CHAPTER-THREE: "A PROFILE OF CEMENT INDUSTRIES IN MADHYA PRADESH"

* Cement Industries in Madhya Pradesh.
* Diamond Cement Industry in Damoh
* Electrostatic Precipitator
* Raw Materials used in Cement Industry
* Manufacture of Cement
* Properties of Cement
* Chemical Analysis of Cement.

TABLES

REFERENCES.
A glance at the world history will give an idea, as to who first used this wonder material and how it developed into the fine quality product, widely used today. Cement as a building material has been known in one form or another since times immemorial. Evidence of its use is believed to have been found in the Indus Civilization of Mohenjo-Dara. One of the Seven Wonders of the World are the Great Pyramids of Egypt are held together by burnt gypsum. Egyptians utilised gypsum plaster as a cementing material as early as 3,000 BC in building their monuments.¹

The aqueducts of Carthage in Africa were built with similar aid long before the Christian era.

The Greek civilization with its Acropolis and Parthenon, the amphitheatres and highways and the remains of Pompeii and ancient Rome, the cathedrals, castles and fortifications of mediaeval Europe, stand in mute testimony to the use of cement in one form or another from ancient times. In India there are many historical monuments like the Ajanta and Ellora caves, and forts, palaces and temples which have stood the test of time and reveal evidence of the use of cement in their structure.
Although cement is a very old material, the cements available up to the end of the eighteenth century were not "hydraulic", that is water resisting. In 1796, however, James Parker of Kent patented "Roman Cement". This was a cement obtained by a very simple process of calcination of the cement stones of the Thames Estuary which yielded a hydraulic cement. Roman cement was weak, its water-resistant properties were sufficiently important to lead to the rapid rise of a Roman Cement industry in the Thames Estuary, which flourished until about the middle of the nineteen century. 

1824 is the year generally accepted as the time when, modern portland cement, as we know it today, was first patented by Joseph Aspdin in Wakefield, Yorkshire, England. Portland cement was not only hydraulic but strong, and thus much superior to the Roman cement. The name Portland was chosen by Joseph Aspdin because of its resemblance to a rock found on the English Isle of Portland. With the invention of Portland cement the essential ingredients for the future development of concrete were provided. Indications of the popularity of Aspdin's Portland cement are provided by its use by Brunel in the Thames Tunnel in 1838, and by the Metropolitan Board of Works in the London Drainage Canal in 1859. Aspdin himself had mean while moved to Gateshead, where he opened
a factory in 1852. Here he maintained the greatest secrecy for certain crucial parts of the production process. The first plant manufacturing portland cement outside England were commissioned in Belgium and Germany in 1855. The interest that it evoked in the technology of cement resulted in such developments as the use of rotary kiln in 1886.

Today, portland cement constitutes over 99 per cent of the total world production of cement. Portland cement is different from the nature cement which is made from cement rock. Modern cement is outcome of the combined research and development efforts of chemists, technologists and architects.

CEMENT INDUSTRIES IN MADHYA PRADESH:

There are following cement Industries in Madhya Pradesh has been shown in the Map and the names and description of these Industries are as under:

1. Banmour Factory:

It was established in 1922 at Banmour in District Morena about 50 Kms. from Gwalior. It was established under Associated Cement Companies undertaking. This Factory produces ordinary Portland cement through Wet industrial process. Its production capacity is more than 60,000 Metric tonnes. This Factory employs some 800 workmen.
MAP 3.1: LOCATION OF CEMENT INDUSTRIES IN MADHYA PRADESH
2. Diamond Cement Factory:

This factory is located in Damoh District and is in the study area.

3. Jamul Cement Plant:

This factory was established in 1965 at Durg by Associated cement companies. Which is the reputed Cement manufacturing company in India. This factory produces about 1.1 Lakh MT. cement through Dry process Portland Blast Furnace Slag. About 1,800 workers get employment in this factory.

4. Kaimore Factory:

It was also established under the Associated cement company in the year 1923 at Kaimore near Katni. This Factory also Produces ordinary Portland and Potslana Cement through Wet process. There is also an Asbestos and cement Sheet Factory at Kaimore. The Production capacity of this factory is about 8 Lakhs Metric tonnes and employs about 2600 workers.

5. Mandhar Cement Factory:

It was established in 1970 at Mandhar some 15 Kms from Raipur. It is a Public Sector cement Factory under Cement Corporation of India. It produces cement through ordinary Portland and Blast furnace Slag.
6. Maihar Cement Factory:

This factory was established in 1981 at Maihar in District Satna. It produces about 75,000 metric tonnes of cement and employs about 1,500 workers.

7. Neemach Cement Factory:

This factory was also laid down in 1981 at Neemach in Mandsor District. Its production capacity is 4 Lakhs MT. of cement and employs 900 factory workers.

8. Satna Cement Works:

Satna Cement Factory, is a private sector, cement manufacturing company. Company covers an area of about 499.82 acres. M/s Birla Jute Manufacturing company Limited runs this factory which was established in 1959 at Satna. Ordinary Portland cement is produced in this factory through wet process. It produces about 6 Lakhs MT. of Cement and gives employment to about 1,100 workers.

