Cost Effectiveness Assessment of Different Nepalese Cement Brands for Selected Sites of Supermarket

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Abstract

The cost of cement is very crucial for the effective construction of any project. Overall objective of this study is to assess the cost effectiveness of cement brands available for ongoing construction projects of Main Supermarket at Bhaktapur, Butwal and Biratnagar. Name of Project(Main) and Brands of Cement(M,Sa & S) are nominated only for Ethical standard though their permission ware taken. The cost difference among applied brands for those sites was evaluated based on design mix.

Magnesia oxide, insoluble residue, setting time and compressive strength properties were found to be different as claimed by the manufacturer in their cement certificates. The results of compressive strength test at 28 days showed that M, Sa and S cements have compressive strength of 55.20 MPa, 55.20 MPa, and 48.90 MPa respectively. These values helped to classify M and Sa cements in 53 – Grade & Class – E category whereas S cement in 43 – Grade & Class – D category. Furthermore, results of design mix showed that M and Sa cements could be adopted in the sites under study with minimum cement content of 340 kg/m³ for M20 and 375 kg/m³ for M25 concretes whereas S cement should be adopted with minimum cement content of 360 kg/m³for M20 and 400 kg/m³ for M25 concretes. Sa cement was found to be cheapest with estimated total cement cost of Nrs.52, 917, 177/- & Nrs.26, 710, 803/- or, estimated unit cost of Nrs.6,140/m³ & Nrs.5,548/m³ for Bhaktapur and Butwal sites respectively whereas, M cement was found to be cheapest for Biratnagar site with estimated total cement cost of Nrs.24, 956, 340/- or, estimated unit cost of Nrs.5,938/m³53 grade cement is cost effective in terms of quality, content and rate assessment so further grading of Ordinary Portland Cement should be done.

Keywords: Ordinary Portland cement, Design Mix, Cost, Grad

Background

Nepal as a developing country is facing many challenges for ensuring steady progress in its infrastructure development. After the massive earthquake that took place on 12th May – 2015; Nepal has set new standards for the construction of buildings. In cities like - Kathmandu, Biratnagar, Dharan, Butwal, Bhairawa, Nepaljung, etc. high rise buildings and commercial complexes are being built-up by following new standards set by the government authorities (Bhattarai & Mishra, 2017). Since, there are high numbers of occupants in these types of buildings, it is very necessary to keep the quality of construction in priority as well as the construction cost into consideration. For the commercial complexes like Main Supermarket, if the construction cost of the building can be minimized which is fixed cost then, these complexes could give cheaper and efficient services to their customers as their Break Even Point (BEP) would be lowered. Based
on recent trends of construction, cost effectiveness is one of the most focused competitive strategies of the industry. Cost effectiveness focuses on operation efficiency for reducing the cost while quality remain constant (Mishra & Regmi, 2017).

In the construction industry, the incurring cost mainly depends upon the construction materials, construction process and the manpower involved. It is noted that materials constitute a large percentage of the costs that go into the building production, claiming it occupies about 63% in relation to labor contribution of 37% in a typical traditional building construction. Since, materials constitute more than 60% of the total cost of the project; the material management is very effective in terms of saving the cost (Adeagbo & Kunya, 2003).

It is found that in domestic cement brands of Nepal the manufacturer have not labeled their cement product whether it is 33 grade or 43 grade or 53 grade. In most of the building construction projects in Nepal, the contractors do not conduct trial mix design and are applying available cement brands in same proportions as stated in nominal mix design to fulfill the strength requirement of concrete (e.g. M20 = 1:1.5:3, and M25 = 1:1:2). This type of concreting approach is indirectly increasing the cost of project in terms of cement cost.

Statement of the Problem

It is noted that for any building project 16.4% of the project’s cost depends on the price of cement, 12.3% on sand, 7.4% on aggregates, 24.6% on steel, 16.5% on furnishing materials like paint, tiles, bricks, and 22.8% on fittings (Singh & Marripoodi, 2016). For concreting works, the price of cement is very expensive in comparison with sand and aggregates. Cement is a complex material if it is not taken proper care then, its quality gets deteriorate with time and even gets as wastage when it comes in contact with moisture. Wastage of cement alone can over run the cost of the project. Therefore, the cost of cement is an important factor to be analyzed for the cost effective construction of any project.

Currently, in Nepal, there are numbers of cement manufacturers like – Ghorahi, Jagdamba, Hetauda, Udaypur cements, etc. Almost all are producing 43 grade cement and some are even producing 53 grade of cement. Till date for Ordinary Portland Cement, the Nepal Bureau of Standards and Metrology (NBSM) has ensured the quality of 33 grade only. There are no specific requirements proposed by the NBSM whether it is 43 or 53 grade which brings a dilemma for construction professionals while selecting a brand of cement. NBSM has not guaranteed any specific grading above 33 grades for OPC (Acharya, 2016).

So, irrespective of grading the cement manufacturers are only allowed to maintain the specific requirements needed by the 33 grade of cement. Hence, it is the major job of the professionals to decide based on the market competitiveness to ensure the quality of cement by conducting various tests needed and the cost analysis. A research highlighting the issues of the quality of cement and suitability of price has not been conducted on local level yet; so this study is focused to analyze the quality of the cement and for the suitability of the cement brand considering the cost. M, S and Sa cements have been analyzed in terms of their quality and suitability considering the cost as these three cement brands are only in construction practices in the case of Main Supermarket.

Research Objectives

The overall objective of the study was to assess the cost effectiveness of the applied cement brand for selected Main Supermarket sites with following specific objectives:-

- To analyze the effect of cement brands on minimum cement requirement per cubic meter for ensuring the required concrete strength.
- To compare the cost difference among the approved different cement brands and analyze the impact on the costs of construction of the selected Main Supermarket projects on the basis of design mix.

Literature Review

Chemical and Physical Properties of Cement

The cement to be used in construction must have certain given qualities in order to play its part effectively in a structure. When these properties lie within a certain range, the engineer is confident that in most of the cases the cement’s performance will be satisfactory. Also, based on these properties, it is possible to compare the quality of cement from different sources. The important chemical and physical properties of cement are given in table – 1.
A. Chemical and Physical Characteristics

1. Lime Saturation Factor (LSF)

The Lime Saturation Factor is a ratio of CaO to the other three main oxides. Applied to clinker, it is calculated as:

\[ \text{LSF} = \frac{\text{CaO}}{2.8\text{SiO}_2 + 1.2\text{Al}_2\text{O}_3 + 0.65\text{Fe}_2\text{O}_3} \]

Where, \( \text{CaO} = \text{Lime, SiO}_2 = \text{Silica, Al}_2\text{O}_3 = \text{Alumina and Fe}_2\text{O}_3 = \text{Iron oxide} \)

Often, this is referred to as a percentage and therefore multiplied by 100.

The LSF controls the ratio of alite to belite in the clinker. A clinker with a higher LSF has a higher proportion of alite to belite than a clinker with a low LSF. Typical LSF values in modern clinkers are 0.92-0.98 or 92% - 98% (Winter, 2005). The Lime saturation factor has a great role on the compressive strength of the cement. If this factor exceeds the margin (90-98%) then, large clusters of belite are present in the clinker that adverse the grinding of the clinker (Ibrahimi, Jamaa, Bagane, Ammar, Lecomte, & and Diliberto, 2015). According to Nepal Standard (N.S) and Indian Standard (I.S) the lime saturation factor can be in the range 0.66 – 1.02.

