**SUMMER TRAINING REPORT**

**On**

**OIL WELL CEMENTING IN ONGC**

Submitted by

**Ayushi Singh**

**Enrollment No : B22CH005**

Under the Guidance of

**Mr. Ram Satish Annavarapu Superintending Chemist in ONGC Dehradun**



**(Batch: 2022 - 2026)**

**INDIAN INSTITUTE OF TECHNOLOGY JODHPUR**

**(IIT J) RAJASTHAN**

**ACKNOWLEDGEMENTS**

I would like to express my heartfelt gratitude to **Mr. M.P. Sinha**, GGM (Drilling), for his invaluable guidance, constant encouragement, and support throughout the course of this project. I am especially thankful to **Dr. RAM SATISH ANNAVARAPU** Chief Chemist, for his deep interest and personal involvement in every stage of the work. His continuous motivation and insightful suggestions were instrumental in the successful completion of this training.

I would also like to acknowledge the kind support and assistance of **Mr. R. P. Baliwan** (Foreman), **Mr. Deepak Painuly**, **Mr. Arjun Bhatt**, and **Ms. Nida Siddiqui** (JTA Chemistry), who helped me immensely during the laboratory work.

Their cooperation and mentorship made this internship a valuable learning experience, and I am truly thankful to each of them.

**(AYUSHI SINGH)**  
B.Tech, Chemical Engineering  
6th Semester  
Roll No: B22CH005  
Indian institute of technology Jodhpur (IIT J) Rajasthan

**CONTENTS**

1. **INTRODUCTION**

**1.1** An Overview of ONGC

**1.2** About IDT

**1.3** Executive summary

**1.4** Company Profile

**2. CEMENT**

* **2.1** Cementation
* **2.2** Cement Additives

**3. SLURRY DESIGN PARAMETERS**

* **3.1** Specific Gravity
* **3.2** Thickening Time
* **3.3** Fluid Loss / Filtration Loss
* **3.4** Free Water
* **3.5** Rheological Parameters
* **3.6** Compressive Strength
* **3.7** Stability Chapter

**4. EXPERIMENT SLURRY DESIGN REPORT**

* **4.1** Source and Composition
* **4.2** Observations and Results

**5. CONCLUSION**

* Summary of Learnings and Experience

**INTRODUCTION**

The **Oil and Natural Gas Corporation (ONGC)** is India’s largest oil and gas exploration and production company and functions as a major Public Sector Undertaking (PSU) under the Ministry of Petroleum and Natural Gas. Headquartered in Dehradun, ONGC is responsible for producing approximately 77% of the nation’s crude oil and 62% of its natural gas, playing a pivotal role in meeting India’s energy demands. Established on 14th August 1956, ONGC has expanded its operations to include both conventional and unconventional energy sources. Apart from oil and natural gas exploration, it is actively involved in the development of alternative resources such as coal-bed methane (CBM) and shale gas, making it a vital contributor to India’s energy security.

**INSTITUE OF DRILLING TECHNOLOGY (IDT)**

The **Institute of Drilling Technology (IDT)**, founded in 1978 and located in Dehradun, serves as ONGC’s premier research and development (R&D) center focused on advancing drilling technologies. Nestled in the scenic Doon Valley, IDT is equipped with state-of-the-art laboratories and staffed by highly skilled and experienced professionals. The institute specializes in key areas such as drilling fluids, cementing techniques, well control, and operational monitoring. In addition to its R&D initiatives, IDT also offers advanced training programs through its Drilling Technology and Well Control Schools, aiming to build a qualified and efficient workforce capable of addressing complex drilling challenges and enhancing the overall operational efficiency of ONGC.

**EXECUTIVE SUMMARY**

This report presents a comprehensive overview of the internship conducted at Oil and Natural Gas Corporation (ONGC), focusing on Oil Well Cementing Operations. The internship provided in-depth exposure to the processes, equipment, additives, and field practices involved in designing and executing cementing jobs essential for safe and efficient drilling operations.