9. Tilda Cement Factory:

This Factory came into existence in 1976 under the Century Mills of Birla group. It stands at Tilda near about 25 Kms. away from Raipur. This factory also adopts the modern Dry process and produces 6 Lakhs MT. of cement. It employs about 1,500 workmen.

10. New Cement Plants:

According to an economic survey made during 1994-95 at present various cement plants are in working which produce 170 lakh metric tons of cement per year. This quantity is larger than that of other states. A
proposal to raise the cement production has been prepared by the State government through establishment of eight other new cement plants. No suitable location for these cement plants has been decided yet. Besides it a large scale cement plants is being established at Raipur by M/s Gracim Cements.

**DIAMOND CEMENT FACTORY:**

Diamond Cement Factory, is a private sector, cement manufacturing company. The Diamond cement factory (Prop. Mysore Cements Ltd.), after acquiring 1689.400 Hectars of land on lease was founded at a small but historical village Narsingarh, some 19 Kms. away from Damoh on the Damoh-Chhatarpur road on the acquired land in 1975. The foundation stone of the company was laid in 1975 and the factory started production in 1983.

The Diamond Cement Factory has been divided into two units located at Narsingarh and Imlai with all its equipments started the cement production in 1983, of which the Narsingarh Unit prepares cement Clinkers while the Imlai Unit finally turns that clinkers by mixing Gypsum with it and grinding the mixture into cement. (Photograph - Narsingarh & Imlai Plants 3.1 and 3.2).

Considerable amount of cement dust particles are emitted into the environment of Near by villages
Photo (3.1) Narsingarh Cement Factory pouring out smoke and cement dust.

Photo (3.2) General view of Imlai Cement Factory with dusted Eucalyptus Trees close to the Factory. Eucalyptus Trees with less chlorophyll and retarded growth.
of Narsingarh and Imlai. These particles, depending upon their size may remain air borne for varying length of time. It has been seen that particles larger than 10 to 80 micron in diameter get easily settled on vegetation and land surface. When suspended in air, particles may absorb and shatter solar radiations, thus reducing the amount of radiation reaching to the earth surface and modifying the heat balance of the atmosphere (Mc Cormick & Ludwig, 1967; Glazier et al. 1976), such radiation and thermal changes could slowly affect the climate and ecosystem in the long run (Mitchel, 1971; Newmann and Cohen, 1972).

**ELECTROSTATIC PRECIPITATOR**

The method is based on ionization and giving the suspended dust particles an electric charge by passing the gas through a high tension field created by discharge electrodes. The particles, separate from the gas onto grounded collecting electrodes. For removing mists liquid film precipitators are employed. Electrostatic separation is one of the best ways of removing dusts, which combines simple design, low pressure, drop and high gas capacity with high collecting efficiency. The method is a universal one, i.e. it can be used for all types of dust of diverse particle size.

To overcome the air pollution caused by cement
dusts, an electrostatic precipitator has been installed in the factory (Photograph 3.3).

The gases carrying the particulate & matter particles between rows of grounded collecting plates & high voltage discharge electrodes. A high unidirectional voltage applied between these electrodes induces ionisation of the gas molecules adjacent to high voltage -ve discharge electrodes. The +ve ion migrate towards the discharge electrode & the -ve electrons and ions towards collecting electrodes.

On their way to the collecting electrodes these -ve electrons & ions further charge the dust particles & the high voltage electrical field between the electrodes cause the particles to move towards the collecting electrodes, where they deposit. The particles are periodically rapped off the electrode to fall down into the bottom hopper.

A precipitator being basically on electric device and the efficiency depends primarily on the power input i.e. the amount of voltage & current that is usefully employed for collection of the dust.

A high voltage direct current rectifier (80 KW -ve voltage) is connected between the emitting framework & the ground, there by breaking strong electrical field between the strips in emitting framework & the
Photo (3.3) General view of Narsingarh Cement Factory showing Electrostatic precipitators.

Photo (3.4) General view of Narsingarh Cement Factory with Raw Material, Lime Stone, Photograph taken from North.
collecting electrodes. The electrical field becomes strongest near the surface of the strips so strong that an electrical discharge, the corona discharge develops along the strips.

RAW MATERIALS USED IN CEMENT INDUSTRY:

The raw materials used in making cements are naturally occurring materials and in part industrial waste products. The naturally occurring materials include gypsum rock (gypsum, CaSO₄·2H₂O, anhydrite, CaSO₄), limestone rock (limestone, chalk, dolomite), clays - clays and marls, silica sand, bauxites. The industrial waste materials utilized in making cements include metallurgical slag, the nepheline sludge of the alumina-manufacturing industry, sludge of the sodium hydroxide process which contains CaCO₃, pyrite cinder, etc.

The main raw materials required for the manufacture of cement are limestone, coal, gypsum, clay, laterite and bauxite. Cement is a weight loosing product. The approximate requirements of these raw materials per tonne of cement are shown below:

- Limestone: 1.4 to 1.6 tonnes
- Coal: Wet process 0.34 tonnes
  Dry process 0.22 tonnes
- Gypsum 0.04 tonnes
- Clay and Laterite 0.0018 tonnes
- Bauxite 0.0037 tonnes.