2. Alumina Modulus (AM)

It shows the factor or ratio or proportion of iron oxide and alumina. It was also called alumina ratio.

\[ \text{Alumina Modulus} = \frac{\text{Al}_2\text{O}_3}{\text{Fe}_2\text{O}_3} \]

Values of alumina ratio are in the range from 1.5 to 2.5. The AR determines the composition of liquid phase

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<table>
<thead>
<tr>
<th>S. No.</th>
<th>Characteristics</th>
<th>As Per 33 Grade</th>
<th>As Per 43 Grade</th>
<th>As Per 53 Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>LSF (Lime Saturation Factor)</td>
<td>0.66 - 1.02</td>
<td>0.66 - 1.02</td>
<td>0.66 - 1.02</td>
</tr>
<tr>
<td>2</td>
<td>AM (Alumina Modulus)</td>
<td>0.66 (min.)</td>
<td>0.66 (min.)</td>
<td>0.66 (min.)</td>
</tr>
<tr>
<td>3</td>
<td>Insoluble Residue (% Mass)</td>
<td>2% (max.)</td>
<td>2% (max.)</td>
<td>2% (max.)</td>
</tr>
<tr>
<td>4</td>
<td>Magnesia (% Mass)</td>
<td>5% (max.)</td>
<td>5% (max.)</td>
<td>6% (max.)</td>
</tr>
<tr>
<td>5</td>
<td>Sulphuric Trioxide (SO$_3$)</td>
<td>3% (max.)</td>
<td>3% (max.)</td>
<td>3% (max.)</td>
</tr>
<tr>
<td>6</td>
<td>Total Loss on Ignition %</td>
<td>4% (max.)</td>
<td>4% (max.)</td>
<td>4% (max.)</td>
</tr>
<tr>
<td>B.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Specific surface (CM$^2$/g)</td>
<td>225m$^2$/Kg. (min.)</td>
<td>225m$^2$/Kg. (min.)</td>
<td>225m$^2$/Kg. (min.)</td>
</tr>
<tr>
<td>2</td>
<td>Setting time (minutes)</td>
<td>Not less than 45 minutes</td>
<td>Not less than 30 minutes</td>
<td>Not less than 30 minutes</td>
</tr>
<tr>
<td></td>
<td>a</td>
<td>Initial setting time</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>Final setting time</td>
<td>Not less than 600 minutes</td>
<td>Not less than 600 minutes</td>
</tr>
<tr>
<td>3</td>
<td>Soundness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a</td>
<td>By le-chataller (MM)</td>
<td>10mm (max.)</td>
<td>10mm (max.)</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>By Auto clave (%)</td>
<td>0.8% (max.)</td>
<td>0.8% (max.)</td>
</tr>
<tr>
<td>4</td>
<td>Compressive Strength (N/mm$^2$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a</td>
<td>072±1hour; 3 days</td>
<td>16 MPa (min.)</td>
<td>23 MPa (min.)</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>168±1hours; 7 days</td>
<td>22 MPa (min.)</td>
<td>33 MPa (min.)</td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>672±4hours; 28days</td>
<td>33 MPa (min.)</td>
<td>43 MPa (min.)</td>
</tr>
</tbody>
</table>


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in the clinker, when it’s lower than 1.5 both oxides are present in their molecular ratios and therefore only tetracalciumaluminoferrite can be formed in the clinker; consequently, the clinker cannot contain tricalcium aluminate. This is the case called Ferrari-cement which is characterized by low heat of hydration, slow setting and low shrinking. A high alumina ratio together with a low silica ratio results among other things, in a fast setting of the cement; this requires the addition of a higher gypsum rate to control the setting time (Aldieb & Ibrahim, 2010). However, the limitation set by Nepal standard and Indian standard for Alumina modulus is minimum 0.66.

3. Insoluble Residue

Insoluble residue is a non – cementing material which is present in Portland cement. This residue material affects the properties of cement, especially its compressive strength. To control the non – cementing material in Portland cement, American Society for Testing and Materials (ASTM) allows the insoluble residue to be not higher than 0.75%. This limitation is much lower than the allowance provided by the British standard which is 1.5%. However, the limitation set by the Nepal standard and Indian standard is 2%. According to a research conducted on effect of insoluble residue on properties of Portland cement, the addition of the insoluble residue from 0.0% to 7.0% by weight in Portland cement found to not affect the normal consistency or setting times of cement but, the compressive strength of cement mortar was affected during the early age and the figure was also found to be reduced as the cement mortar was older. With 7.28% of insoluble residue in the mortar at 1 day, the compressive strength was reduced by 11.5%, but after 60 days, the strength of the same mortar was only reduced by 5.5% as compared to the control mortar. It was also found that the compressive strength of Portland cement mortar with insoluble residue provided by ASTM standard or British standard was still higher than the compressive strength of Portland cement mortar type I allowed by the standards. The limit of insoluble residue given by ASTM standard as 0.75 is rather low and can possibly be increased to 1.5% according to British standard, or even slightly higher, without significantly reducing the compressive strength of cement (Kiattikomol, Jaturapitakkul, & Tangpagasit, 2000).

4. Magnesia (MgO)

Magnesium hydroxide occupies more volume and puts stress on the hardened concrete. This leads to cracks in the concrete structure. As time goes by, these cracks grow deeper, causing leakages or irreparable damage to the structure. Magnesia is one of the major culprits behind late expansion cracks in concrete. Due to formation of expansion cracks in concrete due to volume expansion of magnesia, the durability of concrete will be very poor (Suvasan, 2013). MgO in excess of about 2% appears in the clinker as free MgO. MgO present 1-1.5% in clinker is a very good mineralizer and improves nodulation. If it is quenched it does not give expansion problems. Good nodules are always preferred in burning and it helps in improving cooling efficiency and there by recovering thermal energy from clinker. Within the kiln MgO increases the liquid phase and may therefore promote the formation of clinker minerals. However, too much MgO can increase the liquid phase to problematic amounts and cause excessive coating and even balling of the clinker. MgO at about 2-5% can improve the burn ability of raw mill, promote the absorption of free lime, increase the strength development of cement and shorten the setting time (Mahapatra, 2015).

5. Sulphuric Trioxide (SO3)

To control setting time effectively, cement needs a minimum amount of calcium sulfate, mostly in the form of gypsum added to the clinker. As per N.S and I.S, the maximum allowable SO3-content in the cement is 3% to prevent sulfate expansion. It was reported that increasing the SO3 content above 3.0% had negative effects on durability assessed by strength or expansion measurements (Hanhan, 2004).

6. Total Loss on Ignition (LOI)

Ignition loss (LOI) represents the % weight loss suffered by a sample of cement after heating to 900 – 1000°C (1650 – 1830°F). Any water bonded to hydrated cement particles is expelled above this temperature. The higher the LOI, the less strength the cement will develop. As an indicator it can be used to monitor and improve the quality of the final cement (Harrisson, 2016). N.S and I.S limit the LOI to maximum 4.0%.

7. Specific Surface Area (S.S.A)

Specific surface area of a porous material is defined as the surface area of pores per unit mass or per unit bulk volume of the porous material. For two materials with the same total pore volume, the material with fine pores has a much greater specific surface area than the material with large pores. It is given by the following equation:

\[
S.S.A = \frac{A_s}{V_b} \text{ or } S.S.A = \frac{A_s}{m}
\]

Where, \(A_s\) = total surface area of the pores, \(V_b\) = bulk volume of the material, and \(m\) = mass of the material (Aligizaki, 2006)

Cement fineness is expressed in terms of Particle Size Distribution (PSD) with residues (or passing) on reference sieves or by its specific surface area in Blaine. There are three methods commonly in use at present time to determine the S.S.A. They are Blaine Air Permeability Method, Lea...
and Nurse Air Permeability, and Wagner Turbidity Meter. Specific surface is expressed as the total surface area in square meters of all the cement particles in one kilogram of cement. The higher the specific surface area, the cement is said to be finer (Swenson & Evans, 1953). The size of a cement particle has an important effect on the rate at which it will hydrate when exposed to water. As it reacts, a layer of hydration product forms around the outside of the particle, separating the unreacted core of the particle from the surrounding water. As the layer grows thicker, the rate of hydration slows down. Therefore, a small particle will react much more quickly than a large particle (Thomas & Jennings, 2017).

