International Journal for Environmental Rehabilitation and Conservation
Volume III No. 1 2012 [30 – 37] [ISSN 0975 - 6272]

Comparative study of Eco Cement with OPC and PPC

Vinay Deulkar[1], Manish Verma[2], Umesh Pendharkar[3]

Received: March 23, 2012 | **Accepted**: May 10, 2012 | **Online**: July 27, 2012

Abstract

Around 26 billion tons of CO_2 are released to the atmosphere annually, around 20 billion metric Tons of which is from the burning of fossil fuels and close to a significant 2 billion tones from the production of Portland cement. Over two tons of concrete are produced per person on the planet per annum. There by causing the greenhouse gases are increasing in the environment this is the major problem arising for world .this problem cannot be reduced but this can be minimized by eco friendly material eco cement.

Eco-cements are hydraulic cements containing 15-20% reactive magnesia. When this reactive magnesia react with opc a brucite is form this is capable of absorbing co2 from environment.

The most important characteristic of eco-cements is absorption of CO_2 from atmosphere. Other properties affected include shrinkage, durability and rheology. This paper discusses the potential impact on sustainability of the new eco-cement Technologies for sustainability and comparison of physical properties of Eco Cement with Ordinary Portland Cement (OPC) and Portland pozzolana cement. It also discusses the amount of CO_2 absorb by Eco cement in comparison with OPC and PPC.

Keywords: Brucite | durability | reactive magnesium oxide | reactive magnesia | Portland cement | Portland pozzolana cement

For correspondence:

[1]Ujjain Engineering College Ujjain, M.P.

[2]Medicaps Institute of Science and Technology, Indore

[3]School of Engineering & Technology, Vikram University Ujjain, M.P.

E-mail: vinay_deulkar@yahoo.co.in

Introduction

Eco-Cement is made by heating magnesite in a kiln to produce reactive magnesium oxide (magnesia). That magnesia powder is then added to a conventional Portland cement mix which, in turn, can be mixed with aggregates, in the usual fashion, to make Eco-Cement.

Eco-Cement hydrates in permeable substrates, using mix water, then carbonates. The more magnesia added and the more permeable it is, the more CO_2 the Eco-Cement absorbs. An Eco-Cement concrete block typically takes up

to one year to carbonate fully, occurring quickly at first and then slowing as the process continues. Furthermore, should an Eco-Cement structure reach its end-of-life or become obsolete, it can be almost fully recycled back into cement.

As we know that, incorporating pozzolans into cement mixtures is common practice, but because Portland is alkaline there are strict limits. Magnesium-based cements, however, are significantly less alkaline, leaving room for much larger amounts of bulking material without compromising structural integrity. "We can probably get three of four times more waste into our cement than Portland cement," Mr. Harrison has said buildings could become massive 'carbon stores'.

How do Eco-Cements work?

Eco -Cement is made by blending a small amount of reactive magnesia with conventional hydraulic cements like Portland cement. As the magnesia hydrates it consumes water forming brucite hydrates which can later deliver more water for the more complete hydration of other hydraulic cement components adding to long term strength development. We maintain that lime should not be allowed to remain in concrete as it is far too mobile and reactive. Put some in your next cup of tea if you do not believe this! In Tec-Cement concretes lime produced as a result of the hydration of Portland cement is consumed by what is known as the pozzolanic reaction with silica and alumina and replaced by brucite which is magnesium hydroxide and a much more stable and less soluble alkali. The result is that durability is significantly improved. Many other properties of concrete are favorably affected including the flow characteristics (rheology) and dimensional change.

A. *Chemical Reaction of Eco Cement*

$MgCO_3 \rightarrow MgO + \downarrow CO_2$ - Efficient low temperature calcinations

$MgO + H_2O \rightarrow Mg(OH)_2$ – Hydration

$Mg(OH)_2 + \downarrow CO_2 + 2H_2O \rightarrow MgCO_3 + 3H_2O$ – Carbonation

In the cycle of chemical reaction of eco cement it does not take much energy to go from one state to another, it occurs at low temperature. Magnesium Oxide which hydrates to magnesium hydroxide and then carbonates is ideal for scrubbing CO_2 out of the air and sequestering the gas into the built environment.

Methodology in Manufacturing the Eco Cement

1. Magnesite (a compound of magnesium) is obtained from quires and then it heated in a kiln to around 600 to 750 degrees C. The lower firing temperature of the Tec-Kiln makes it easier to use free energy such as wind or solar or even waste energy and Tec Eco plan to make a kiln that does not use fossil fuels and in which the CO_2 gases produced from the magnesium carbonate as it decomposes is captured and contained for further use or safe disposal.
2. Eco cement also wants to grind in the hot area of his kiln for increased efficiency.
3. The heating process produces reactive magnesia.
4. The reactive magnesia (powder) is added in ordinary Portland cement.
5. The resulting blended powder is eco Cement.