For production of blended cements, granulated
blast furnace slag and fly ash are the major components added to the clinker.

LIMESTONE:

Limestone has proved to be the strongest factor in the locational shifts of the cement factories. Cement factories are, in fact, located in close proximity to the sources of raw materials. Most cement manufacturing units are established within a radius of 15 to 20 kilometers of the limestone deposits. Limestone deposits are spread all over the country in fairly large quantities. Ordinarily good limestone deposits are found in India therefore most of the cement factories are located near the limestone deposits. Usually, the location of the factories was determined not only by the nearness but also by the abundance of the supplies of limestone.

India is favoured with enormous reserves of cement grade limestone distributed all over the country and are supposed to be virtually inexhaustible at the present rate of consumption. The total reserves of limestone of all grades have been calculated to be 50,100 million tonnes of which 41,000 million tonnes (81.8 per cent) can be categorised a cement grade.12

Limestone comes from the calcareous family of rocks. Calcium carbonate dominates its percentage in the mineral along with sand and iron substances. The
rocks which contains \( \text{MgCO}_3 \) is known as Dolomite. If the Lime-stone takes some changes, it forms crystals and that changed form is known as Marbel.

This Mineral is used in the production of Lime and Cement. With the establishment of cement factories the importance of Lime has increased to a great extent. It is decomposed in the stone furnace before taking in use.

The land of Narsingarh area (Damoh District) on lease was given to Diamond cements for the mining of main raw material \(^{13}\) i.e. lime stones for a period of 20 years w.e.f. 31.7.1975 to 30.7.1995 by the Government.

Limestones consists mainly of calcium carbonate with a small proportion of magnesium carbonate, silica, iron oxide and some clayey material are usually present as impurity. On weathering limestone gives rise to acidic soils since most of the calcium is washed away in solution. The resultant soil may even be deficient in lime.

The General sequence of the different beds in this area is based on geological mapping & sub-surface data obtained by dreilling was established as under -

Over burdened soil
Upper shale
Upper shaly Lime stone
Upper grey lime stone
Middle shaly lime stone
Lower grey lime stone
Lower shale
The characteristics, morphology and different physical aspects for all the above mentioned beds can be illustrated in order to understand the structure of soil:

Over burdened soil:

It is brown to dark brown in colour. As in the case of other formations the thickness of it is also found to increase in deep direction.

Upper shale:

It is overlain by overburdened soil & underlain by shaly limestone. This formation is olive green greenish grey, brownish or purplish in colour, soft & friable therefore easily weathered into soil.

Upper shaly lime stone:

It is overlain either by the upper shale or overburdened soil & underlain by limestone. It is hard, compact brownish grey, grey to dark drey in colour with occasional occurance of thin views of calcite. Bands of grey lime stone upto one meter in thickness occur occasionaly within this shaly lime stone horizon.

Upper Grey Lime Stone:

The most important formation in this series is the upper grey lime stone which is the only productive band. This band is overlain by the upper shaly limestone & underlain by middle shale or lower shale. The lime
stone is medium to fine grained, massive hard & compact. The colour of the lime stone varies from grey to dark grey or purple in colour.

**Lime Stone Requirements:**

The installed Clinkering Capacity of two kilns of Diamond Cement's is 10 LTPA, however due to efficient management of different output parameters, the two are producing 13.5 LTPA of clinker on a sustained basis. As desired by M/s Diamond Cements, the annual limestone requirements is calculated on the basis of 13.5 LTPA of clinker production (Photograph 3.4: Showing Lime Stone).

According to officials of M/s Cements, the clinker to lime stone ratio is 1:1.45 i.e. 1.45 tonnes of limestone is required to manufacture 1 tonne of clinker. On the basis of the above clinker to limestone ratio, the limestone requirement works out to 19.6 LTPA. M/s Diamond cements also desired that the quality of lime stone supplies from quarry should be in the range of 44.5% CaO.

The range of variation in Lime stone Quality which is found in Damoh District is given below -

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Area I</th>
<th></th>
<th>Area II</th>
<th></th>
<th>Area III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mini%</td>
<td>Maxi%</td>
<td>Mini%</td>
<td>Maxi%</td>
<td>Mini%</td>
</tr>
<tr>
<td>Titrated CaO</td>
<td>44.2</td>
<td>46.9</td>
<td>42.5</td>
<td>46.5</td>
<td>44.3</td>
</tr>
<tr>
<td>Titrated MgO</td>
<td>1.9</td>
<td>2.7</td>
<td>2.2</td>
<td>2.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Major Oxides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SiO₂</td>
<td>8.7</td>
<td>14.2</td>
<td>9.7</td>
<td>14.1</td>
<td>11.6</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>1.1</td>
<td>1.7</td>
<td>1.3</td>
<td>2.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>1.3</td>
<td>1.7</td>
<td>1.4</td>
<td>2.1</td>
<td>1.4</td>
</tr>
<tr>
<td>CaO</td>
<td>41.3</td>
<td>45.5</td>
<td>40.9</td>
<td>45.1</td>
<td>43.6</td>
</tr>
<tr>
<td>MgO</td>
<td>2.1</td>
<td>2.8</td>
<td>2.3</td>
<td>2.9</td>
<td>2.2</td>
</tr>
</tbody>
</table>
OTHER RAW MATERIALS:

Clay:

Next to limestone clay is also important. Clay is used as a raw material. During 1974-75, a total of about 5,60,000 tonnes of clay was consumed by 18 units\textsuperscript{14}. The cement plants have both captive and non-captive clay mines. The plants, which are major consumers of clay, have their own mines.

