Split Tensile Strength

Three cylinders of concrete specimens of size 150 mm □□*300 mm with paper sludge as self curing agent for each different paper sludge ratios were casted. The curing of concrete was implemented with two conditions, with full water curing and self curing (i.e. without any contact of water) and the specimens were tested at the age of 3 days, 7 days and 28 days in the compressive testing machine. Apply the load horizontally, till the failure occurs and note the maximum load at failure. The load at failure shall be the maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine. (As per IS 5816-1970).

Split tensile strength in N/mm^2 =

□□*ld*

Where, P = Maximum load at failure in N,

l = height of the specimen in mm,

d = diameter of the specimen in mm.

E. Flexural Strength

Three beams of concrete specimens of size 500*75*75 mm with paper sludge as self curing agent for each different paper sludge ratios were casted. The curing of concrete was implemented with two conditions, with full water curing and self curing (i.e. without any contact of water) and the specimens were tested at the age of 3 days, 7 days and 28 days in the universal testing machine. The third point loading method is adopted to determine the flexural strength. The minimum span between supports shall not be less than 2.5 multiplied by the average depth of the specimen. Place the test specimen horizontally on its supports as a simply supported beam. If full contact is not obtained between the specimen and the load applying blocks and supports compressible shims shall be used to level and seat the specimen thereby ensuring the uniform application of load. The load at failure shall be the maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine. (As per IS 516- 1959).

$a \geq 133$ mm, F_{cr} = Pl/bd^2

$a \geq 110$ mm, F_{cr} = $3Pa/bd^2$

ach other which is perimeter as per IS code provocationand also for ratio 1:11 the consistency is not much more compared to the provocation.

F. Compressive Strength

Three cubes of concrete specimens of size 150*150*150 mm with paper sludge as self curing agent for each different paper sludge ratios were casted. The curing of concrete was implemented with two conditions, with full water curing and self curing (i.e. without any contact of water) and the specimens were tested at the age of 3 days, 7 days and 28 days in the compressive testing machine. Apply the load axially, till the failure occurs and note the maximum load at failure. The load at failure shall be the maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine. (As per IS 516- 1959).

If a < 110mm, the beam fails. Where,
P = Maximum load at failure in N, l = length of the beam in mm,
b = breadth of the beam in mm, d = depth of the beam in mm,
a = cracking distance in mm.

V. RESULTS AND DISCUSSIONS

A. Compressive Strength

The compressive strength of concrete with paper sludge as a self curing agent by means each normal curing and self curing specimens were tested at the age of 3days, 7days and 28 days. The results were shown in Table 5.1.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

Table 5.1 Compressive Strength of Concrete by using Paper Sludge as a Self Curing Agent

Sludge ratio	Compressive Strength (N/mm^2)					
	Normal Curing			Self Curing		
	3 days	7 days	28 days	3 days	7 days	28 days
1:7	9.20	15.82	18.30	6.67	12.90	15.90
1:9	9.84	16.28	22.05	6.69	13.26	17.85
1:11	11.38	16.90	25.60	7.75	15.80	21.73
1:15	12.36	19.70	29.19	10.97	16.34	23.66

The result shows that the compressive strength of 1:15 ratio concrete with paper sludge as a self curing agent is 29.19N/mm2. It is 1.5 times that of the nominal concrete when it is in normal curing. The compressive strength of self curing is 23.66N/mm2 which is higher than the nominal concrete. The graph in the fig 5.1 shows an detail report about the compressive strength of paper sludge concrete with the two different curing condition self curing and normal curing for 3days, 7days and 28 days . As in both condition 1:15 ratios gives high strength than other mix ratios.

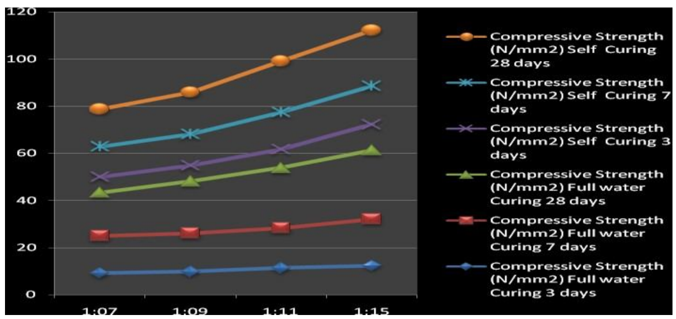


Fig 5.1 Compressive Strength of Concrete by using Paper Sludge as a Self Curing Agent

B. Split Tensile Strength

The results of split tensile strength of concrete with paper sludge as a self curing agent by means each normal curing and self curing specimens were tested at the age of 3days, 7days and 28 days were shown in Table 5.2 and Fig 5.2.

