Expertise
and insight
for the future

Susan Shrestha

Proper Mixing of C25 Concrete and Strength Test

Metropolia University of Applied Sciences

Bachelor of Engineering

Sustainable Building Engineering

Bachelor's Thesis

11 March 2019

Author Title Number of Pages Date	Susan Shrestha Proper Mixing of C25 Concrete and Strength Test 38 11 March 2019
Degree	Bachelor of Engineering
Degree Programme	Civil Engineering
Professional Major	Sustainable Building Engineering
Instructors	Sunil Suwal, Jorma Säteri, Head of Department

The purpose of this bachelor's thesis was to highlight the needs of caution during concrete mix to overcome all possible disputes and failures in concrete mixing. The project aimed at delivering important steps necessary to be taken during and after concrete mixing process to achieve quality concrete.

To set up the background for the study, a literature review on concrete, cement, aggregates, admixtures, a trial mix was carried out. This review highlighted the importance of proper mix design, concrete element properties, concrete properties, the influence of admixtures on concrete and the importance of compressive strength test. Three different trials mix for C25 concrete grade were carried out in concrete lab. The amount of water in the trials was fixed as well as same aggregates were used for all three trials. The major component of concrete i.e. cement, aggregates were tested before the trials mix. After the concrete mix the specimens were tested on 7th and 28th day to find out the compressive strength of concrete mix.

Three different strength of C25 concrete were achieved as a result of trials. One trials failed to meet the Mean targeted strength of C25 concrete whereas two trials achieved Mean targeted strength. The failure in one trial shows that even following proper caution there might still be some factor that might affect the concrete strength. Therefore it shows the importance of proper concrete mix.

From three different results received, the graph was obtained which shows the correlation between compressive strength and water/cement ratio. This graph can be used to predict the strength of C25 concrete in different water/cement ratio. The thesis can be also used as a proper guideline for any concrete mixes as the thesis has summarized the importance of different test and steps to be taken before and after the concrete mix.

Keywords	C25, Concrete, Mix trials, Compressive strength test

List of Abbreviations

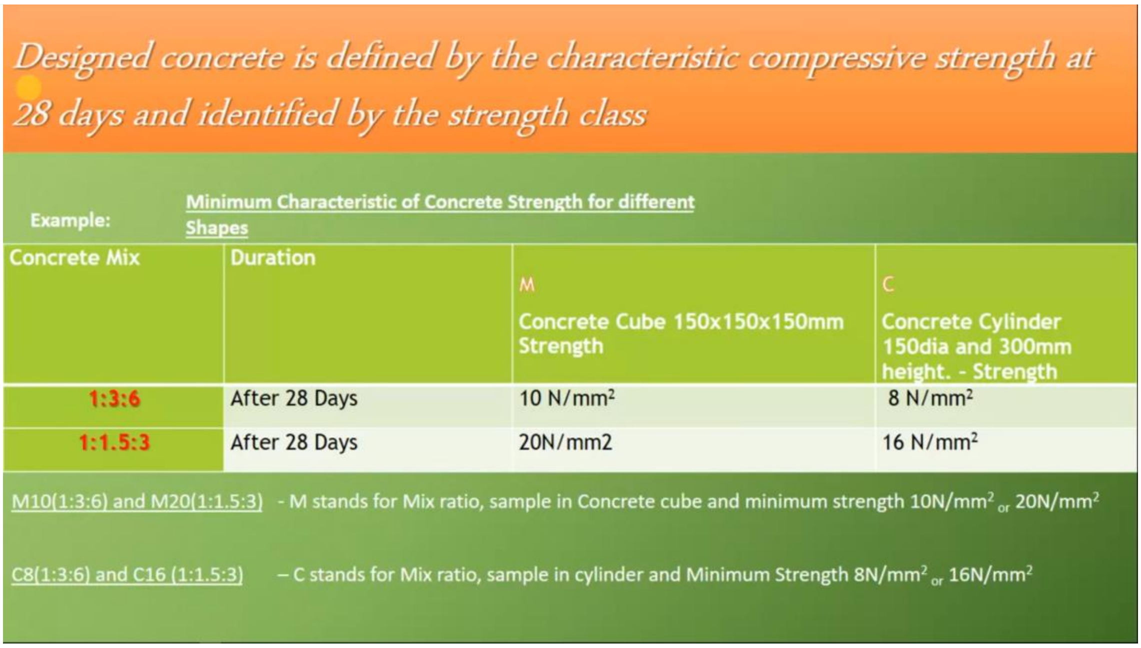
ASTM	American Society for Testing and Materials
BS	British Standard
C3S	Tricalcium Aluminate
SSD	Bulk specific gravity
ACI	American Concrete Institute

Contents

1 Introduction

The primary objective of this thesis is to provide information on the proper mixing process of C25 grade concrete, to be used as a guideline for concrete mixing. Concrete is a mixture of three components: water, cement and aggregates. The cement paste hardens through a chemical reaction called hydration, and gains strength. The quality of the cement paste generally determines the characteristics of the concrete. The hydration between cement and water makes the concrete harden. The complete hardening of concrete takes 28 days after casting. The strength of concrete is calculated in grades which also refer to the resistance of concrete against a certain compressive force. [1.]

There are different concrete grades, for example, M10, M20, M30, and M40 but there is also the conventional grading of concrete where the strength of concrete is graded as C15, C20, and C25. The M and C terms used stand for the mix ratio in concrete which are either cubic or cylindrical in shapes. Figure 1 below shows the characteristic compressive strength at 28 days and according to the strength class. [2.]


Designed concrete is defined by the characteristic compressive strength at 28 days and identified by the strength class

Example: Minimum Characteristic of Concrete Strength for different Shapes

Concrete Mix	Duration	M Concrete Cube 150x150x150mm Strength	C Concrete Cylinder 150dia and 300mm height. - Strength
1:3:6	After 28 Days	10 N/mm^2	8 N/mm^2
1:1.5:3	After 28 Days	20N/mm2	16 N/mm^2

M10(1:3:6) and M20(1:1.5:3) - M stands for Mix ratio, sample in Concrete cube and minimum strength 10N/mm^2 or 20N/mm^2

C8(1:3:6) and C16 (1:1.5:3) – C stands for Mix ratio, sample in cylinder and Minimum Strength 8N/mm^2 or 16N/mm^2

Figure 1. Difference between M and C concrete grade [3.]

The C25 grade concrete is concrete that can withstand the compressive strength of 25MPa per square millimeter on the 28th day after casting. The C25 specimen can be a cube or cylindrical. [4.] The C25 concrete is medium strength concrete. C25 concrete is used in all construction areas. It is a multipurpose concrete mix, usually used for foundation of infrastructure. [5.]

Several factors affect the strength of concrete. Even with the same water/cement ratio or aggregate proportioning, the result can vary if the mix design or handling of fresh concrete is not carried out correctly. [6.] This thesis includes the theoretical research of some significant and critical components of concrete, which have a considerable impact on concrete strength and grade. The study is supported by performing a case study of the concrete mixing. The mixing of C25 concrete is tested by performing strength tests on the three trial mixes of concrete.