For experimental work of this paper the readymade the reactive magnesia (MgO

powder) available in market is added in OPC about 15%.

Comparison of Physical Properties

For the comparison of physical properties of Eco cement, about 15% MgO powder is properly mixed with the OPC. For this preparation the MgO powder is produced from the chemical shop. Other two samples OPC 53 grade and PPC were used. All general physical properties of Eco cement are checked and compared with the ordinary Portland cement and Portland pozzolana cement as under.

A. Fineness Test

The Sieve test is preferred for this purpose. Weigh correctly 100 grams of all three samples, took it on IS sieve No. 09 (90 microns). Break down the air set lumps in the samples with the fingers. Continuously sieving has been done in circular and vertical motion for the period of 15 minutes. The residue left on the sieve was weighed. Three samples of each cement that is PPC, OPC and Eco cement was checked, the average results are as under-

S. No.	Type of Cement	Average residue left
01	OPC	4.5 %
02	PPC	3.5 %
03	Eco Cement	2 %

Table I: Results of fineness test on cement samples

As per standers the residue should not be more than 10%. But it is observed that Eco cement is finer than PPC and OPC.

B. Standard Consistency Test

This is the test conducted to estimate the quantity of water to be mixed in cement to form a paste of normal consistency for use in other tests. The conventional method of Vicat apparatus is used. Three trials are taken for all three samples of cements, for different percentage of water. The standard consistency found for all samples is under-

S. No.	Type of Cement	standard consistency
01	OPC	41 %
02	PPC	38 %
03	Eco Cement	40 %

Table II: Standard consistency

The above observations shows the standard consistency of OPC, PPC and Eco cement was found nearly same from different trials.

C. Soundness Test

It is very important that the cement after setting shall not undergo any appreciable change of volume. This will cause serious difficulties for durability of structures when unsound cement is used. The testing of soundness of the cement, to ensure that the cement does not show any appreciable subsequent expansion is of prime importance. The unsoundness of the cement is due to excess of lime and magnesia or excessive proportion of the sulphates. As Eco cement contains percentage of magnesia more than OPC and PPC there may be fear of unsoundness, so this test become very essential while comparing the Eco cement with other types of cements. The soundness of all there

samples of cements are tested by using the Le-Chatelier apparatus. There samples of each cement sample is boiled with the Le-Chatelier mould. The differences between the initial and final distance of indicator points were noted. The average results are as under –

S. No.	Type of Cement	Average differences between the initial and final distance of indicator points
01	OPC	2.33 mm
02	PPC	1.67 mm
03	Eco Cement	3.00 mm

Table III: Soundness of cement samples

Here from the observation the eco cement is looking somewhat unsound in comparison with OPC and PPC. But as per the standard the average differences between the initial and final distance of indicator points of Le-Chatelier mould must not exceed 10 mm, so though the expansion of Eco cement is slightly more but it is well within the limit, so Eco cement can't stated as unsound.

D. Setting Time Test

The initial setting time is regarded as the time elapsed between the moment that the water is added to the cement, to the time that the paste starts losing its plasticity. The final setting time when the paste is completely lost its plasticity and has attained sufficient firmness to resist certain pressure. In actual construction dealing with cement paste, mortar or concrete certain time is required for mixing, transporting, placing, compacting and finishing. During this time cement paste, mortar, or concrete should be in plastic condition. The time interval for which the cement product remains in plastic condition is known as the initial setting time. Normally a minimum of 30 minutes is given for mixing and handling operations. Once the concrete is placed in the final position, compacted and finished, it should lose its plasticity in the earliest possible time so that it is least vulnerable to damage from external destructive agencies. This time should not be more than 10 hours, which often referred as final setting time.

Initial Setting Time Test: For this test conventional Vicat Apparatus is used with as usual procedure –

S. No.	Type of Cement	Initial Setting Time
01	OPC	115 Minutes
02	PPC	190 Minutes
03	Eco Cement	135 Minutes

Table IV: Initial setting time

Final Setting Time Test: For this test also conventional Vicat Apparatus is used with as usual procedure -

S. No.	Type of Cement	Final Setting Time
01	OPC	175 Minutes
02	PPC	310 Minutes
03	Eco Cement	290 Minutes

Table V: Final setting time

As per IS 12269 – 1987 (for OPC) and IS 1489 (Part 1): 1991 (for PPC) initial setting time in minutes shall not be less than 30 and final setting time shall not be more than 600. The both setting times of Eco cement are within the limits of 30 minutes and 600 minutes.