8. Setting Time

Cement when mixed with water forms paste which gradually becomes less plastic, and finally a hard mass is obtained. In the process of setting, a stage is reached when the cement paste is sufficiently rigid to withstand a definite amount of pressure. The time to reach this stage is termed as setting time.

Setting time is divided into two parts:-

- **Initial Setting Time** – The time at which the cement paste loses its plasticity is termed as the initial setting time.
- **Final Setting Time** – The time taken to reach the stage when the paste becomes a hard mass is known as the final setting time.

For an OPC, the initial setting time should not be less than 30 minutes and final setting time should not be more than 600 minutes. In practice, the length of time for which a concrete mixture will remain plastic is usually more dependent on the amount of mixing water used and atmospheric temperature than on the setting time of cement (Gambhir, Concrete Making Materials-I: Cement, 2013).

9. Soundness

The change in the volume of hardened concrete due to delayed or slow hydration of free lime, magnesia and calcium sulfate present in cement is known as unsoundness. It causes undesirable stresses resulting in cracks. It is essential that concrete does not undergo a large change in volume after it has set. The tests for unsoundness are the Le Chateler and Autoclave tests. According to N.S and I.S, the expansion carried out should not be more than 10 mm in the Le Chatlier test and 0.8% in Autoclave test (Sinha, 2002).

10. Compressive Strength

Cement mortar cubes (1:3) having an area 5000 mm$^2$ are prepared and tested in compression testing machine. Standard sand (IS: 650) is used for the preparation of cement mortar. For OPC, the compressive strength at 3 days, 7 days and 28 days given by N.S and I.S is listed in the table - 2.

<table>
<thead>
<tr>
<th>Grade of Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class – A</td>
</tr>
<tr>
<td>(32.5 - 37.5 MPa)</td>
</tr>
<tr>
<td>Class – B</td>
</tr>
<tr>
<td>(37.5 - 42.5 MPa)</td>
</tr>
<tr>
<td>Class – C</td>
</tr>
<tr>
<td>(42.5 - 47.5 MPa)</td>
</tr>
<tr>
<td>Class – D</td>
</tr>
<tr>
<td>(47.5 – 52.5 MPa)</td>
</tr>
<tr>
<td>Class – E</td>
</tr>
<tr>
<td>(52.5 – 57.5 MPa)</td>
</tr>
<tr>
<td>Class – F</td>
</tr>
<tr>
<td>(57.5 – 62.5 MPa)</td>
</tr>
</tbody>
</table>

Grade of Concrete

Concrete is generally graded according to its compressive strength. The various grades of concrete as stipulated in IS: 456 - 2000 and IS: 1343 - 1980 are as follows:

a. Ordinary Concrete: M10, M15, M20
b. Standard Concrete: M25, M30, M40, M45,M50, M55
c. High Strength Concrete: M60, M65, M70, M75, M80.

The designation of concrete mix, the letter M refers to the mix and number specifies the characteristic strength of 150mm cubes at 28 days expressed in MPa (N/mm$^2$).

Workability

The property of concrete which determines the amount of useful internal work, necessary to produce full compaction is called workability. It is the amount of energy to overcome friction while compacting. It can also be defined as
the relative ease, with which concrete can be mixed, transported, molded and compacted (Srinivas, 2016).

Tests for Workability / Tests in Fresh Concrete

Among various tests that can be conducted to ensure the workability of fresh concrete, the Slump test is the most widely in practice in the construction field of Nepal.

i. Slump Test

Slump test indicates the behavior of a compacted concrete cone under the action of gravitational forces. The apparatus consist of a mould in the shape of a truncated metal cone, open at both ends. The internal diameter of the slump cone is 200 mm at the base, 100 mm diameter at the top and has a height of 300 mm. This device is usually provided with foot pieces and handles. Basically the procedure consists of filling the metal cone with concrete in three layers and each layer is compacted 25 times by a 16 mm rod. Thereafter, the metal cone is lifted, leaving the concrete sample behind, which slumps down by the action of gravity. Slump is measured from the highest point. The test is suitable only for concretes of medium to high workabilities (i.e. having slump values of 25mm – 125mm). It is limited to concretes with maximum size of aggregates less than 38 mm (Laskar, 2009).

Tests in Hardened Concrete

i. Compressive Strength

The strength of brittle materials like concrete are generally rated in terms of compressive strength. This is the amount of stress that the concrete can withstand before it cracks. It is the most important and useful properties of concrete. In most structural applications, concrete is employed primarily to resist compressive strength. Compressive strength is also used as qualitative measure of other properties of hardened concrete. The compressive strength of concrete is generally mean to 28 days strength and is determined by testing sample concrete cubes or cylinders of standard sizes made in laboratory or field or cores drilled from hardened concrete at site. Mathematically, it is expressed as Failure Load per unit area.

Design Mix of Concrete

Simply, the design mix is the process of selecting suitable ingredients of concrete and determining their relative quantities with the object of producing as economically as possible concrete of certain minimum properties, notably strength, durability, and a required consistency. The main objective of design mix is to lower the cost of concrete by avoiding the high cement content in selecting the mix proportions as because the cost of cement is several times higher than aggregates (Neville, 2011).

Methodology

Study Area

This research is limited to the computation and comparison of the reinforced concrete quantity of the Main Supermarket that were constructed in Butwal, Bhaktapur and Biratnagar The research was focused to assess the cement cost by comparing the cement in terms of their quality and price with the case of Main Supermarket. These three sites were selected on the basis of their locations (i.e. Western, Central & Eastern Regions of Nepal) so that if any variations in cement cost due to location arise it may be included in the research.

Figure No. – 1,2 and 3 are the three sites of Main Supermarket located at Butwal, Biratnagar and Bhaktapur having built up area 5,834 Square meters, 82,209 Square feet and 185,778 Square feet respectively.

![Figure 1. Main Supermarket, Butwal; (SBEC, 2017)](image-url)
Figure 2. Main Supermarket, Biratnagar; (SBEC, 2017)

Figure 3. Main Supermarket, Bhaktapur; (SBEC, 2017)
Study Population

M Cement, S Cement, Sa Cement confirming to NS 49:2041 (NBC101:1994, 2064), were selected as sample as these three brands of cements were only used by the Main Supermarket for its reinforced cement concrete (R.C.C) structures.

Table 3. Sample Size for Lab Tests

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Particulars</th>
<th>Nos.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cement Bags – 1 of each brand for 3 sites</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>Fine Aggregates - 20 sacks from each site</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>Coarse Aggregates - 20 sacks from each site</td>
<td>60</td>
</tr>
</tbody>
</table>

Fine and coarse aggregates used in the design mixes at lab were obtained from each selected sites under case study. Standard aggregate sampling technique was applied for the selection of coarse and fine aggregates. For this research, the sample of cement used for design mix was obtained from the manufacturer. Two types of design mixes with varying cement content for M20 and M25 concretes from three brands of cement for each site were made at lab and their results were analyzed.

Table 4. Sample Size for Key Informant Interview

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Particulars</th>
<th>Nos.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lab Technician – Multi Lab</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Contractor’s Project Manager – 1 of each site</td>
<td>3</td>
</tr>
</tbody>
</table>

Purposive sampling technique was applied to conduct Key Informant Interview of project managers – 1 of each site and of lab technician of Multi lab who was involved in lab tests.