Research Objective

The final year project aimts to show how to perform concrete mixing, and what essential steps need to be considered during concrete mixing. The strength of the mixture is tested to achieve quality concrete. The research is based on C25 concrete mixture.

The target is not merely to learn about the mechanics of concrete mixing, but also to specify some critical tests of concrete like strength, workability, desnisty and air contents. The research includes the handling and curing of concrete materials such as cement, aggregates to achieve quality concrete.

Even though there are national codes that already provide the standards, ratios and proportions of specific concrte grades, there might be lots of factors which can lead to failure of concrete strength and quality. This study amis to learn about the importance of a proper concrete mix, concrete elements, and tests. As a result, the study helps to minimise possible disputes. The primary purpose is to prevent the loss of concrete, time and money.

2 Concrete Technology

Concrete was invented in about 1300 BC. The material used for making it is crude cement, which was obtained by crushing and burning gypsum or limestone. [7.] The technology of concrete making improved significantly after 1793 when John Smeaton discovered a modern method of producing hydraulic lime for cement. He used limestone with clay and fire it until it turned into clinker which was later ground into powder. In 1824, Joseph Aspdin introduced Portland cement to the world. His technique was to burn finely ground chalk and clay until the carbon dioxide in them was removed entirely. [8.]

The present-day concrete is a mixture of Portland cement, coarse and fine aggregates, water and admixtures. The concrete is composed of the aggregates and of water-cement paste. The paste is made of Portland cement and water which binds the aggregates. The concrete later changes into of rocklike mass when the concrete paste hardens because of a chemical reaction. Concrete is one of the critical elements in the construction industry. It is used more than any construction material. It is also the second most used materials for construction. Although concrete has poor tensile stress resistance it can be reinforced to overcome the problem. Concrete is widely used in construction industry for its durability and compatibility. Concrete can easily be moulded into different shapes and sizes while steel and wood lack this ability. [9.]

The ingredients used in concrete water, cement and aggregates, are cheaper and readily available, unlike to steel. Concrete, when reinforced, can take bending and tension forces. Concrete has very high compressive strength which makes it better for structures and components under compressive loads compare than steels. Concrete can be massive in size and has better unit weight than steel. Concrete has water tightness which makes it usable for water retaining structures like bridges, tunnels and dams. [10.] A new technology is the use of admixtures in concrete to make it workable, durable, economical, and able to withstand extreme weather conditions. [10.]

2.1 Concrete Curing

Curing is the maintenance of fresh concrete by providing adequate moisture and temperature for a period of time to achieve the desired properties of concrete. Curing should be carried out right after placing and finishing of concrete. The curing process cannot be overemphasized or be neglected. Curing of concrete is necessary because it has a strong influence on the hardening of concrete. Curing also affects the durability, water tightness, strength, abrasion resistance, volume stability and many other properties of concrete. Furthermore curing prevents the freezing and thawing to concrete. Concrete slab which is exposed to weather needs proper curing to develop strength and freeze-thaw resistance. When cement is mixed with water, it is hydrated. Hydration is critical for the strength and durability of concrete. Freshly mixed concrete contains enough water for hydration, but concrete itself produces heat. The heat evaporate the water, which can prevent adequate hydration. The surface of the concrete is susceptible to insufficient hydration as it is the first to dry up. Therefore concrete structure must be watered to prevent evaporation and to ensure proper hydration. [11.]

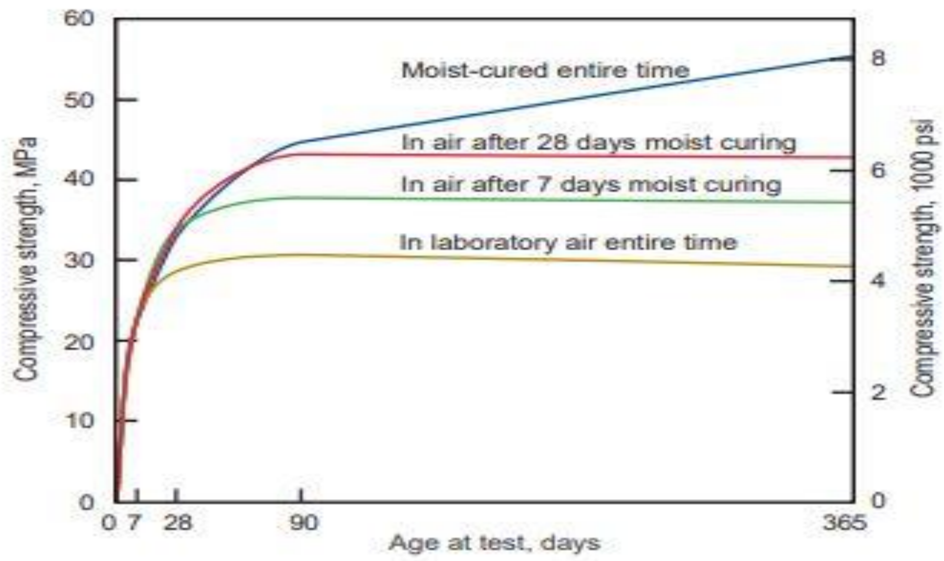


Figure 2. Curing effect on concrete for strength gain. [12.]

With proper curing concrete becomes stronger and more impermeable, resistive to stress, freezing and thawing. The improvement of concrete is rapid during the first days and continues slower after some time. Figure 2 shows the strength of concrete in relation to various period of moist curing. The concrete that has been moist-cured entire time has the best strength compared concrete with shorter moist curing periods. [11.]

2.2 Concrete Properties and Their Effect on concrete

The properties of fresh concrete are its air content, density, and slump, discussed below. These properties of concrete influence the properties of hardened concrete.

The density of fresh concrete

The first important step after the manufacturing of fresh concrete is to calculate its density. The density of fresh concrete is useful information that can be used to create a concrete masonry unit. The density of concrete can affect the physical, aesthetic, engineering and economic characteristics of concrete. [13.]

Slump

The slump test of fresh concrete is one of the most critical tests of trial mix design. The slump test defines the workability of concrete. Workability refers to the ease with which the fresh concrete can be placed on site. Good quality concrete should be easy to mix and transport, should not segregate during placing and consolidation, and should have good furnishing characteristics. Fresh concrete should be uniform throughout a batch and able to prevent energy loss. [14.] The workability of concrete can also be defined as the amount of mechanical energy and high fluidity which can flow and pass without segregation and fill the spaces in the mould with little or no compaction process. [15.]

The slump of concrete may take various shapes when a slump test is performed. Based on the profile of slumped concrete, it can be classified as one of three forms: a collapse slump, a shear slump and a true slump. [16.]

