IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Physical & Chemical Properties of Cement - A Study

A. D. Dahegaokar & A. D. Dudhe
Department of Physics, N.S.Science and Arts College, Bhadrawati Dist.Chandrapur, India

Abstract

This paper presents physical and chemical properties of Indian cement as per the information of Cement Information System (CIS) Department for Promotion of Industry and Internal Trade (DPIIT) Government of India, Ministry of Commerce & Industry declared that all over India there are 183 cement manufacturing companies while in Maharashtra state 21 and in our Chandrapur district are 05. In this paper we know about basic information about cement and then try to prepare the polymer composites in the laboratory. Cement plays a crucial role in economic development of any country having more than hundred and fifty years. Cement used extensively in construction of anything, from a small building to a multipurpose project. Cement is a fine powder material untwining silicates of calcium, formed out of raw materials consist of calcium oxide, silica, aluminium oxide and iron oxide.

Keywords: Cement, Properties, Physical and Chemical

Introduction:

Cement is a binder, a substance that sets and hardens and can bind other materials together. Cements used in construction can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to be used in the presence of water. Non-hydraulic cement will not set in wet conditions or underwater, rather it sets as it dries and reacts with carbon dioxide in the air. It can be attacked by some aggressive chemicals after setting. Hydraulic cement is made by replacing some of the cement in a mix with activated aluminum silicates, pozzolanas, such as fly ash. The chemical reaction results in hydrates that are not very water-soluble and so are quite durable in water and safe from chemical attack. This allows setting in wet condition or underwater and further protects the hardened material from chemical attack (e.g., Portland cement). Cement is one of the most used for construction materials, in the world with its low cost, simple process, excellent strength and good compatibility it is widely popular in the civil engineering field. Cement mixed with fine aggregate together mortar for masonry or with sand and gravel produce concrete. The general formula for cement is CaO.AI2O3.Xh2O which represents the basic compounds that make the majority of cement the cement was invented by Joseph asp din and he was from UK. Joseph Aspdin invented Portland cement in1824 by burning finely ground chalk and clay.

After the independence of year 1947 cement in India remained a control commodity for near about four decades. The cement price and distribution of cement were controlled by the government the quality of Indian cement is at par with best production anywhere in the world. Today India is second largest cement producing country in world with capacity of 160.24x106 t/a. The quality of Indian cement is also improved impressively, with better strength and durability properties the most important change shift In consumer preferences from high strength to high performances concrete which was promoted by greater quality awareness among the consumer. In 1914, India Cements Company Ltd was established in Porbandar Gujarat with a capacity of 10,000 tons at present India is second largest cement producing country in the world, next only to China both in quality and technology.

TYPES OF CEMENT:

In cement industry producing a range of six main varieties of cement like Portland Blast Furnace Slag (PSC), Sulphate Resisting cement (SRC), Portland Pozzolana cement (PPC) Ordinary Portland cement (OPC) Oil Well cement and white cement. Cement produced in India compulsory conforms to Indian Standard specification issued by the Bureau of Indian Standards (BIS). These are five certified types of cement – Portland cement, Portland Blast Furnace cement, Sulphate Resisting Portland cement, Masonry cement and pulverized fuel ash cement. Many types of cement are available in markets with different compositions and for use in different environmental conditions and specialized applications. A list of some commonly used cement is described in this section:

Ordinary Portland cement: Ordinary Portland cement (OPC) is mostly used for common structures and also for important civil works. In India, about 70% of cement is of this category. This type of cement used in construction when there is no exposure to sulphates in the soil or ground water.

Sulphate resisting Portland cement: It has a maximum C_3A content by 3.5% and minimum fineness by 2500 cm'/g Firmer than ordinary Portland cement. Sulphate forms the sulpha-aluminates which have expensive properties and so causes disintegration of concrete.

Rapid hardening Portland cement :

- It is firmer than Ordinary Portland Cement
- It contains more C_3S are less C_2S than the ordinary Portland cement.
- Its 3 days strength is same as 7 days strength of ordinary Portland cement.

Low heat Portland cement

- Heat generated in ordinary Portland cement at the end of 3days 80 cal/gm. While in low heat cement it is about 50cal/gm of cement.
- It has a low percentage of C_3A and relatively more C_2S and less C_3S than O.P. Cement.

