



Study and Review of Properties and Applications of Portland Pozzolana Cement

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ABSTRACT

Portland Pozzolana Cement (PPC) is prepared by adding Pozzolanic materials to ordinary Portland Cement. The artificial pozzolana materials used in the manufacturing of PPC such as fly ash, silica fume, rice husk, blast furnace slag, are actually industrial waste, which is produced in large amounts. These artificial pozzolana materials when used in concrete can reduce consumption of natural resources, diminish the effect of pollutants in the environment and it is economical and reliable. The main objective of this paper is to focus on the properties and applications of Portland Pozzolana Cement and make effective use of different industrial by-products in the manufacturing of cement. We found that both PPC and ordinary portland cement (OPC) are commonly used types of cement in construction. Nowadays, PPC is used as a substitute for ordinary Portland cement (OPC cement). Since PPC contains pozzolanic materials, it helps to enhance the strength of concrete. The quantity of PPC required in making the concrete is less when compared to OPC. PPC is a green material that contributes towards sustainable development.

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1. INTRODUCTION

Pozzolana is a siliceous or aluminous siliceous material that is not cementitious, but in finely divided form, and the presence of moisture, chemically reacts with calcium hydroxide released by the hydration of Portland cement to form calcium silicate hydrate and other cementitious materials (Hassan *et al.*, 2019; Nawel *et al.*, 2020). The incorporation of pozzolana into a concrete mix improves properties such as durability, strength, resistance to sulfates, and weathering (Pham *et al.*, 2020; Adesina, 2020). The durability of pozzolana is attested by ancient Roman structures some of which are still standing today. The advantages of using pozzolana as a partial replacement of Portland cement in construction have been reported. Raw Materials used are (Sivakrishna *et al.*, 2020).

- (i) Pozzolana: Fly ash used in the manufacture of Portland -Pozzolana cement shall conform to IS 269: 1981
- (ii) Portland Cement Clinker: The Portland cement clinker used in the manufacture of Portland-Pozzolana cement shall comply in all respects with the chemical requirements of Is 269: 1989
- (iii) Portland Cement: Portland cement for blending with fly ash shall conform to IS 269:1989
- (iv) Other Admixtures: Not more than 1% may be added

Portland pozzolana cement (PPC) is integrated cement, which is formed by synthesizing ordinary portland cement (OPC) with pozzolanic materials in a certain proportion (Pal & Gupta., 2020; Kirupa & Sakthieswaran, 2015). It is commonly known as PPC cement. The main objective of this paper is to focus on the properties and applications of Portland Pozzolana Cement and make effective use of different industrial by-products in the manufacturing of cement. We found that both PPC and ordinary portland cement (OPC) are commonly used types of cement in construction. Nowadays, PPC is used as a substitute for ordinary Portland cement (OPC cement). Since PPC contains pozzolanic materials, it helps to enhance the strength of concrete. The quantity of PPC required in making the concrete is less when compared to OPC. PPC is a green material that contributes towards sustainable development. In this article, we discuss the properties, manufacture, characteristics, advantages, and disadvantages of PPC.

2. WHAT IS POZZOLANA OR POZZOLANIC MATERIAL?

Pozzolana is a volcanic powder found in Italy near Vesuvius. A pozzolanic material can be natural or artificial which contains silica and aluminous in a reactive form (Nicoara *et al.*, 2020; Abdullah *et al.*, 2012). These materials usually don't possess any cementitious properties, but when it is mixed with water or moisture or lime to undergo reaction with calcium hydroxide to form compounds possessing cement properties. Types of pozzolana materials are (Wong *et al.*, 2020; Seleem *et al.*, 2011):

- (i) Artificial pozzolana: Fly ash, silica fume, rice husk, blast furnace slag
- (ii) Natural pozzolana: Burnt clay, pumicite, diatomaceous Earth.

