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An Experimental Study on Strength of Concrete by Partial Replacement of Cement with Rice Husk Ash (RHA) and Chemically Curing with Polyethylene Glycol-400 (PEG-400)

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Abstract— *This paper covers a study on the determination of strength of concrete by partial replacement of cement with admixtures Rice Husk Ash (RHA) and Polyethylene Gycol-400 (PEG-400). RHA is an admixture used in concrete construction because it has high content of silica, about 90%, which means it shows pozzolanic activity; it shows cementitous property and because of this reason we can partially replace it and study its effectiveness on the strength of the concrete. PEG-400 chemical is a shrinkage reducing admixture and it is used as a curing material in this study. PEG-400, a self-curing agent, provides additional moisture for better hydration in the concrete. It reduces the shrinkage of the concrete thereby avoiding the evaporation of water from the concrete.*

Keywords*: concrete, compressive strength, tensile strength, flexure strength, rice husk ash, polyethylene glycol-400, self-curing.*

1. Introduction

Presently the construction industries and companies are booming with the advancement and so there is a high demand of buildings – residential buildings, and important buildings like hospitals, schools, communication buildings/towers, power plant structures. Civil engineering is a discipline of science that deals with designing of structures, constructing them, and maintaining them. The sole purpose of a civil engineer is to build a structure that is safe and which will withstand the course of time. Strength is the most important aspect of any structure and has been the main topic of discussion in the world of civil engineering. Apart from the conventional method of building; using cement, aggregates, and water, we can also partially replace cement by weight using admixtures. Here, rice husk ash (RHA) is partially replaced with cement by weight and its impact on the strength is evaluated. Polyethylene glycol-400 (PEG-400) is also partially replaced with cement by weight and is used for chemically curing the concrete and finally its impact on the strength is studied. The construction industries greatly rely on the conventional materials; cement and aggregates for concrete production. Since concrete is the basic material in civil engineering, its demand in infrastructural development is growing day by day. Keeping this in mind, the non-availability of natural resources in the future is also considered. So the need to use other materials other than cement arises [7]. Instead of dumping the waste materials, they can be used for various purposes. In construction industries there is a trend in using waste materials as a supplementary cementitous material [2]. Fly ash and RHA are the most commonly used agro-based waste materials due to their pozzolanic property [2, 8]. Using these waste products not only produces a diversified quality of blended cement but also reduces the cost and decreases the consumption of energy used due to production of cement which only effects the environment by emitting CO2 [2, 4, 8]. It is estimated that 1 tonne of CO2 is emitted per 1 tonne of cement produced. And globally, 5% to 7% of CO2 emission leads to global warming [9]. RHA, an agricultural residue obtained by burning the husk at a controlled temperature of 550°C to 700°C for one hour, transforms the silica content in the ash to amorphous state. The reaction of amorphous SiO2 is directly proportional to the specific surface area of the ash. The ash produced is pulverized/grounded into fine powder and mixed with cement to give blended cement [1, 2]. RHA contains 95% silica in non-crystalline or amorphous state [2, 3]. The reaction of amorphous SiO2 with CaOH during cement hydration produces C-S-H gel which helps in the improvement of the concrete strength and durability [2]. The ash properties differ due to the difference in incinerating conditions, fineness, heating rate, and geographic location [3]. Its effect on the physical properties of concrete are associated with the size particles of RHA. The finer the particle, the better it acts as a refinement on the pore structure of RHA. It also acts a nucleation point for hydration, and limit the development of crystals created during hydration. Due to its filler effect property the compressive strength of concrete is increased and the water permeability is decreased. In addition, RHA affects the fresh property of concrete by improving the workability and the water binder ratio [2]. But it is seen that the filler effect property has more impact on the strength properties of concrete than the pozzolanic property of RHA [3]. The advantages of using RHA are – used as admixtures due to its filler property, economical substitute, and as a source of silica [5]. It is also highly porous and light in weight so it is useful when the weight of structure is of primary concern. Its absorbent and insulating properties are also useful for numerous industrial applications [6]. So, instead of dumping RHA, which will only cause environmental pollution, we can use it for other purposes including in construction industries [10]. Curing of concrete is a process of maintaining sufficient moisture in the concrete during its hydration and/or pozzolanic activity so that its strengths, microstructure, and durability are developed. Therefore, proper curing of concrete is necessary. In the conventional type, curing is done externally by water [11]. In the past few years, concrete technology has been going through fast development. The concept of self-curing in the recent years is also gaining its popularity and is making steady progression from laboratory practice to on-site practice [12]. Internal or self-curing is defined as a method that provides additional moisture to the concrete for more efficacious hydration [11]. Water evaporates continuously from an exposed surface because of the difference in chemical potential or free energy between vapour phase and liquid phase. By adding polymers like polyethylene glygol-400, it forms hydrogen bonds with water molecules to reduce the chemical potential of the water molecules which in turn slows down the vapour pressure and as a result lessens the rate of evaporation of water from the surface [11, 13, 15, 20]. Polyethylene glycol, a condensation polymer of ethylene oxide and water, is an example of water soluble polymers. And its general formula is given by H(OCH2CH2)nOH where n is the average number of repeating oxyethylene groups approximately at a range of 4 to 180. Since it is a type of water soluble polymer, it acts as a shrinkage reducing admixture and reduces self-desiccation of hardened concrete [14, 19]. The significance of internal curing is that when mineral admixtures react with blended cement completely the demand for water (internally or externally) is more as compared when conventional cement is used. When this water is not available readily, autogenous deformations and early-aged cracks are formed. And because of the chemical shrinkage taking place during cement hydration, empty pores are formed in the cement paste which decreases its internal relative humidity and shrinkage causing early-age cracking [11, 13, 15, 17]. The function of self-curing admixtures is to decrease the evaporation of water from the concrete which will in turn increase the water retention capacity of the concrete thereby increasing the strength and durability of the concrete [16]. In short, self-curing keeps the relative humidity high, avoids self-desiccation, eliminates autogenous shrinkage and cracking, reduce permeability, and maintains the strength and durability of concrete [12, 18]. The potential materials that can provide internal water reservoir are – a) lightweight aggregate e.g. natural aggregate which are mostly volcanic like pumice, tuffs, and synthetic aggregate like clay, slate, crushed burnt bricks, b) super absorbent polymers (SAP), c) shrinkage reducing admixtures (SRA) e.g. propylene glycol type like PEG-400 [11, 13].