TYPES OF CEMENT PROCESS:

The cement manufacturing process involves mining, crushing, grinding of raw materials (principally limestone and clay), blending of raw meal, calcining the materials in a rotary kiln, cooling the resulting clinker, mixing the clinker with gypsum, and milling, storing, and bagging the finished cement. The raw materials used to make cement may be divided into four basic components: lime (calcareous), silica (siliceous), alumina (argillaceous), and iron (ferriferous). Approximately 1450 kilograms (kg) of dry raw materials are required to produce one tonne of cement. Approximately 35% of the raw material weight is removed as carbon dioxide (CO_2) and water vapour. The basic chemistry of cement manufacturing process begins with the decomposition of clay minerals into SiO_2 and Al_2O_3 on the one hand, and of calcium carbonate ($CaCO_3$) at about 900 °C to leave calcium oxide (CaO, lime) liberating CO_2, on the other hand. The latter process is known as calcination. This is followed by the clinkering process, in which the CaO reacts at high temperature (typically 1450 °C) with silica, alumina, and ferrous oxide to form the silicates, aluminates, and ferrites of calcium. The resultant clinker is then ground together with gypsum and other additives to produce cement.

Chemical Composition of Cement: The relative proportion of three oxide compositions is responsible for influencing the various properties of cement, like lime, silica and alumina. An increase in lime content beyond a certain value makes it difficult to combine completely with other compounds. Consequently, free time will exist in the clinker and will result in unsound cement. An increase in silica content at the expense of alumina and ferric oxide makes the cement difficult to fuse and form clinker.

Table: 1 Chemical Composition of Cement

Oxide	Composition (%)	Average
Lime Cao	60-65	63
Silica, SiO_2	17-25	20
Alumina,Al_2O_3	3-8	6
Iron oxide, Fe_2O_3	0.5-6	3
Magnesia, MgP	0.5-4	2
Sulphur Tri-oxide	1-2	1.5
Sode/or potash (Na2O + K2O)	0.5-1	1

1. Lime (CaO): If lime is provided in excess then the cement becomes unsound and if it is in deficiency then the strength is reduced therefore chances of quick setting will be enhanced.
2. Silica (SiO_2): It imparts strength to the cement due to the formation of di-calcium and tri-calcium silicates. If it is in excess then the strength of the cement would be enhanced therefore setting time gets prolonged, hence it prevents quick setting.
3. Alumina (Al_2O_3): It imparts the quick setting property of cement. If it is in excess then the strength of cement is reduced and the chances of rapid hardening would be increased. It acts as a flux and it lowers the clinker temperature
4. Calcium Sulphate ($CaSO_4$): It is a retarder (admixture). If it is in excess then it slows down the quick setting which dominates to increase the strength. It is a gypsum form.
5. Iron Oxide (Fe_2SO_4): It imparts colour, hardness, and strength to the cement. If it is in excess, then it imparts more coloured to the cement (grey).
6. Magnesia (Mgo): It imparts hardness and colour (yellow) to the cement, if it is in small quantity, and if it is in excess then it imparts unsoundness to the cement.
7. Sulphur (S): If it is in reference quantity then it imparts strength to the cement and if it is in excess then the unsoundness is increased.
8. Alkalies (Soda and Potash) (Na2O + K20): Most of the alkalies present in raw materials are carried away by the flue gases heating and the cement contents only a small amount of alkalies. If they are in excess in cement then they cause a number of troubles such as alkali-aggregate reaction, efflorescence and staining when used in concrete, brickwork or masonry mortar.

Properties of Cement:

Unlike all other building materials, cement does not change the environment and will not erode if exposed to the elements. Some of the interesting properties of cement include durability and resistance to change in shape. It can mould into any form, and it does not decay. It has a low water absorption rate, which allows the cement to dry completely. It has high tensile strength.

Physical Properties of Cement: Different blends of cement used in construction are characterized by their physical properties. Some key parameters control the quality of cement. The physical properties of are based on Fineness of cement, Soundness, Consistency, Strength, Setting time, Heat of hydration, Loss of ignition, Bulk density and Specific gravity (Relative density).These physical properties are discussed in details in the following segment.
1. Fineness of Cement: The size of the particles of the cement is its fineness. The required fineness of good cement is achieved through grinding the clinker in the last step of cement production process. As hydration rate of cement is directly related to the cement particle size, fineness of cement is very important.
2. Soundness of Cement: Soundness refers to the ability of cement to not shrink upon hardening. Good quality cement retains its volume after setting without delayed expansion, which is caused by excessive free lime and magnesia.
3. Consistency of Cement: The ability of cement paste to flow is consistency.