Method of Data Collection

The required data were collected from two sources:

a. Primary source
   - Experimental results were obtained from lab tests and from sites: - Various tests such as Magnesia oxide, insoluble residue, setting time and compressive strength of cement were conducted at lab on selected brands of cement to evaluate the qualitative properties of cement. Reports of compressive strength test were also collected from sites to analyze the quality of concrete being achieved at sites. Experimental results that were obtained from lab tests and from sites.
   - Key informants interview who were involved in the construction period at sites: - A set of questionnaire was prepared for the key informants. Then, the key informant interview was conducted by purposive sampling method among project managers of each site and lab technician of Multi lab to know about the quality of concrete, inventory of cement and its management process.

a. Secondary source
   - Literature review: - Various publications, reports and standard codes set by Nepal and India related with the research objectives were studied and reviewed. The publications, reports, and standard codes were taken from libraries and internet.

Lab Tests

Tests on Cement

i. For Chemical Properties
   a) Magnesia Oxide (MgO)

In this test method, magnesium was precipitated as magnesium ammonium phosphate from the filtrate after removal of calcium. The precipitated was ignited and weighed as magnesium pyrophosphate. The MgO equivalent was then
calculated.
MgO (%) = W \times 72.4

b) Insoluble Residue

The insoluble material is an inactive part of cement. It was determined by stirring 1 gram of cement in 40ml of water and then 10ml of concentrated hydrochloric acid (HCl) was added. The mix was boiled for 10 minutes. Any lump, if present, was broken and the solution was filtered. The residue on filter was washed with disodium trioxide (Na$_2$O$_3$) solution, water and HCl in the given order and, finally, again with water. The filter paper was dried, ignited, and weighed to give an insoluble residue. The minimum the residue, the better is the cement (ASTM:C114-07, 2007).

1. For Physical Properties

a) Setting Time of Cement

i) Initial Setting Time

• The test block was confined in the mould and rested on the non-porous plate, under the rod bearing the needle.
• The needle was lowered gently until it came in contact with the surface of test block and then was released quickly allowing it to penetrate into the test block.
• In the beginning the needle completely pierced the test block. This procedure was repeated after every 2 minutes until the needle failed to pierce the block for about 5mm measured from the bottom of the mould. This time was noted as $t_2$.

ii) Final Setting Time

• For determining the final setting time, the needle of the Vicat’s apparatus was replaced by the needle with an annular attachment.
• The time ($t_3$) was recorded when the annular attachment failed to make an impression on the surface of the test block.

iii) Results

Initial setting time=$t_2-t_1$
Final setting time=$t_3-t_1$

Where,

$t_1$=Time at which water was first added to cement
$t_2$=Time when needle failed to penetrate 5 mm to 7 mm from bottom of the mould
$t_3$=Time when the needle made an impression but the attachment failed to do so (IS:4031(Part-5)-1988, 2002).

b) Compressive Strength

Cement mortar cubes (1:3) having an area 5000mm$^2$ were prepared (i.e. Nine cubes of each brand of cement) and tested in compression testing machine. The compressive strength at 3 days, 7 days and 28 days were found out.

Procedure:

• 200 grams of cement and 600 grams of standard sand (i.e. 200 grams of Grade – 1, Grade – 2 and Grade – 3) were mixed thoroughly.
• (P/4)+3)% of water was added to the dry mix of cement and sand, (where P = % of water that was required for preparing paste of standard consistency). It was mixed thoroughly for a minimum of 3 minutes to obtain a mix of uniform color.
• The mould was filled with entire quantity of mortar using a suitable hopper attached to the top of the mould and was vibrated it for 2 minutes at a specified speed of 12000±400 per minute to achieve full compaction.
• The mould was removed from the machine and was kept in a place with temp of 27±2°C and relative humidity of 90% for 24 hours.
• At the end of 24 hours; the cubes were removed from the mould and submerged in fresh clean water. The cubes were taken out of the water only at the time of testing (i.e. at 3, 7 & 28 days).
• The load was applied steadily and uniformly, starting from zero at a rate of 35 N/mm$^2$/minute until the cube was not broken (IS:4031(Part-6)-1988, 2002).

Tests in Fresh Concrete

i. Slump Test

The test was carried out with a mold called the slump cone. The slump cone was placed on a horizontal and non-absorbent surface and was filled in 3 equal layers of fresh concrete, each layer being tamped 25 times with a standard tamping rod. The top layer was struck off level and the mold was lifted vertically without disturbing the concrete cone. The subsidence of concrete in millimeters so obtained was termed as the slump. After test, when the concrete slump evenly all around was called true slump (Gambhir, Properties of Fresh Concrete, 2013).

Procedure of Design Mix

• Target mean strength for mix design was taken as:

The target mean compressive strength at 28 days is given by,

$$f_t = f_{ck} + t.s$$

Where $f_{ck}$ is the characteristic compressive strength at 28 days, $t$ is the time when the needle made an impression but the attachment failed to do so (IS:4031(Part-5)-1988, 2002).
where, \( f_{ck} \) = required characteristic compressive strength
\( t = 1.65 \)
\( s \) = standard deviation obtained from table – 3.4 of approximate contents given after design mix.

### Table 5. Assumed Standard Deviation

<table>
<thead>
<tr>
<th>Grade of concrete</th>
<th>Assumed Std. deviation (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M20, M25</td>
<td>4</td>
</tr>
</tbody>
</table>


- Water cement ratio was selected as:

The table – 3.5 below given by IS: 456 – 2000 for minimum cement content and maximum water – cement ratio for different grades of concrete was followed.

### Table 6. Minimum Cement Content

<table>
<thead>
<tr>
<th>Min. Cement Content (Kg/m³)</th>
<th>Maximum Water - Cement Ratio</th>
<th>Min. Grade of Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>0.55</td>
<td>M20</td>
</tr>
<tr>
<td>300</td>
<td>0.5</td>
<td>M25</td>
</tr>
</tbody>
</table>


- Water content in the mix was selected as:

For maximum nominal size of aggregate (e.g. 20mm) = 186 kg/m³ is the maximum amount of water content per cubic meter of concrete from IS: 10262 – 2009 Table – 2.

In the experiment that was conducted, the mix was designed for the pump able concrete having maximum nominal size of aggregate 20mm, the slump value ranging from 110mm to 120mm with maximum water content = 170 kg/m³.

- Entrapped air was estimated as:

From IS: 10262 – 1982 Table – 3, entrapped air = 2% for maximum nominal size of aggregate 20 mm.

- Cement content was determined as:

The cement content was calculated from water – cement ratio and the final water content was arrived after adjustment.

Cement content = mass of water/ (water/cement ratio).

- Coarse and fine aggregates were determined as:

\[ V = \left( \frac{W + C}{S_{fa} + (1/P) \times (fa/Sfa)} \right) \times \frac{1}{1000} \]

\[ Ca = \left( \frac{1-P}{P} \right) \times fa \times \left( \frac{Sca}{Sfa} \right) \]

Where,

\[ Ca = \text{total masses of coarse aggregate/kg.} \]

\[ fa = \text{total masses of fine aggregate/m³} \]

\[ C = \text{mass of cement} \]

\[ W = \text{mass of water} \]

\[ P = \text{ratio of fine aggregate to total aggregate by absolute volume} \]

\[ Sfa, Sca = \text{specific gravity of saturated surface dry fine and coarse aggregate.} \]

- Then, the concrete mix proportions for the first trial mix were determined.

- Trial mixes with suitable adjustments were done till the final mix proportions were arrived at (Raj & Ilakkiya, 2014).

### Tests in Hardened Concrete

i. Compressive Strength Test

- Total 54 sets of cubes of dimension (150 mm X 150 mm X 150 mm) were made for M20 concrete (i.e. 18 cubes were made from 3 brands of cements for each different cement contents of 320 kg/m³, 340 kg/m³ & 360 kg/m³).