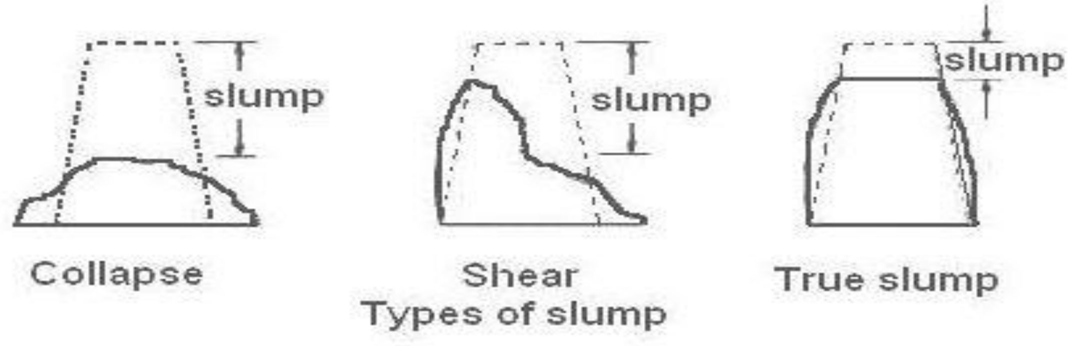


Figure 3. Types of slumps. [17.]

A collapse slump is concrete that completely collapses when moulded in a slump cone. When the slump collapses, it generally means that the mix contains too much water and has high workability, which is not appropriate for a slump test. A slump that makes the top portion of the concrete shear off and other parts get slips or slide down is called a shear slump. It may occur due to a lack of cohesion of the mix. A true slump is a slump that subsides and maintains the shape of the slump cone. [17.]

Air Content

Air content affects the strength of concrete after it has hardened. If the effect of air content is not considered in trials, it can lead to failure of the concrete specimen and a loss of time and money. Air content in fresh concrete causes air voids in the concrete which are not fixable after the concrete is hardened. Air entrainment is an essential component of concrete mixtures exposed to harsh climatic conditions. It is highly relevant to address the air content in the design, specification and construction stages. Air content entraining is essential to reduce the cycle of freezing and thawing of concrete. The air voids form in concrete once it has set. Air content is easier to control in fresh concrete. The materials used in the production of concrete - supplementary cementitious materials, admixtures, aggregates and water - are significant factors that affect the air content in concrete. [18.]

Figure 4. Comparison of air content. [19.]

There are different techniques to control the air content of concrete. Some steps to decrease the air content can already be taken while selecting the materials for concrete making. The use of less alkaline cement, the fineness of cement and the usage of an air-entraining admixture can help to reduce the air content in concrete. The use of fly ash can decrease air content while increasing the carbon content. The admixture used in concrete to reduce water can affect the air content as those admixtures are lignin-based materials. The aggregates need to go through several tests, and their specific gravity and water absorption capacities should be addressed as they also affect the increase and decrease in the air content of concrete. [18.] Figure 4 shows concrete with no air entrainment on the left and air entrained concrete on the right.

3 Cement

Cement, a finely grained compound, is a mixture of clinker and gypsum that have been ground into a fine powder. Cement is one of the critical materials used in concrete as a binding agent. It has a significant impact on the strength of the concrete. When making concrete, the cement is mixed with water. The mixture then hardens after a period called the setting time of cement. The gypsum in cement is necessary to prevent early setting and hardening and allows the users to work with the cement for a long time. [20.]

The grade of cement is classified according to its compressive resistance strength. The compressive resistance strength of cement is established with a compressive strength test on cement mortar. The cement mortar is made of cement, water and natural sand.

The analysis is carried out on the 28th day of the casting of cement mortar. The strength of cement is measured in megapascals (MPa). [20.]

The use of a higher grade of cement allows the user to achieve a higher strength with the same water-cement ratio. Another way to choose the correct cement grade for a targeted strength is the use of cement curves, which are also used to classify the water-cement ratio. However, the user should not entirely depend on the cement grade, because the strength of concrete also depends on the way the cement is stored, and on concrete mixing, curing, casting, hydration and many other factor. In some cases, cement with a lower grade can be used to make stronger concrete than higher-quality cement that has been stored for a long time in degradable condition. [21.]

3.1 Cement Properties and Testing

There are several factors which affect the properties of cement. It is essential to know the properties of cement since then can profoundly affect the setting and hardening of the cement. Various test can be performed to understand the properties of cement. The testing of cement is based on its fineness, setting time, bending strength, chemical composition, the heat of hydration and soundness. It is essential to know the type and strength of cement before using it in concrete because it plays a significant role in obtaining the strength of concrete. [22.]

Fineness of cement

The fineness of cement directly influences the hydration, strength, setting, and heat hydration and hardening properties of cement. If the cement particles are finer, the total surface area is larger and the area in contact with water is also larger which speeds up hydration, the setting and hardening of cement. Fine cement also gives high early strength. Cement with too small particles reacts quickly with water and carbon dioxide in the air which react with cement and decline the quality of cement. In general, the grain size of cement particles is in the range of 7-200 µm. [23.]

The fineness test of cement is carried out by sieving cement on of standard sieve. A good quality cement contains less than 10% of cement particles which are bigger than

90 µm. To carry out of fineness test, 100 gm of cement is sieve with a standard sieve of size 90µm. The calculation is done with the formula below.

% of cement retained on standard sieve = $\frac{W2}{W1} * 100$ (1)

Where

W1 is the 100 gm of cement used for test

W2 is the residue retained on standard sieve. [23.]

Setting time

It is essential to know the setting properties of cement, also known as the stiffening of cement paste. It is the state when cement starts to change from fluid into rigid state. The setting property of cement is tested with Vicat apparatus where the cement paste is penetrated with several needles with the different diameters at in different intervals of time. [24.]

Soundness of cement

The soundness of cement can be explained as the volume stability of cement. The soundness is the ability of cement paste to hardened and retain volume without delayed expansion. Cement expands because of excessive amount of lime and magnesia. [25.] It is not good for cement to undergo changes in its volume which can lead to catastrophic failures in a construction process.

The soundness test of cement is carried out with a Le Chatelier test. The apparatus consists of a small cylinder with two indicators with pointed ends. The cement paste is allowed to set in the device for 24 hours in water at near to room temperature. An initial reading is recorded after 24 hours. The mould with cement is then boiled in water, and checked how much expansion the indicator points at. The increase describes the expansion property of the cement. [25.]

Cement’s composition

The characteristics setting and hardening of cement are affected by several factors. The cement’s composition such as the minerals of cement and their ratios are directly related to the characteristics of cement reacting with water. For example, high tricalcium aluminate (C3A) content increases the setting and hardening of cement. Cement with high C3A content also releases a lot of heat when hydrating. [26.]