4. Strength of Cement: Three types of strength of cement are measured – compressive, tensile and flexural. Various factors affect the strength, such as water-cement ratio, cement-fine aggregate ratio, curing conditions, size and shape of a specimen, the manner of molding and mixing, loading conditions and age.

5. Compressive Strength: It is the most common strength test. A test specimen (50mm) is taken and subjected to a compressive load until failure. The loading sequence must be within 20 seconds and 80 seconds.

6. Tensile strength: Though this test used to be common during the early years of cement production, now it does not offer any useful information about the properties of cement.

7. Flexural strength: This is actually a measure of tensile strength in bending. The test is performed in a 40 x40 x 160 mm cement mortar beam, which is loaded at its centre point until failure.

8. Setting Time of Cement: Cement sets and hardens when water is added. This setting time can vary depending on multiple factors, such as fineness of cement, cement-water ratio, chemical content, and admixtures. Cement used in construction should have an initial setting time that is not too low and a final setting time not too high. Hence, two setting times are measured:

9. Heat of Hydration: When water is added to cement, the reaction that takes place is called hydration. Hydration generates heat, which can affect the quality of the cement and also be beneficial in maintaining curing temperature during cold weather. On the other hand, when heat generation is high, especially in large structures, it may cause undesired stress. The heat of hydration is affected most by C3S and C3A present in cement, and also by water-cement ratio, fineness and curing temperature. The heat of hydration of Portland cement is calculated by determining the difference between the dry and the partially hydrated cement (obtained by comparing these at 7^{th} and 28^{th} days).

10. Loss of Ignition: Heating a cement sample at 900 - 1000°C (that is, until a constant weight is obtained) causes weight loss. This loss of weight upon heating is calculated as loss of ignition. Improper and prolonged storage or adulteration during transport or transfer may lead to pre-hydration and carbonation, both of which might be indicated by increased loss of ignition.

11. Bulk density: When cement is mixed with water, the water replaces areas where there would normally be air. Because of that, the bulk density of cement is not very important. Cement has a varying range of density depending on the cement composition percentage. The density of cement may be anywhere from 62 to 78 pounds per cubic foot.

12. Specific Gravity (Relative Density): Specific gravity is generally used in mixture proportioning calculations. Portland cement has a specific gravity of 3.15, but other types of cement may have specific gravities of about 2.90.

Chemical Properties of Cement:

The raw materials for cement production are limestone (calcium), sand or clay (silicon), bauxite (aluminium) and iron ore, and may include shells, chalk, marl, shale, clay, blast furnace slag, slate. Chemical analysis of cement raw materials provides insight into the chemical properties of cement.

1. Tricalcium aluminate (C3A): Low content of C3A makes the cement sulphate-resistant. Gypsum reduces the hydration of C3A, which liberates a lot of heat in the early stages of hydration. C3A does not provide any more than a little amount of strength. Type I cement: contains up to 3.5% SO3 (in cement having more than 8% C3A) Type II cement: contains up to 3% SO3 (in cement having less than 8% C3A)

2. Tricalcium silicate (C3S): C3S causes rapid hydration as well as hardening and is responsible for the cement's early strength gain an initial setting.

3. Dicalcium silicate (C2S): As opposed to tricalcium silicate, which helps early strength gain, calcium silicate in cement helps the strength gain after one week.

4. Ferrite (C4AF): Ferrite is a fluxing agent. It reduces the melting temperature of the raw materials in the kiln from 3,000°F to 2,600°F. Though it hydrates rapidly, it does not contribute much to the strength of the cement.

5. Magnesia (MgO): The manufacturing process of Portland cement uses magnesia as a raw material in dry process plants. An excess amount of magnesia may make the cement unsound and expansive, but a little amount of it can add strength to the cement. Production of MgO-based cement also causes less CO2 emission. All cement is limited to a content of 6% MgO.

6. Sulphur trioxide: Sulphur trioxide in excess amount can make cement unsound.

7. Iron oxide/ Ferric oxide: Aside from adding strength and hardness, iron oxide or ferric oxide is mainly responsible for the colour of the cement.

8. Alkalis: The amounts of potassium oxide (K_2O) and sodium oxide (Na_2O) determine the alkali content of the cement. Cement containing large amounts of alkali can cause some difficulty in regulating the setting time of cement. Low alkali cement, when used with calcium chloride in concrete, can cause discoloration. In slag-lime cement, ground granulated blast furnace slag is not hydraulic on its own but is "activated" by addition of alkalis. There is an optional limit in total alkali content of 0.60%, calculated by the equation $Na_2O + 0.658\ K_2O$.