2. Experimentation

2.1. Materials used

2.1.1. Cement. Ordinary Portland Cement (OPC) of grade 43 with specific gravity 3.15, fineness 4.5g, consistency 29.5%, initial setting time 32 minutes, final setting time 278 minutes, and soundness of 0.3 cm.

2.1.2. Aggregates. Very fine sand (zone IV) with fineness 2.05475, specific gravity 2.66. Coarse aggregates of size 10mm and 20mm with specific gravity 2.71 and 2.72 respectively, and water absorption of 0.99% for both sizes.

2.1.3. Rice Husk Ash. Finely grounded RHA collected from Ludhiana, India.

2.1.4. Polyethylene glycol-400. Liquid PEG-400 collected from medical store Jalandhar, India.

2.2. Test instrument

Compression Testing Machine (CTM) with a capacity of 1000 KN.

2.3. Mix proportion and casting of concrete specimen

A mix of M25 grade was proportioned. RHA blended cement is prepared by replacing OPC by its weight in percentages of 11%, 18%, and 22%. PEG-400 is replaced with OPC by its weight in percentages of 0.5%, 1%, and 1.5%. The two admixtures are added in two ways – RHA and RHA+PEG-400. Concrete cubes of 150mm*150mm*150 mm, concrete cylinders of 200mm*100mm, and concrete beams of 500mm*100mm*100mm are casted and kept for 24 hours. After 24 hours, the casts are opened and the concrete specimens are cured externally for 7, 14, and 28 days.

2.4. Compressive strength of concrete cube

Compressive strength of RHA blended concrete and RHA+PEG-400 blended concrete are tested after 7, 14, and 28 days of external curing.

Figure 1. Compression Test

2.5. Tensile strength of concrete cylinder

Tensile strength of RHA blended concrete and RHA+PEG-400 blended concrete are tested after 7, 14, and 28 days of external curing.

Figure 2. Tensile Test

2.6. Flexure strength of concrete beam

Flexure strength of RHA blended concrete and RHA+PEG-400 blended concrete are tested after 7, 14, and 28 days of external curing.