E. Compressive Strength Test

The compressive strength of hardened cement is the most important of all the properties. Therefore, it is not surprising that the cement is always tested for its strength at the laboratory before the cement is used for important works. Strength test are not be made on neat cement paste because of difficulties of excessive shrinkage and subsequent cracking of neat cement. Strength of cement is indirectly found on cement sand mortar in specific proportions. The standard sand is used for finding the strength of cement. It shall conform to IS 650 – 1991. For checking the compressive strength of all three samples of cements that is OPC, PPC and Eco cement 555 grams of standard sand, 185 grams of cement sample has been taken. It means ratio of cement to sand was 1:3. The amount of water $\frac{P}{4}$ + 3.0 percent of combined weight of cement and sand and mixed the three ingredients thoroughly until the mixture is of uniform color. The time of mixing kept between 3 to 4 minutes. Immediately after mixing, the mortar is filled into a standard cube of size 7.06 cm, the area of the face of the cube was equal to 50 square centimeters. Compaction is done by standard specified manner. Nine cube of each sample of cement that is OPC, PPC and Eco cement are prepared and kept for curing in the tank. Three cubes of each cement sample are tested after 3, 7 and finally 28 days of curing. The results are tabulated under-

S. No.	Days of Curing	Cement sample	Average Compressive Strength of three cubes in Mpa
01	03 Days	OPC	29.75
		PPC	25.82
		Eco	24.50
02	07 Days	OPC	38.91
		PPC	31.50
		Eco	30.00
03	28 Days	OPC	54.28
		PPC	37.28
		Eco	36.61

Table VI: Compressive Strength of Cement Samples

According to IS 12269 – 1987 the minimum compressive strength of OPC 53 grade should be 27 MPa in 03 days, 37 MPa in 07 days and 53 MPa in 28 days of curing. And as per IS 1489 (Part 1) 1991 the minimum compressive strength of PPC should be 16 MPa in 03 days, 22 MPa in 07 days and 33 MPa in 28 days of curing. For OPC and PPC the testing of compressive strength meets the norms of standards. For Eco cement no standard norms are available, but from testing it is observed that the compressive strength of the Eco cement is less than OPC but its strength is very nearer to PPC. It means where strength criteria has prime important but using PPC it can be

replaced by Eco cement to achieve its other benefits.

Measurement of CO_2 absorbed by the cement sample product

It is theoretically clear that due to excess MgO the Eco cement will absorb more CO_2 as compare to other cements. To demonstrate this comparison a set has been developed in the laboratory. Instead of measuring CO_2 level from Air of closed chamber or container it will measure the amount of CO_2 absorbed by product of Eco cement and other cement. For this purpose set up of lime water and CO_2 reaction was developed in the laboratory. We can measure the amount of calcium carbonate [$CaCO_3$] precipitated due to lime water and CO_2 reaction as under –

$Ca(OH)_2 + CO2 \rightarrow CaCO3 + H_2O$
(lime water) (white precipitate)

Reagents required: 1) Con. H_2SO_4 – foe washing the gas CO_2 and absorb the water vapors.

2) Dilute H_2SO_4 – dilute 1:4. Add acid to the water and stir it continuously.

3) Lime water – Add excess of water to the lime keep for overnight, decant and filter it properly.

4) Powder of cement product – powder cement product of 28 days cured and kept open in air for 7 days. For this purpose the cubes which were prepared for compressive strength test was left for 7 day in open and then grind to get the powder.

Glassware preferred: For proper demonstration of the experiment in laboratory the glassware of Agawal scientific glass industries (ASGI) are choose, which is well known in this field and ISO 9001 : 2008 certified company.

1) RB flask B-19, 250 ml

2) Adaptor 1030 with socket B-19, cone B-19

3) Bottle gas washing B-29, 250ml

4) Funnel separating Cone B-19

Procedure adopted:

1) Take nearly 75 to 100 ml of lime water in the gas washing bottle and weigh iit with the help of chemical balance correctly. Note down the initial weight of bottle with lime water.

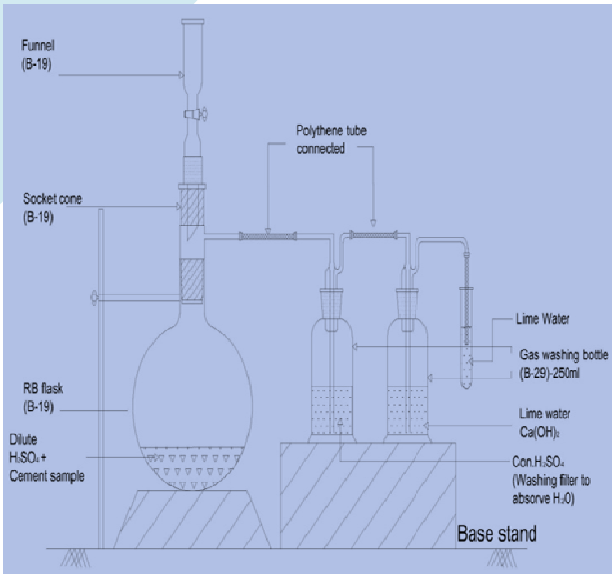
2) Take about 10 to 15 grams of power of cement product, pour it in the round base (RB) flask and assemble as shown in the figure.