Laterite and Bauxite:

Laterite imparts flux action in the burning process inside the kiln and thereby provides clinker formation at considerably lower temperature.

Cement plants receive bauxite supplies from non-captive mines. Most of these mines are far away, even as far as about 1,000 Kms.

Gypsum:

Gypsum is an essential additive. This mineral is produced mainly in several western districts of Rajasthan, some districts of southern Tamil Nadu, some Himalayan foot hill areas of Uttar Pradesh, some parts of Kutch and other places in Gujrat and Baramula and Doda districts of Jammu and Kashmir States. The cement factories from all over the country obtain gypsum from the source that may be the nearest\textsuperscript{15}. 
Granulated Slag:

Blast furnace slag is known to have been used for cementitious purposes as early as 1774 when it was admixed with slaked lime. The primary object was to use waste material, but now it has grown into a potential cement raw material. The various steel plants are a plentiful sources of slag, and at least 15 factories use slag for making cement. India produced 3,165 million tonnes Blast Furnace Slag Cement in 1979.

Four alternatives exist for complete utilisation of slag available in the country in producing blast furnace slag cement. They are as follows:

- Setting up new cement plants next to steel mills;
- transporting slag to nearby steel plants;
- transporting of clinker to grinding units to be set up near steel plants and
- transport of both clinker and slag to a grinding plant to be located in places of maximum consumption of cement.

Coal:

Coal is another important raw material. It is used both as a raw material for cement making and as a source of power. About a quarter to half a ton of coal is required for every ton of cement produced.

Coal for cement plants is mainly supplied from coal fields in Bihar and West Bengal and partly from
Madhya Pradesh and Andhra Pradesh. In general, the cement plants in the other regions receive their coal supplies from the nearest coal-field to cut down the transport cost and improve the utilization of railway wagons.

**Fly-ash:**

Fly-ash is an industrial waste of thermal power stations using pulverised coal. Fly-ash is used in different industries at present. There are about 40 major thermal power plants in India which produce 7 million tonnes of fly-ash every year\(^\text{18}\). At present 6 cement plants use fly-ash in India.

**MANUFACTURING PROCESS:**

There are two processes by which cement is manufactured. They are the "Wet process" and the "Dry process". In India, both wet and dry methods are in vogue. In 1974-75 the wet process is employed by 32 units for manufacturing cement. While 16 units adopted the dry process, four units were found to adopt a semi-dry method\(^\text{19}\).

**TYPES OF CEMENT PRODUCED:**

There are as many as eight varieties of cement produced in India, viz., Portland cement, blast furnace slag cement, pozzolana cement, grey cement, hydrophobic cement, oil-well cement, rapid hardening cement and white cement. The most commonly used varieties of cement are portland, grey, blast furnace slag and pozzolana cement.
(i) Ordinary Portland Cement:

On hydration, this type of cement for which Joseph Aspdin was granted a patent in 1824 attains a colour resembling that of limestone of Isale of Portland, and hence the name\(^{20}\). Its cementing properties function both in water and in air. This is the most widely used cement for all types of construction. It is a standard product with high strength and great durability and is suitable product with high strength and great durability and is suitable for a multitude of jobs ranging from foundation slabs to sky-scrapers. Among the various types of cement produced in India.

(ii) Pozzolona Cement:

Pozzolona Cement first used by Romans. Its name has been derived from Pozzuoli, an ancient town near Naples in Italy\(^{21}\). Natural or artificial pozzolonic material is interground with portland clinker to produce pozzolona cement. This type of cement suitable for use in heavy structures like dams which have to last many years\(^{22}\).

(iii) Blast Furnace Slag Cement:

This type of cement produced by grinding the portland clinker together with granulated furnace slag. The production of slag cement has lately assumed great importance in India in view of the large quantity of slag available from Indian Steel Plants. It is suitable for bridge piers and Sea port construction. It is also useful in the construction of industrial plants.
(iv) **White Cement**:

Mostly used for tiles, terrazzo, artistic decorations and for exterior and interior finishes in all types of buildings. Being pure white, this cement can be coloured to any desirable shade by mixing it with pigment. The production of white cement in India in 1960 was about 8,000 tonnes when it was produced only in one factory. Five years later, the quantity produced was 68,500 tonnes in two factories.\(^{23}\)

(v) **Oil Well Cement**:

Oil well cement is also a true portland cement. The Shahabad factory of the A.C.C. Ltd. Only one factory in India which produces oil well cement.\(^{24}\)

(vi) **Rapid Hardening Cement**:

This cement is specially useful for meeting the demands for speed in modern construction. It has the properties of rapidly developing a high strength at an early stage, resulting in considerable reduction of the construction period. It is used for laying heavy machinery foundations and in pre-stressed concrete.