Gypsum content

The gypsum amount in cement also influence the regulating the setting time of cement. Cement condenses quickly and mixes with water and generates heat if gypsum is not used in cement. The reaction is caused by of tri-calcium aluminate (C3A) in cement which causes the hydration of calcium sulfoaluminate and affects the regular use if cement. The content of gypsum in cement should be in right proportion. Too much gypsum can also accelerate the setting time of cement as it can act like a clotting agent itself, and destroy the cement uses. [26.]

Water content

The water amount in cement has a huge impact on the strength and setting time of cement. An increase in the water amount will enhance the number of capillary porosities and decrease the strength, as well as increase the setting time of cement. [26.]

Admixture in cement paste

The admixture can have a significant impact on cement properties as it can influence the chemical composition like tricalcium silicates and tricalcium aluminate of cement. The setting, hydration and hardening of Portland cement are compelled by tricalcium silicate (C3S) and tricalcium aluminate (C3A). These chemical composition can be slowed down or accelerated by the use of admixture as a result it affects setting and hardening of cement. [26.]

Storage of cement

The binding capacity of cement is always affected by its storage process. If the cement is exposed to moisture, it can easily be destroyed. It is estimated that the cement losses 10%-20% of its strength after 3 months, 15%-30% in six months and up to 40% after one year. That is why cement should be use is within 3 months of its manufacture. [26.]

4 Fine and coarse aggregates

Aggregates are one of the major elements for concrete. The right type and quality of aggregates cannot be compromised while making concrete. The amount of fine and coarse aggregates in concrete is up to 60% to 75% of the concrete volume and 70% to 85% by mass. The aggregates have a significant effect on the properties of both freshly mixed and hardened concrete. Fine aggregates consist of natural sand or crushed stone. The maximum nominal size of fine aggregates is 5mm. They are made of natural gravel and sand which are dug or dredged from a pit, river, lake, or seabed. The grading limit of fine aggregates is carried out by a sieve analysis, which is the percentage of aggregate particles that pass through a sieve. Coarse aggregates are made of a combination of gravel or crushed stone. The size of coarse aggregates is larger than 5 mm. The normal, acceptable range for aggregates is between 5 mm to 40 mm. Coarse aggregates are made by crushing quarry rock, boulders, cobbles, or large-size gravel. Coarse aggregates increase the strength of concrete. The strength of coarse aggregates is defined by the crushing strength of rock and the crushing and impact values of aggregates. [27.]

4.1 Combined gradation of aggregates

Combined gradation of fine and coarse aggregates is important to ensure that an amount of aggregates with a minimum amount of void space is obtained. The proper combine gradation of concrete saves the amount of cement and water paste in concrete and helps to improve the dimensional stability and the durability of concrete. Combined gradation of aggregates:

- Increases the workability of concrete.
- Lowers the cracking potential of concrete as it helps to reduce thermal and drying shrinkage.

- Increases the durability of concrete by lowering permeability.
- Is economical as it reduces cement paste consumption for concrete mixing.
- Supports sustainability as it makes better use of the aggregates and increases the durability of the concrete. [28.]

4.2 Specific gravity and water absorption of aggregates

Specific gravity of aggregates can be simplified as the ratio of the volume of aggregates to the equal volume of water used for making concrete. The specific gravity of the aggregates is vital to know because it explains the strength and quality of the aggregates. Aggregates with higher specific gravity are stronger compared to ones with low specific gravity. [29.]

The water absorption capacity of aggregates is the ability of aggregates porosity and absorption property which influence the bonding between the aggregates and the cement paste. Aggregates with all pores full are called saturated aggregates and dried surface aggregates are called saturated-surface-dry. The aggregates in saturated surface dry conditions evaporate some water from their pores, these are called air dry aggregates. [29.]

The specific gravity of aggregates is calculated with the formula which is based on ASTM standards.

$$\text{Specific gravity (SSD): } S / (B+S-C) \qquad (2)$$

Where

S is the weight of dry material. B is the weight of flask and water up to calibration mark .C stands for weight flask and SSD aggregate and water up to calibration mark. The water absorption percentage of aggregates is calculated with the formula:

$$Absorption\,\% = (S - A)/A * 100) \qquad (3)$$

Where A is the weight of oven dried material. Testing the specific gravity and water absorption of aggregates is necessary to detect any change of material, or possible contamination. It is necessary to know the specific gravity is necessary for calculating the percentage of voids and the solid volume of aggregates in computations of yield. The water absorption capacity of aggregates needs to be indicated because if aggregates are highly absorptive, it can lead to low durability of concrete. High absorption of aggregates gives an increase in weight of material, due to the water in their pores. [30.]

5 Admixtures

Concrete admixtures are important ingredients in concrete. They are used during the mixing of concrete for several reasons. Different admixtures have a different purpose in making concrete. The type of admixture that is added to concrete depends on its functions. Some of the known admixtures are air-entraining, water-reducing, plasticisers, accelerating, retarding, hydration-control, corrosion inhibitors, shrinkage reducers, alkali-silica reactivity inhibitors, and colouring admixtures. Other than that there are admixtures used for bonding, workability, permeability reducing, foaming, damp proofing, grouting, gas-forming, anti washout, pumping and many other purposes. The concrete used in construction should be workable, durable, strong, and wear-resistant. These properties can be achieved easily and economically using of suitable admixture. Some of the reasons for the use of admixtures in concrete mix are:

- Some admixtures such as of superplasticizer help to increase the flowability of concrete with retarded set. It can minimize the water-cement ratio.
- A water reducer can be used to reduce the water content in concrete by at least 5%
- An accelerator can be used to accelerate the early setting and hardening time of concrete.
- Air-entraining admixtures can be used to reduce air content in concrete.
- Anti washout admixtures can make cohesive concrete for underwater placement.
- A bonding admixture can be used to increase the bonding strength of concrete.
- Corrosion inhibitors reduce steel corrosion activity.

- Shrinkage admixtures can be used to reduce drying shrinkage in concrete. [31.]

Despite of the all advantages of using admixtures, they are not a substitute of mix design. The effectiveness of an admixture is related for example to the type, brand, amount, water content, and temperature, mixing time, slump and, aggregates of concrete, etc. In general, the use of admixtures cannot replace of good mix design. However, admixtures are essential for the optimisation of the concrete mix design. The proper use of admixtures, when carried out in proper conditions, is a way to find the optimum result of the mix design of concrete. [31]

5.1 Water-reducing admixtures

The quantity of water that is used in a concrete mix can be controlled by using water-reducing admixtures. A general water reducing admixture can reduce the water content by approximately 5 to 10% and provide a true slump and a long time for workability, compared to concrete that does not contain any water reducing admixtures. These admixtures prevent concrete from setting before it is cast on site, reduce the water-cement ratio and increase the strength of concrete. [32.]