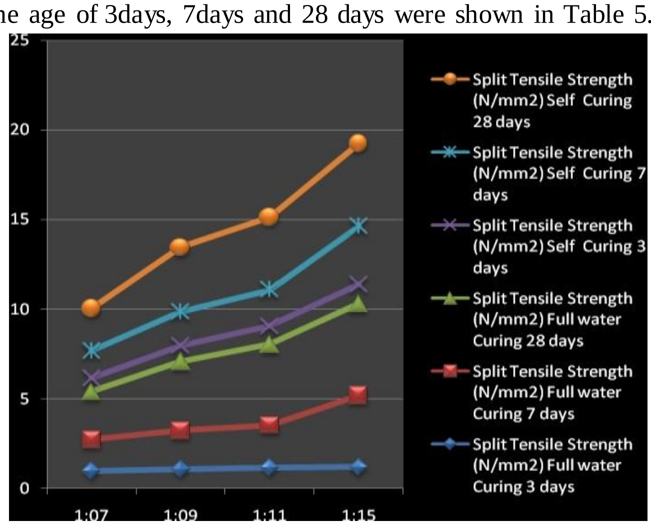


Fig 5.2 Split Tensile Strength of Concrete by using Paper Sludge as a Self Curing Agent

C. Flexural Strength

The results of flexural strength of concrete with paper sludge as a self curing agent by means each normal curing and self curing specimens were tested at the age of 3days, 7days and 28 days were shown in Table 5.3 and Fig 5.3.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

Table 5.3 Flexural Strength of Concrete by using Paper Sludge as a Self Curing Agent

Sludge ratio	**Flexural Strength (N/mm^2)**					
	Normal Curing			**Self Curing**		
	3 days	**7 days**	**28 days**	**3 days**	**7 days**	**28 days**
1:7	3.30	4.40	5.30	2.40	3.40	4.50
1:9	4.25	5.30	6.70	3.20	4.32	5.60
1:11	5.80	6.40	7.40	4.30	5.42	6.80
1:15	6.74	7.30	8.30	5.40	6.50	7.40

Table 5.2 Split Tensile Strength of Concrete by using Paper Sludge as a Self Curing Agent

Sludge ratio	Split Tensile Strength (N/mm^2)					
	Normal Curing			Self Curing		
	3 days	7 days	28 days	3 days	7 days	28 days
1:7	0.99	1.73	2.68	0.75	1.53	2.36
1:9	1.08	2.15	3.84	0.90	1.89	3.59
1:11	1.17	2.35	4.50	1.02	2.05	4.05
1:15	1.19	3.99	5.12	1.07	3.27	4.61

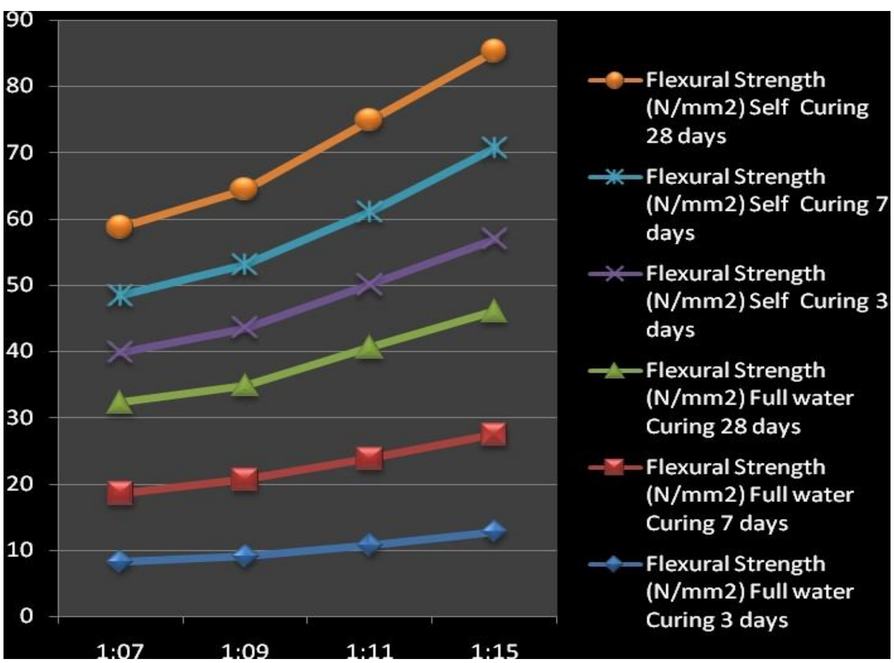


Fig 5.3 Flexural Strength of Concrete by using Paper Sludge as a Self Curing Agent