(vii) **Hydrophobic Cement**:

Hydrophobic Cement which was first produced in Russia is now being made in many countries. By virtue of its properties such as pumpability, superior workability, and stability to stand storage and transport under humid conditions, it has gained extreme usage.\(^{25}\)
(viii) Grey Cement:

Grey cement is being produced in India in increasing quantities. This is evident from the fact that the production which was about 1,17,000 tonnes in 1994 rose to 7,98,000 tonnes in the very next year.

**PROPERTIES OF CEMENT**

Cement is a non-metallic mineral product. It is a basic building material. Cement is considered as the best and most important building material in strength, durability and water resistance for construction purposes. It will be difficult to imagine a modern society without cement and steel. Together with oil and electricity they have come to symbolise all that we cherish in modern living.

Colloid chemistry processes of cement are very important in silicate technology. To be able to use cements in structural practice and in industry the behaviour of the various components of the cement in a mix with water must be known. The binding properties of cements are based on the ability of silicates and aluminates of calcium to unite with water, and form high-strength crystals. Tri-calcium silicate hydrolyzes, according to the equation

$$3\text{CaO} \cdot \text{SiO}_2 + 2\text{H}_2\text{O} = 2\text{CaO} \cdot \text{SiO}_2 \cdot \text{H}_2\text{O} + \text{Ca(OH)}_2$$
Hydration of di-calcium silicate and tri-calcium aluminate takes place in the following way:

\[ 2\text{CaO} \cdot \text{SiO}_2 \cdot \text{H}_2\text{O} + \text{H}_2\text{O} = 2\text{CaO} \cdot \text{SiO}_2 \cdot 2\text{H}_2\text{O} \]
\[ 3\text{CaO} \cdot \text{Al}_2\text{O}_3 + 6\text{H}_2\text{O} = 3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{H}_2\text{O} \]

The mechanism of setting and hardening of a cement which has been mixed with water can be represented in the following way. First, soluble compounds dissolve in water and form saturated solutions. During the second stage, colloid, jelly-like, low-solubility hydrosilicates, hydroaluminates and hydroferrites of calcium are formed (by the reactions given above), together with calcium hydroxide. During this period the mass is plastic and can easily be shaped. In the third stage, crystallization occurs within the jelly-like mass, with the various newly-formed colloids crystallizing at different rates. The calcium hydroxide and the hydroaluminate of calcium crystallize first. As a result of formation of crystals throughout the dough-like mass it solidifies, but it does not as yet possess high strength. This stage is known as setting of the cement.

The characteristic features of the following stage of hardening are closer packing; crystallization of the mass of the gel, which consists of hydrosilicates of calcium; drying of the mass, and an increase in its strength due to intergrowth and interwining of the crystals. The most important of the phenomena which result in the
increase in the mechanical strength of a cement is crystallization of the mineral that solidifies at the highest rate, i.e. of tri-calcium silicate, and the rate of increase in strength of the cement rock depends on the content of this component in the clinker.

**Classification & Specification**

The classification of Cement and their applications are as under:

<table>
<thead>
<tr>
<th></th>
<th>33 GRADE</th>
<th>43 GRADE</th>
<th>53 GRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPRESSIVE STRENGTH (KG/CM²) MIN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3D</td>
<td>160</td>
<td>230</td>
<td>270</td>
</tr>
<tr>
<td>7D</td>
<td>220</td>
<td>330</td>
<td>370</td>
</tr>
<tr>
<td>28D</td>
<td>330</td>
<td>430</td>
<td>530</td>
</tr>
</tbody>
</table>

**APPLICATION -**

- **GENERAL PURPOSE**
- **CONSTRUCTION CEMENT**
- **MORTARS, BEAMS,**
- **COLUMNS WHICH ARE DESIGNED FOR AVERAGE LEVEL OF STRENGTH**
- **FOR SPECIALISED WORKS SUCH AS PRESTRESSED PRECAST CONCRETE.**
- **HIGH STRENGTH CONCRETE WHERE DESIGNS ARE BASED ON HIGHER LEVEL OF STRENGTHS**
Specifications for special cement are as given below:

**SPECIFICATIONS FOR SPECIAL CEMENTS:**

<table>
<thead>
<tr>
<th>Property</th>
<th>High Strength Cements 43 Grade</th>
<th>53 Grade</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>OPC</td>
<td>OPC</td>
</tr>
<tr>
<td></td>
<td>I.S. 8112</td>
<td>I.S. 12269</td>
</tr>
</tbody>
</table>

a) **Chemical Requirements**

<table>
<thead>
<tr>
<th>(1) LSF</th>
<th>0.66 to 1.02</th>
<th>0.80 to 1.02</th>
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</thead>
<tbody>
<tr>
<td>(2) A/F</td>
<td>-</td>
<td>0.66</td>
</tr>
<tr>
<td>(3) I.R.% (Max.)</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>(4) MgO % (Max.)</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>(5) SO₃ % (Max.)</td>
<td>2.5(C₃A&lt;5)</td>
<td>2.5(C₃A&lt;5)</td>
</tr>
<tr>
<td></td>
<td>3.0(C₃A&gt;5)</td>
<td>3.0(C₃A&gt;5)</td>
</tr>
<tr>
<td>(6) LOI % (Max.)</td>
<td>5.0</td>
<td>4.0</td>
</tr>
<tr>
<td>(7) C₃A % (Max.)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(8) C₃S % (Min.)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

