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A STUDY ON EFFECT OF CURING COMPOUNDS ON RECYCLED AGGREGATE CONCRETE ON STRENGTH AND OTHER PROPERTIES

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Abstract - Concrete curing is of paramount importance in order for concrete to meet performance requirements. Conventionally, curing has been conducted by means of water sparkling, wet burlap or a curing compound. For performance and environmental reasons, internal curing has been gaining increased attention. However, more data is needed for the effectiveness of this curing technique when used in various concrete mixtures. This investigation addresses potential utilization of internal curing in high performance concrete. Conventional mixtures were prepared and were thoroughly cured either by water or by a curing compound or left non-cured. Fresh concrete and Hardened concrete properties were assessed including slump, unit weight, compressive and flexural strength, and durability tests such as shrinkage assessment, rapid chloride permeability test (RCPT) and abrasion resistance. Experimental work is backed up with a simplified feasibility analysis with case study, incorporating initial and future costs to better judge potential of this technique. Properly cured concrete has improved durability and surface hardness that makes concrete less permeable which makes it more resistant to damping. Good and complete curing is not always practically possible due to many reasons, particularly for high grade concretes. The chemical used in this experiment like poly ethylene glycol PEG4000 and sodium ligno sulphonate to increase the strength of concrete. With this experiment it is evident that using different recycle aggregate and chemicals, the strength of the concrete can be increased.

Keywords- peg 4000, recycled aggregate concrete, sorbital , glycrin

I. Introduction

Recycling is the act of processing the used material for use in creating new product. The usage of natural aggregate is getting more and more intense with the advanced development in the infrastructure area. In order to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement materials. Recycled aggregate is comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. These materials are generally from buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes. The aim for this on-going project is to determine the utilization of recycled coarse aggregates for application in high strength structural concrete, which will give a better understanding on the uses of concrete with recycled coarse aggregates, as an alternative material to natural coarse aggregate in structural concrete.

II. Curing

Curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration. It may be either after it has been placed in position (or during the manufacture of concrete products), thereby providing time for the hydration of the cement to occur. Since the hydration of cement does take time – days, and even weeks rather than hours – curing must be undertaken for a reasonable period of time if the concrete is to achieve its potential strength and durability. Curing may also encompass the control of temperature since this affects the rate at which cement hydrates.

The curing period may depend on the properties required of the concrete, the purpose for which it is to be used, and the ambient conditions, i.e., the temperature and relative humidity of the surrounding atmosphere. Curing is designed primarily to keep the concrete moist, by preventing the loss of moisture from the concrete during the period in which it is gaining strength. Curing may be applied in a number of ways and the most appropriate means of curing may be dictated by the site or the construction method.

Types of curing

- Self-curing or internal curing.
- Conventional curing.
- Accelerated curing.

i) Self curing or Internal curing (IC)

Internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing water. Conventionally, curing concrete means creating conditions such that water is not lost from the surface i.e.,

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curing is taken to happen from outside to inside. In contrast, internal curing is allowing for curing from the inside to outside through the internal reservoirs (in the form of saturated lightweight fine aggregates, superabsorbent polymers, or saturated wood fibers) created. 'Internal curing' is often also referred as 'Self-curing'.

The ACI-308 Code states that "internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing water". Conventionally, curing concrete means creating conditions such that water is not lost from the surface i.e., curing is taken to happen 'from the outside' through the internal reservoirs (in the form of saturated lightweight fine aggregates, superabsorbent polymers, or Saturday wood fibers) Created. 'Internal curing' is often also referred as **Self-curing**.

Methods of Self-curing

Currently, there are two major methods available for internal curing of concrete. The first Method uses saturated porous lightweight aggregate (LWA) in order to supply an internal source of water, which can replace the water consumed by chemical shrinkage during cement hydration. The second method uses poly-ethylene glycol (PEG) which reduces the evaporation of water from the surface of concrete and also helps in water retention.

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 autogenous deformation and (early-age) cracking may results. 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. Often specially in HPC, it is not easily possible to provide curing water from the top surface rate required to satisfy the on-going chemical shrinkage, due to the extremely low permeability's often achieved.

Mechanism of Internal curing

Continuous evaporation of moisture takes place from an exposed surface due to the difference in chemical potentials (free energy) between the vapour and liquid phases. The polymers added in the mix mainly from hydrogen bonds with water molecules and reduce the chemical potential of the molecules which in turn reduces the vapourpressure, thus reducing the rate of evaporation from the surface.When mineral admixtures react completely in a blended cement system, their demand for curing water (external and internal) can be much greater than that in a conventional ordinary Portland cement concrete. When this water is not readily available, significant autogenously deformation and (early-age) cracking may result.