3. MANUFACTURE OF PPC

There are several points in the PPC:

- (i) The primary raw materials used for this cement manufacture are limestone (CaCO_3) and clay (SiO_2 , Al_2O_3 , Fe_2O_3). Rocks are loaded into trucks and transported to the crushers, where they are crushed into fine particles.

- (ii) Fine particles of clay and limestone are fed into the air-swept ball mills in desired proportions as per requirement and mixed very well before it is sent to silos for storing.
- (iii) This mixture is then pre-heated up to 800-1000°C where calculations of CaCO₃ to CaO takes place.
- (iv) The pre-heated mixture is then sent into the kiln where the mixture is heated to 1450°C in a rotary kiln. The modules formed from the burning process are called clinker. The clinker is cooled by a rotary cooler.
- (v) This clinker is now mixed with gypsum and pozzolana materials in the required proportion and thus the Portland Pozzolana Cement is obtained.

4. PROPERTIES OF PORTLAND POZZOLANA CEMENT

The very first property liberates only a small amount of heat and it can offer more resistance to attack of aggressive water. PPC can reduce the leaching of calcium hydroxide. However fly ash and calcined clay are used for changing the property of cement, they can't impose any changes to the strength of the hardened concrete. That is strength will be similar to ordinary Portland cement concrete as expected. The chemical properties of PPC cement are shown in **Table 1**.

The physical properties of PPC are

- (i) Fineness: When tested by the air permeability method described in **IS 4031 (Part 2): 1988**, the specific surface of Portland-pozzolana cement shall be not less than 300 m²/kg.
- (ii) Soundness: When tested by the 'Le Chatelier' method and autoclave test described in **IS 4031 (Part 3): 1988**, un-aerated Portland-pozzolana cement the average drying shrinkage of mortar bars shall not have an expansion of more than 10 mm and 0.8 percent respectively.
- (iii) Setting Time: The setting time of Portland-pozzolana cement, when tested by the Vicat apparatus method described in **IS 4031 (Part 5): 1988**, shall be 30min (Minimum) for the initial setting time and 600min (Maximum) for the final setting time
- (iv) Compressive strength: The average compressive strength tested in the manner as described in **IS 4031 (Part 6): 1988** shall be as follows: At 72 ±1h, it is 16 Mpa/min; At 168 ± 2h, it is 22 Mpa/Min; and At 672 ±4h, it is 33 Mpa/min
- (v) Drying shrinkage: The average drying shrinkage of mortar bars prepared and tested in accordance with **IS 4031 (Part 10)**.

Table 1. The chemical properties of PPC.

No	Characteristics	Required value
1.	Total loss on ignition (% by mass)	Not more than 5.0
2.	Magnesia (% by mass)	Not more than 6.0
3.	Insoluble residue (% by mass)	Not more than $x + 4(1000 - x)/ 100$
4.	Sulphuric anhydride %	Not more than 3.5%
5.	Total chloride content %	Not more than 0.10%

5. CAMPARISON BETWEEN OPC AND PPC

In **Table 2**, the main differences between OPC and PPC types of cement are given.

Table 2. Comparison between OPC and PPC.