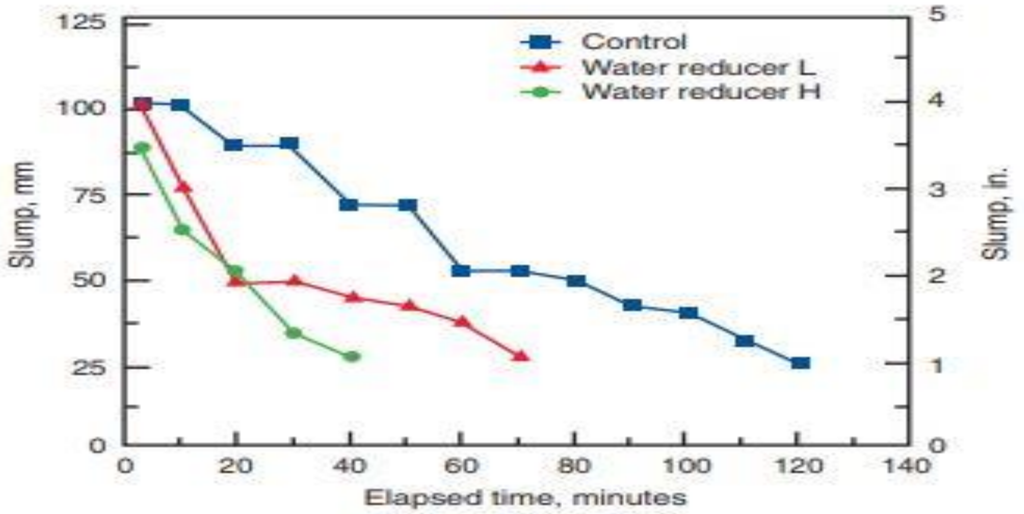


Figure 5. Slump loss in concrete containing conventional water reducer compared with the control mixture. [33.]

Figure 1 describes the slump loss at 23 degrees Celsius in concretes that contain conventional water reducers, which have been compared with a control mixture. Even though water reducers reduce water content, they can increase drying shrinkage which can cause cracks in concrete. [31]

5.2 Air-entraining admixtures

Air-entraining admixtures are chemical compounds that can be added directly to the concrete materials. They are used to stabilise air bubbles in concrete. Air entrainment provides a considerable improvement in the durability of concrete exposed to freezing and thawing. In the air entraining process, microscopic air bubbles are purposely introduced and stabilised. An entrained air admixture helps to improve concrete's resistance to surface scaling which is typically caused by chemical deicers. Furthermore, air-entraining admixture helps to improve the workability of fresh concrete and to reduce and eliminate segregation and bleeding. It is also possible to entrain air into concrete with an air-entraining cement. There is a specific type of Portland cement that is made by adding an air-entraining clinker during the manufacturing of cement. [31.]

6 Mix Design

Mix design can be explained as the process of selecting suitable ingredients for concrete as well as calculating their relative proportions for the targeted strength and durability as economically as possible. The essential ingredients of concrete are almost always the same, but their relative proportioning defines the concrete's grade and strength. Mix design is carried out because it guarantees that the concrete used for a construction site gains its necessary strength on the 28th day [32.].

6.1 The Advantage of Mix Design

Mix design is done to achieve required quality concrete at the site. There are several mix trials that are done to concrete before it is used in any construction site. Good quality concrete is strong, impervious, durable and economical. [32.]

Mix design helps to optimise the use of available materials. It also provides flexibility and minimises the risks and obstacles in site conditions. Mix design makes the selection of the concrete materials easier, such as the water ratio, the size of the aggregates, the admixtures and the cement. Mix design prevents disputes and the loss of time, and money during construction work [28.]. Other advantages of mix design are that it helps to achieve form finishes, an early estimation of strength of the concrete, pump ability and a lower density [33.].

6.2 The Base for Mix Design

The primary objective of mix design is to find the optimised result for concrete, which is the most economical and sustainable for the consumer. Quality concrete should have strength, cohesion, durability and workability. These properties of concrete are based on the right properties of the materials, like cement, sand and aggregates. Hence, mix design can be simplified as a process of making trials to find the right proportion of the concrete constituent scientifically. Mix design also needs a base to start and to find the best results in the fewest possible trials. [33.] The consumer can practice different code standards for performing mix design. Some of the codes that guide the fundamentals of mix design are:

- American Concrete Institute (ACI).
- British Standard (DOE).
- Volume method or Basic mix method.

The codes provide technical specifications and guidelines for mix design. There are commonly used as the design base. Some of the critical features needed in mix design are:

- Mean target strength
- The curve of cement based on its strength
- Water-cement ratio
- Cement content
- The proportions of fine and coarse aggregates. [31.]

Mean target strength

The mean target strength of concrete is determined from the specified compressive strength after the 28th day of casting. [34.]

The minimum required average strength can be calculated with formulas

$$Fcr' = \mathrm{Fc}' + 6.9\mathrm{MPa}(1000\mathrm{psi}) \quad (4)$$

When f c ′ is smaller than 20.7 MPa (3000 psi)

$$Fcr' = Fc' + 8.3\ MPa(1200psi) \quad (5)$$

When f c ′ greater than equal to 20.7 MPa (3000 psi) and f c ′ less than equal to 34.5 MPa (5000 psi)

$$Fcr' = 1.10\ Fc' + 4.8MPa\ (700psi) \quad (6)$$

When f c ′ is greater than 34.5 MPa (5000 psi)

For C25 concrete,

Fc '(Characteristic strength) = 25 N/mm^2 (MPa)

So, target strength,

$Fcr' = Fc' + 8.3\ MPa(1200psi)$ = 25 + 8.3 MPa = 33.3 MPa

Here, 8.3 MPa is the standard deviation obtained from the table of approximate contents assumed after concrete design mix. The normal range of assumptions that can be made for any certain grade is 10 MPa above the characteristic strength. Fcr' is the targeted mean strength. The ACI code has predefined deviation for certain grade of concrete can tolerate. According to the ACI method if the characteristic strength is between 20.7 to 34.5 MPa the standard deviation is 8.3 MPa. [34.]

Strength –based uses of Cement

The strength of cement is determined with either a conventional method or the accelerated curing reference mix method. The cement is picked or classified from the curve based on the strength of cement. In general, almost all cement types can give the targeted strength, but the proportion of cement to the other ingredients of concrete might not mix properly, so it is necessary to select the right cement grade for true concrete strength. [35.]

Table 1. Cement grade curve. [35.]

Curve	The strength of cement (N/mm2)
A	31.9 – 36.8
B	36.8 – 41.7
C	41.7 – 46.6
D	46.6 – 51.5
E	51.5 – 56.4
F	56.4 – 61.3

Table 1 i.e. Cement grade curve are used to find out grade of cement should that are applicable for certain concrete grades to get the characteristic strength of concrete. For example, C25 concrete can use the cement from curve A. The range of curve A satisfy the characteristic strength of C25 concrete But it doesn't mean C25 cannot use the cement from other curves in fact, it might be better for a user to use cement with higher strength so that the user can easily achieve their targeted strength for concrete.