From the above results, shows that the flexural strength of 1:15 ratio concrete with paper sludge as a self curing agent at the age of 28 days was 18.66N/mm with full water curing and 14.61N/mm


Fig 5.4 Sample Specimen of Dry Paper Sludge


FIG 5.5 Paper Sludge Mixed with Water


Fig 5.6 Oil Coating on Moulds


Fig 5.7 Placing of Fresh Concrete

Fig 5.8 Prepared Specimens of Paper Sludge Concrete

Fig 5.9 De-moulded Specimens

Fig 5.10 Normal cured Specimens

Fig 5.11 Self Cured Specimens

Fig. 5.12 Compressive Strength Test with Normal cured Specimen

Fig 5.13 Split Tensile Strength Test with Normal Cured Specimen

Fig 5.14 Compressive Strength Test with self cured Specimen

Fig 5.17 Flexural Strength with Normal Cured Specimen


Fig 5.18 Flexural Strength Test with Self Cured Specimen


Fig 5.19 Failure Patten of Beam in Flexural Strength Test

VI. CONCLUSION

A. Utilization of paper sludge as internal curing agents results in good strength. The compressive strength of 1:11 and 1:15 was effective than the other two ratio. The result of 1:15 ratio gives result for self curing at a maximum o

B. 23.66 N/mm^2 compared to the other two ratios the consistency and initial setting time of 1:7 and 1:9 has been increasein the paper sludge concrete and also there is a minimum strength loss.

C. These 1:11 ratio has comparatively high strength than the control concrete but the consistency that is the water cement ratio is high compared to the 1:15 ratio and control concrete.

D. When it‟s curried with water the strength of 1:15 ratio is 29.19N/mm^{2}at 28 days and 1:11 gives 25.60 N/mm^{2}at 28 days.

E. The results of split tensile strength for 1:15 ratio paper sludge concrete at the age of 28 days was found to be 5.12N/mm^2 with normal curing and 4.61N/mm^2 with self curing.

F. The results of flexural strength for 1:15 ratio paper sludge concrete at the age of 28 days was found to be 8.3N/mm^2 with normal curing and 7.4N/mm^2 with self curing.

G. From these results, the paper sludge was used as a self curing agent attains the approximate strength for 1: 15 ratio.