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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.

Following are the list of some chemicals which are hydrophilic in nature.

i. Polyvalent alcohol

ii. Poly ethylene glycol (peg)

iii. Poly-acrylic acid

iv. Xvlitol, sorbitol

Conventional curing

Water Curing General Water curing is carried out by supplying water to the surface of concrete in a way that ensures that it is kept continuously moist. The water used for this purpose should not be more than about 5°C cooler than the concrete surface. Spraying warm concrete with cold water may give rise to 'thermal shock' that may cause or contribute to cracking. Alternate wetting and drying of the concrete must also is avoided as this causes volume changes that may also contribute to surface crazing and cracking.

Accelerated curing

Accelerated curing is any method by which high early age strength is achieved in concrete. These techniques are especially useful in the prefabrication industry, wherein high early age strength enables the removal of the formwork within 24 hours, thereby reducing the cycle time, resulting in cost-saving benefits. The most commonly adopted curing techniques are steam curing at atmospheric pressure, warm water curing, boiling water curing and autoclaving.

A typical curing cycle involves a preheating stage, known as the "delay period" ranging from 2 to 5 hours; heating at the rate of 22 °C/hour or 44 °C/hour until a maximum temperature of 50−82 °C has been achieved; then maintaining at the maximum temperature, and finally the cooling period. The whole cycle should preferably not exceed 18 hours.

At heightened temperatures, the hydration process moves more rapidly and the formation of the Calcium Silicate Hydrate crystals is more rapid. The formation of the gel and colloid is more rapid and the rate of diffusion of the gel is also higher. However, the reaction being more rapid leaves lesser time for the hydration products to arrange suitably, hence the later age strength or the final compressive strength attained is lower in comparison to normally cured concrete. This has been termed as the crossover effect.

The optimum temperature has been found to be between 65 and 70 °C, beyond which the losses in later age strength have been found to be considerably higher

III. Literature Review

Dhir etal. (1994) Hefocused on achieving optimum cure of concretewithout the need for applying external curing methods. The chemical ability to reduce evaporation from solution and to improve water retention in OPC was measured by weight loss. Initial surface absorption and compressive strength tests were made to determine surface permeability and strength development. The scanning electron micro scope was used to determine the influence of admixtures on cement paste microstructure and obtained conclusion is, it is possible to improve water retention in cement paste by means of chemical addition to the mix. Improved water retention does not always lead to proportionate increase in degree of cement hydration and hence better concrete properties, although in many cases it does. A number of chemicals improved concrete surface characteristics. It appears that the presence of chemical is enhancing hydration, beyond that is achieved by the water retention.

Liang et al. (2002) He observed that combination of wax preferably paraffin wax and glycol preferably polyethylene glycol (PEG), when added to concrete enables internal curing which in many respects is equal to or superior to traditional forms of curing concrete .

The internal curing compound used has 10%PEG, 57%paraffin wax, 33% water (composition2).The curing compound was tested for the following parametersThe test results were compared with two other curing compounds, membrane curing and no curing conditions.

The curing compounds used were

- Compound 1 – Water, wax emulsion& high MW polyethylene oxide.
- Compound 2 – Water, paraffin wax, PEG (current invention).
- Compound 3 – Water based polyether.

The following conclusion has been reached

Internal curing composition 2 exhibits moisture retention characteristics similar to those of the solvent borne resin membrane and performs better than 3 day water curing. Internal curing composition 1 & 2 give compressive strength similar to those of the solvent borne resin membrane, however composition 3 shows a significantly lower strength at higher dosages. Porosity and absorption values of internal curing values of internal curing compound are comparable with solvent borne resin membrane and 3 days of water curing.

Jayadevan, V.R Valsalakumary and O.B. Sufeera The study conducted Test were conducted at the accelerated curing tank at the Construction Materials Division of the Kerala Engineering Research Institute. Though initial studies were not very encouraging added to minor shortcomings in precisely following the procedure due to lack of experience, initial results themselves were indicating that the formula used, may require some modification. It was therefore necessary to generate adequate test data. To get sufficient data, accelerated strength determination was conducted on all mix designs for various grades of concrete from M25 to M40. Accelerated testing was conducted with extreme care to ensure that described procedure is followed thoroughly. The results of the same were compared with the 7 and 28 days strengths of the normally cured cubes. In all 9 cubes of same water cement ratio were cast and the average of the 3 cubes were considered for 7 days, 28 days and for accelerated curing method and conclusion on the studies conducted has given totally discouraging results for the reliability of accelerated curing techniques proposed by the Bureau of Indian Standards. To develop and suggest a new correlation equation, much extensive studies and data analysis are required. But to establish that the current method is not dependable, these studies are ample. It is an extremely involved effort to do the accelerated strength tests according to the code specifications. But then if the results are inconsistent it is very disappointing. It is suggested that BIS may seriously look into the issue of revising the concerned code by referring to the international codes which are more elaborate in this subject.