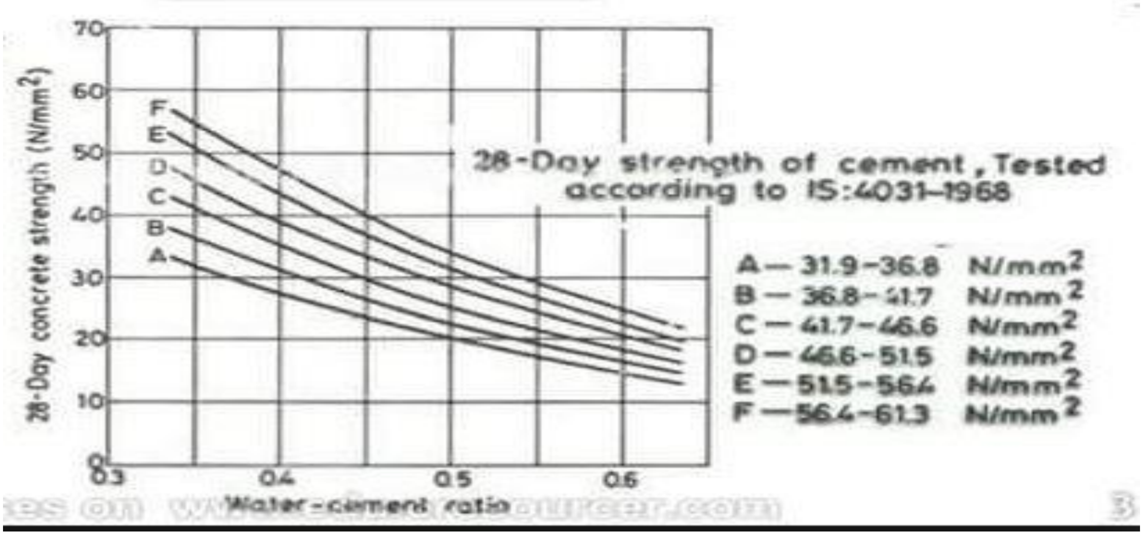


Figure 6. Cement grade curve. [36.]

The cement can be classified into several curves as shown in table 1. Figure 6 also shows the same information along with the influence of water cement ratio applied to the mix design. [35.]

Water / Cement Ratio

The water/cement ratio is the ratio of the weight of water to the weight of cement in concrete. Water is used in concrete as a bonding agent. The water in concrete also shapes the workability of concrete. The air voids in concrete depend on the ratio between water and cement. They increase with an increase in water, which results in a decrease in concrete strength. Therefore, it can be stated that the relation between the strength of concrete is inversely proportional to the ratio of water and cement. [37.]

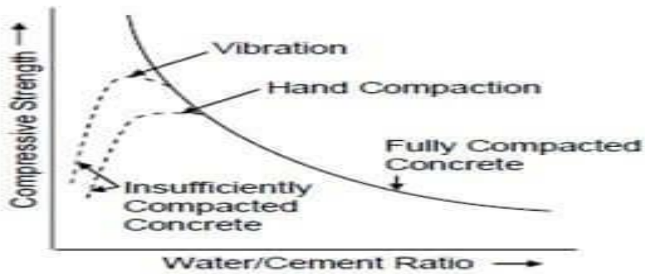


Figure 7. Strength vs W / C ratio. [38.]

Figure 7 shows that the mix has the highest strength when the water/cement ratio is at its lowest and the compressive strength of the mix decreases with increased use of water for the mix. The curve also depends on the compaction which can be achieved by using vibrators or manual hand compaction. However, a low water/cement ratio does not guarantee the best compressive strength of concrete. For example, using larger aggregates with a low ratio of water/cement can lead to the development of tensile stresses as a result of shrinkage and creep. This kind of mixture can result in cracking of the concrete because of a loss of bond between cement and aggregates. [36.]

As shown in figure 7 under full compaction, compressive strength is inversely proportion to water cement ratio. The water/cement ratio can be calculated as,

$$fc = K1/(K2\text{^}(W/C)) \quad (7)$$

Where,
Fc is the compressive strength,
K1, K2 are empirical constant,
W/C is the water to cement ratio. [36.]

Another use of water/cement ratio is the workability of concrete, as more water is required to make concrete workable. Another reason that affects the water demand is the use of an admixture, such as a water reducing agent which allows the user to reduce the amount of water and still make the concrete workable. [39.]

Calculation of Cement Content

Once the water content and water-cement ratio is determined, the amount of cement per volume of the concrete can be calculated. The cement content is determined using following formula:

$$cement\ content = \frac{\text{free water content}}{water-cement\ ratio} \quad (8)$$

The result value is checked against the range specified. Here free water content depend upon the type of maximum size of aggregates used in concrete. [40.]

7 Compressive strength test

A compressive strength test is a process of measuring the strength of hardened concrete specimens using a compression-testing machine shown in figure 8. Concrete mix design provides wide ranges of mechanical and durability properties in concrete to meet the requirements of structures. The compressive strength test is most commonly used test to measure the properties of concrete. The compressive strength of concrete is the load at which the specimens collapse. The SI unit of this strength is a mega-pascal (MPa). [41.]

The test results are used to guarantee that the concrete mixture meets the requirements of the specified strength, F'c. Compressive strength test results are also used for quality control, acceptance of concrete and assumption of concrete strength in structure. Two different types of concrete specimens, cubes and cylinders, can be used as concrete specimens. [18.] Different codes use different concrete specimens. For example, British standard (BS) code uses cubes because their strength is higher than that of cylinders because of the platen effect applied to cubes. The strength of a cube is 20% higher than that of a cylindrical specimen. Cylindrical concrete specimens are used because they give precise strength of concrete which is almost equal to the true strength of concrete. The proportion of the shape is same as the stress distribution under axial load. The American Society for Testing and Materials (ASTM) code used cylindrical concrete specimens. [42.]

The compressive strength test is calculated as a results from the average of 3 concrete specimens. The test are made on 7th and 28th day after the casting of the concrete specimens. Different codes design the average strength, F'cr, which is higher than the characteristic strength of concrete. The F'cr strength of concrete is generalized as a mean target strength of concrete. The mean targeted strength are the targeted strength of concrete than characteristic strength of concrete its self. The mean targeted strength is necessary to avoid the risk of not complying with strength specifications. [42.]

Figure 8. Compressive strength test using a compression machine. [43.]

It is important for concrete to comply with the strength requirements of the specification. Any strength test should comply with the criteria below:

- None of the three tests should break the tested concrete specimen before characteristic strength of concrete is reached, if they do, the mix design is not accepted as following the specification.
- The mean targeted strength is calculated as the average of three separate, consecutive tests that are either equal or exceed the characteristic strength, F'c.

The failure in an individual test below the characteristic strength does not mean that the designed concrete does not meet specifications. Several factors may affecting the required average strength. The failed result may be the result of a failure in testing, fabrication handling, curing or testing of concrete specimens not conducted by contracted procedures. [44.]

