



Study and Review of Ordinary Portland Cement

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ABSTRACT

This research aimed to investigate the environmental, economic, and functional performances of ordinary portland cement (OPC). In short, we discussed the definition, the chemical composition and physical performance, and the manufacturing process of OPC. We hope that this paper can be a reference for practitioners and civil engineers.

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1. INTRODUCTION

“Cement” in general, can be defined as any material which has the property to bind together different materials through different reactions (Paul et al., 2018; Bohhoue et al., 2021). Commonly the reactions that are involved are aided by the presence of water. This report intends to give a very brief overview of the Ordinary Portland Cement generally available in the market and the major properties of that cement

Ordinary Portland Cement (OPC) is the most used type of cement, which is suitable for all general concrete constructions. It is the most commonly produced and used type of cement around the world, with annual global production of around 3.8 million cubic meters per year. This cement is suitable for all kinds of concrete construction (Imbabi et al., 2012).

This research aimed to investigate the environmental, economic, and functional performances of ordinary portland cement (OPC). In short, we discussed the definition, the chemical composition and physical performance, and the manufacturing process of OPC.

2. CHEMICAL COMPOSITION AND CONDITION OF OPC

The chemical constituents of Portland cement are in **Table 1** (Ali et al., 2008). The constituents forming the raw materials undergo chemical reactions during burning and fusion and combine to form the following compounds called bogue compounds (see **Table 2**) (Vidican et al., 2008). Detailed information about the composition in the bogue compound is presented in **Table 3**.

In short, by adding water, the aluminate generating the maximum heat, and the dicalcium silicate generating the minimum. Due to this condition, tricalcium aluminate is formed. The proportions of the above four compounds vary in the various Portland cements. Tricalcium silicate and dicalcium silicates contribute the most to the eventual strength. The initial setting of Portland cement is due to tricalcium aluminate. Tricalcium silicate hydrates quickly and contributes more to the early strength.

The contribution of dicalcium silicate takes place after 7 days and may continue for up to 1 year. Tricalcium aluminate hydrates quickly generate much heat and make only a small contribution to the strength within the first 24 hours. Tetracalcium aluminoferrite is comparatively inactive.

Table 1. Chemical constitutions of ordinary Portland cement.

Component	Amount
Lime (CaO)	60.00-67.00%
Silica (SiO ₂)	17.00-25.00%
Alumina (Al ₂ O ₃)	3.00-8.00%
Iron oxide (Fe ₂ O ₃)	0.50- 6.00%
Magnesia (MgO)	0.10-4.00%
Sulphur trioxide (SO ₃)	1.00-3.00%
Soda and/or Potash (Na ₂ O+K ₂ O)	0.50-1.30%

Table 2. Bogue compounds.

Compound	Abbreviated designation
Tricalcium silicate (3CaO.SiO ₂)	C3S
Dicalcium silicate (2CaO.SiO ₂)	C2S
Tricalcium aluminate (3CaO.Al ₂ O ₃)	C3A
Tetracalcium aluminoferrite (4CaO.Al ₂ O ₃ .Fe ₂ O ₃)	C4AF

All four compounds generate heat when mixed responsible for most of the undesirable properties of concrete.

Cement having less C3A will have higher ultimate strength, less generation of heat, and less cracking. The table below gives the composition and percentage of found compounds for normal and rapid hardening and low heat Portland cement.

Table 3. Composition and compound of Portland cement.

Portland Cement	Normal	Rapid hardening	Low heat
(a) Composition: Percent			
Lime	63.1	64.5	60
Silica	20.6	20.7	22.5
Alumina	6.3	5.2	5.2
Iron Oxide	3.6	2.9	4.6
(b) Compound: Percent			
C3S	40	50	25
C2S	30	21	35
C3A	11	9	6
C3A	12	9	14

3. THE MANUFACTURING PROCESS OF ORDINARY PORTLAND CEMENT

3.1. Extraction and Processing

Raw materials employed in the manufacture of cement are extracted by quarrying in the case of hard rocks such as limestones, slates, and some shales, with the aid of blasting when necessary. Some deposits are mined by underground methods. Softer rocks such as chalk and clay can be dug directly by excavators.

The excavated materials are transported to the crushing plant by trucks, railway freight cars, conveyor belts, or ropeways. They also can be transported in a wet state or slurry by pipeline. In regions where limestones of sufficiently high lime content are not available, some processes of beneficiation can be used. Froth flotation will remove excess silica or alumina and so upgrade the limestone, but it is a costly process and is used only when unavoidable.

3.2. Manufacture of Cement

There are four stages in the manufacture of portland cement: (1) crushing and grinding the raw materials, (2) blending the materials in the correct proportions, (3) burning the prepared mix in a kiln, and (4) grinding the burned product, known as "clinker," together with some 5 percent of gypsum (to control the time of the set of the cement). The three processes of manufacture are known as the wet, dry, and semidry processes and are so termed when the

raw materials are ground wet and fed to the kiln as a slurry, ground dry and fed as a dry powder, or ground dry and then moistened to form modules that are fed to the kiln.