H. The nominal mix of M$_{20}$ grade gives 20to23.66 N/mm^2 strength when it is with paper sludge as self curing agent.

I. Therefore, we can also use the paper sludge as a self curing agent in concrete.

REFERENCES

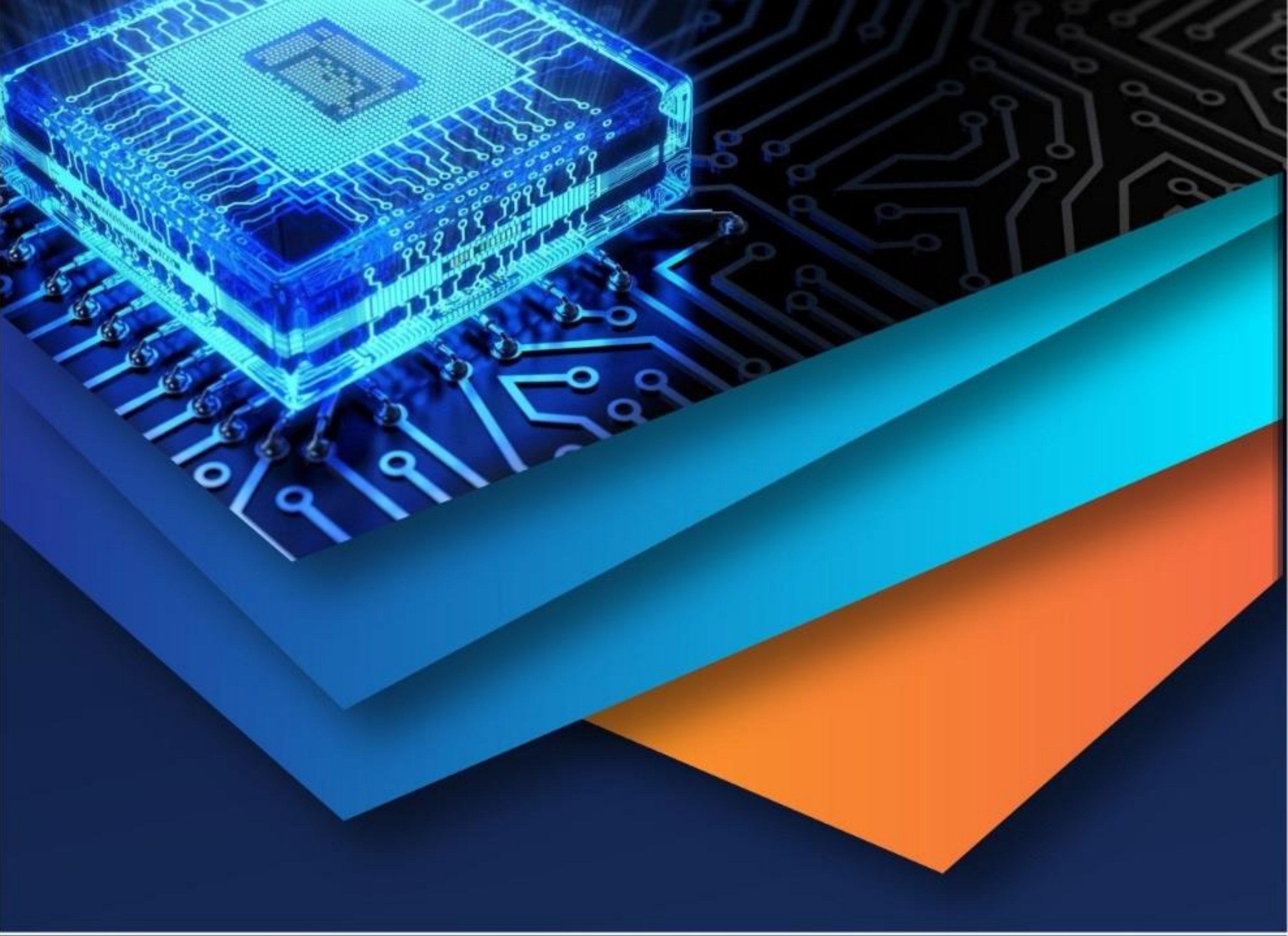
[1] Bentz D.P, K. K. Hansen, H. D. Madsen, F. Vail and E.J.Griesel (2001) Drying/hydration in cement pastes during curing Materials and Structures/Mat6riaux et Constructions, Vol. 34, pp 557-565

[2] Dhir, R. K., Hewlett, P. C., Lota, J. S., and Dyer, T. D., (1994) An Investigation into the feasibility of formulating 'self-cure' concrete. Materials and Structures/Materiauxet Constructions, Vol. 27, No. 174, pp. 606-615.

[3] Fujiwara .H, M. Maruokab The application of paper sludge ash to extremely stiff consistency concrete product. science direct research.

[4] Geetha .M Dr.R.Malathy (2011) Comparative Study of Strength and Durability Properties of Polymeric Materials as Self Curing Agents International Journal of Engineering Science and Technology Vol. 3 No. 1, pp 766-771.