Figure 3. Flexure Test

3. Results and Discussions

3.1. Compression test

Table 1. Compressive Strength of Cubes

Replacement (%)	7days (N/mm^2)	14days (N/mm^2)	28days (N/mm^2)
0%	21.758	26.638	30.516
RHA (11%)	25.390	26.701	31.634
RHA+PEG-400 (11%+0.5%)	26.771	31.558	32.727
RHA (18%)	21.743	25.197	29.287
RHA+PEG-400 (18%+1%)	25.053	27.554	30.587
RHA 22%	21.367	21.671	27.463
RHA+PEG-400 (22%+1.5%)	21.594	25.664	29.779

3.2. Split tensile test

Table 2: Tensile Strength of Cylinders

Replacement (%)	7days (N/mm^2)	14days (N/mm^2)	28days (N/mm^2)
(0%)	2.543	2.547	2.740
RHA (11%)	3.425	3.585	3.667
RHA+PEG-400 (11%+0.5%)	3.702	4.308	4.448
RHA (18%)	2.143	3.075	3.194
RHA+PEG-400 (18%+1%)	2.543	3.319	4.065
RHA 22%	1.555	2.537	2.771
RHA+PEG-400 (22%+1.5%)	2.458	3.635	3.623

3.3. Flexure Test

Table 3. Flexure Strength of Beams

Replacement (%)	7days (N/mm^2)	14days (N/mm^2)	28days (N/mm^2)
(0%)	6.126	6.696	9.353
RHA (11%)	6.783	8.403	10.26
RHA+PEG-400 (11%+0.5%)	7.73	10.623	12.713
RHA (18%)	5.426	7.163	8.28
RHA+PEG-400 (18%+1%)	6.456	8.37	9.176
RHA 22%	5.346	6.396	6.593
RHA+PEG-400 (22%+1.5%)	5.416	6.586	7.56

For all the tests, it is seen that the strengths increases as the replacements increases. The strengths also increase as the curing days increases and the maximum strength is found after 28 days of curing for all the replacements. RHA when replaced at 11% gave maximum strength and then there is a fall in the strength after 11% i.e., for 18% and 22% for all the curing days. Also when RHA+PEG-400 is replaced, the strengths increase as the replacement of RHA and PEG-400 increases for up to 11% and 0.5% replacement respectively and there is a fall in the strength after that i.e., for the combination of 18% RHA and 1% of PEG-400, and 22% of RHA and 1.5% of PEG-400 for all the curing days. Therefore, the strength is found to be optimum when replaced with 11% RHA, and 11% RHA and 0.5% PEG-400 for all the curing days. Also another observation is that the strength obtained after 11% and 11%+0.5% replacement is approximately near to the value of control mix. Therefore, we can conclude that RHA and PEG-400 as an admixture performs best when 11% and 0.5% is replaced respectively. The difference between adding RHA only and RHA+PEG-400 is that addition of PEG-400 increased the strength of concrete more as compared to that of control mix and also to that of RHA blended concrete.

4. Conclusions

1. It has been concluded that the admixtures can be used as an effective material in place of cement to improve the strength of the concrete.
2. The concrete cubes are tested on the basis of compressive force and it is seen that it can bear a maximum load of 31.643 N/mm^2 for 28 days of curing when replaced with 11% of RHA and when replaced with a combination of 11% of RHA and 0.5% of PEG-400, it showed more strength gain of 32.727 N/mm^2 for the same number of curing days for a concrete design mix of M25.
3. The concrete cylinders are tested on the basis of split tensile force and it is seen that it can bear a maximum load of 3.667 N/mm^2 for 28 days of curing when replaced with 11% of RHA and when replaced with a combination of 11% of RHA and 0.5% of PEG-400, it showed more strength gain of 4.448 N/mm^2 for the same number of curing days for a concrete design mix of M25.
4. The concrete beams are tested on the basis of flexural force and it is seen that it can bear a maximum load of 10.26 N/mm^2 for 28 days of curing when replaced with 11% of RHA and when replaced with a combination of 11% of RHA and 0.5% of PEG-400, it showed more strength gain of 12.713 N/mm^2 for the same number of curing days for a concrete design mix of M25.
5. The strengths of the concrete specimens also increased as the curing days increased. The maximum strength gain was found when the specimens were cured for 28 days for all the mixes.
6. RHA when added with PEG-400 showed two major differences as compared to when RHA alone was added – a) addition of PEG-400 to RHA gave more strength than when only RHA was added and b) addition of PEG-400 improved the curing of the concrete because PEG-400 acts as a shrinkage reducing admixture and avoids the loss of water in the concrete by maintaining the water quantity which showed more gain strength.
7. Addition of PEG-400 also reduced the use of water and it will be useful in places where the water availability is limited.

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