9. Free lime: Free lime, which is sometimes present in cement, may cause expansion.

10. Silica fumes: Silica fume is added to cement concrete in order to improve a variety of properties, especially compressive strength, abrasion resistance and bond strength. Though setting time is prolonged by the addition of silica fume, it can grant exceptionally high strength. Hence, Portland cement containing 5-20% silica fume is usually produced for Portland cement projects that require high strength.

11. Alumina: Cement containing high alumina has the ability to withstand frigid temperatures since alumina is chemical-resistant. It also quickens the setting but weakens the cement.

Uses of Cement: Cement is a versatile building material used in many ways in our daily lives, such as home repair, paving driveways and sidewalks, sculptures, foundations of houses, parking lots, stadiums, constructing buildings, and manufacturing products; the most important of these being construction. It is used in constructing skyscrapers, bricks, pipes and bridges. It is also used as an adhesive to hold building materials together and can be used as an alternative to mortar, a mixture of cement, water, and sand. The primary use of cement is to support and strengthen any construction.

Advantages of Cement:

1. It is a solid, durable and cheap material.
2. It is easy to make without any complicated manufacturing process, and it is inexpensive to Produce.
3. It has a wide range of applications.
4. It is even easy to use.
5. It is a highly versatile material used in applications that require quick-drying, thermal insulation, and protection.

Disadvantages of Cement:

1. The major disadvantage of cement is its rapid deterioration.
2. Cement creates an extremely heavy product, which takes a long time to use. This heavy product can cause health hazards for the people working in the building sites.

Conclusion

In the above article we have study the physical and chemical properties of cement. In addition, we have also study the types, uses, advantages and disadvantages of cement. We have discussed why cement is a vital building material. Cement has become the primary building material used for construction in the world today. Therefore, it is an essential component of the construction industry, and it provides a strong base for the concrete.

References

[1]. Dr. Ravi. B., Shambhulingappa. F. Nallanavar "History & Growth of Cement industry in India – A Study" 2022 JETIR January (2022), Volume 9, Issue 1 www.jetir.org (ISSN-2349-5162) JETIR2201559 Journal, f401- f408

[2]. Anoop Singh Gaharwar, Naveen Gaurav, A P Singh, Hira Singh Gariya, Bhoora "A Review Article on Manufacturing Process of Cement, Environmental Attributes, Topography and Climatological Data Station: IMD, Sidhi M.P" Journal of Medicinal Plants Studies (2016); 4(4): 47-53

[3]. Luca Lavagna and Roberto Nisticò An Insight into the Chemistry of Cement—A Review Appl. Sci. (2023) , 13, 203. https://doi.org/10.3390/app13010203 https://www.mdpi.com/journal/applsci

[4]. "History of cement". Www.understanding-cement.com. Retrieved 17 December (2018)

[5]. Francis, A.J. The Cement Industry 1796–1914: A History, David & Charles. ISBN 0-7153-7386-2, Ch. 5. (1977).

[6]. Blezard, Robert G. (2004) "The History of Calcareous Cements" in Hewlett, Peter C., ed. Lea's chemistry of cement and concrete 4th ed. Amsterdam: Elsevier Butterworth-Heinemann. pp. 1–24. ISBN 9780080535418

[7]. Russo, Ralph (2006) "Aqueduct Architecture: Moving Water to the Masses in Ancient Rome" Archived 12 October (2008) at the Way back Machine, in Math in the Beauty and Realization of Architecture, Vol. IV, Curriculum Units by Fellows of the Yale-New Haven Teachers Institute 1978–2012, Yale-New Haven Teachers Institute.

[8] Balamurali Kanagaraj , Eva Lubloy, N. Anand , Viktor Hlavicka , Tattukolla Kiran "Investigation of physical, chemical, mechanical, and microstructural properties of cement-less concrete – state-of-the-art review" Construction and Building Materials 365 (2023) 130020

[9]. P. Duxson, S.W. Mallicoat, G.C. Lukey, W.M. Kriven, J.S.J. van Deventer, 'The effect of alkali and Si/Al ratio on the development of mechanical properties of metakaolin-based geopolymers', Colloids and Surfaces A: Physicochemical and Engineering Aspects 292 (2007),8–20.

[10]. G. Fang, et al., 'Workability and mechanical properties of alkali-activated fly ash-slag concrete cured at ambient temperature', Construction and Building Materials 172 (2018)