- Similarly, another total 54 sets of cubes were made for M25 concrete (i.e. 18 cubes were made from 3 brands of cements for each different cement contents of 360 kg/m³, 375 kg/m³ & 400 kg/m³).

- The concrete was poured in the mold and tempered properly so as not have any voids. After 24 hours, these molds were removed and test specimens were submerged in water for curing.

- Specimens were tested by compression testing machine after 7 days and 28 days curing.

- Weights of each specimen were noted before testing.

- The load was applied without shock and continuously increased at the rate of approximately 140 kg/mm² per minute until no further load was borne by the specimen.

- The maximum load that was applied to the specimen divided by the cross – sectional area of specimen means the compressive strength of concrete.

- Average of 3 values was taken as the representative of the batch provided. (I.S:516-1959, 2002).

### Cost Analysis

Cost analysis was done into two parts as:

a) Based on location of sites: - From the interview of project manager the total cement cost of each sites were found. The total cement cost includes the factory cost and the transportation cost. First of all, the factory cost of cement per (50 kg.) bag was tabulated in table – 4.4 which includes the rate with excise duty and VAT per bag. Then, the transportation cost to site from factory was tabulated.

b) Based on estimated concrete quantities of sites: -
Again, from the interview of project manager estimated concrete quantities of each site were found and tabulated. Finally for all three sites; the comparison of cement cost between Sa, M and S cements were done.

**Average Mean Compressive Strength of Concrete Cubes At Sites**

Compressive strength reports were collected from all selected sites; i.e. Five test reports for M20 and M25 from all three sites. The average of 28 days compressive strength for all three sites was tabulated. The average mean of 28 days compressive strength tabulated was calculated for each site.

Average Mean \(a\) = , where \(a = \text{average mean of 28 days compressive strength}, \sum x = \text{sum of all the values}, n = \text{numbers of values}, \text{and } x = \text{expected 28 days compressive strength at field.} \)

If \(a \geq x\) then, the strength would be achieved by concretes at field condition.

**Table 7. Research Matrix**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Objective</th>
<th>Data Collected</th>
<th>Source of Information</th>
<th>Interpretation &amp; Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>To analyze the effect of cement brands on minimum cement requirement per cubic meter for ensuring the required strength.</td>
<td>Cement certificates from manufacturer were collected and quantitative requirement of cement content (Kg/m3) were obtained by design mix to access the concrete requirement using selected cement brands.</td>
<td>Cement certificates issued by the manufacturer, trial mixes in lab.</td>
<td>Experimental and quantitative analysis. Variation in cement content was observed.</td>
</tr>
<tr>
<td>2</td>
<td>To compare the cost difference among the approved different cement brands and analyze the impact with the case study of selected projects on the basis of design mix.</td>
<td>Quantitative requirement of cement in bags needed to cast the estimated R.C.C quantity of the project were calculated and Total cost of the cement for the project were analyzed based on their quality and quantity.</td>
<td>Purposive sampling technique was conducted among Project Managers of each site.</td>
<td>Quantitative analysis was done and the results were compared and assessed.</td>
</tr>
</tbody>
</table>

**Results and Discussion**

Sa, M, and S cements were analyzed at laboratory. Design mix of M20 and M25 concretes were trailed by varying the cement content and the cubes were tested in lab at an interval of 7 days and 28 days.

**Comparison Based on Cement Properties**

Chemical & physical properties were compared and listed in table – 8.
The presence of Magnesia oxide in all three brands of cement were found to be within the safe limit allowed by NS and I.S specifications from table – 1 (i.e. max. 5% for 33 and 43 grades, and max. 6% for 53 grade). Among these three brands of cements, M cement was found to have magnesia oxide 1.65% by weight of cement which was below 2%. Though, the presence of magnesia oxide in these three cements were not more than 5% as allowed by N.S and I.S specifications, it is better and safer to choose the cement having lower magnesia oxide content as because the magnesia is one of the major culprit behind late expansion cracks development in concrete. Sa and S cements were found to have MgO content 3.20% and 2.72% respectively which was found to be above 2% so, both cements were found to have free lime.

It was found that the presence of insoluble residue in these three cements was within the safe limit allowed by N.S and I.S specifications from table – 2.2 (i.e. max 2%). The minimum the presence of insoluble residue, the cement is said to be better. So, M cement was found to be better in comparison with Sa and S cements as its presence was lower than other two cements (i.e. M =0.34%, Sa = 0.75% and S = 0.61%).

Initial setting time of these three cements was found to be much higher than that specified by N.S and I.S specifications from table – 2.2 (i.e. min. 45 minutes for 33 grade and 30 minutes for 43 and 53 grades). Initial setting time of S, Sa and M cements was found to be 2.36, 1.25 and 1.20 hours respectively. During the field inspection of Main Supermarket construction sites, it was found that the contractor had been using the concrete pump to pump the concrete from mixture hopper to the area of placement. The concrete were easily placed in the required area within an hour of mixing the cement with water. Hence, both Sa and M cements were found to be preferable to Main Supermarket sites in comparison with S cement based on the nature of their work.

Final setting time of these three cements was again found to be within the safe limit allowed by N.S and I.S Specifications (i.e. max. 10hrs). Comparison of these three cements showed that final setting time of M and Sa cements were almost same (i.e. 4.35& 4.50 hours). It was found to be almost 1 hour quicker than the S cement having final setting time of 5.30 hours. Hence, both cements were found to be preferable in accordance with S cement for Main Supermarket sites as because the construction period of Main Supermarket was found to be very short and the contractor have to allocate extra budget for their formworks if final setting was not quicker.

Comparison of compressive strength analysis showed that these three cements have passed the N.S Specification of 33 grade. But according to I.S specifications from table – 1 and table – 2., M and Sa cements were found to be of 53 grade and in Class – E category whereas S cement was found to be of 43 grade and in Class – D category.

Table 8. Comparison Based On Cement Properties

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Particulars</th>
<th>Sa Found at lab</th>
<th>Claimed by Company</th>
<th>S Found at lab</th>
<th>Claimed by Company</th>
<th>M Found at lab</th>
<th>Claimed by Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chemical Characteristics</td>
<td>3.20%</td>
<td>4.65%</td>
<td>2.72%</td>
<td>2.12%</td>
<td>1.65%</td>
<td>2.25%</td>
</tr>
<tr>
<td>a.</td>
<td>Magnesia oxide (% by mass)</td>
<td>3.20%</td>
<td>4.65%</td>
<td>2.72%</td>
<td>2.12%</td>
<td>1.65%</td>
<td>2.25%</td>
</tr>
<tr>
<td>b.</td>
<td>Insoluble residue (% by mass)</td>
<td>0.75%</td>
<td>1.28%</td>
<td>0.61%</td>
<td>1.07%</td>
<td>0.34%</td>
<td>1.69%</td>
</tr>
<tr>
<td>2</td>
<td>Physical Characteristics</td>
<td>1.25 hours</td>
<td>2.32 hours</td>
<td>2.36 hours</td>
<td>2.30 hours</td>
<td>1.20 hours</td>
<td>1.30 hours</td>
</tr>
<tr>
<td>a.</td>
<td>Initial setting time</td>
<td>4.50 hours</td>
<td>3.50 hours</td>
<td>5.30 hours</td>
<td>3.50 hours</td>
<td>4.35 hours</td>
<td>3.35 hours</td>
</tr>
<tr>
<td>b.</td>
<td>Final setting time</td>
<td>072±1hour; 3 days</td>
<td>28.04 MPa</td>
<td>38.10 MPa</td>
<td>26.75 MPa</td>
<td>34.28 MPa</td>
<td>30.40 MPa</td>
</tr>
<tr>
<td>c.</td>
<td>Compressive Strength (MPa)</td>
<td>168±1hours; 7 days</td>
<td>38.10 MPa</td>
<td>46.80 MPa</td>
<td>35.71 MPa</td>
<td>40.63 MPa</td>
<td>40.70 MPa</td>
</tr>
<tr>
<td></td>
<td>672±4hours; 28days</td>
<td>55.20 MPa</td>
<td>60.80 MPa</td>
<td>48.90 MPa</td>
<td>51.07 MPa</td>
<td>55.20 MPa</td>
<td>55 MPa</td>
</tr>
</tbody>
</table>