General instructions for a compressive strength test are:

- Either cylindrical or cubical concrete specimens are used for the compressive strength test. The specimens' size can vary, as maybe mentioned in the company specification. Smaller specimens are easier to make and handle in the laboratory.

- The mass of the specimen is recorded, to avoid of any disputes.

- The concrete specimen used must not have dried out before testing. The specimens are kept in mounds for 24 hours and then in water for curing.

- The bearing surface of the test machine is cleaned.

- The specimen is placed in the machine so that the load can be applied to the opposite sides of the cube cast. The specimen is aligned centrally on the base plate of the testing machine. Cylindrical specimens are placed in the centre of the machine. The ends of cylindrical specimens must not depart from perpendicularity with the cylinder axis by more than 0.5 degrees.

- The maximum load is noted, and any unusual features are also recorded. [44.]

7.1 Calculation of Compressive Strength

A minimum of three specimens should be tested for all ages, i.e. 7 and 28 days. The strength of the specimens should not vary by more than 15% of the average strength, or the result is rejected. The crushing strength is always the result of an average of three specimens. The important measures and reading required for the calculation of the strength test of concrete before and after the compressive strength test are,

- Size of specimens
- Area of specimens
- Characteristic compressive strength at 7^{th} day
- characteristic compressive strength at 28^{th} day
- Compressive strength is equal to the load / Area in N/mm^2. [44.]

7.2 Test reports

A test should include an identification mark of the specimen, the date of the test, the age of the specimen, curing conditions, and the manufacturing date of the specimen. It can also include the appearance of a fallen specimen or any unusual characteristics, shown during the test. [44.]

8 Case study

The case study that deals with the compressive test of C25 mix is based on the technical test carried out for the Melamchi Water Supply Project. The project is located in Melamchi, Sindhupalchok District of Nepal. The Nepalese government funds this project. The main project objectives are to reduce the chronic water shortage situation within the Kathmandu valley. The primary work of this project is to construct a 26.3 km long water diversion tunnel which will divert 170 million litres of raw water to Kathmandu valley daily. The trial mix design, compressive strength test, and case study of concrete C25 were carried out at the laboratatoryof the Melamchi Water Supply Project lab. All the equipment and material used in this process were from the Melamchi Water Supply Project. This study was also carried out to produce a C25 concrete mix with excellent workability. It was necessary for concrete to have good slump and workability because the batching plant of concrete was far away from the actual working site. The concrete should not set before it was cast at the working site.

The case study provides detailed information and maps the progress of the concrete mixing. Furthurmore, it offers understanding of the reasons behind possible disputes that might occur during concrete mixture and strength test. The case study is necessary as it offers a complete picture of how to perform concrete mixing, test strength of concrete and what conclusions can be drawn from the research.

8.1 Description of ingredients

The ingredients used in the trial mix and their quantity are recorded. Three trials are carried out, all with same ingredients, but different cement quantities. Tables 2, 3, 4 and 5 below contain the description of all the ingredients used in the three trials. From table 2 it is possible to read the water-cement ratio used in the three trials. The aggregate sizes in the concrete have same proportions in all three trials i.e. 4:3:3 this means that if the total weight of aggregates is 100 grams, the natural sand amount would be 40 grams, the amount of 5-10 mm aggregates would be 30grams and the amount of 10-20 mm aggregates would be 30 grams.

Table 2. Initial ratio and proportions of trial mixes.

Concrete Class / Concrete Grade	$C_1$25	$C_2$25	$C_3$25
Water Cement (W/C) Ratio	0.460	0.486	0.515
Water Binder Ratio	0.460	0.486	0.515
Mass Ratio; M = W / (C + ∑kP) (k02 for silica); RefCAP vol-7 ; 1.2.1	0.459	0.486	0.515
% of the admix.1(Normal tam cem 11R) by the total cementitious material	0.5	0.5	0.5
Max size of aggregates (mm)	20	20	20
% of 0-5mm, sand by the total aggregate	40	40	40
% of 5-10mm, crushed coarse aggregate by the total agg	30	30	30
% of 10-20mm crushed coarse aggregate by the total agg	30	30	30

The amount of water in all three trials is kept fixed at 175 Kg/ m^3. Same aggregates are used for the three trials, so they have the same specific gravity and water absorption properties. However the moisture content on the aggregates is different.40 liters of concrete was made the aggregates proportions and water cement ratios. The quantity of cement water plasticizer and aggregates can be read from table 3.

Table 3. Quantity list of concrete materials used for making 3 different trials.

Trials	Cement kg	Water kg	plasticizer kg	0-5 N.sand kg	5-10mm Agg kg	10–20 mm Agg kg
1	15,217	6,059	0,077	29,021	21,273	21,448
2	14,400	6,715	0,072	28,735	21,446	21,503
3	13,592	5,641	0,072	29,925	21,784	21,850

Table 4 shows the passing percentage of different aggregates through different sieve sizes. The natural sand, 5-10 mm aggregates and 10-20 aggregate were sieved. The residue of aggregates was recorded and plotted in a graph to get the combined grading of aggregates.

Table 4. Sieving result of aggregates.

Sieve size mm	N-sand	0-10mm	10-20mm	Combined-grading	Upper-limit	Lower-limit
37.50	62.5	100	100	100	100	100
20.00	80	100	93.4	98.00	95.00	100
5.00	95.0	8.2	0.4	39.10	35.00	55.00
0.600	99.4	1.5	0.2	19.40	10	35
0.150	99.9	0.9	0.1	2.40	0.00	8.00

The graph in figure 9 shows the combined grading of all aggregates. This graph is important and the finding is necessary because it tells the nature of aggregates. For example 10-20 mm aggregates do not only contain aggregates size of 20mm. There may also be bigger aggregates than 20 mm size aggregates in among the 10-20mm aggregates.

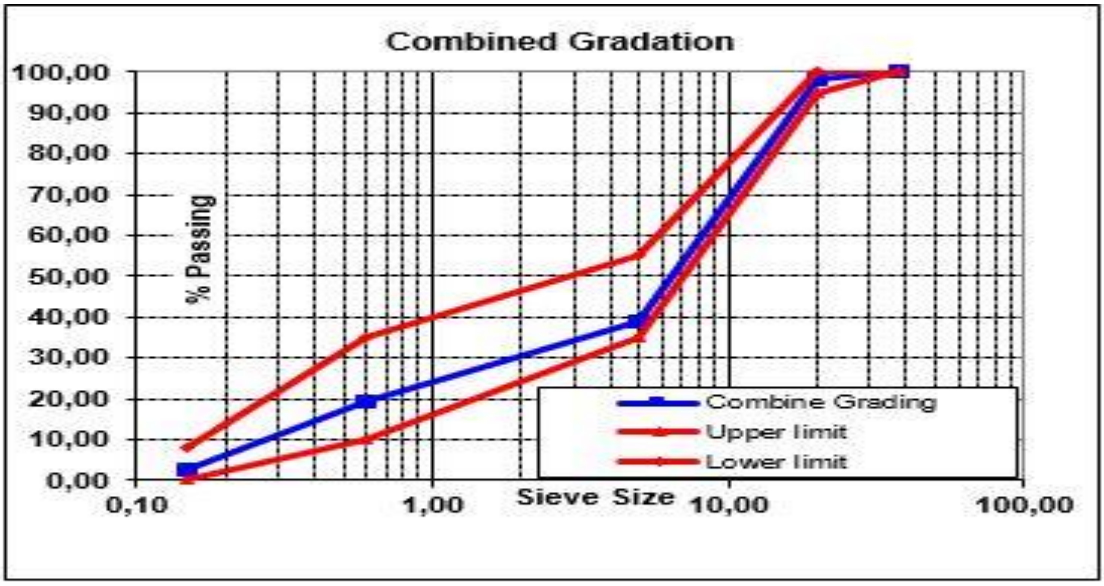


Figure 9. Curve of aggregates passing through a sieve.