No.	Sources	OPC	PPC
1	Definition/ Components	A mixture of limestone and other raw materials like argillaceous, calcareous, gypsum is prepared and then ground to prepare OPC.	PPC is prepared by adding Pozzolanic materials to OPC. So, the main components are OPC clinker, gypsum, and pozzolanic materials (15~35%) which include calcined clay, volcanic ash, fly ash, or silica fumes.
2	Strength	Initial strength is higher than PPC.	PPC has higher strength than OPC over a longer period of time.
3	Heat of hydration	Generates more heat than PPC in hydration reaction which makes it less suitable for mass casting.	It has a slow hydration process and thus generates less heat than OPC.
4	Durability	Less durable in aggressive weather.	More durable in aggressive weather.
5	Cost	Costlier than PPC.	Cheaper than OPC.
6	Environmental Impact	Emits CO ₂ during the manufacturing process.	It constitutes industrial and natural waste which makes it eco-friendly.
7	Application/ uses	It is suitable where fast construction is required but not suitable for mass concreting due to heat issues as mentioned above.	It is suitable for all types of construction work. For example RCC casting of buildings, mass concreting for bridges.
8	Setting Time	Lower than PPC. Its initial setting time is 30 minutes and the final setting time is 280 minutes. Its faster setting time helps faster construction.	The setting time of PPC is higher than OPC. Its initial setting time is 30 minutes and the final setting time is 600 minutes. Its slower setting time helps to get better finishing.
9	Fineness	OPC has finiteness of 225 sq.m/kg. It has lower fineness than PPC. So, it has higher permeability resulting in lower durability.	OPC has finiteness of 300 sq.m/kg. It has higher fineness than OPC. So, it has lower permeability resulting in higher durability.
10	Grades available	33 Grade, 43 Grade, and 53 Grade OPC cement are available.	No specified grade of PPC cement is available.
11	Workability	Lower than PPC.	Higher than OPC.
12	Resistance against chemical attack	It has lower resistance against alkalis, sulfates, chlorides, etc.	It has higher resistance against alkalis, sulfates, chlorides, etc.

6. APPLICATIONS, ADVANTAGES, DISADVANTAGES, AND CEMENT GRADE

The applications are

- (i) It is effective for hydraulic structures, marine structures, construction adjacent to the seashore, dam construction, etc.
- (ii) It is suitable for pre-stressed and post-tensioned concrete members.
- (iii) It is also applied in masonry mortars and plastering.
- (iv) Since it comes with a superior surface finish, it is utilized in decorative and art structures.
- (v) It is employed in developing precast sewage pipes.
- (vi) It is suitable for rough concreting conditions

The advantages are

- (i) it is an eco-friendly cement as the material used in the manufacture are made of natural recycled waste.
- (ii) It is very fine cement hence very good when used for plastering works.
- (iii) Pozzolana consists of silica material which makes it cheap and hence reduces the cost of the cement making it economical to use.
- (iv) Pozzolana cement has very good resistance against sulfate attack hence is used in hydraulic structures, marine structures, construction near the seashore, dam construction, etc.
- (v) PPC is used in pre-stressed and post-tensioned concrete members.
- (vi) It reduces the carbon monoxide emission from the concrete making it environmentally friendly.
- (vii) As the pozzolana materials are very fine, they can fill gaps between the reinforcement and aggregate, thus reducing the shrinkage, honeycomb formation and bleeding can be reduced, which in turn increases the strength and durability of concrete.

The disadvantages are the fact that the initial strength obtained is less, which affects the de-shuttering of supports early. Other disadvantages are

- (i) As it contains more fine material, handing over concrete is difficult.
- (ii) When compared to the OPC setting time is less for PPC
- (iii) Reduction in alkalinity reduces the resistance to corrosion of steel reinforcement
- (iv) As the strength of this concrete gains slowly, the curing process is very important.
- (v) Any error in this could cause durability problems.

In many areas of the world, the PPC is graded similarly to OPC depending upon their compressive strength, at 28 days. As per India Standard, the PPC cement strength is considered equivalent to 53 grade OPC cement. Many cement brands recommended using BIS for grading PPC just like grading OPC. They also suggested using a higher amount of fly ash content from 25% to 35%. Recently, the United Kingdom has increased the fly ash content in PPC in BIS from 10-25% to 15-35%.

The main results from the PPC are:

- (i) Produces low heat of hydration.
- (ii) Offers greater resistance to the attack of aggressive waters than normal Portland cement.
- (iii) Reduces the leaching of calcium hydroxide liberated during the setting and hydration of cement.

7. CONCLUSION

Both OPC and PPC have commonly used cement in construction. Nowadays, PPC is used as a substitute for ordinary Portland cement (OPC cement). Since PPC contains pozzolanic materials, it helps to enhance the strength of concrete. The quantity of PPC required in

making the concrete is less when compared to OPC. PPC is a green material that contributes towards sustainable development.

8. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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