3.2. Crushing and grinding

All except soft materials are first crushed, often in two stages, and then ground, usually in a rotating, cylindrical ball, or tube mills containing a charge of steel grinding balls. This grinding is done wet or dry, depending on the process in use, but for dry grinding the raw materials first may need to be dried in cylindrical, rotary dryers.

Soft materials are broken down by vigorous stirring with water in wash mills, producing a fine slurry, which is passed through screens to remove oversize particles.

3.3. Blending

A first approximation of the chemical composition required for a particular cement is obtained by selective quarrying and control of the raw material fed to the crushing and grinding plant. Finer control is obtained by drawing material from two or more batches containing raw mixes of slightly different compositions. In the dry process, these mixes are stored in silos; slurry tanks are used in the wet process. Thorough mixing of the dry materials in the silos is ensured by agitation and vigorous circulation induced by compressed air. In the wet process, the slurry tanks are stirred by mechanical factors, compressed air, or both. The slurry, which contains 35 to 45 percent water, is sometimes filtered, reducing the water content to 20 to 30 percent, and the filter cake is then fed to the kiln. This reduces the fuel consumption for burning.

3.4. Burning

The earliest kilns in which cement was burned in batches were bottle kilns, followed by chamber kilns and then by continuous shaft kilns. The shaft kiln in a modernized form is still used in some countries, but the dominant means of burning is the rotary kiln. These kilns—up to 200 meters (660 feet) long and six meters in diameter in wet process plants but shorter for the dry process—consist of a steel, cylindrical shell lined with refractory materials. They rotate slowly on an axis that is inclined a few degrees to the horizontal. The raw material feed, introduced at the upper end, moves slowly down the kiln to the lower, or firing, end. The fuel for firing may be pulverized coal, oil, or natural gas injected through a pipe. The temperature at the firing end ranges from about 1,350 to 1,550 °C (2,460 to 2,820 °F), depending on the raw materials being burned. Some form of heat exchanger is commonly incorporated at the back end of the kiln to increase heat transfer to the incoming raw materials and so reduce the heat lost in the waste gases. The burned product emerges from the kiln as small modules of clinker. These pass into coolers, where the heat is transferred to incoming air and the product cooled. The clinker may be immediately ground to cement or stored in stockpiles for later use.

In the semidry process the raw materials, in the form of Modules containing 10 to 15 percent water, are fed onto a traveling chain grate before passing to the shorter rotary kiln. Hot gases coming from the kiln are sucked through the raw modules on the grate, preheating the Modules.

3.5. Grinding

The clinker and the required amount of gypsum are ground to a fine powder in horizontal mills similar to those used for grinding the raw materials. The material may pass straight through the mill (open-circuit grinding), or coarser material may be separated from the

ground product and returned to the mill for further grinding (closed-circuit grinding). Sometimes a small amount of a grinding aid is added to the feed material. For air-entraining blocks of cement (discussed in the following section) the addition of an air-entraining agent is similarly made.

Finished cement is pumped pneumatically to storage silos from which it is drawn for packing in paper bags or for dispatch in bulk containers

4. TYPES OF ORDINARY PORTLAND CEMENT

Bureau of Indian Standards (BIS) has classified OPC into 3 different grades namely, OPC 33 Grade, OPC 43 Grade, and OPC 53 Grade cements (See **Table 4**). The grade number indicates the minimum compressive strength that the cement is required to attain at the end of 28 days eg., the minimum compressive strength of 53 Grade OPC attained on the 28th day shall not be less than 53 MPa or 530 kg/sqcm. It may be noted that OPC 33, OPC 43, and OPC 53 grades do not differ in chemical content. The only difference is that the higher grade cements are ground much finer during the final grinding process, creating a product that is much stronger and more durable than the less finely ground cement.

4.1. 33-Grade cement.

As per Indian standard, IS 269-2015, 33 Grade of cement means a compressive strength of cement after 28 days is 33N/mm². This grade of cement is outdated and no one is using it in recent times. 33 grade of cement is not suitable for making more than M20 grade of concrete.

This grade of cement is used for general construction under normal environmental conditions. But low compressive strength and availability of higher grades of cement have impacted the use and demand of OPC 33.

Table 4. Compressive strength in the type of OPC 2.

Period	Compressive strength		
	33-grade ¹	43-grade ²	53-grade ³
72 +/- 1 h	Not less than 16 N/mm	Not less than 23 N/mm ²	Not less than 27 N/mm ²
168 +/- 2 h	Not less than 22 N/mm	Not less than 33 N/mm ²	Not less than 37 N/mm ²
672 +/- 4 h	Not less than 33 N/mm ²	Not less than 43 N/mm ²	Not less than 53 N/mm ²

Note: ¹IS Code – IS 269: 1989 for OPC, 33 Grade; ²IS Code – IS 8112: 1989 for 43 Grade OPC; ³IS Code – IS 12269: 1987 for Specification for 53-grade OPC.

4.2. 43-Grade Cement.

As you already know 43 grade of cement means the compressive strength of cement when tested under the CTM is 43N/mm² as per Indian standards, IS 8112-2013. Concrete of grade up to M30 grade can be made using 43-grade cement.