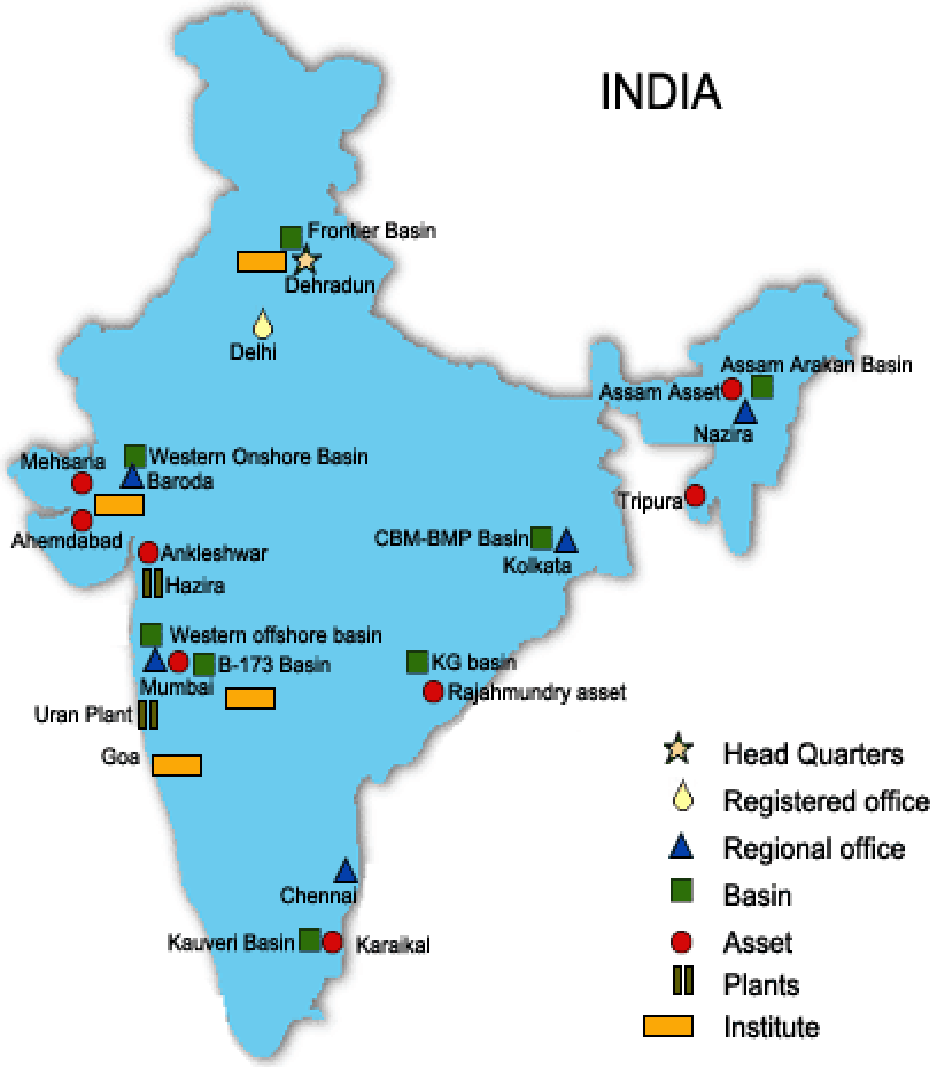
During the internship, I gained practical insights into the design of cement slurries, incorporating critical parameters such as thickening time, compressive strength, fluid loss, free water content, and static gel strength. I also studied the roles of various cement additives like retarders, dispersants, fluid loss agents, silica fume, and weighting materials (e.g., Micromax), and how they are optimized for different wellbore conditions including High Temperature High Pressure (HTHP) environments.

Hands-on learning was supported through the observation and understanding of laboratory testing using advanced cement testing equipment .

I also explored the real-time application of cementing in field operations, such as primary cementing, remedial cementing, and plug placement, along with the evaluation of zonal isolation and well integrity post-cementing.

The internship enhanced my technical understanding, analytical skills, and knowledge of safety and quality control standards followed in the upstream oil and gas industry. It was an enriching experience that bridged the gap between academic learning and industrial application, offering a strong foundation for future endeavors in petroleum and cementing technologies.

**ONGC OFFICES IN INDIA**



**COMPANY PROFILE**

**Origin of ONGC:**

ONGC was set up under the visionary leadership of Pandit Jawahar Lal Nehru. Pandit Nehru reposed faith in Shri Keshava Dev Malviya who laid the foundation of ONGC in the form of Oil and Gas division, under Geological Survey of India, in 1955. A few months later, it was converted into an Oil and Natural Gas Directorate. The Directorate was converted into Commission under an act of Parliament and named as Oil & Natural Gas Commission on 14th August 1956. In 1993, Oil and Natural Gas Commission was converted in to a corporation, and registered under the Companies Act ,1956. In 1997, it was recognized as one of the Navratnas by the Government of India. Subsequently, it has been conferred with Maharatna status in the year 2010.

**EVOLUTION OF ONGC:**

1955- Oil and Gas Directorate, Government of India

1956- Oil and Natural Gas Commission

1959- Autonomous Statutory body

1993- Public Limited Company

1997- A Navratna PSU

2000-A Flagship Oil PSU

2010- A Maharatna PSU

ONGC as an integrated Oil & Gas Corporate has developed in-house capability in all aspects of exploration and production business i.e., Acquisition, Processing & Interpretation (API) of Seismic data, drilling, work-over and well stimulation operations, engineering & construction, production, processing, refining, transportation, marketing, applied R&D and training, etc.

**OVERVIEW OF THE COMPANIES BUSINESS**

At present, ONGC is a Public Sector Company with Central Government holding approximately 81.57% of total equity shares. ONGC is a major producer of Oil & Gas in India and the biggest wealth creator in the recent years. ONGC has its registered Office and Corporate Office at New Delhi. Oil and Natural Gas Corporation Limited is the largest Exploration and Production Company in India. The principal activities of ONGC include acquisition of mineral interests in properties, exploration (including prospecting), development, production, transportation and marketing crude oil and natural gas. It also produces several value-added products (VAPs) like Liquefied Petroleum Gas (LPG), Naphtha, Superior Kerosene Oil (SKO), Ethane-Propane (C2-C3), High Speed Diesel (HSD), Sulphur, Low Sulphur Heavy Stock (LSHS), ATF at their crude & gas processing facilities.