(Lab Tests, 2017)
The results of compressive strength test conducted at lab for three brands of cements having constant source of aggregate, sand and chemical for each different site showed that for M20 grade of concrete all three cement brands passed the targeted mean strength at 28- days i.e. 26.60 MPa; with the minimum cement content 340kg/m$^3$. It was found that for M20 concrete, the compressive strength of cubes made by S cement with minimum cement content 340kg/m$^3$ at controlled environment of lab just satisfied the targeted mean strength at 28days with the every site under case study. It was found that in order to minimize the risk factor of concrete failure at site conditions, if S cement is to be applied in selected sites under case study, the minimum cement requirement should be 360kg/m$^3$ whereas for Sа and M both could be applied with minimum cement content 340kg/m$^3$ to achieve M20 concrete.

**Table 9. Results of Design Mix Obtained from Lab for M-20 Grade of Concrete**

<table>
<thead>
<tr>
<th>Name of Cement</th>
<th>7-days compressive strength (N/mm$^2$)</th>
<th>28-days compressive strength (N/mm$^2$)</th>
<th>Targeted Mean Strength at 28-days (N/mm$^2$)</th>
<th>Saturated Surface Dry Weight (Kg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bhaktapur</td>
<td>Biratnagar</td>
<td>Butwal</td>
<td>Bhaktapur</td>
</tr>
<tr>
<td>Sa OPC</td>
<td>20.00</td>
<td>20.44</td>
<td>20.30</td>
<td>25.78</td>
</tr>
<tr>
<td>S OPC</td>
<td>18.07</td>
<td>18.81</td>
<td>17.78</td>
<td>25.19</td>
</tr>
<tr>
<td>M OPC</td>
<td>20.59</td>
<td>20.74</td>
<td>20.89</td>
<td>25.93</td>
</tr>
<tr>
<td>Sa OPC</td>
<td>21.04</td>
<td>23.85</td>
<td>22.07</td>
<td>29.78</td>
</tr>
<tr>
<td>S OPC</td>
<td>19.70</td>
<td>20.23</td>
<td>19.41</td>
<td>27.41</td>
</tr>
<tr>
<td>M OPC</td>
<td>22.67</td>
<td>23.26</td>
<td>23.04</td>
<td>30.22</td>
</tr>
<tr>
<td>Sa OPC</td>
<td>23.26</td>
<td>23.33</td>
<td>23.11</td>
<td>30.81</td>
</tr>
<tr>
<td>S OPC</td>
<td>22.07</td>
<td>22.08</td>
<td>22.59</td>
<td>29.48</td>
</tr>
<tr>
<td>M OPC</td>
<td>23.85</td>
<td>23.88</td>
<td>23.26</td>
<td>30.96</td>
</tr>
</tbody>
</table>

The results of compressive strength test conducted at lab for three brands of cements having constant source of aggregate, sand and chemical for each different site showed that for M20 grade of concrete all three cement brands passed the targeted mean strength at 28- days i.e.26.60 MPa; with the minimum cement content 340kg/m$^3$. It was found that for M20 concrete, the compressive strength of cubes made by S cement with minimum cement content 340kg/m$^3$ at controlled environment of lab just satisfied the targeted mean strength at 28days with the every site under case study. It was found that in order to minimize the risk factor of concrete failure at site conditions, if S cement is to be applied in selected sites under case study, the minimum cement requirement should be 360kg/m$^3$ whereas for Sa and M both could be applied with minimum cement content 340kg/m$^3$ to achieve M20 concrete.

**Table 10. Results of Design Mix Obtained from Lab for M-25 Grade of Concrete**

<table>
<thead>
<tr>
<th>Name of Cement</th>
<th>7-days comp. strength (N/mm$^2$)</th>
<th>28-days comp. strength (N/mm$^2$)</th>
<th>Targeted Mean Strength at 28-days (N/mm$^2$)</th>
<th>Saturated Surface Dry Weight (Kg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bhaktapur</td>
<td>Biratnagar</td>
<td>Butwal</td>
<td>Bhaktapur</td>
</tr>
<tr>
<td>Sa OPC</td>
<td>22.67</td>
<td>23.04</td>
<td>22.81</td>
<td>30.37</td>
</tr>
<tr>
<td>S OPC</td>
<td>23.41</td>
<td>22.07</td>
<td>21.93</td>
<td>29.19</td>
</tr>
<tr>
<td>M OPC</td>
<td>23.41</td>
<td>23.56</td>
<td>23.26</td>
<td>30.96</td>
</tr>
<tr>
<td>Sa OPC</td>
<td>26.07</td>
<td>27.11</td>
<td>26.96</td>
<td>34.22</td>
</tr>
<tr>
<td>S OPC</td>
<td>25.33</td>
<td>25.26</td>
<td>25.48</td>
<td>32.59</td>
</tr>
<tr>
<td>M OPC</td>
<td>27.11</td>
<td>28.30</td>
<td>27.26</td>
<td>34.37</td>
</tr>
<tr>
<td>Sa OPC</td>
<td>29.93</td>
<td>30.00</td>
<td>29.63</td>
<td>36.74</td>
</tr>
<tr>
<td>S OPC</td>
<td>28.44</td>
<td>28.59</td>
<td>27.56</td>
<td>35.26</td>
</tr>
<tr>
<td>M OPC</td>
<td>30.81</td>
<td>30.87</td>
<td>29.48</td>
<td>37.33</td>
</tr>
</tbody>
</table>

Again from the lab test results for M25 grade of concrete, it was found that all three cement brands passed the targeted mean strength at 28 – days i.e. 31.60 MPa with minimum cement content 375kg/m$^3$. It was found that for M25 concrete, the compressive strength of cubes made by S cement with minimum cement content 375kg/m$^3$ at lab environments
was very close and had nearly attained the targeted mean strength at 28 days for all the selected sites under case study. Hence, again to minimize the risk factor of concrete failure at site conditions, the minimum cement content for S cement should be 400kg/m$^3$ if applied otherwise, Sa and M cements could be applied with minimum cement content 375kg/m$^3$ for M25 concrete.

Analysis of Cement Cost

Comparison of Cement Costs Based on Site’s Location

The cost analysis of cement including the excise duty, value added tax (VAT) and transportation cost to the site showed the following results for the construction sites taken into consideration.

Table 11. Cement Cost According to the Location of Sites

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Rate With Excise Duty And VAT Per Bag (50kg)</th>
<th>Transportation Cost To Site From Factory Per Bag (50kg)</th>
<th>Total Cement Cost To Site Per Bag (50kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bhaktapur</td>
<td>Biratnagar</td>
<td>Butwal</td>
</tr>
<tr>
<td>Sa</td>
<td>700.00</td>
<td>700.00</td>
<td>700.00</td>
</tr>
<tr>
<td>S</td>
<td>760.00</td>
<td>760.00</td>
<td>760.00</td>
</tr>
<tr>
<td>M</td>
<td>750.00</td>
<td>775.00</td>
<td>750.00</td>
</tr>
</tbody>
</table>

From table-1 and table – 8, it was also found that though S cement if of 43 grade, the price of S cement was higher than other cements in the market. It is due to the good marketing strategies of the marketing team of S cement and the customers are unaware about the grade of cements.

Total Cost Analysis of Cement

a) The estimated concrete quantities of Main Supermarket sites were found and then, total cemen Main Supermarket – Bhaktapur: - The required concrete quantities of M20 & M25 were 708.95m$^3$ and 7,909.49m$^3$ respectively. To cast these concrete quantities 64,142 bags of cement were estimated if M or Sa cement is adopted whereas 68,380 bags of cement were estimated, if S cement is adopted. The difference in cement bags was 4,238.

b) Main Supermarket – Biratnagar: - The required concrete quantities of M20 & M25 were 323.10m$^3$ and 3,789.48m$^3$ respectively. To cast these concrete quantities 31,293 bags of cement were estimated if M or Sa cement is adopted whereas 33,362 bags of cement were estimated, if S cement is adopted. The difference in cement bags was 2,068.

Main Supermarket – Butwal: - The required concrete quantities of M20 & M25 were 433.30m$^3$ and 4,381.19m$^3$ respectively. To cast these concrete quantities 35,805 bags of cement were estimated if M or Sa cement is adopted whereas 38,169 bags of cement were estimated, if S cement is adopted. The difference in cement bags was 2,363.

it was found that factory cost of Sa cement was the cheapest one i.e. Nrs.700/- per sack whereas factory cost of S and M were nearly equal with Nrs.760/- and Nrs.750/- respectively per sack for Bhaktapur and Butwal sites. The price of M cement for Biratnagar site was found to be highest i.e. Nrs.775/- per sack. The increment of Nrs.25/- per sack was found because in eastern region the M cement has captured its market and there were no other cement brands to compete with. It was also found that even though there was increment of Nrs.25/- per sack; in eastern region total cement cost was still lowest due to transportation cost in comparison with Sa and S cement with the case of Biratnagar site under study i.e. Nrs.797.50/- per sack.

Similarly, the total cement cost of Sa cement was found to be lowest including excise duty, VAT and transportation cost for Bhaktapur and Butwal sites with price Nrs.825/- per sack and Nrs.746/- per sack respectively.
the cost of cement to construction sites and the cost difference was tabulated in the above table – 11. From table – 11, it was found that Sa cement is cheapest for Bhaktapur and Butwal sites with estimated cement cost of Nrs.52,917,177.65/- and 25,613,497.63/- respectively whereas M cement is cheapest for Biratnagar site with estimated cement cost of Nrs.26,710,803.48/-. For Bhaktapur site, if M cement was used in case of Sa then the cement cost would have been raised by Nrs.1,667,692/- and if S cement was used then the cement cost would have been raised by Nrs.4,864,225/-. Similarly, for Biratnagar site the cement cost would have been raised by Nrs.1,667,692/- and by Nrs.2, 400,662/- if Sa and S cements were used instead of M. Similarly, for Butwal site the cement cost would have been raised by Nrs.3, 544,731/- and by Nrs.5, 160,546/- if M and S cements were used instead of Sa cement.

Average Cost Analysis of Cements

Based on estimated total quantities of concretes and cements, costs of cement per cubic meter applicable to sites were found and comparisons were done.

From table – 12, it was found that Sa cement was cheapest for Bhaktapur and Butwal sites with estimated cement cost Nrs.6,140/- per m$^3$ & Nrs.5,548/- per m$^3$ respectively whereas M cement was cheapest for Biratnagar site with estimated cement cost Nrs.6,094/- per m$^3$.

The cost difference was also found for each site as:

- For Bhaktapur site, the cost differences with respect to Sa were Nrs.193.50/- per m$^3$ and Nrs.564.40/- per m$^3$ if M and S cements were used.
- For Biratnagar site, the cost differences with respect to M were Nrs.156.37/- per m$^3$ and Nrs.571.23/- per m$^3$ if Sa and S cements were used.
- For Butwal site, the cost differences with respect to M were Nrs.736.26/- per m$^3$ and Nrs.1,071.88/- per m$^3$ if Sa and S cements were used.

<table>
<thead>
<tr>
<th>Name of Site</th>
<th>Cost Of Cement To Construction Sites Per Cubic Meter</th>
<th>Cost Difference Per Cubic Meter From Chosen Brand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sa</td>
<td>M</td>
</tr>
<tr>
<td>Main Supermarket - Bhaktapur</td>
<td>6,139.99</td>
<td>6,333.50</td>
</tr>
<tr>
<td>Main Supermarket - Biratnagar</td>
<td>6,094.70</td>
<td>5,938.33</td>
</tr>
<tr>
<td>Main Supermarket - Butwal</td>
<td>5,548.00</td>
<td>6,284.26</td>
</tr>
</tbody>
</table>

Table 11. Comparison of Total Cement Cost Based on Estimated Cement Quantities

<table>
<thead>
<tr>
<th>Name of Site</th>
<th>Total Cost Of Cement To Construction Sites</th>
<th>Total Cost Difference From Chosen Brand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sa</td>
<td>M</td>
</tr>
<tr>
<td>Main Supermarket - Bhaktapur</td>
<td>52,917,177.65</td>
<td>54,584,870.52</td>
</tr>
<tr>
<td>Main Supermarket - Biratnagar</td>
<td>25,613,497.63</td>
<td>24,956,340.08</td>
</tr>
<tr>
<td>Main Supermarket - Butwal</td>
<td>26,710,803.48</td>
<td>30,255,534.77</td>
</tr>
</tbody>
</table>

Table 12. Average Cost Analysis of Cements
Conclusion

1. The grade of cement was found to be the key factor on cement content requirement for ensuring the required concrete strength in terms of quality. M and Sa cements were found to be less in consumption in terms of weight per cubic meter than S cement in order to attain the same quality of concrete.

2. Based on 28 days compressive strength results of design mixed concrete, the minimum cement requirement per cubic meter were found with the selected brand of cements. i.e. M and Sa cements were found to have minimum cement content of 340kg/m³ & 375 kg/m³ whereas S cement was found to have minimum cement content of 360 kg/m³ and 400 kg/m³ for M20 and M25 concretes respectively. This showed that M and Sa were two cement brands that would be economical than S cement for Main Supermarket project under case study.

3. Based on total cost of cement by adding factory cost and transportation cost, it was found that for Biratnagar site M cement was economical while Sa cement was found to be economical for Butwal and Bhaktapur site.

4. It was found that Sa cement was cheapest for Bhaktapur and Butwal sites with estimated cement cost Nrs.6,140/- per m³ & Nrs.5,548/- per m³ respectively whereas M cement was cheapest for Biratnagar site with estimated cement cost Nrs.6,094/- per m³.

5. Though S cement was of 43 grade the market price of cement was costlier than Sa and M which were of 53 grade.

6. Design mix technique was found to be adopted by the contractor of Main Supermarket projects. It was also found that a cement management process of their own had been developed and adopted at sites when the cement handling behavior at their sites were analyzed. Only the lacking part was that the warehouse of cement needed to be upgraded and the curing technique was not proper.

7. Project managers were found to be aware about the design mix technique and the consequences of change in sources of sand, aggregates, and admixtures. But, the quality control technique for concrete was found to be satisfactory at sites since there was no batching plant for effective control in mixing of ingredients of concrete.

Acknowledgements

We are thankful to respondents, project owner, Lab staff and Cement manufacturer without their support it could not have been completed.