b) **Physical Requirements**

| (1) Fineness, cm²/g, (Min.) | 2250 |
| (2) Setting Time (Minutes)  |
| Initial (Min.)              | 30   |
| Final (Max.)                | 600  |

| (3) Soundness               |
| A.C. Expn. % (Max.)         | 0.8 (unaerated) or 0.5 (aerated) |
| L.C. Expn. mm, (Max.)       | 10.0 (unaerated) or 5.0 (aerated) |

| (4) Compressive Strength    |
| 3 days, kg/cm²              | 230  |
| 7 days, kg/cm²              | 330  |
| 28 days, kg/cm²             | 430  |
| 270                          |      |
| 370                          |      |
| 530                          |      |
LOW ALKALI LOW HEAT OF HYDRATION CEMENT:

Mainly used for massive structure such as dams, piers etc. Also in construction where Alkali reactive aggregates are used.

Product Characteristics:

* Total Alkalies Expressed as Na₂O
  (Na₂O + 0.658 K₂O) - Less than 0.6%

* Low heat of hydration
  7 days (Max.) CAL/GM  65
  28 days (Max.) CAL/GM  75

* Resists deleterious Alkali Silica reaction in concrete.

* Concrete shrinkage cracks due to high heat of Hydration Avoided.

Heat of Hydration (CAL/GM):

<table>
<thead>
<tr>
<th></th>
<th>PPC</th>
<th>Requirement</th>
<th>OPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 days</td>
<td>50-55</td>
<td>Max. 65</td>
<td>55-60</td>
</tr>
<tr>
<td>28 days</td>
<td>60-65</td>
<td>Max. 75</td>
<td>64-70</td>
</tr>
</tbody>
</table>
CHEMICAL ANALYSIS OF CEMENT:

Sampling:

The samples of the cement taken as per requirements of IS: 3535-1966 and the relevant standard specification for the type of cement being tested. The representative sample of the cement selected as above mixed thoroughly before use.

Methodology:

(i) Determination of Silica: 0.5 g of cement sample transferred to an evaporating dish, moisten with 10 ml of distilled water at room temperature to prevent lumping, add 5 to 10 ml of hydrochloric acid, and digest with the aid of gentle heat and agitation until the sample is completely dissolved. Dissolution may be aided by light pressure with the flattened end of a glass rod. Evaporated the solution to dryness. Without heating the residue any further, treated it with 5 to 10 ml of hydrochloric acid and then with an equal amount of water. Then covered the dish and digested for 10 minutes on the water bath. Diluted the solution with an equal volume of hot water, immediately filter through an ashless filter paper (Whatman No. 40), and wash the separated silica (SiO₂) thoroughly with hot water and reserve the residue.

Again evaporated the filtrate to dryness, baking the residue in an oven for one hour at 105 to 110°C. Then residue treated with 10 to 15 ml of hydrochloric (1:1) and heated the solution on water bath. Solution diluted
with an equal volume of hot water, catch and wash the small amount of silica it contains on another filter paper. Reserve the filtrate and washings for the determination of alumina, ferric oxide, CaO and MgO etc.

The papers containing the residues transferred to a weighed platinum crucible. Dry and ignited the papers, first at a low heat until the carbon of the filter paper is completely consumed without inflaming, and finally at 1100 to 1200°C until the weight remains constant.

Treated the ignited residue thus obtained, which will contain small amounts of impurities, with 1 to 2 ml of distilled water, about 10 ml of hydrofluoric acid and 2 drops of sulphuric acid and evaporated cautiously to dryness. Finally heat the small residue at 1050 to 1100°C for a minute, cool and then weigh. The difference between this weight and the weight of ignited sample represents the amounts of silica:

\[
\text{Silica percent} = 200 \left( W_1 - W_2 \right)
\]

where, \( W_1 = \text{weight of silica + (insoluble impurities - residue)} \), and \( W_2 = \text{weight of impurities} \).

(ii) Determination of Ferric Oxide: Filtrate prepared during silica determination, then mixed the filtrates and make up the volume in a 250 ml volumetric flask. EDTA Method: 25 ml of makeup solution taken and then add dilute ammonium hydroxide (1:6) till turbidity appears.
Clear the turbidity with a minimum amount of dilute HCl acid (1:10) and add a few drops in excess to adjust the pH to approximately 1 to 1.5. Shake well. Then add 100mg of sulphosalicylic acid and titrated with 0.01 M EDTA solution carefully to a colourless solution.

**Calculation** - The %age of Fe$_2$O$_3$ calculated as below -

\[
1 \text{ ml of } 0.01 \text{ M EDTA} = 0.7985 \text{ of Fe}_2\text{O}_3
\]

Iron oxide (Fe$_2$O$_3$) % = \( \frac{0.7985 \times V}{W} \)

where, \( V \) = Volume of EDTA used in ml, and \( W \) = Weight of the sample in g.