**PRODUCTS OF ONGC:**

The main and joint products of ONGC are as under:

Main Products are: -

* Crude Oil
* Natural Gas

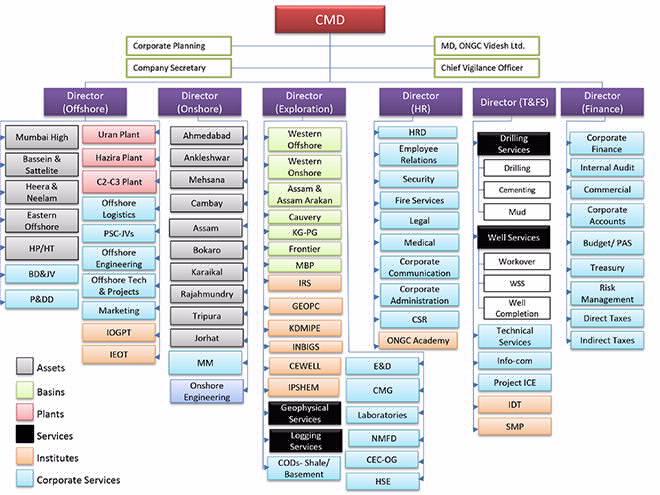
Joint Products are: -

* LPG
* Aromatic Naphta
* Superior Kerosene Oil
* C2 - C3 (Ethane - Propane)

**BOARD OF DIRECTORS**

The Company is managed by the Board of Directors, which formulates strategies, policies and reviews its performance periodically. The Chairman & Managing Director (CMD) and Six Whole-Time Directors viz. Director (Onshore), Director (Technology & Field Services), Director (Finance), Director (Offshore), Director (Exploration) and Director (Human Resource), manage the day-to-day business affairs of the Company under the overall supervision, control and guidance of the Board.

**ORGANIZATIONAL STRUCTURE**

****

**CEMENTING HISTORY**

Historically, one of the earliest and most persistent challenges in well construction was **controlling fluid invasion**, especially **water ingress behind the casing**. Initially, drillers used rudimentary techniques to seal off water-bearing zones. One such method involved wrapping **canvas or leather bags filled with swelling seeds** around the casing shoe to act as a primitive barrier once they expanded in the presence of water (see *Figure 1*).

The concept of using **cement to seal the annulus** dates back to **1859 in Russia**, where Romanovsky reportedly attempted it in a water well. In the United States, **John R. Hill** patented the first method involving the placement of cement in a borehole in 1871. His technique described positioning cement before inserting the casing and allowing it to set, thereby sealing water courses. Further experimentation led to the first oil well cementing attempt in **1881 in Pico, California**, by **Wallace Hardison and Lyman Stewart** of Hardison & Stewart Oil Company. However, the early cement materials were substandard and failed to achieve lasting seals.

A major breakthrough occurred with the advent of **Portland cement**, patented in 1824 by **Joseph Aspdin**, a British bricklayer. Named after its resemblance to stone quarried on the Isle of Portland, this type of cement could **set and harden under water**, making it ideal for wellbore conditions. His son, **William Aspdin**, later advanced the formulation, contributing to what is now considered **modern Portland cement**.

By the late 1800s, companies began experimenting with Portland cement in oil well applications. In **1903**, **Frank F. Hill** of Union Oil Company tackled fluid losses in unconsolidated formations by pouring 20 sacks of Portland cement mixed with water into the hole, then manipulating casing position and using air pressure to push cement into the annulus. This marked the beginning of effective cement placement in wells. Later, Hill innovated by pumping cement through **tubing with a packer**, eliminating the need for drilling out hardened cement inside the casing.

Despite these advancements, cementing was still seen as costly and labor-intensive until **Almond A. Perkins**, founder of **The Perkins Oil Well Cementing Company**, revolutionized the process around **1910**. He introduced the **two-plug method**: a bottom plug was used to displace drilling mud, followed by the cement slurry, and then a top plug pushed by water. This ensured efficient displacement and minimized cement setting inside the casing. The plugs were originally made of cast iron and leather discs.

One of the most transformative figures in cementing history, **Erle P. Halliburton**, joined Perkins' company in 1918 as a truck driver and went on to establish the **Halliburton Oil Well Cementing Company** in **1924**. He further refined cementing techniques, equipment, and reliability, laying the groundwork for what would become the industry standard in well cementing.

**INTRODUCTION**

Oil and gas production is among the most intricate and technologically sophisticated industries in the world. One of the critical operations that ensures well integrity, safety, and sustained hydrocarbon production is **well cementing**. Far from being a simple filling procedure, cementing is a meticulously designed and engineered process that plays a pivotal role in achieving **zonal isolation**, providing **structural support**, offering **corrosion protection**, and managing **subsurface pressures** throughout the life of the well.

An **oil well** is essentially a precision-engineered borehole drilled into the earth’s subsurface to extract hydrocarbons—such as crude oil and natural gas—for surface processing and commercial use. The drilling is carried out in stages using a **telescopic approach**, where each subsequent section is drilled with a smaller diameter bit. After each stage, **steel casing pipes** are inserted into the borehole to provide mechanical strength and prevent collapse. The **annular space** between the casing and the borehole wall is then filled with **cement slurry**, a homogenous mixture of cement, water, and various additives tailored for specific well conditions such as pressure, temperature, and formation characteristics.

This placement of cement in the annular space, known as **primary cementing**, ensures that the casing is securely bonded to the formation and prevents unwanted migration of fluids between subsurface layers. It protects freshwater aquifers from contamination by hydrocarbons or saline formation water and isolates production zones from non-productive or dangerous layers. In deep wells, multiple casing strings are installed and cemented, each providing additional zonal isolation as drilling progresses to greater depths.

**OBJECTIVES OF CEMENTING**

Cementing is a standard procedure involving the placement of a cement slurry—typically a mixture of cementing materials and water—into the **annular space** between the outer surface of the casing and the wellbore wall. This operation is usually performed by pumping the slurry through the casing to the annulus.

The cementing of casing annuli is universally practiced across the oil and gas industry for several essential reasons, each tailored to meet specific wellbore requirements. The key objectives include:

1. **To bond and support the casing:** Cement holds the casing in place and reinforces its position within the borehole.
2. **To restrict fluid movement between formations:** This helps prevent contamination of shallow freshwater zones by hydrocarbons or saline water and blocks crossflow between different geological layers.
3. **To isolate production or injection zones:** Cement provides zonal isolation by sealing off specific intervals from overlying or underlying permeable formations.
4. **To protect casing from corrosion:** Cement serves as a barrier against corrosive subsurface fluids that could damage the steel casing.
5. **To prevent casing damage from mechanical shocks:** It shields the casing from sudden pressure surges or loads during further drilling or production.
6. **To stabilize weak or unconsolidated formations:** Cement supports formations prone to collapse or sloughing.
7. **To seal off lost circulation zones:** It helps restore wellbore integrity by plugging formations that absorb drilling fluids.

**OIL WELL CEMENT**

Oil well cement is used for securing casing strings during drilling operations in oil and gas wells. It is mixed with water to form a **cement slurry**, which undergoes physical and chemical changes upon hydration. These changes cause the slurry to set and harden, forming a solid mass that bonds the casing to the wellbore and ensures **zonal isolation**.

**1.1 Chemistry of Oil Well Cement**

Oil well cements are typically **Portland cements**, primarily composed of:

* **Tricalcium Silicate (C₃S)**
* **Dicalcium Silicate (C₂S)**
* **Tricalcium Aluminate (C₃A)**
* **Tetracalcium Aluminoferrite (C₄AF)**

These compounds determine the cement’s performance, such as setting time, strength development, and resistance to environmental conditions. Minor compounds like **alkalis, magnesium oxide**, and **free lime** also influence its properties.

**1.2 Manufacturing of Portland Cement**

There are two main processes: **wet and dry**, with the dry process being more energy efficient and commonly used today. The five stages include:

1. **Crushing and Grinding**: Limestone and clay are crushed into fine powder.
2. **Proportioning**: Blending in the right ratios to form raw feed.
3. **Heating in Rotary Kiln**: The feed is heated to 1400–1500°C to form **clinker**.
4. **Clinker Cooling**: Hot clinker is cooled for further processing.
5. **Grinding with Gypsum**: Clinker is ground with ~5% gypsum to produce **Portland cement**, which regulates setting time.

**1.3 Classification of Oil Well Cements (API)**

According to the **American Petroleum Institute (API)**, oil well cements are classified into Classes **A, B, C, D, G, and H**, based on depth, pressure, temperature, sulfate resistance, and setting time. Each class has specific applications:

* **Class A**: For shallow wells where special properties are not needed.
* **Class B**: For moderate to high sulfate environments.
* **Class C**: For high early strength requirements.
* **Class D**: Retarded cement for deeper wells.
* **Class G & H**: Widely used for deep wells with adjustable properties.

In **ONGC**, **Class G (HSR - High Sulfate Resistant)** cement is commonly used due to its superior performance and durability in harsh environments.

**TYPES OF CEMENTATION**

Cementation operations in oil wells are broadly classified into two categories: **Primary Cementation** and **Secondary (Remedial) Cementation**. Both serve essential functions in maintaining well integrity, ensuring zonal isolation, and extending the productive life of the well.

**PRIMARY CEMENTATION**

**Primary cementation** is conducted immediately after the casing has been lowered into the wellbore. The main objective is to place cement slurry in the annular space between the casing and the formation to ensure proper bonding and zonal isolation.

**Procedure:**

1. **Mud Circulation:**  
   Prior to cement placement, mud circulation is performed to homogenize the drilling fluid and remove residual drill cuttings. High flow rates are used to ensure efficient mud removal, which is critical for successful cement bonding.
2. **Spacer Pumping:**  
   A **spacer fluid** is pumped after mud circulation to create a buffer between the mud and the cement slurry. It helps displace residual mud and prevents contamination that could affect cement properties. In some cases, fresh mud may also be pumped before the spacer.
3. **Plug System:**  
   A **wiper plug system** ensures mechanical separation between fluids during cementing:
   * **Bottom Plug**: Released before the cement slurry, it has a **hollow, drillable metal core** with a **rupture diaphragm**. It cleans the casing wall and allows cement to flow once the diaphragm ruptures under pressure.
   * **Top Plug**: Dropped after the cement slurry, it has a **solid, drillable core** and prevents backflow into the casing.
4. **Cement Slurry Pumping and Displacement:**  
   The cement slurry is pumped into the casing after the bottom plug, followed by the top plug. The slurry is then displaced using drilling mud. As the bottom plug reaches the **float collar**, the diaphragm bursts, allowing cement to flow into the annulus. Displacement continues until the top plug reaches the float collar, causing a **"plug bump"** or **pressure spike**, indicating completion of cement placement.
5. **Waiting on Cement (WOC):**  
   After placement, the well is shut in to allow the cement to set and gain strength under bottom-hole conditions. The **WOC time** is determined based on lab-tested compressive strength development of the slurry.

**SECONDARY CEMENTATION**

**Secondary cementation** refers to any cementing operation performed after the primary job. It is mainly used for well repairs, isolating problem zones, or preparing a well for abandonment.

**Purposes of Secondary Cementing:**

* **Repair faulty primary cement jobs** to restore zonal isolation.
* **Prevent water ingress** from above or below the producing zone.
* **Reduce gas-oil ratios** by isolating gas-bearing zones from oil-producing intervals.
* **Seal casing leaks** caused by corrosion, cracks, or mechanical damage.
* **Redirect injection fluids** in multizone injection wells by plugging selected zones.
* **Permanently abandon** depleted or water-encroached zones.

**Methods:**

1. **Squeeze Cementing:**  
   Cement is forced under pressure into the formation, perforation tunnels, or behind the casing to seal leaks or isolate zones.
2. **Plug Cementing:**  
   A cement plug is placed at a specific location inside the wellbore to seal off zones, support directional drilling, or abandon sections.

In both methods, a **calculated cement column** is placed using spacers and cement slurry to achieve the desired isolation or repair.

**CEMENT ADDITIVES**

Additional chemicals are used to control slurry density, rheology, and fluid loss, or to provide more specialized slurry properties

Cement additives are used to modify the properties of cement slurry for specific well conditions such as temperature, pressure, fluid loss, or setting time. Additives can be dry blended with cement or mixed into water before slurry preparation.

Over 100 additives for cement are available and thesecan be classified under one of the following categories are :

* 1. Accelerators
  2. Retarders
  3. Extenders
  4. Dispersants
  5. Weighing agents
  6. Fluid loss addititves
  7. Defoamers and antifoams
  8. Silica Fumes

**1. Accelerators**

Accelerators speed up the setting time and early strength development, especially in shallow or low-temperature wells.

Accelerators may be added to the mix-water to reduce the thickening and setting times of the slurry, with the purpose of avoiding unnecessary time spent waiting on cement. Calcium Chloride is the most common type of accelerator used. Other, less frequently used accelerators are Sodium Chloride and Potassium Chloride.

* **Calcium Chloride (2–4% BWOC):** Increases heat of hydration, reduces WOC time; but can affect fluid loss additives and is hygroscopic.
* **Sodium Chloride (3–10% BWOW):** Enhances bonding in salt formations; acts as dispersant; higher concentrations may retard setting.
* **Sodium Silicate (0.2–3% BWOC):** Compatible with CMHEC-based slurries; corrosive at high concentrations but effective without harming fluid loss properties.

**2. Retarders**

Retarders delay the setting of cement slurry to allow sufficient time for placement, especially in deep or high-temperature wells.

**Retarders (e.g., DO60, D124)**

* **Delay the setting time** of the cement slurry.
* Prevent **premature hardening** of cement during placement.
* Allow **longer pump time**, especially in **high-temperature** or **deep wells**.

Help in achieving uniform slurry placement and **prevent bridging or blockages** in long casing sections.

🟡 *Why Important?*  
Without retarders, cement can set before reaching the desired depth — causing incomplete zonal isolation or even operational failure.

**3. Fluid Loss Additives**

These additives reduce water loss from slurry into formation, preventing dehydration and preserving cement integrity.

* **Mechanism:** Form micelle films, adjust slurry viscosity, and improve particle distribution.
* **Advantages:** Prevents formation damage, gas migration, and lost circulation.

**(Examples: DO47, D198)**

**Use:**

* Minimize loss of water from slurry into porous formations.
* Maintain slurry hydration, preventing premature setting.
* Reduce formation damage and filter cake thickness.
* Essential in highly permeable zones or loss circulation areas.

🟡 *Why Important?*  
Uncontrolled fluid loss can weaken the cement structure, reduce bond strength, and lead to poor zonal isolation**.**

**4. Dispersants (Friction Reducers)**

Dispersants reduce slurry viscosity, improving pumpability and flow.

**Dispersants (Examples: DBM, D154)**

* Reduce slurry viscosity and improve flow characteristics.

Prevent flocculation and agglomeration of cement particles.

* Help maintain uniform slurry consistency for better pumpability.
* Allow use of higher solids concentration without increasing viscosity.

🟡 *Why Important?*  
Dispersants ensure that slurry flows easily through the narrow annular space between the casing and borehole wall.

**Factors Affecting Dispersant Efficiency:**

1. Cement fineness
2. C₃A content
3. Soluble alkali sulfates
4. Cement aging
5. Mixing method and water temperature

**5. Lightweight Additives (Extenders)**

These reduce slurry density to prevent lost circulation and reduce bottom-hole pressure.

* **Water-based Extenders (e.g., Bentonite, Sodium Silicate):** Reduce density via increased water content.
* **Low-density Solids (e.g., Diatomaceous earth, Volcanic ash):** Physically lower slurry density.
* **Limitations:** Can reduce compressive strength and increase permeability.

**Key Types:**

1. **Bentonite:**
   * Swells in water, increases slurry volume
   * High water requirement → reduced density
   * Also improves rheology and suspension
2. **Diatomaceous Earth:**
   * Naturally porous, low-density siliceous material
   * Good for reducing density and thermal insulation
3. **Sodium Metasilicate:**
   * Chemical extender
   * Reduces density and enhances slurry compatibility
4. **Ultra Lightweight Cement Systems:**
   * Incorporate hollow microspheres or foaming agents
   * Ideal for weak, fractured formations
   * Density as low as 7–10 ppg (pounds per gallon)
5. **Heavyweight Additives**

**Purpose:**  
Used to **increase slurry density** for controlling high formation pressures and maintaining well control.

**Key Types:**

**Hametite (Fe₂O₃):**

* High specific gravity (~5.05)
* Commonly used heavyweight additive

**Ilmenite (FeTiO₃):**

* Slightly lower specific gravity (~4.5)
* Good alternative to hematite
* Enhances rheology and temperature resistance

1. **WEIGHING AGENTS**

Weighing agents are normally required to produce cement slurry of high specific gravity. The main requirements for weighing agents are:

Example: **Micromax**

**Use:**

* Increase **cement slurry density** (e.g., from 15.8 ppg to 18+ ppg).
* Used in **high-pressure wells** to counter formation pressure.
* Micronized material = low settling rate and **stable slurry**.
* Allows **high-density slurries** without excessive viscosity.

🟡 *Why Important?*

High-density slurries prevent **formation fluid influx**, **well kicks**, or **blowouts**.

1. **DEFOAMERS and ANTIFOAMS**

While mixing cement, and/or when preparing mix water, containing retarders, salts, fluid loss additives and/or bentonite, foaming is often experienced. To control such problems antifoams and defoamers are available.

Antifoams should be used before adding any other chemicals.

* Defoamers remain effective when added after foam-causing chemicals.

In practice, such distinction may be difficult to ensure and therefore both antifoams as well as defoamers should be added in advance in re-circulating cement mixer.

1. **SILICA FUME (SiO₂)**

**Use:**

* **Increases compressive strength** and reduces **permeability**.
* Reacts with calcium hydroxide to form additional **C–S–H gel** (main strength phase).
* Provides **thermal stability** in **HTHP (High Temperature High Pressure)** wells.
* Fills **micro voids** in cement matrix – improves **durability**.

🟡 *Why Important?*  
Silica additives enhance cement’s resistance to **thermal stress**, **CO₂/acid attack**, and **long-term degradation**.

**CEMENT SLURRY PREPARATION**

1. **Mix liquid additives first**: Add any **liquid chemicals** (like retarders, dispersants) to the water and mix well.
2. **Add dry materials**: Slowly add **cement powder** and **dry additives** (like bentonite) into the water while stirring.
3. **Use a mixer**: Use a **propeller-type mixer** – start at **low speed (4000 rpm)** to add cement, then **high speed (12000 rpm)** for complete mixing.
4. **Mixing time**: Mix for **15 seconds at low speed**, then **35 seconds at high speed** (total ~1 minute).
5. **For light slurries**: If using materials like **microspheres**, mix gently at low speed to avoid breaking them.
6. **Check slurry quality**: After mixing, test the slurry for **density, flowability, and setting time**.
7. **Simulate well conditions**: Test the slurry at **high pressure and temperature** to ensure it will perform well in the actual well.

**CEMENT SLURRY INSTRUMENTS**

1. Speed Mixer

2. Mud Balance

3. Atmospheric Consistometer

4. Viscometer(Rhelogy)

5. Fluid Loss Apparatus

6. HTPT Consistometer

7. Compressive Strength

1. **SPEED MIXER**

The Speed Mixer is a high-speed laboratory mixing device designed to homogeneously blend cement, water, and additives without incorporating air. It rapidly produces a well-dispersed slurry, which is essential for obtaining accurate and reproducible test results.

**Significance in Cement Slurry Testing**

* Ensures a uniform mixture of components prior to testing.
* Eliminates air entrapment, which can otherwise affect results such as density, thickening time, and strength.
* Reduces preparation time while maintaining consistency across batches.
* Used as a preliminary step before testing with consistometers, fluid loss apparatus, and UCA.

1. **MUD BALANCE**

The mud balance is a mechanical device used to measure the density of cement slurry or drilling mud. It operates based on the principle of equilibrium, where a cup filled with slurry is counterbalanced on a calibrated arm. The primary components of the mud balance include:

* Graduated beam: Marked with various units such as g/cm³, lb/gal (ppg), and lb/ft³.
* Metal cup with vented lid: Holds a fixed volume of slurry and ensures that excess air and slurry are expelled.
* Counterweight: Slides along the arm to balance the beam.
* Bubble level: Assists in achieving a perfectly horizontal alignment.
* Base stand: Holds the beam in position for accurate measurement.

**Procedure**

1. The slurry cup is completely filled with the prepared cement slurry.
2. The lid is placed firmly to expel excess slurry through the vent hole, ensuring no air is trapped inside.
3. The cup is placed into the holder on the beam.
4. The counterweight is adjusted until the beam is level (as indicated by the bubble).
5. The slurry density is read directly from the scale at the pointer.

**Significance**

* Ensures the slurry has **sufficient hydrostatic pressure** to prevent influx of formation fluids.
* Confirms correct **additive dosage** and slurry mix during pre-job quality checks.
* Helps **identify any settling** or separation in the slurry which could impact performance.
* Used as a **quality control tool** both in the laboratory and in field operations.

**3.ATMOSPHERIC CONSISTOMETER**

The Atmospheric Consistometer is a laboratory instrument used to simulate the mixing and conditioning of cement slurry at atmospheric pressure and elevated temperatures. It is a vital tool in cement slurry testing, helping to evaluate the consistency, stability, and uniformity of the slurry before conducting further performance tests.

**Purpose and Function**

The main purpose of the atmospheric consistometer is to condition the cement slurry by subjecting it to controlled temperature and agitation, mimicking the downhole circulation conditions prior to placement. This helps determine if the slurry can maintain pumpability and uniform dispersion throughout the job.

**Principle**

* The cement slurry is placed inside a rotating cylindrical container submerged in a heated oil bath.
* The bath temperature is gradually raised to simulate wellbore temperature conditions (usually up to 90–93°C or more).
* As the container rotates (typically at 150 rpm), the slurry is agitated continuously for a specified duration (commonly 20 or 30 minutes).
* During this time, the slurry’s consistency is monitored visually or recorded digitally (in automated models).

**Applications in Cementing**

* Pre-conditioning slurry before tests like fluid loss, rheology, or thickening time.
* Evaluating how slurry behaves under thermal agitation.
* Identifying early signs of instability, such as gelling, separation, or premature thickening.
* Ensures additives are uniformly dispersed and slurry remains homogeneous.

**4.VISCOMETER**

The rheology instrument, commonly known as a viscometer, is an essential device used in the cementing laboratory to measure the flow behavior of cement slurry. Rheological properties such as viscosity, yield point, and gel strength are critical for understanding how a slurry will behave during mixing, pumping, and placement in the wellbore.

**Purpose and Function**

The primary purpose of the viscometer is to determine how cement slurry flows under applied shear stress. This is crucial for ensuring that the slurry can be easily pumped, suspend solids, and prevent settling during placement.

**Working Principle**

The viscometer used in cement labs typically operates on the rotational principle:

* A bob and sleeve system is used, where the outer sleeve rotates at different speeds while the inner bob remains suspended in the slurry.
* The torque required to rotate the sleeve is measured and correlated to the shear stress and shear rate applied to the fluid.
* Using this data, rheological parameters are calculated based on models like the Bingham Plastic or Power Law.

**Key Rheological Parameters Measured**

| **Parameter** | **Description** | **Importance** |
| --- | --- | --- |
| **Plastic Viscosity (PV)** | Resistance due to internal friction between slurry particles | Affects pumping pressure |
| **Yield Point (YP)** | Stress needed to initiate flow | Indicates ability to lift and suspend solids |
| **Gel Strength** | Stress required to restart flow after static period | Predicts fluid behavior after shutdown or static hold |

**5.FLUID LOSS APPARATUS**

The Fluid Loss Apparatus is a critical instrument used in the cementing laboratory to evaluate the filtration behavior of cement slurry. It helps determine the amount of water (filtrate) that escapes from the slurry when subjected to differential pressure, simulating its behavior in a permeable formation. Controlling fluid loss is essential to ensure slurry stability, maintain hydration, and prevent formation damage.

**Purpose and Function**

The main function of the fluid loss apparatus is to measure the fluid retention capacity of the cement slurry. It is used to test the effectiveness of fluid loss control additives and to ensure that the slurry will not dehydrate prematurely when pumped into porous formations.

**Working Principle**

* A fixed volume of cement slurry is poured into a pressurized cell, which contains a filter paper at the bottom.
* The cell is sealed and subjected to a constant pressure (usually 100 psi) using compressed air or nitrogen.
* As pressure is applied, water (filtrate) from the slurry passes through the filter paper and is collected in a graduated cylinder.
* The test is usually conducted for 30 minutes, and the volume of filtrate is measured.

**6.HIGH PRESSURE HIGH TEMPRATURE (HTPT CONSISTOMETER)**

The High Pressure High Temperature (HPHT) Consistometer is one of the most critical instruments in cement slurry testing. It is used to evaluate the thickening time of a cement slurry under simulated downhole conditions, where both pressure and temperature are elevated. The instrument plays a vital role in ensuring that the slurry remains pumpable long enough to be placed at the desired depth before setting begins.

**Purpose and Function**

The HPHT consistometer measures how the consistency of a cement slurry changes over time under controlled high-pressure and high-temperature conditions. The thickening time is the key output, which indicates the amount of time available for safe pumping and placement before the slurry sets.

**Working Principle**

* A prepared cement slurry is placed in a pressurized metal cell inside the consistometer.
* The cell is rotated at a standard speed (usually 150 rpm) to simulate movement during pumping.
* The slurry is subjected to simultaneous increases in temperature and pressure, replicating real downhole conditions (up to ~30,000 psi and ~600°F).
* A viscosity measuring device records the change in Bearden Consistency (Bc) over time.
* The point at which the consistency reaches 70 Bc is considered the end of thickening time (slurry is no longer pumpable).

**7.COMPRESSIVE STRENGTH TESTING MACHINE**

The Compressive Strength Testing Machine is used to determine the mechanical strength of hardened cement samples. It measures the load-bearing capacity of set cement when subjected to axial compressive force. This property is vital in oil well cementing, as the cement sheath must withstand various stresses after setting, including formation pressure, casing loads, and thermal expansion.

**Purpose and Function**

The purpose of this instrument is to quantify the compressive strength of cement after a defined curing period (typically 24, 48, or 72 hours). The results help engineers verify if the cement formulation meets the required structural and zonal isolation standards.

**Working Principle**

1. Cement slurry is poured into molds (usually 2-inch cubes or cylinders) and cured in a curing chamber under specific temperature and pressure conditions.
2. After curing, the hardened cement specimen is placed between the platens of the Universal Testing Machine (UTM) or compressive strength testing frame.
3. A gradually increasing axial load is applied to the specimen until it fails (cracks or shatters).
4. The maximum load at failure is recorded.
5. Compressive strength is calculated using the formula:

**Key Output Parameter**

| **Parameter** | **Description** |
| --- | --- |
| **Compressive Strength** | Maximum axial load a sample can withstand before failure, reported in **psi** or **MPa** |

**Applications in Cementing**

* Verifies that set cement can **withstand downhole pressure and casing loads**.
* Assesses the impact of **additives** such as silica fume, pozzolans, and weighting agents (e.g., Micromax).
* Helps compare performance of different **cement designs**.
* Determines **early strength development**, which is important when resuming drilling operations.

**CEMENT SLURRY PARAMETERS**

The cement slurry design plays a vital role in the success of oil well cementing operations. The key parameters include:

1. **Specific Gravity**
2. **Thickening Time**
3. **Fluid Loss / Filtration Loss**
4. **Free Water**
5. **Rheological Parameters**
6. **Compressive Strength**
7. **Stability**

**1.** **Specific gravity (Density of slurry)**

**Definition:**  
Specific gravity is the ratio of the density of the cement slurry to the density of water. It is a crucial parameter for ensuring proper displacement of drilling fluids and achieving zonal isolation.

**Measurement Tool:**  
***Mud Balance*** – provides accurate measurement of slurry weight (in lb/gal or g/cc).

**Importance:**

* Determines the **hydrostatic pressure** exerted by the slurry column.
* Ensures **effective displacement** of drilling mud.
* Helps in **balancing formation pressure** and preventing formation fluid influx.

**Design Guidelines:**

* The specific gravity of slurry is usually maintained **0.2–0.5 g/cc higher than the drilling mud**.
* It is controlled by adjusting **water-to-cement ratio** and using **weighting agents**.

**Measurement Tool:**  
*Mud Balance* – provides accurate measurement of slurry weight (in lb/gal or g/cc).

**2. Thickening Time**

**Definition:**  
Thickening time is the time period during which the cement slurry remains in a **pumpable or flowable state** under simulated wellbore conditions of **pressure and temperature**.

**Test Equipment:**  
*Consistometer* (Atmospheric or HPHT) is used to simulate wellbore conditions during testing

**Importance:**

* Ensures **sufficient time** for mixing, pumping, and placement of slurry.
* Prevents premature setting which can lead to **pumping failure** or incomplete placement.
* Excessive thickening time may lead to **gas migration** and **poor bonding**.

**Measurement Unit:**  
*Bearden Consistency (BC) units* – 100 BC is typically considered as the limit of pumpability.

**3. Fluid Loss / Filtration Loss**

**Definition:**  
Fluid loss refers to the **amount of water separated from the slurry** into the surrounding formation, especially before the slurry sets.

**Measurement Tool:**  
*HPHT Filter Press* – simulates downhole pressure and temperature to evaluate filtration behavior

**Importance:**

* Excess fluid loss leads to **slurry dehydration**, **poor bonding**, **plugging of annulus**, or **channeling**.
* Affects **compressive strength** and **durability** of the cement.

**Ideal Requirement:**  
Fluid loss should be controlled to **less than 50 ml in 30 minutes** for critical wells.

**4. Free Water**

**Definition:**  
Free water is the **amount of unbound water** that separates from the slurry when it is static before setting.

**Importance:**

* High free water can result in **gas migration**, **channel formation**, and **poor bonding**.
* Affects **slurry stability**, especially in deviated and horizontal wells.

**Test Procedure:**

* Slurry is poured in a **250 ml graduated cylinder**, kept vertical or inclined (for deviated well simulation).
* Left undisturbed for **2 hours** and the water collected on top is measured.

**Acceptance Criteria:**  
Free water should be **less than 1.5% by volume**.

**5. Rheological Parameters**

**Definition:**  
These parameters describe the **flow behavior of the slurry** and its ability to **carry cuttings**, **maintain suspension**, and **resist sagging**.

**Measured Using:**  
*Fann Viscometer* at various RPMs (600, 300, etc.)

**Importance:**

* Determines **pumpability**
* Influences **surge/swab pressure**
* Helps maintain **solid particle suspension**

**6. Compressive Strength**

**Definition:**  
Compressive strength measures the **mechanical strength** of set cement to **withstand downhole pressure and support the casing**.

**Test Method:**

* Prepare **2-inch cement cubes**.
* Cure under bottom-hole pressure and temperature for 8, 12, 16, and 24 hours.
* Measure strength using **compressive strength machine** or **ultrasonic methods**.

**Typical Requirement:**

* Minimum 500 psi in 24 hours for primary cementing.

**Importance:**

* Ensures **zonal isolation**
* Prevents **shear failure**, **micro-annulus formation**
* Supports **casing** and withstands **formation stresses**

**7. Stability**

**Definition:**  
Stability of a slurry refers to its ability to **maintain uniform distribution of solids** and avoid **sedimentation** or **phase separation** over time.

**Indicators of Unstable Slurry:**

* **Settling of particles**
* **Increase in free water**
* **Variation in specific gravity** between top and bottom

**Stability Criteria:**  
Specific gravity variation within the slurry must be ≤ **0.02–0.05 g/cc**.

**Importance:**

* Critical in **horizontal and deviated wells**
* Ensures **uniform compressive strength**
* Prevents **gas migration** and **channeling**