References


33. Raj N, Iliakkiya D. (2014). masterbuilder.co.in. Retrieved from...


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Appendix

Appendix – A2/1

Calculations

For M20 Design Mix, Cement Content = 320 kg/m$^3$, Slump Value = 120 mm, where,

a) Target mean strength at 28 days for M20 concrete is given by

$$F_t = f_{ck} + t.s$$

$$= 20 + 1.65 \times 4$$

$$= 26.60 \text{ N/mm}^2$$

Where, $F_t$ = target mean strength of concrete at 28 days

$f_{ck}$ = required characteristic compressive strength

$t = 1.65$ and $s = \text{assumed standard deviation from table 3.6 for M20 concrete}$

b) Test data required:

1) Specific gravity of cement = 3.15 Kg/m$^3$
2) Specific gravity of fine aggregate = 2.638 Kg/m$^3$
3) Specific gravity of coarse aggregate = 2.694 Kg/m$^3$
4) Specific gravity of water = 1.00 Kg/m$^3$
5) Specific gravity of super plasticizer = 1.20 Kg/m$^3$

c) Mass of water = w/c x cement content

$$= 0.531 \times 320$$

$$= 170\text{kg/m}^3$$

d) Volume of water = mass of water/ specific gravity of water

$$= (170/1)$$

$$= 170\text{dm}^3/\text{m}^3$$

e) Mass of admixture = 0.6% x mass of cement content

$$= (0.6/100) \times 320$$

$$= 1.92\text{kg/m}^3$$

f) Volume of admixture = mass of admixture/specific gravity of super plasticizer

$$= 1.92/1.2$$

$$= 1.6\text{dm}^3/\text{m}^3$$

g) Volume of cement = mass of cement/specific gravity of cement

$$= 320/3.15$$

$$= 101.59\text{dm}^3/\text{m}^3$$

h) Volume of total all in aggregate = ((Total volume - 2% of entrapped air) x 1000) - (volume of water + volume of admixture + volume of cement)

$$= ((1-0.02) \times 1000) - (170 + 1.6 + 101.59)$$

$$= 980-273.19 \text{dm}^3/\text{m}^3$$

$$= 706.81\text{dm}^3/\text{m}^3$$

i) Volume of coarse aggregate = volume of total all in aggregate x 60% x specific gravity of coarse aggregate

$$= 706.81 \times 0.6 \times 2.694$$

$$= 1142\text{kg/m}^3$$

j) Volume of fine aggregate = volume of total all in aggregate x 40% x specific gravity of fine aggregate
Appendix – A3/1

Calculations

For M25 Design Mix, Cement Content = 360 kg/m$^3$, Slump Value = 110 mm, $w/c = 0.472$ where, $w/c =$ water cement ratio

a) Target mean strength at 28 days for M25 concrete is given by

$$F_t = f_{ck} + t.s$$

$$= 25 + 1.65 x 4$$

$$= 31.60 \text{ N/mm}^2$$

Where, $F_t =$ target mean strength of concrete at 28 days

$f_{ck} =$ required characteristic compressive strength

$t = 1.65$ and $s = 4;$ assumed standard deviation from table 3.6 for M25 concrete

b) Test data required:

- Specific gravity of cement = 3.15 Kg/m$^3$
- Specific gravity of fine aggregate = 2.638 Kg/m$^3$
- Specific gravity of coarse aggregate = 2.694 Kg/m$^3$
- Specific gravity of water = 1.00 Kg/m$^3$
- Specific gravity of super plasticizer = 1.20 Kg/m$^3$

c) Mass of water

$$= w/c \times \text{cement content}$$

$$= 0.472 \times 360$$

$$= 170 \text{kg/m}^3$$

d) Volume of water

$$= \frac{\text{mass of water}}{\text{specific gravity of water}}$$

$$= \frac{170}{1}$$

$$= 170 \text{dm}^3/\text{m}^3$$

e) Mass of admixture

$$= 0.72\% \times \text{mass of cement content}$$

$$= 0.72/100 \times 360$$

$$= 2.592 \text{kg/m}^3$$

f) Volume of admixture

$$= \frac{\text{mass of admixture}}{\text{specific gravity of super plasticizer}}$$

$$= 2.592/1.2$$

$$= 2.16 \text{dm}^3/\text{m}^3$$

g) Volume of cement

$$= \frac{\text{mass of cement}}{\text{specific gravity of cement}}$$

$$= 360/3.15$$

$$= 114.3 \text{dm}^3/\text{m}^3$$

h) Volume of total all in aggregate

$$= (\text{Total volume - 2\% of entrapped air} \times 1000) - (\text{volume of water + volume of admixture + volume of cement})$$

$$= ((1-0.02) \times 1000) - (170 + 2.16 + 114.3)$$

$$= 980 - 286.46 \text{ dm}^3/\text{m}^3$$

$$= 693.54 \text{ dm}^3/\text{m}^3$$

i) Volume of coarse aggregate

$$= \frac{\text{volume of total all in aggregate} \times 60\% \times \text{specific gravity of coarse aggregate}}{}$$

$$= 693.54 \times 0.6 \times 2.694$$
\[ j) \text{ Volume of fine aggregate} = \text{volume of total all in aggregate} \times 40\% \times \text{specific gravity of fine aggregate} \\
= 693.54 \times 0.4 \times 2.638 \\
= 732\text{kg/m}^3 \]

**Appendix – A3/3**

**Calculations:**

For M25 Design Mix, Cement Content = 400kg/m\(^3\), Slump Value = 110mm, where,

a) Target mean strength at 28 days for M25 concrete is given by

\[ F_t = f_{ck} + t.s \]
\[ = 25 + 1.65 \times 4 \]
\[ = 31.60 \text{ N/mm}^2 \]

Where, \( F_t \) = target mean strength of concrete at 28 days
\( F_{ck} \) = required characteristic compressive strength
\( t = 1.65 \) and \( s = 4 \); assumed standard deviation from table 3.6 for M25 concrete

b) Test data required:
1) Specific gravity of cement \( = 3.15 \text{ Kg/m}^3 \)
2) Specific gravity of fine aggregate \( = 2.638 \text{ Kg/m}^3 \)
3) Specific gravity of coarse aggregate \( = 2.694 \text{ Kg/m}^3 \)
4) Specific gravity of water \( = 1.00 \text{ Kg/m}^3 \)
5) Specific gravity of super plasticizer \( = 1.20 \text{ Kg/m}^3 \)

c) Mass of water \( = w/c \times \text{cement content} \)
\( = 0.425 \times 400 \)
\( = 170\text{kg/m}^3 \)

d) Volume of water \( = \text{mass of water/ specific gravity of water} \)
\( = (170/1) \)
\( = 170\text{dm}^3/\text{m}^3 \)

e) Mass of admixture \( = 0.72\% \times \text{mass of cement content} \)
\( = (0.72/100) \times 400 \)
\( = 2.88\text{kg/m}^3 \)

f) Volume of admixture \( = \text{mass of admixture/ specific gravity of super plasticizer} \)
\( = 2.88/1.2 \)
\( = 2.40\text{dm}^3/\text{m}^3 \)

g) Volume of cement \( = \text{mass of cement/ specific gravity of cement} \)
\( = 400/3.15 \)
\( = 126.98\text{dm}^3/\text{m}^3 \)

h) Volume of total all in aggregate of admixture + volume of cement \( = ((\text{Total volume} - 2\% \text{ of entrapped air} \times 1000))-(\text{volume of water} + \text{volume of cement}) \)
\( = ((1-0.02) \times 1000) - (170 + 2.40 + 126.98) \)
\( = 980-299.38 \text{dm}^3/\text{m}^3 \)
\( = 680.62\text{dm}^3/\text{m}^3 \)

i) Volume of coarse aggregate \( = \text{volume of total all in aggregate} \times 60\% \times \text{specific gravity of coarse aggregate} \)
j) Volume of fine aggregate

\[
\text{Volume of fine aggregate} = \text{volume of total all in aggregate} \times 40\% \times \text{specific gravity of fine aggregate}
\]

\[
= 680.62 \times 0.4 \times 2.638
\]

\[
= 718 \text{kg/m}^3
\]