This type of cement is used in making plain cement concrete(PCC) and for plastering the walls, brickwork mortar, precast items like tiles, cement pipes.

4.3. 53 Grade cement

This is a high grade of cement where anyone can easily buy from the market. The strength of cement having the compressive strength of 53N/mm² is called 53 grade of cement. The setting time of cement is quicker when compared with the 33 and 43-grade cement. Any grade more than M25 is easily achievable by using 53 grade of cement

This type of cement is used in precast walls, concrete roads, Bridges, Dams, RCC for structural works.

5. PHYSICAL PROPERTIES

The following physical properties should be checked before selecting a Portland cement for civil engineering works. IS 269-1967 specifies the method of testing and prescribes the limits, as follows:

- (i) **Fineness.** It is measured in terms of the percentage of weight retained after sieving the cement through a 90-micron sieve or by the surface area of cement in square cm per gram of cement. according to IS code specification weight retained on the sieve should not be more than 10 percent. In terms of the specific surface should not be less than 2250 cm²/gm.
- (ii) **Significance and Why to test fineness test of Cement?** particles in cement results in quick setting, leaving no time for mixing, handling We know that cement hydrates with the presence of water. When cement is mixed with the water, a thin layer is formed around the particle. This layer grows bigger and makes cement particles separate. Due to this, the hydration process slows down. Therefore, the smaller particle will react much quicker than the larger particle. A particle with dia 1µm will react entirely in one day, whereas the particle with dia 10µm takes about one month. So the particle size distribution is more critical in attaining the final strength of cement in the allowable time. But too much smaller and placing. So to increase the setting time of cement, cement is ground in a different range of particle sizes. The following proportions are usually maintained in Cement: About 10% of the cement of fine particles is smaller than 2 µm, 10% of wt of cement is made of particles larger than 50 µm, and only a few wt % is particles larger than 90 µm.
- (iii) **Soundness.** The soundness of cement can be defined as its ability to retain its volume after it gets hardened. This means that a properly sound cement will undergo minimum volume change after it converts into the hardened state. in the soundness test of cement, we determine the amount of excess lime.
- (iv) **Significance of soundness test of cement.** Cement is a composition of lime silica, magnesia, alkaline, sulfur trioxide, iron oxide, and calcium sulfate. among which, lime constitutes 60-70 %. Hence a cement deficient in lime will set quickly and will affect the property of cement. Lime content is the higher amount will make the cement unsound. An unsound cement will affect the quality of the cement work performed.
- (v) **Specific Gravity.** We calculate specific gravity to know the behavior of the material in water. Every material has its specific gravity, and it ranges between 0.1-100. if the specific gravity of the material is less than 1, then it sinks in water. The specific gravity of cement or density of cement is ranging between 3.1-3.16 g/cc by this, cement is 3.16 times heavier than the water of the same volume. The excessive presence of moisture content in cement affects the workability and strength of cement. for nominal mix design, the specific gravity of cement should be 3.15 g /cc.

6. ENGINEERING PROPERTIES

Following are the engineering properties of cement

- (i) **Compressive strength.** In technical terms, compressive strength of cement means, The ability of cement specimen to resist the compressive stress when tested under compressive testing machine [CTM] at 28 days. Apparatus required for test: (1) Compressive test machine conforms to IS: 14858(2000); (2) Steel cubes of 7.06 cm molds conforming to IS:10080-1982.

- (ii) **The heat of hydration.** The heat of hydration is the heat generated when water and portland cement react. The heat of hydration is most influenced by the proportion of C3S and C3A in the cement but is also influenced by water-cement ratio, fineness, and curing temperature. As each one of these factors is increased, the heat of hydration increases. In large mass concrete structures such as gravity dams, hydration heat is produced significantly faster than it can be dissipated (especially in the center of large concrete masses), which can create high temperatures in the center of these large concrete masses that, in turn, may cause undesirable stresses as the concrete cools to ambient temperature. Conversely, the heat of hydration can help maintain favorable curing temperatures during winter.
- (iii) **Setting time.** When cement is mixed with water, it hydrates and makes cement paste. This paste can be molded into any desired shape due to its plasticity. Within this time cement continues with reacting water and slowly cement starts losing its plasticity and set harden. This complete cycle is called the Setting time of cement.
- (iv) **Initial Setting time of Cement.** The time to which cement can be molded in any desired shape without losing its strength is called the Initial setting time of cement. For Ordinary Portland Cement, The initial Setting Time is 30 minutes
- (v) **Final setting time of Cement.** The time at which cement completely loses its plasticity and became hard is the final setting time of cement. For Ordinary Portland Cement, The Final Setting Time is 600 minutes (10hrs).
- (i) **Calculation of Initial and Final Setting time of Cement:** As Per IS: 4031 (Part 5) – 1988. Initial and final setting time of cement is calculated using VICAT apparatus conforming to IS: 5513 – 1976.

7. CONCLUSION

This research aimed to investigate the environmental, economic, and functional performances of ordinary portland cement (OPC). In short, we discussed the definition, the chemical composition and physical performance, and the manufacturing process of OPC. We hope that this paper can be a reference for practitioners and civil engineers.

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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