[5] Haejin Kim and Dale Bentz (2008) Internal Curing with Crushed Returned Concrete Aggregates for High Performance Concrete to be published in NRMCA Concrete Technology Forum: Focus on Sustainable Development.
[6] IS 516-1959 (Reaffirmed 1999) Indian Standard code of practice for Methods of tests for strength of concrete Bureau of Indian Standards, New Delhi
[7] IS 5816-1970. Indian Standard code of practice for Methods of tests for splitting tensile strength of concrete cylinders. Bureau of Indian Standards, New Delhi
[8] IS 10262-1982. (Reaffirmed 2004). Indian Standard code of practice for recommended guidelines for concrete mix design. Bureau of Indian Standards, New Delhi.
[9] IS 12269-1982. (Reaffirmed 2004). Indian Standard specifications for 53 grade ordinary Portland cement. Bureau of Indian Standards, New Delhi.
[10] Jensen O.M, P. Lura, Techniques and materials for internal water curing of concrete, Mat. Struct. Vol. 39, pp 817–825.
[11] Jiajun Y.E HU Shuguang WANG Fazhou ZHOU Yufei LIU Zhichao (2006) Effect of Pre-wetted Light-weight Aggregate on Internal Relative Humidity and Autogenous Shrinkage of Concrete Journal of Wuhan University of Technology - Mater. Sci. Ed. Vol. 21 No. 1, pp135-137.
[12] Johansen N.A, M.J. Millard, A. Mezencevova, V.Y. Garas, K.E. Kurtis (2009) New method for determination of absorption capacity of internal curing agents Cement and Concrete Research vol.39,pp 65–68.
[13] Kannan S .U, Selvamony C., M. S. Ravikumar and S. Basil Gnanappa (2010) Investigations and Study on the Effect of Ar Glass Polymer Fibres In Self-Compacting Self-Curing Concrete ARPN Journal of Engineering and Applied Sciences VOL. 5, NO. 2, pp 41-45.
[14] Karen Friedemann, Wiete Scho¨nfelder Frank Stallmach , Jo¨rg Ka¨rger (2008) NMR relaxometry during internal curing of Portland cements by lightweight aggregates Materials and Structures vol 41, pp1647–1655.
[15] Kovler . K, I. Schamban, S. (1999) Influence of mix proportions and curing conditions on tensile splitting strength of high strength concretes I garish I and A. Bentur2 Materials and Structures/Mat6riaux et Constructions, Vol. 32, pp 500-505.
[16] Kovler,K. Bentur,A. and Zhutovsky,S., (2002)Efficiency of lightweight aggregates for internal curing of high strength concrete to eliminate autogenous shrinkage. Materials and Structures/Materiaux et Constructions, Vol. 34, No. 246, pp. 97- 101.
[17] Linnu.L.U, YANG Wen, HE Yongjia, WU Jing, HU Shuguang (2009) Internal Curing Using Water- releasing Material for High Strength Micro-expansive Concrete Journal of Wuhan University of Technolotgy-Mater. Sci. Ed. Vol.24 No.3 pp 510-514
[18] Lopez .M,L.F.Kahn, K.E. Kurtis, (2006) High- strength self-curing low-shrinkage concrete for pavement applications, Int. J. Pavement Eng., accepted for publication.
[19] Mannan MA, Ganapathy C (2004) Concrete from an agricultural wastes-oil palm shell (OPS). Build Environment.vol. 39(4), pp441–448.
[20] Mather, B., (2001) "Self-Curing Concrete, Why Not?" Concrete International, Vol. 23, No.1, pp. 46- 47.
[21] Mohr B.J , L. Premenko, H. Nanko, K.E. Kurtis, (2005) Examination of wood derivedPowders and fibers for internal curing of cement-based materials, in: B. Persson, D. Bentz, L.O.Nilsson (Eds.),Proceedings of the 4th International Seminar on Self-Desiccation and Its Importance in Concrete Technology,pp229–244.
[22] Ole Mejlhede Jensen Pietro Lura (2006) Techniques and materials for internal water curing of concrete Materials and Structures vol. 39. pp 817–825
[23] Pasko Jr., T. J (1998) Concrete Pavements Past, Present, And Future. Public Roads Magazine, Federal Highway Administration (FHWA). Vol. 62
[24] Persson .B (2000) Consequence of cement constituents, mix composition and curing conditions for self-desiccation in concrete Materials and Structures/Mat & iaux et Construc6ons, Vol. 33, pp 352-362.
[25] PietroLura, OleMejlhede, Jensen,Shin-Ichi, Igarashi (2007)Experimental observation of internal water curing of concrete Materials and Structures vol.40,pp 211–220
[26] Roberto Troli, Antonio Borsoi, Silvia Collepardi, Glenda Fazio, Mario Collepardi, Saveria Monosi, (2005)self-compacting / curing/compressing concrete 6th International Congress, Global Construction, Ultimate Concrete Opportunities, Dundee, U.K. 5-7
[27] Ronaldo S. Gallardo, Mary Ann q. Adajar (2006) Structural performance of concrete with Paper sludge as fine aggregates partial Replacement enhanced with admixtures Symposium on Infrastructure Development and the Environment pp1-10
[28] Teo D.C.L M. A. Mannan V. J. Kurian (2010) Durability of lightweight OPS concrete under different curing conditions Materials and Structures Vol. 43 pp1-13
[29] Tikalsky Ole Mejlhede Jensen Pietro Lura (2006) Techniques and materials for internal water curing of concrete Materials and Structures vol. 39. pp 817–825
[30] Zhutovsky, k.kovler and A.Bentur (2002) Efficiency of light weight aggregates for internal curing of high strength concrete to eliminate autogenous shrinkage materials and structures Vol 35 pp 97-101
[31] Zhutovsky s. Kovler and bentur, Influence of cement paste matrix properties on the autogenous curing of high-performance concrete cement and concrete composites Vol 26 no.5 ,2004pp 499-507.



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY