A REPORT ON

"QUALITY ASSESSMENT OF DIFFERENT CEMENTS IN NEPAL"

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CHANGUNARAYAN, BHAKTAPUR, NEPAL

26th January, 2023

ACKNOWLEDGEMENT

We, the group members, would like to express our special thanks of gratitude to our teachers, from the Department of Civil Engineering, Nepal Engineering College as well as to Pokhara University who gave us this golden opportunity to undertake this project. We would also like to thank, **H.O.D. of Civil Engineering Department, Assoc. Prof. Ramesh Khanal** sir for authorizing us to use the laboratories and our lab instructors **Mr. Bikash Shrestha** and **Mr. Prabhakar Bist** for navigating us through every experiment. This opportunity has helped us to be involved in research and it helped us to gain more knowledge.

This research for the project is a lesson to learn for the development of our self-skills and analysis. Furthermore, we would like to express our sincere gratitude to our Project Supervisor **Asst. Prof. Tejeshwini Singh** for guiding us for the research and a platform where we can express our findings.

Thank you,

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ABSTRACT

This report investigates the quality of various cement types in Nepal, analyzing key parameters by conducting thorough laboratory tests to evaluate factors like compressive strength, initial setting time, final setting time, fineness etc. By examining these parameters, the study aims to highlight and provide insights into the performance variation among different brands of cement available in the Nepalese market. It employs a comprehensive approach to access the quality of diverse cement products in Nepal. The findings of this report aim to aid industry professionals and construction firms in making informed decisions about the selection of cement, contributing to the enhancement of construction practices and infrastructure development in Nepal. The findings emphasize the dual importance of maintaining high-quality standards in cement production and recognizing the socio-economic role of the industry. A robust cement sector not only ensures the structural integrity of construction projects but also stimulates economic growth and job creation. The report encourages ongoing collaboration between regulatory bodies, manufacturers, and local communities to foster sustainable development, ensuring the cement industry contributes positively to Nepal's socio-economic landscape.

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CHAPTER 1

1 INTRODUCTION

1.1 GENERAL BACKGROUND

In the context of Nepal, cement is an important building material for both residential and commercial construction. Nepal has a large construction industry due to the country's ongoing development and rebuilding efforts following the 2015 earthquake. The demand for cement in Nepal has been increasing over the years and the country imports a significant amount of cement to meet the demand. The quality of cement produced in Nepal has been a concern in the past. However, the government has been working to improve the quality of cement by implementing stricter regulations and quality control measures. The government has also been encouraging the use of alternative building materials. The purpose of this report is to assess the quality of cements manufactured in Nepal and to identify any areas where improvements can be made. The report will focus on evaluating the chemical and physical properties of the cements, as well as their performance in various applications. The proposed solution is to conduct a thorough analysis of the cements and to provide varying information and compare the quality of the cements. This assessment will help to ensure that the cements manufactured in Nepal meet the necessary quality standards and to improve the quality of cements for the benefit of the construction industry in Nepal.

1.2 STUDY AREA

This study aims to conduct a comprehensive analysis of the quality of different cements in Nepal, recognizing the critical role of construction materials in the country's infrastructure development. The research was conducted in the urban and suburban regions of Kathmandu, Nepal. Primary location of interest with in the study area includes Mahalaxmisthan, Tokha, Dhapasi and Milanchowk, Mulpani. These sites were chosen for their construction sites as it was critical to understand the dynamic of cement usage pattern. These locations were chosen based on their significance and relevance to the study's objectives.

1.3 STATEMENT OF PROBLEM

The construction industry in Nepal relies heavily on cement as a vital building material, and it is essential that the cements used meet the necessary quality standards. However, there have been concerns about the quality of cements manufactured in Nepal, with reports of poor strength, poor durability, and other issues. This has led to a lack of confidence in the quality of cements manufactured in Nepal and raised concerns about the safety and durability of the structures built with these cements. The problem is that there is a need for a comprehensive assessment of the quality of cements manufactured in Nepal to identify any areas where improvements can be made and to ensure that the cements meet the necessary quality standards. This assessment will help to address the present quality of cements and ensure the safety and durability of the structures built with these cements, benefiting the construction industry and the general population in Nepal by improvising the quality of cement in future.

1.4 OBJECTIVES

The main objectives of this study were:

I. To analyze the samples to determine their chemical and physical properties.
II. To evaluate the performance and environmental impact of various cements.
III. To compare the results with the relevant standards and codes and verify if it meets the standards as claimed by the company or not.
IV. To study about socio-economic impact of cement in our society.

1.5 SIGNIFICANCE OF STUDY

After the completion of the study, the cements manufactured in Nepal will have multiple aspects and will impact various stakeholders in different ways. The study will evaluate the quality of cements, ensuring that they meet relevant standards and regulations and are safe for their intended use. This will help to protect consumers and ensure that they will get the value for their money.
Additionally, the study will provide valuable insights into the strengths and weaknesses of the cement manufacturing industry in Nepal, helping manufacturers to produce better-quality cements

and increase the competitiveness of the industry. The quality assessment of cements manufactured in Nepal will also help to support the development of high-quality and sustainable infrastructure in the country, as cement is a critical component in the construction of infrastructure, such as buildings, roads, and bridges. Moreover, the study will help to promote the export of these products to other countries, increasing international trade and supporting the country's economy. Overall, the study on the quality assessment of cements manufactured in Nepal will have far-reaching benefits for consumers, the industry, the economy, and the country as a whole.

1.6 LIMITATIONS

There were some limitations while doing the tests in the laboratory:

I. The room temperature affected the results of the tests and accurate result was not obtained.
II. The testing machines might have errors which caused inaccurate readings.
III. Some tests like compressive strength test were dangerous and require specialized equipment and training which increased the risk of accidents and injuries in the lab.
IV. Sample size of cement was very small that the test cannot be generalized due to varying results.
V. Honey comb formations during moulding of cement concrete led to inaccurate as well as unfair results for compressive strength test.
VI. Some tests were not possible to do smoothly or chronologically due lack of time.

CHAPTER 2

2.1 LITERATURE REVIEW

Cement is a fine powder made from a mixture of limestone, clay, sand, and iron ore. Cement alone is used as a grouting material but it is widely used in mortar and concrete. Mortar is cement mixed with sand or crushed stone that are less than 5mm in size. Concrete is a mixture of cement, sand or other fine aggregates. Cement is a crucial construction material in the construction industry. It is used to make a wide variety of structures, from buildings and bridges to roads and sidewalks.

Cement is manufactured from calcareous material, such as limestone or chalk, and of silica and alumina found as clay or shale. Manufacturing consists of grinding the raw materials into very fine powder, mixing them in suitable proportions and burning them in a large rotary kiln at a temperature of about 1400 degree centigrade (Mishra A.K., 2018) when the material melts and partially fuses into clinker. The clinker is cooled and after that it is ground to a fine powder, along with the addition of some gypsum, a resulting the product as the commercial Portland cement used throughout the world. The raw materials can be mixed and ground either in water or in a dry condition; hence giving the names wet and dry process. The mixture is fed into a rotary kiln. The kiln is slightly inclined. The mixture is fed at the upper end while pulverized coal is blown in by an air blast at the lower end of the kiln. When the mixture of raw materials moves down the kiln, it is progressively subjected to higher temperature as a result of which various chemical changes take place along the kiln: First being the water driven off and CO_2 is liberated from calcium carbonate. After Passing through a series of chemical reactions in the kiln, 20 to 30 percent of the dry material becomes liquid, and lime, silica and alumina recombine. (Mishra & Jha, 2019) The compounds are fused into balls of 3 to 25 mm in diameter and is known as clinker. Afterwards, the clinker drops into coolers. The cool clinker, which is very hard, is grinded with gypsum in order to prevent flash setting of the cement. The ground material is cement. The cement can be manufactured by dry process as well as wet process. In wet process, ground raw materials are mixed with water and are converted into slurry before burning in rotary kiln.

Cement is a material having adhesive and cohesive properties enabling it to form good bond with other materials. In concrete, cement is the main constituent which is the only active binding media and the only component scientifically controlled. Cement has the property of setting and hardening

by virtue of chemical reactions with water at normal temperature. Ordinary Portland Cement (OPC) is the most common type of cement in widespread use around the world because it is a basic ingredient of concrete and mortar. It is a fine powder produced by grinding Portland cement clinker (more than 90%) (Mishra A.K., 2018), a limited amount of calcium sulphate which controls the set time and up to 5% minor constituents. The OPC or the Ordinary Portland Cement is the most widely produced cement in Nepal. Also due to high consumption of cement, the production is also high which causes the increase in duration between manufacturing and use of the cement on construction work (Banstola Prabin, 2021).Infrastructure being the major indicator of development and the R.C.C structures being the most common, popular, easy and durable method of construction, demand of cement is increasing every year. Over the past few years, cement production has followed an upward trend in Nepal. Currently, 55 cement industries are in operation with an annual capacity of 15 million metric tons (Bank, N.R., 2021). Cement consumption in different sectors like household, bridges, dams, roads etc. showed increasing trend in cement consumption. Preference of suppliers of cement was not found to be associated with price of cement. Mostly, cement is used as a mortar in masonry, precast pipes and elements, pointing and plastering works and for different type of concreting the structural elements. It is manufactured through a controlled chemical combination of calcium, silicon, aluminum, iron and other ingredients in the required temperature. Chemical composition between the ingredients, their sufficiency and the temperature during its manufacturing process highly influences its consistency of strength development. Thus, the manufacturing process of different cements such as Ordinary Portland Cement (OPC), Pozzolana Portland Cement (PPC) and Portland Slag Cement (PSC) differs from each other as per their property related with their strengths. Based on the property of cement, they are used for different purpose in different places considering the climatic factors that affects the quality of cement (Mishra and Jha, 2019).

Cement is used as a binder or concrete while constructing various types of masonry. Portland cement concrete has clearly emerged as the material of choice for the construction in the world today. This is due to low cost of materials and construction for concrete structure as well as low cost of maintenance. Therefore, much advancement of Concrete technology has occurred depending on (i) the speed of construction (ii) the strength of concrete (iii) the durability of concrete and (iv) the environmental friendliness of industrial material like, fly ash, blast furnace slag, silica fume, metakaolin etc. (P.Ghosh, 2005)

The sieving method is a way to determine the fineness of cement by measuring the particle size distribution of the cement. The method involves passing a sample of cement through a set of sieves of different mesh sizes. A sieve is a device with a mesh or perforated surface that separates larger particles from smaller particles. The sieves used for fineness test of cement are usually made of stainless steel and have distinct size openings, typically ranging from 90 microns to 45 microns. (Mishra & Jha, 2019)

The consistency of cement is a measure of the wetness or plasticity of the cement paste. It is determined by measuring the amount of water required to produce a cement paste of standard consistency. The standard consistency is defined as the water content at which the cement paste can be molded into a ball of cement paste that will retain its shape without breaking or slumping. The Vicat's apparatus is method that can be used to determine the consistency or initial setting time of cement. The Vicat's apparatus consists of a cylindrical metal plunger that is inserted into the cement paste at a specific depth. The Vicat's apparatus is used to determine the consistency of cement by measuring the length of plunger dip. The initial setting time of cement is the time it takes for cement to start solidifying after water has been added to it. The initial setting time test is performed in order to determine the time at which the cement paste can no longer be molded and starts to stiffen. The test is used to ensure that the cement conforms to the specifications set by the Nepal Bureau of Standards and Metrology (NBSM). The initial setting time of cement is typically determined using a device called a Vicat's apparatus. The apparatus consists of a cylindrical metal needle that is inserted into the cement paste at a specific depth. The time is recorded when the needle comes into contact with the bottom of the cement paste and does not penetrate any further.

The compressive strength of cement is a measure of the ability of the cement to withstand loads that tend to compress it. The compressive strength test is typically performed on a cement sample that has been cured for a specific period of time, usually 3, 7, 28 days or longer. In Nepal, the compressive strength test is typically performed using a device called a compression testing machine or a universal testing machine. The machine consists of a loading frame, a loading platen, and a cylindrical specimen mold.

The soundness of cement is determined by measuring its ability to retain its original volume after being subjected to the cycles of expansion and contraction caused by the absorption and loss of moisture. (Chaudhari, 2018)

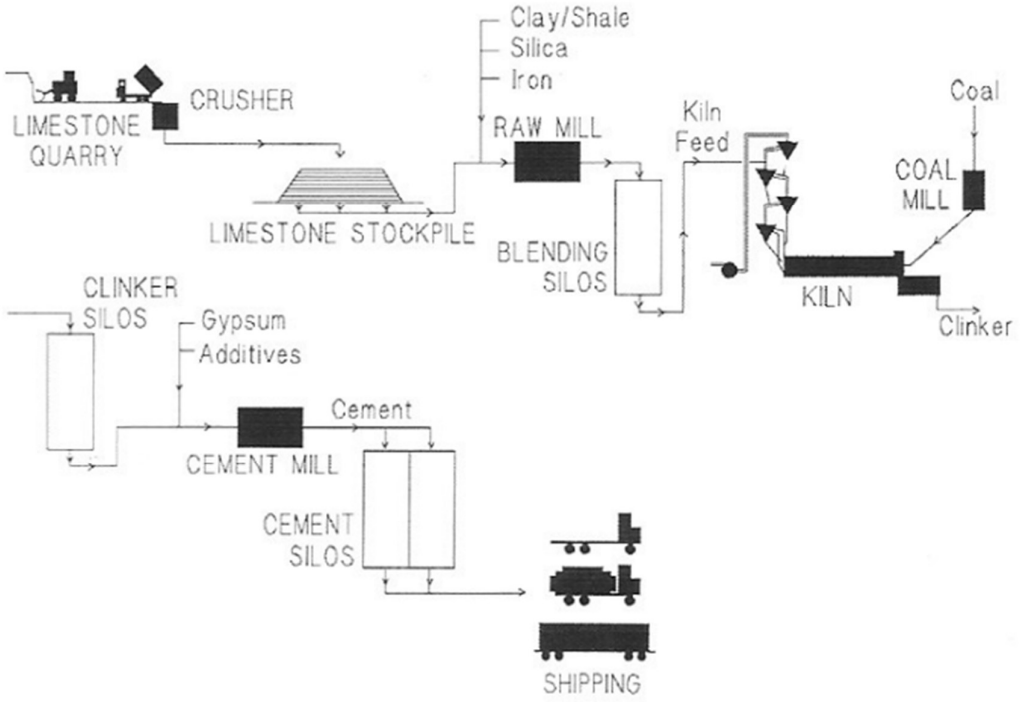

Figure 1: Manufacture process of cement in an industry (Pandey, 2008)

CHAPTER 3

3. METHODOLOGY

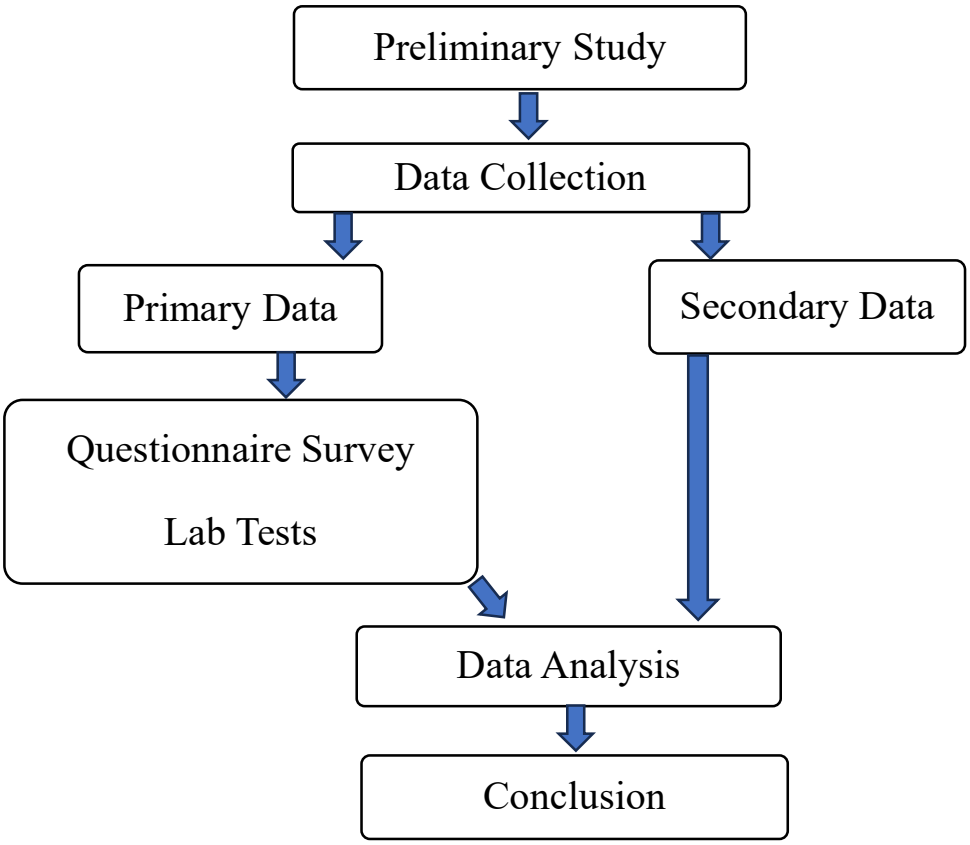

Figure 2: Framework of the project

The quality assessment of cement in Nepal is typically done through testing and analysis of physical and chemical properties of the cement. This includes tests such as the fineness test, the soundness test, the setting time test, and the compressive strength test. The tests were performed in accordance with the standards and specifications set by the Indian Standard (IS). The test results were then used to determine the compliance of the cement with the standards and to assess the overall quality of the cement. The testing and analysis were typically done in laboratory of our college.

3.1 PRELIMINARY STUDY

Initially while exploring this subject matter, the literature review was studied by analyzing and studying various research papers on the report related topic. Conducting a literature review helped to identify the gaps in our knowledge and to know and establish our own context. It helped to guide through the report by amplifying our knowledge. Literature review served as a crucial foundational step that shaped the direction of the report.

3.2 DATA COLLECTION

Data collection involved gathering information and observation through different research papers, internet and through performing different experiments and survey. For primary data, surveying was conducted in few construction sites, and also required experiments were performed and for secondary data internet was referred.

3.3 METHOD OF DATA COLLECTION

3.3.1 PRIMARY DATA

Primary data collection was started by conducting surveys and experiments.

- **SURVEY:**

  Survey in research is crucial for systematically gathering data from a sample population as it generates quantitative and qualitative data, enabling analysis, identification of trends and helps to draw a meaningful conclusion. The survey was conducted through written questionnaires made focusing cement usage and personal preference of people working in construction sites.

  Site Description: Different sites finalized for the survey were located in Mahalaxmisthan, Lalitpur, the other two were located at Milanchowk, Mulpani, one was located at Tokha and one was located at Dhapasi, Kathmandu.

➢ EXPERIMENTS:

We conducted laboratory tests on five different brands of 43 grade OPC cements including **Shivam cement, Huaxin cement, Arghakhanchi cement, United cement** and **Brij cement**. The tests which were performed are listed below:

I. Fineness Test

The fineness of cement was determined by sieve analysis of cement. Here, 100gm of cement was passed through a standard sieve of 90μm. The residue on sieve was calculated and the fineness is expressed as the percentage retained on the 90μm sieve.

II. Compressive Strength Test

First of all, cement concrete cubes were made using M20 concrete ratio(1:1.5:3). The compressive strength test for M20 grade concrete was done by preparing cube specimens of 15cm x 15cm x 15cm. The cubes were cured with water for 7 days and 28 days. After the curing period, the cubes were subjected to compressive loading using a testing machine until failure occurs. The maximum load at failure was recorded, and the compressive strength was calculated.

III. Consistency Test

For the consistency test of cement, Vicat apparatus with plunger was used. The cement paste was prepared by mixing a specific amount of cement with a defined water content. The Vicat plunger was then lowered into the paste, and the depth of penetration was measured. Consistency was determined by adjusting the water content until the penetration met the required 5-7mm from the bottom of the mould.

IV. Initial Setting Time Test

For the initial setting time of cement, Vicat apparatus with needle was used. The cement paste was prepared by mixing cement with a specified volume of water (i.e. 0.85 times the volume of water required for consistency of the cement). The time was recorded starting from adding the water while gauging the cement and the mould was filled under 3-5 mins.

The Vicat needle was then gently placed on the surface of the paste, and it was released until the reading showed 5-7 mm from the bottom of the mould. This process was repeated in every 10 mins gaping until 30 minutes and then, in 5 mins gaping afterwards. The initial setting time is the duration from the start of mixing until the cement paste resists penetration by the needle.

V. Final Setting Time Test

For the initial setting time of cement, Vicat apparatus with needle was used. The cement paste was prepared by mixing cement with a specified volume of water (i.e. 0.85 times the volume of water required for consistency of the cement). The time was recorded starting from adding the water while gauging the cement and the mould was filled under 3-5 mins. The final setting time is the moment when the needle makes no noticeable impression and the cement paste has gained sufficient strength to resist penetration. The sample was tested repeatedly under certain intervals. The time elapsed from the start of mixing until this point was recorded as final setting time of the cement.

VI. Specific Gravity Test

The specific gravity of cement was determined by using kerosene. 60gm of cement was weighed and poured very slowly in the Le-Chatelier flask after its initial reading was taken. After pouring, the final reading was taken, and specific gravity of the cement was determined by volumetric analysis.

3.3.2 SECONDARY DATA

The internet was referred for the secondary data. Here, different standards, product specification and technical data provided by the manufacturer was looked into to compare and discuss our own experimentally obtained data.

CHAPTER 4

4.1 DATA COLLECTION AND ANALYSIS

4.1.1. FINENESS OF CEMENT

For conducting the fineness test of cement, we used the sieve analysis method.

Mass of sample taken = 100gm

S/N	Sample	Mass of cement passing	% passing	% retained
1	Brij	90gm	90%	10%
2	Arghakhanchi	90gm	90%	10%
3	Shivam	94gm	94%	6%
4	Huaxin	94gm	94%	6%
5	United	94gm	94%	6%

Table 1: Fineness of cement

4.1.2. COMPRESSIVE STRENGTH TEST

Here in this test, we prepared specimen concrete of grade M20 of size 15cm x 15cm x15cm.

Figure 3: Compressive strength testing machine

Figure 4: Compressive strength test of cement concrete cube

S/N	Sample	Compressive Strength (7 days)
1.	United cement	9.33 N/mm^2
2.	Arghakhanchi cement	6.44 N/mm^2
3.	Brij cement	6.67 N/mm^2
4.	Shivam cement	11.11 N/mm^2
5.	Huaxin cement	17.556 N/mm^2

Table 2:Compressive strength

4.1.3. CONSISTENCY TEST OF CEMENT

In this test, the collected samples of cement were mixed with water to form a paste of standard consistency using Vicat's Apparatus with plunger.

S/N	Sample	Consistency
1.	United cement	28%
2.	Arghakhanchi cement	26%
3.	Brij cement	27%
4.	Shivam cement	31%
5.	Huaxin cement	26%

Table 3: Consistency of cement

4.1.4. INITIAL SETTING TIME TEST

The initial setting time is the time between the addition of water to the cement and the time at which the needle comes into contact with the bottom of the paste.

Figure 5: Initial setting time of cement

S/N	Sample	Initial setting time(min)
1.	United cement	45
2.	Arghakhanchi cement	45
3.	Brij cement	30
4.	Shivam cement	40
5.	Huaxin cement	30

Table 4: Initial setting time of cement

4.1.5. FINAL SETTING TIME TEST

The final setting time test for cement involved assessing the time taken for the cement paste to harden, indicating the end of the plastic state. The final setting time was determined when the needle's penetration stabilized.

Figure 6: Final setting time of cement

S/N	Sample	Final Setting Time
1.	United cement	9hr 46 min
2.	Arghakhanchi cement	8hr 55min
3.	Brij cement	9hr 25 min
4.	Shivam cement	9hr 30 min
5.	Huaxin cement	9hr

Table 5: Final setting time of cement

6. SPECIFIC GRAVITY

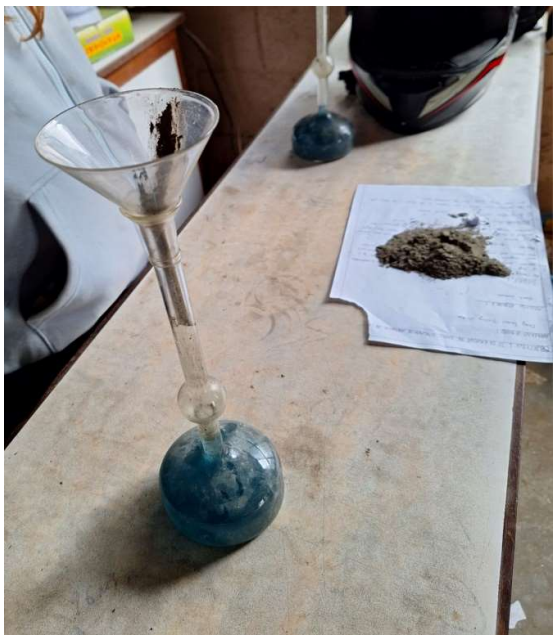

Figure 7: Specific gravity test

Mass of sample taken=60gm

S/N	Sample	Specific Gravity
1.	United cement	3.03
2.	Arghakhanchi cement	3.14
3.	Brij cement	2.99
4.	Shivam cement	3.15
5.	Huaxin cement	3.12

Table 6: Specific gravity of cement

7. SURVEYING

We prepared the questionnaire and went to different construction sites and meeting the respective personnels who have knowledge and practices to use cements. Some of the pictures of the sites we have visited are as below:

Figure 8: Site location (Mahalaxmisthan and Milanchowk, Mulpani), Cement: Shivam

Figure 9: Site location (Tokha, Kathmandu), Cement used: Arghakhanchi

Figure 10: Site location (Greenland, Dhapasi), Cement used: Shivam

Figure 11: Site location (Dhapasi, Kathmandu), Cement used: Sarbottam

CHAPTER 5

5.1 RESULT AND DISCUSSION

Tests	IS	Shivam	Arghakhanchi	Brij	United	Huaxin
Fineness % retained	10%	6%	10%	10%	6%	6%
Compressive Strength	(12-15)Mpa	11.11Mpa	6.44Mpa	6.67Mpa	9.33Mpa	17.556Mpa
Consistency	(25-30)%	31%	26%	27%	28%	26%
Initial Setting Time	(30-45)min	40min	45	30min	45min	30min
Final Setting Time	10hrs	9hr 30min	8hr 55min	9hr 25min	9hr 46min	9hr
Specific Gravity	3.1-3.25	3.15	3.14	2.99	3.03	3.12

Table 7: Comparison between IS and experiment

According to IS 4031 Part 1, the specific surface area should not be less than 3700 cm^2/g for 43 grade Ordinary Portland Cement (OPC). All samples meet the Indian standard, with percentages passing ranging from 90% to 94%.

According to IS 4031 Part 4, the consistency of cement paste should range between 25% to 30%. All samples fall within the recommended range, indicating suitable consistency and Shivam cement was having higher percentage of water content for consistency (i.e. 31%).

According to IS 4031 Part 5, it specifies that the initial setting time should not be less than 30 minutes for ordinary Portland cement. All samples meet the standard, with initial setting times ranging from 30 to 45 minutes. Based on the results obtained after series of tests of different cement, initial setting time of Brij cement and Huaxin cement was better among other cement brands (i.e. 30 minutes).

According to IS 4031 Part 5, it recommends a final setting time not exceeding 600 minutes for ordinary Portland cement. All samples comply with the standard, with final setting times ranging from 8hr 55min to 9hr 46min.

According to IS 4031 Part 11, it recommends a specific gravity between 3.10 to 3.25 for ordinary Portland cement. All samples fall within the specified range, meeting the Indian standard for

specific gravity. Among them, specific gravity of Shivam cement and Arghakhanchi cement was observed to be better.

For M20 grade concrete, a common approximation is to assume that the 7-day compressive strength is approximately 60-75% of the 28-day compressive strength. Using the characteristic 28-day compressive strength of M20 concrete as 20 N/mm² (as per IS 456:2000), the estimated 7-day compressive strength would be:

7-day compressive strength ≈ 0.60 * 20 N/mm² to 0.75 * 20 N/mm²

7-day compressive strength ≈ 12 N/mm² to 15 N/mm²

Since, the compressive strength of Shivam cement was very near to the standard value despite of having honeycomb formation in the cube. The compressive strength of United cement as well as Huaxin cement was also quite good. The compressive strength of Huaxin cement sample was greater than the standard values due to proper compaction of concrete mixture while molding the concrete cube and there was no any honeycomb formation.

The fineness, consistency, initial setting time, final setting time, and specific gravity of the cement samples generally met Indian standard codes. However, the compressive strength of some samples at 7 days is below the recommended value, suggesting a potential concern for early strength development. Continuous monitoring and additional tests over different curing periods is necessary for a comprehensive evaluation of cement quality. It's important to note that the interpretation of results may also depend on specific use cases and project requirements. Further analysis and consultation with relevant authorities or experts in the field are recommended for a thorough assessment.

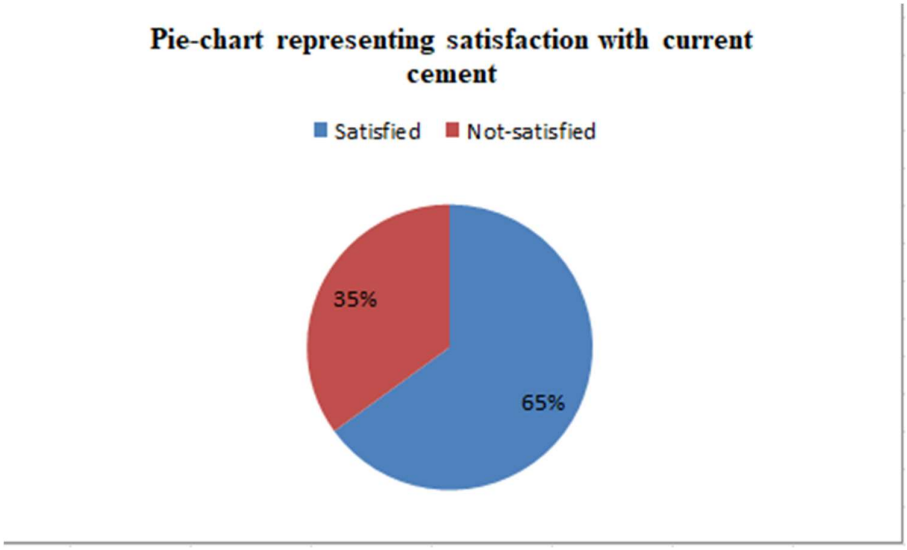

Figure 12: Pie-chart of consumer satisfaction

We had questionnaire survey about the socio-economic impact of cement on consumers. According to the data collected, about 65% of consumers were satisfied with the quality of cement they have used and about 35% of consumers are not satisfied at all. This study shows that some consumers have some concerns about the quality of cement as the cement companies are not publishing their company's standard codes about the quality of cement produced due to which there is still lack of transparency between the manufacturer and consumers.

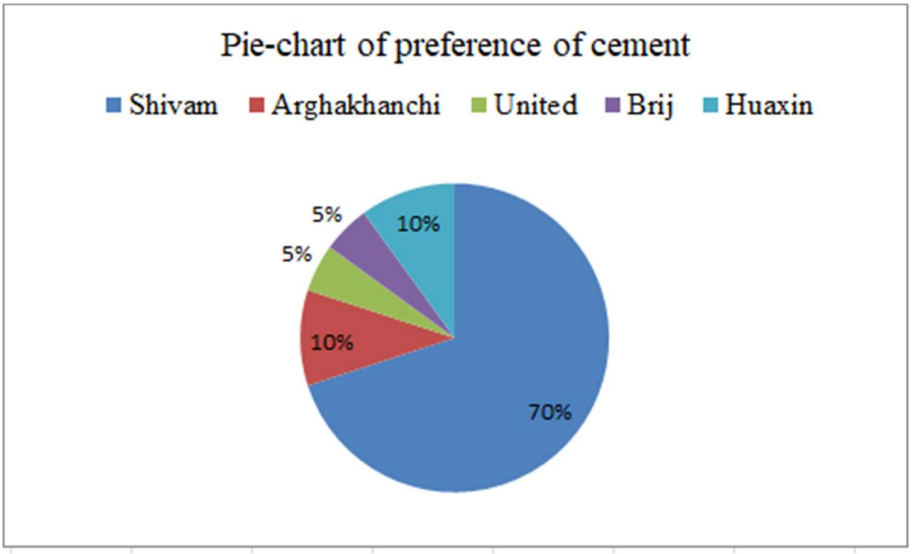

Figure 13: Pie-chart of preference of cement

According to the above pie-chart, Shivam cement was the most preferred cement brand in our study areas. As this cement has also shown some good results while testing in laboratory and it has gained much popularity for its quality delivery. About 70% of consumers preferred to Shivam cement whereas Arghakhanchi and Huaxin cement was the second most preferred brands with 10% each and United and Brij cement were the least preferred cement brand with only 5%. This variation is due to the use of Shivam cement in majority of sites as well as the quality trust that the people have in Shivam cement.

CHAPTER 6

6.1 CONCLUSION

The different cement brands were assessed and compared to obtain data with standard codes. The fineness test is crucial for evaluating the particle size distribution of cement. A higher fineness indicates better reactivity and strength development. Incomplete sieving during the test can lead to inaccurate results. Compressive strength is a fundamental indicator of cement performance in structural applications. Higher compressive strength suggests superior load-bearing capacity. Improper curing or specimen preparation can impact test accuracy. Also, the honey comb formation in cement cubes made a weak portion for failure. Assessing the initial setting time helps to determine the workability of cement in construction. Prompt setting is essential for proper handling and placement. Inconsistent temperature during testing can affect the setting time. The final setting time indicates when the cement has fully hardened. It is critical for determining the time available for construction activities. Ambient temperature fluctuations may influence the final setting time. Due to low temperature while doing tests, there was some fluctuations in final setting time. Consistency measures the ability of cement to retain its shape without excessive water. Adequate consistency ensures proper workability in construction. Variations in mixing technique can impact the consistency test results.

Regular quality assessments are essential to ensure the reliability and performance of cement in construction projects. Compliance with established standards, such as Nepal Standard or Indian Standard, is vital for consistent quality control. Collaboration with reputable suppliers and manufacturers is crucial to obtaining reliable cement with consistent properties. Ongoing monitoring and adjustments in the manufacturing process help maintain quality standards over time. Continuous research and development in cement technology contribute to the improvement of product performance and sustainability. It is important to note that the sources of error mentioned are not exhaustive, and attention to standard testing procedures is essential to minimize potential inaccuracies in the assessment of cement quality.

CHAPTER 7

7.1 RECOMMENDATIONS FOR FURTHER RESEARCH

1. Environmental Control and Standardization:
   Conduct tests in controlled environmental conditions to mitigate the impact of room temperature variations. Implement standardized temperature control protocols during testing to ensure consistent and reliable results.

2. Equipment Calibration and Maintenance:
   Regularly calibrate and maintain testing machines to minimize errors. Implement a robust quality control program for testing equipment, including periodic inspections and recalibrations.

3. Safety Protocols and Specialized Training:
   Develop and enforce strict safety protocols for hazardous tests like compressive strength testing. Provide specialized training for personnel handling such tests to reduce the risk of accidents and injuries. Invest in advanced safety equipment and technologies.

4. Optimal Sampling Strategies and Statistical Analysis:
   Increase the sample size to enhance the statistical validity of test results. Conduct a comprehensive statistical analysis to identify trends and patterns, ensuring that findings are representative and can be generalized with confidence.

5. Concrete Mix Design and Prevention of Defects:
   Implement meticulous concrete mix design and casting techniques to minimize honeycomb formations during molding. Explore innovative molding methods and materials to achieve a smoother surface, ensuring accurate and fair results in compressive strength tests.

6. Efficient Time Management and Sequential Testing:
   Allocate sufficient time for each test to ensure smooth and chronological execution. Develop a well-structured testing schedule, and consider the use of automation or streamlined processes where applicable to optimize time utilization without compromising accuracy.

7. Alternative Test Methods and Technology Integration:

   Investigate alternative testing methods that may be less time-consuming or resource-intensive. Explore emerging technologies that could streamline testing processes without compromising accuracy.

8. Collaboration and Knowledge Sharing:

   Foster collaboration with industry experts, research institutions, and regulatory bodies to exchange knowledge and best practices. Stay informed about advancements in testing methodologies and technologies to continually improve testing protocols.

9. Personnel Training and Availability:

   Ensure the availability of qualified personnel for surveying, site visits, and testing. Invest in training programs to enhance the skill set of personnel involved in cement quality assessment.

10. Documentation and Transparent Reporting:

    Thoroughly document testing procedures, environmental conditions, and any deviations encountered during the tests. Transparently report limitations and challenges faced during the research, including the availability of the right personnel during surveying or site visits, to facilitate a better understanding of the study's context.

    By addressing these consolidated recommendations, future research endeavors can enhance the reliability, safety, and overall effectiveness of cement quality assessment, overcoming the identified limitations.

APPENDIX I

STANDARD CODES:

Based on the following Indian standards, we have compared and analyzed our data from lab report.

The standard codes are as below:

1. IS 4031 Part 1
2. IS 4031 Part 4
3. IS 4031 Part 5
4. IS 4031 Part 11
5. IS 456:2000

APPENDIX II

QUESTIONNAIRES:

Survey on Cement Usage and Preference in Construction Projects

This survey aims to gather information about the user's preference and practices related to cement in construction projects.

Questionnaire:

1. Demographic information:
   a) Name:
   b) Occupation:
2. Usage Patterns and Brand Preferences:
   a) How frequently do you use cement in your projects?
      i) Regularly ii) Moderately iii) Rarely
   b) Are there any specific types of cement you prefer?
      i) Yes ii) No
   c) Are there any brands you prefer?
      ……..
   d) Among these cement brands which do you prefer?
      i) Shivam ii) Brij iii)Arghakhanchi iv) Huaxin v)United
   e) What brand do you reckon is cost-effective?
      ……
3. Quality and Standards:
   a) How important is the quality of cement in your project?
      i) Crucial ii) Significant iii) Insignificant
   b) Satisfaction with your current cement:
      i) Satisfied ii) Neutral iii) Dissatisfied
4. Social Impact:
   a) How familiar are you with the environment impact of cement production?
      i) Very familiar ii) Somewhat familiar iii) Not familiar at all
   b) In your opinion, should there be more emphasis on developing sustainable and socially responsible practices in cement industry?
      i) Definitely ii) Maybe iii) Not sure iv) Probably not
   c) To what extent do you think the socio-economic impact of cement production should be considered in regulatory decision?
      i) Very much ii) Somewhat iii) Not much iv) Not at all

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