3) Add nearly 100 ml of dilute H_2SO_4 from dropping funnel till it shows effloresces. It generates the carbon dioxide gas which will pass through con. H_2SO_4 initially which absorbs the H_2O vapors. Later on it will bubble in the bottle of lime water. Due reaction of CO_2 with lime water, lime water turns to cloudy milky.

4) To check the saturation of the lime water extra test tube filled with lime water again can be attached to the out let of the bottle. When the lime water in the test tube starts become milky it shows the saturation in bottle of lime water.

5) Weigh the lime water bottle after experiment. If the weight of lime water increases it shows the amount of CO_2 from cement product sample.

The figure shows the detail demonstration of the experiment. The extra test tube is also shown in the figure to check the saturation of the lime water in the gas washing bottle.



Chemical Reactions:

(A) $MgO + CO_2 \rightarrow MgCO_3 \rightarrow Mgo + CO_2\uparrow$

(kept for few days) (acid)

(B) $CaO + CO_2 \rightarrow CaCO_3 \rightarrow CaO + CO_2\uparrow$

(kept for few days) (acid)

Reaction *(A)* is for OPC and PPC

Reaction *(A)* + *(B)* are for Eco cement.

Results Obtained:

S. No.	Type of cement product	Weight of bottle before reaction (Grams)	Weight of bottle after reaction (Grams)	Weight of Absorbed CO_2 (Grams)
01	OPC	170.00	170.15	0.15
02	PPC	170.00	170.19	0.19
03	Eco	170.00	170.88	0.88

Table VI: Results of CO_2 Measurements

From above results it is very clear now that due to presence of more magnesia Eco cement absorb about 70 to 80 percent more CO_2 from the atmosphere. In OPC and PPC only CaO is present with very less presence of MgO, as per reaction *(A)* stated above the it will absorb very less amount of CO_2 whereas in Eco cement MgO is present in more quantity, so absorption of CO_2 is greater than OPC and PPC. Reactive magnesia is a new tool that can reduce CO_2 and water from environment those are the major problem for a world. This magnesia when mixed with OPC the powder is formed this powder is eco cement. The initial cost of eco cement is high but this cost can be reduced by large production of cement. The magnesium carbonate is easily bring from quarry when this is burn in kiln magnesium is form.

Conclusion

From all this experimental Work the following conclusions can be made about the comparison of Eco cement with OPC and PPC.

Absorption of CO_2 from the atmosphere is major advantage of Eco cement. It is justified by using the demonstration of lime water and CO_2. From the developed set up the reaction is carried out on the all samples of the cement products. From the results it is very clear that due to presence of more magnesia Eco cement absorb about 70 to 80 percent more CO_2 from the atmosphere in comparison of OPC and PPC. This cement is recommended in that components of the construction where the area of exposure is greater as it absorbs the CO2 level form atmosphere as the area of exposure is more the action of Eco cement is more.

As a major conclusion we can state that the cement with near about same physical properties with grater environmental advantage can be manufacture widely.

References

Cole- 1295. , W. and Kroone, B. (1960). "Carbon dioxide in hydrated Portland cement" American Concrete Institute Journal 31(12): 1275

Beaudoin, J. J., Ramachandran, V. S., et al. (1977). "Impregnation of Magnesium Oxy chloride Cement with Sulfur" American Ceramic Society Bulletin 56: 424.

Tec eco eco-cement masonry product update. By A John W Harrison

Tec, Eco and Enviro-Cements: New Markets for Reactive Magnesia John Harrison, Managing Director, TecEco Pty Ltd, Australia

"The Concrete Jungle Overheats", New Scientist, vol 175 issue 2351, 19 July 2002,

IS 12269 -1987 (Reaffirmed 1999) Indian Standard Specification for the 53 Grade Ordinary Portland cement

IS 1489 (Part 1): 1991 Indian Standard Portland Pozzolana Cement Specification

D. A. Abrams, Design of Concrete Mixtures, Bulletin 1, Structural Materials Research Laboratory, Lewis Institute, Chicago, 1918.

"Carbon Dioxide Sequestration by Direct Mineral Carbonation: Results from Recent Studies and Current Status" Proceedings of the 25th International Technical Conference on Coal Utilization & Fuel Systems: 153 – 164

M. S. Shetty, Concrete Technology, Theory and Practice, S. Chand & Company Ltd. New Delhi.