Nirav R Kholia, Prof. Binita A Vyas, Prof. T. G. Tank The properties of hardened concrete, especially the durability, are greatly influenced by curing since it has a remarkable effect on the hydration of the cement. The advancements in the construction and chemical industry have paved way for the development of the new curing techniques and construction chemicals such as Membrane curing compounds, Self-curing agents, Wrapped curing, Accelerators, Water proofing compounds etc. With the growing scale of the project conventional curing methods have proven to be a costly affair as there are many practical issues and they have been replaced by Membrane curing compounds and Self-curing agents up to some extent as they can be used in inaccessible areas, Vertical structures, Water scarce areas etc .It is most practical and widely used curing method. In this review paper effort has been made to understand the working and efficiency of curing methods which are generally adopted in the construction industry and compared with the conventional water curing method. And obtained conclusion is conventional water curing is the most efficient method of curing as compared to Membrane curing, Self-curing, Wrapped curing and Dry air curing methods. Using Membrane curing and Self-Curing methods one can achieve 90% of efficiency as compared to Conventional Curing method. Self Curing method is most suitable for high-rise buildings especially in columns and inaccessible areas. Membrane curing compounds are most practical and widely used method it is most suitable in water scarce area. Wrapped curing is less efficient than Membrane curing and Self-Curing it can be applied to simple as well as complex shapes**.** Dry-Air curing should be avoided at the construction sites because designed design strength is not achieved by this method. The average efficiency of the curing compound increases with curing age initially by reduces at later age. Application of the curing compound is significantly dependent on the time of application of the compound**.** Curing of concrete is mostly governed by two parameters Temperature and Period.

Mr. Tushar R Sonawane, Prof. Dr. Sunil ,S. Pimplikar Use of recycled aggregate in concrete can be useful for environmental protection. Recycled aggregates are the materials for the future. The application of recycled aggregate has been started in a large number of construction projects of many European, American, Russian and Asian countries. Many countries are giving infrastructural laws relaxation for increasing the use of recycled aggregate. This paper reports the basic properties of recycled fine aggregate and recycled coarse aggregate & also compares these properties with natural aggregates. Basic changes in all aggregate properties are determined and their effects on concreting work are discussed at length. Similarly the properties of recycled aggregate concrete are also determined. Basic concrete properties like compressive strength, flexural strength, workability etc. are explained here for different combinations of recycled aggregate with natural aggregate. Codal guidelines of recycled aggregates concrete in various countries are stated here with their effects, on concreting work. In general, present status of recycled aggregate in India along with its future need and its successful utilization are discussed here and obtained conclusion is use of recycled aggregate up to 30% does not affect the functional requirements of the structure as per the findings of the test results. Various tests conducted on recycled aggregates and results compared with natural aggregates are satisfactory as per IS 2386. Due to use of recycled aggregate in construction, energy & cost of transportation of natural resources & excavation is significantly saved. This in turn directly reduces the impact of waste material on environment

Polyethylene Glycol (PEG 4000)

Polyethylene glycol is a condensation polymer of poly ethylene oxide and water with general formula H $(OCH_2CH_2)_{OH}$, where n is a average number of repeating ox ethylene groups typically from 4 to about 180.The low molecular weight members from n=2 to n=4 are diethylene glycol ,tri ethylene glycol and tetra-ethylene glycol respectively, which are produced as pure compounds.

The low molecular weight compounds up to 700 are colourless ,odourless viscous liquids with a freezing point from 10^0 C (di ethylene glycols), while polymerized compounds with higher molecular weights than 1,000 are wax like solids with melting point up to 56-61^0C for n 180. The abbreviation (PEG) is termed in combination with a numeric suffix which indicates the average molecular weights . one common feature of PEG appears to be water soluble . the specifications of PEG are shown in table below . it is also soluble in many organic solvents including aromatic hydrocarbons (not aliphatic). They are used to make emulsifying agents and detergents ,and as plasticizers ,humectants, and water soluble textile lubricants.

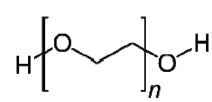

Fig Chemical structure of PEG

Physical and Chemical Properties

Physical State and Appearance: liquid.