(iii) **Determination of Alumina (EDTA Method)**: 25 ml of makeup filtrate solution taken and then titrate iron at pH approximately 1 to 1.5 with EDTA using sulphosalicylic acid as indicator. Add 15 ml standard EDTA solution. Then add 1 ml of phosphoric acid (1:3), 5 ml of sulphuric acid (1:3) and one drop of thymol blue into the titration flask. Add ammonium acetate solution by stirring until the colour changes from red to yellow. Add 25 ml of ammonium acetate in excess to obtain pH approximately 6. Heat the solution to boiling for one minute and then cool. Add 50 ml of solid xylenol orange indicator and bismuth nitrate solution slowly with stirring until the colour of solution changes from yellow to red. Add 2 to 3 ml of bismuth nitrate solution in excess. Titrated with 0.01 M EDTA solution to a sharp yellow end point red colour.
Calculation - The %age of $\text{Al}_2\text{O}_3$ calculated as below-

$$V = V_1 - V_2 - (V_3 \times E)$$

where, $V = \text{Volume of EDTA for alumina in ml.}$

$V_1 = \text{Total volume of EDTA used in the titration in ml,}$

$V_2 = \text{Volume of EDTA used for iron in ml, (Fe}_2\text{O}_3 \text{ determination)}$

$V_3 = \text{Total volume of bismuth nitrate solution used in the titration in ml, and}$

$E = \text{Equivalence of 1 ml of bismuth nitrate solution.}$

$1 \text{ ml of 0.01 M EDTA} \equiv 0.5098 \text{ mg of Al}_2\text{O}_3$

Aluminium oxide ($\text{Al}_2\text{O}_3$) percent $= \frac{0.5098 \times V}{W}$

where, $W = \text{Weight of the sample in g.}$

(iv) Determination of Calcium Oxide (EDTA Method) : 10ml of makeup filtrate solution taken in a conical flask. Warm the solution on a hot plate and add drop by drop 1:1 ammonium hydroxide with constant shaking till a turbidity appears. Filter through Whatman filter paper No. 41 and wash the filter paper 2 to 3 times taking 5 to 10 ml to distilled water each time. Add 2 to 3 drops of nitric acid followed by about 50 mg of solid potassium periodate. Keep the flask on water bath till pink colour develops. Shake and allow to cool to room temperature. Add 5 ml of 1:1 glycerol with constant stirring and then 5 ml of diethylamine. Add 20 ml of 4 N sodium hydroxide
solution and shake well to adjust the pH to 12. Add approximately 50 ml of distilled water and 100 mg of solid Patton Reeders indicator and titrated against 0.01 M EDTA solution. The end point of titration is reached when one to two drops of EDTA produce a sharp change in colour from violet to blue.

**Calculation** - The %age of CaO calculated as below:

\[
1 \text{ ml of } 0.01 \text{ M EDTA } = 0.5608 \text{ mg of CaO}
\]

\[
\text{Calcium Oxide (CaO) percent } = \frac{0.05608 \times 25 \times V}{W}
\]

where, \( V \) = Volume of EDTA used in ml, and \( W \) = Weight of the sample in g.

(v) **Determination of Magnesia (EDTA Method)**: 10 ml of makeup filtrate solution taken, then add 5 ml of 1:1 triethanolamine with constant shaking and 20 ml of buffer solution pH 10. Add 50 mg of the solid thymol phthailexone indicator followed by approximately 50 ml of distilled water. It is titrated against standard 0.01 M EDTA solution until the colour changes from blue to clear pink. This titration gives the sum of calcium and magnesium oxide present in the solution. Titre value of magnesium oxide is obtained by subtracting the titre value of calcium oxide from the total titre value.

**Calculation** - The %age of MgO calculated as below:

\[
1 \text{ ml of } 0.01 \text{ M EDTA } = 0.4032 \text{ mg of MgO}
\]

\[
\text{Magnesium oxide (MgO) % } = \frac{0.04032 \times 25 \times (V_1 - V)}{W}
\]
(vi) Determination of Sulphuric Anhydride: To one gram of the sample, add 25 ml of cold water, and while the mixture is stirred vigorously and 5 ml of hydrochloric acid. Heat the solution and grind the material with flattened end of a glass rod until it is evident that the decomposition of the cement is complete. Dilute the solution to 50 ml and digest for 15 minutes at a temperature just below boiling. Filter and wash the residue. Dilute the filtrate to 250 ml and heat to boiling. Add slowly drop by drop, 10 ml of hot barium chloride (100 g/l) solution and continue the boiling until the precipitate is well formed. Digest the solution on a steam-bath for 4 hours. Filter the precipitate through a Whatman No. 42 filter paper and wash the precipitate thoroughly. Place the filter paper and the contents in a weighed porcelain crucible and slowly incinerate the paper without inflaming. Then ignite at 800 to 900°C, cool in a desiccator and weigh the barium sulphate obtained.

Calculation - The percentage of $\text{SO}_3$ calculated as below -

$$\text{SO}_3 \text{ percent} = W \times 34.3$$

where

$W =$ weight of residue (BaSO$_4$) in g; and

$34.3 =$ molecular ratio of $\text{SO}_3$ to BaSO$_4$ (0.343), multiplied by 100.
(vii) Determination of Insoluble Residue: Digest the filter paper containing the residue which was set aside during determination of SO$_3$ in 30 ml of hot water and 30 ml of 2 N sodium carbonate solution maintaining constant volume, the solution being held at just below the boiling point for 10 minutes. Filter and wash with dilute hydrochloric acid (1:99) and finally with hot water till the residue is free from chlorides. Ignite the residue in a tared crucible at 900 to 1000$^\circ$C, cool in a desiccator and weigh.