Odour: Not available.

Taste: Not available.

Molecular Weight: 4000 (average)

Colour: White

pH (1% soln/water): 4.5 - 7.5

Boiling Point: > 200 °C

Melting Point: 60 - 63 °C

Critical Temperature: Not available.

Specific Gravity: 1.127

Vapour Pressure: < 0.01

Vapour Density: > 1

Volatility: Not available.

Odour Threshold: Not available.

Water/Oil Dist. Coeff: Not available.

Iconicity (in Water): Not available.

Dispersion Properties: Not available.

Solubility: Soluble in water.

PEG4000

Super plasticizers, also known as **high range water reducers**, are chemical admixtures used where well-dispersed particle suspension is required. These polymers are used as dispersants to avoid particle segregation (gravel, coarse and fine sands), and to improve the flow characteristics (rheology) of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of the water to cement ratio, not affecting the workability of the mixture, and enables the production of self-consolidating concrete and high performance concrete. This effect drastically improves the performance of the hardening fresh paste. The strength of concrete increases when the water to cement ratio decreases. The addition of super plasticizer in the truck during transit is a fairly new development within the industry. Admixtures added in transit through automated slump management systems, allows concrete producers to maintain slump until discharge without reducing concrete quality

Concrete using sodium lignosulphonate

- To improve the effectiveness of the water content of a concrete mix by using sodium Lignosulphonate.
- To determine the characteristics of self-curing concrete such as compressive and split tensile strength by adding self-curing agent in varying percentage.
- To compare the strength between conventional and self-curing concrete.

Test on concrete using sodium lignosulphonate

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- To compare the strength between conventional and self-curing concrete.

S.no	Index Item	standard value	Test result
1	Appearance	Dark brown	meet the requirement
2	lignosulpho nate	50%(min)	55
3	Dry matter	92%(min)	94
4	Moisture contents	7.0%(max)	3.9
5	PH value	(7-11)	8
6	In organic salts (NA2 SO4)	5.0%(max)	1.9
7	Total reading	4.0%(max)	4.1
8	water insoluble matter	2.50%	1.3

V. Experimental Programme

General

The experimental programme was planned as the following cubes were casted which involves 1.5% of self-curing agent PEG4000 for M40 under different self-curing condition and 9 cubes of conventional concrete were casted.

Compressive strength test was conducted at 14 and 28 days of curing. The graph is plotted against compressive strength versus number of days of curing.

Experimental programme for concrete

The experimental program was designed to investigate the strength of self-curing concrete by adding poly ethylene glycol PEG4000 @ 1.5% by weight of cement to the concrete and conventional concrete by sorbitol self curing and accelerated curing.

The experimental program was aimed to study the workability, compressive strength. To study the properties, M40 grade was considered.

Table 4.3.4 Results Of Preliminary Tests On Cement

S.no	Cement tests	Results obtained	Range	code
1	Normal consistency of cement	32 mm for30% of water	26 to 33mm	IS: 4031-4-1996

2	Initial setting of cement	30 minutes	30 minutes	IS:4031-5-1996
3	Final setting of cement	620 minutes	600 minutes	IS:4031-5-1996
4	fineness of cement	95% fine	Not exceed 100%	IS:4031-1-1996

Table 4.4.1Preliminary test results on Fine aggregate

S.no	**Fine aggregate tests**	**Results obtained**	**Code**
1	Bulking of sand	5.26 %	Is :2386-3 196
2	Water absorption	1% 1 % of its weight	-- -

Table 4.5.2 Preliminary test results on Coarse aggregate

S.no	**Coarse aggregate tests**	**Results obtained**	**Code**
1.	Aggregate impact test	28.35 %(satisfactory)	IS: 2386- 4 - 196
2.	Water absorption test	0.92 % of its weight	--

Accelerating curing tank

In this type of curing the accelerated by placing the specimen in curing tank and heated at a temperature of 95^0c for whole one day then cubes are removed from the tank and tested for compressive strength.

Fig : Accelerated curing tank

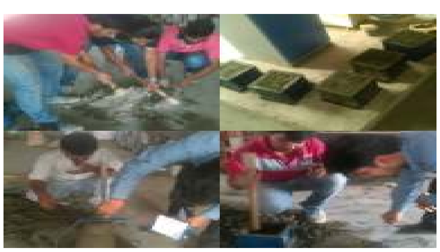


Fig : Casting of specimens

VI. Mix Proportions

Cement = 396 kg /m^3

Fly ash = 69 kg /m^3

Water = 139.5kg /m^3

Fine aggregate = 712 kg /m^3

Coarse aggregate = 1192 kg /m^3

Admixture = 2.93 kg/m^3

Water cement ratio = 0.35

Table 5.1.2 Mix Ratio Of Concrete

s.no	mix	cement : fine aggregate : coarse aggregate : water : fly ash
1	m40	1 : 1.92 : 3.23 : 0.35 : 0.18

Slump test results for self-curing concrete

S.no	Peg4000(%)	Slump test (mm) for m40	Degree of workability
1	1.5	25	Low
2	1.5	**30**	Medium

Slump test results for conventional concrete

s.no	Slump test (mm) for M40	Degree of workability
1	45	Low
2	50	Medium

Slump test results for sodium lignosulphonate

s.no	Slump test (mm) for M40	Degree of workability
1	45	Low
2	50	Medium

Experimental study on concrete using sodium lignosulphonate

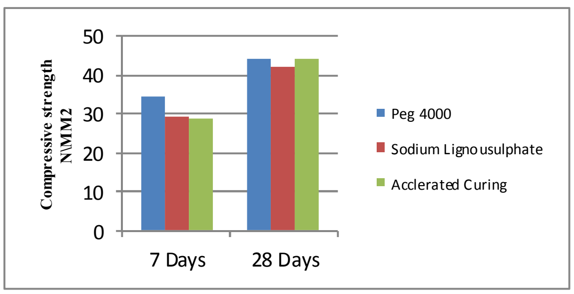
It is significant that the ingredient material of concrete remain consistently distributed within the concrete mass during the various stages of handling and that full compaction is achieved, and making sure that the characteristics of concrete which affect full compaction like consistency, mobility and compatibility are in conventionalitywith relevantcodes of practice. The test carry out in this paper is compressive and split tensile test.

In this experiment we found strength of self-curing concrete by adding sodium lignosulphonate (chemical admixture) at, 1.5% and also comparing with conventional concrete to study the compressive strength and split tensile strength.

VI. Results

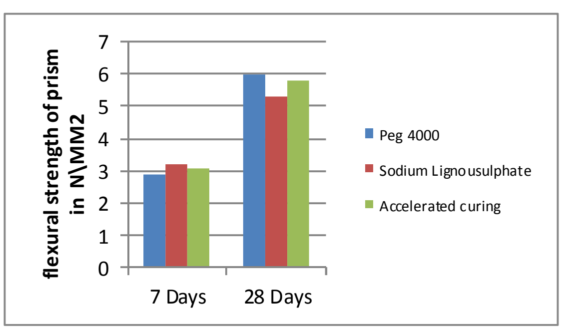
Compressive strength results for mix M40

S.no	cube size	chemical used	7 days n/mm2	28days n/mm2
1	150mmx150mmm x150mm	peg 4000	34.56	44.45
2	150mmx150mm x150mm	sodium lignousulphate	29.3	42.2
3	150mmx150mm x150mm	acclerated curirg	29.1	44.3



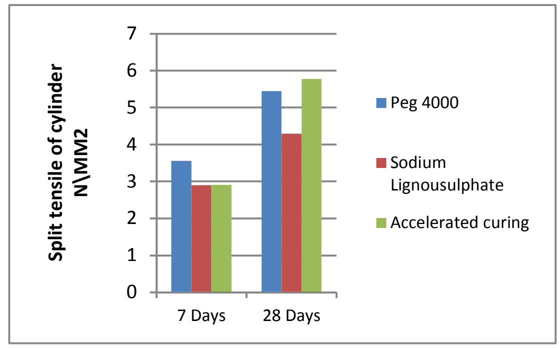
Flexural Strength of Prism Result for Mix M40

S.no	cube size	chemical used	7 days	28days
1	150mmx150mm x700mm	peg 4000	2.92	5.96
2	150mmx150mm x700mm	sodium lignousulphate	3.20	5.31
3	150mmx150mm x700mm	accelerated curing	3.10	5.81



Split Tensile of Cylinder Result for Mix M40

s.no	cube size	chemical used	7 days	28days
1	150mm x300mm	peg 4000	3.56	5.45
2	150mm x300mm	sodium lignousulphate	2.9	4.29
3	150mm x300mm	accelerated curing	2.91	5.78



VII. Conclusion

In present study strength due to different curing compounds were evaluated.

Average compressive strength for 28 days of concrete when cured with self curing compound peg 4000 and sodium lingo sulphate with slight (negligible).

While flexural steength was higher when cured with peg 4000, the split tensile sterength was also improved with peg 4000 by this we can conclude that peg 4000 will yeld better reults and curing methods also effect the strength.

Further investigations are required for effect on other properties

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