(viii) Determination of free Lime: Weigh one gram of finely ground sample of Portland cement into a flask, and add 60 ml of the Glycerol-ethanol solvent to the flask and titration proceed as in the standardization of the ammonium acetate solution using anhydrous BaCl$_2$ as an accelerator. The end point is considered to have been reached when no further colour appears in the solution during continuous boiling for one hour.

Calculation - The % age of Free Lime Calculated as below-

$$\text{Free calcium oxide (CaO), percent} = \frac{E \times V}{W} \times 100$$

Where, $E =$ CaO equivalent of the ammonium acetate solution in grams per millilitre, and $V =$ Millilitres of ammonium acetate solution required by the sample.

Results of Chemical Analysis of Cement:

The results of 5 samples of cement collected from different shops at Damoh District are given in Table No. 3.1.

Affected Study Area by Diamond Cement Industry Pollution:

In Imlai and Narsingarh Cement Plants, various villages situated within 5.0 Kms. range, which are affected by pollution (Map 2.3) for water and soil are given in Table No. 3.2.
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of the Cement Constituents</th>
<th>Samples</th>
<th>Samples</th>
<th>Samples</th>
<th>Samples</th>
<th>Samples</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>1.</td>
<td>Calcium oxide (CaO)</td>
<td>59.8</td>
<td>60.3</td>
<td>63.5</td>
<td>57.82</td>
<td>60.47</td>
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<tr>
<td>2.</td>
<td>Silica (SiO₂)</td>
<td>20.87</td>
<td>20.8</td>
<td>20.0</td>
<td>21.85</td>
<td>19.6</td>
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<tr>
<td>3.</td>
<td>Alumina (Al₂O₃)</td>
<td>4.41</td>
<td>4.7</td>
<td>4.8</td>
<td>4.8</td>
<td>5.1</td>
</tr>
<tr>
<td>4.</td>
<td>Ferric Oxide (Fe₂O₃)</td>
<td>3.72</td>
<td>3.7</td>
<td>3.9</td>
<td>3.8</td>
<td>3.92</td>
</tr>
<tr>
<td>5.</td>
<td>Magnesia (MgO)</td>
<td>3.7</td>
<td>3.6</td>
<td>4.0</td>
<td>4.41</td>
<td>3.82</td>
</tr>
<tr>
<td>6.</td>
<td>Sulphuric Anhydride (SO₃)</td>
<td>1.99</td>
<td>2.0</td>
<td>1.8</td>
<td>2.45</td>
<td>1.86</td>
</tr>
<tr>
<td>7.</td>
<td>Free Lime</td>
<td>0.78</td>
<td>0.9</td>
<td>1.5</td>
<td>0.98</td>
<td>1.17</td>
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<tr>
<td>8.</td>
<td>Insoluble Residue (I.R.)</td>
<td>2.35</td>
<td>3.5</td>
<td>1.2</td>
<td>2.35</td>
<td>1.76</td>
</tr>
<tr>
<td>S. No.</td>
<td>Distance from Factory (Kms.)</td>
<td>IMLAI UNIT</td>
<td>NARSINGARH UNIT</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Direction From Factory</td>
<td>Name of The Locality/Village/Town</td>
<td>Direction From Factory</td>
<td>Name of the Locality/Village/Town</td>
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<tr>
<td>1.</td>
<td>0.5</td>
<td>N.E.W.S.</td>
<td>Imlai</td>
<td>N.E.W.S.</td>
<td>Narsingarh</td>
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<tr>
<td>2.</td>
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<td>Simri-Rajaram</td>
<td>N-E</td>
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<td>Berkheda</td>
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<td>Singpur</td>
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<td>4.</td>
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<td>Hinnai-Umari</td>
<td>E</td>
<td>Jhira</td>
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<td>E</td>
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<td>5.</td>
<td>3.5</td>
<td>W</td>
<td>Madla</td>
<td>E</td>
<td>Imlizog</td>
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<tr>
<td>6.</td>
<td>4.0</td>
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<td>Hirdepur</td>
<td>W</td>
<td>Kirunganj</td>
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<tr>
<td></td>
<td></td>
<td>N-E</td>
<td>Khajari</td>
<td>N</td>
<td>Motha</td>
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<tr>
<td>7.</td>
<td>4.5</td>
<td>E</td>
<td>Dharampura</td>
<td>N-W</td>
<td>Lukayan</td>
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<tr>
<td>8.</td>
<td>5.0</td>
<td>E</td>
<td>Manpura</td>
<td>S-E</td>
<td>Piparia-Champat</td>
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<td>E</td>
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<td>S</td>
<td>Parsoria</td>
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REFERENCES


10. Ibid, Chemical Technology 2, 1979, Silicate Technology 5, p. 112.


24. Cement Production and Despatches, Various issue, Office of the Cement Controller, Govt. of India, New Delhi.