Table 4 and figure 9 shows the higher and lower passing rate of aggregated through different sieves in different perspectives.

8.2 Specific Gravity and Water Absorption Test

The study was made at the Jalpa crusher plant. Jalpa crusher plant was the retailers who sells the aggregates to Melamchi Water Supply Project. The specific gravity and water absorption of 3 different aggregates were measured in this plant laboratory. The aggregates were of 0-5 mm natural sand, 10 mm aggregates and 20 mm aggregates. Two tests were carried out to all aggregates to calculate their average specific gravity and water absorption. The average of the result of the two tests was taken as the specific gravity and water absorption of each aggregates.

From tables 10, 11 and 12 in appendix 1 it is possible to read all the of specific gravity and water absorption tests of the aggregates. From the tests it was possible to calculated average specific gravity (oven dried), specific gravity (SSD) and apparent specific gravity of the aggregates.

The average specific gravity of aggregates includes the overall volume of the particles of the aggregates as well as the volume of the water permeable voids. The average apparent specific gravity, on the other hand, only includes the volume of the aggregate particles and does not include any water permeable voids. It is one of the reasons why the apparent specific gravity has the highest value of specific gravity of values aggregates such as bulk dry gravity or average specific gravity. [25.] Tables 5, 6 and 7 shows the final average specific gravity, average apparent specific gravity and average water absorption properties of the aggregates.

8.3 Slump test for fresh concrete

The slump test for the fresh concrete was made at Bahune pati laboratory owned by the Melamchi Water Supply Project. The three trials gave three different results. All slumps were true slumps. A true slump is a fresh concrete which quickly subsides, keeping more or less the shape of the conical mould used in making a slump. Table 8, below shows the results of the slump test results of the three trials for concrete mix design.

Table 5. Slump result from three trials.

Time	slump	%air	Density	Temperature
Trial 1				
initial	180	3.6	2336	Sample=24.0
30 min	150			Air = 25.9
				Water = 25.8
Trial 2				
Initial	150	2.6	2364	Sample = 22.5
30 min	130			Air = 24.0
				Water = 22.5
Trial 3				
initial	200	1.9	2385	Sample = 20.03
30min	170			Air = 21.0
				Water = 21.5

Figure 10 shows the comparative changes between the initial height of the slump and the height 30 minutes after the slump test. The slump test after 30 min is carried out if the concrete is still workable. The result from this slump test shows that the concrete has good workability. The concrete is still workable after 30 minutes of concrete mixing.

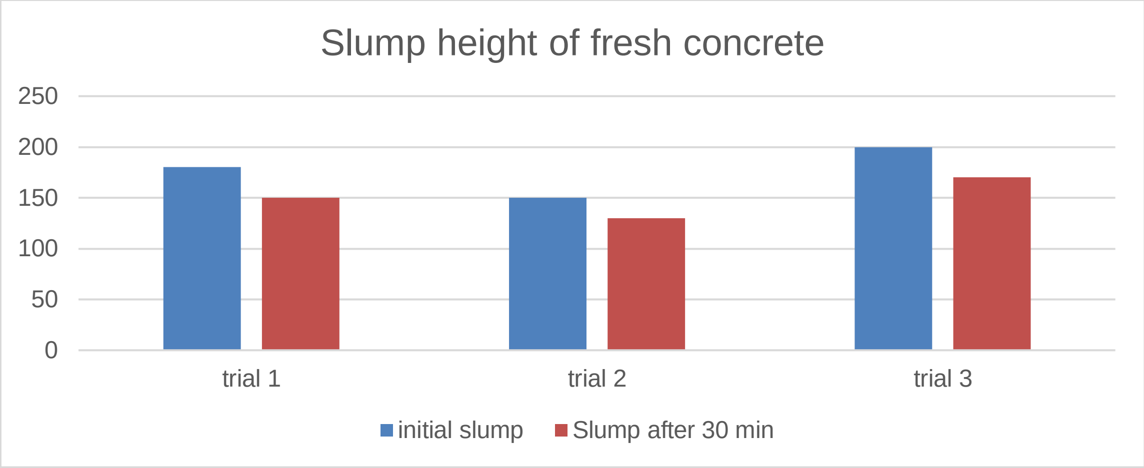


Figure 10. Slump height of fresh concrete.

Table 5 and figure 10 show the same phenomenon from two different perspectives. Whereas from figure 10, it's easier to see the different in workability of concrete over time.

8.4 Concrete Air Content

The air content in the trial mix was controlled by the use of an admixture and also by increasing the size of aggregates and decreasing the amount of natural sand when making the concrete mix. The air content of fresh concrete was measured with an Air meter, and the result received is considered as the apparent air content" % A1". The average concrete air content "%As" was obtained by subtracting the correction factor "%G for sand and the aggregates from the apparent Air content, i.e. average concrete air content $\%As = \%A1 - \%G$ (9)

The average air content in fresh concrete for the three different trials is shown in tabe 9 below:

Table 6. Air content of the three trials.

Trial	Apparent Air content % A1	Sand & Agg correction factor %G	Average air content %As = %A_1 -%G
Trial 1	3.6	0.5	3.1
Trial 2	2.6	0.5	2.1
Trial 3	1.9	0.5	1.4

The maximum allowed air content in fresh concrete was 4.0. The study shows that the 3rd trial mix contained the best air content among the three trial mixes i.e. 1.4, whereas the first trial mix had the highest air content i.e. 3.1, but within an acceptable range indexed in the specification.

8.5 Unit weight for fresh concrete

Another finding from the mixed trial was the unit weight for fresh concrete. The average unit weight of concrete was calculated by dividing the weight of sample concrete with the volume of its container. The unit weight for the samples is shown in table 10 below

Table 7. Unit weight of the fresh concrete.

Trial	The weight of Sample gm C	The volume of Container gm D	unit weight of fresh concrete gm C / D
1	16352	7000	2.336
2	16548	7000	2.364
3	16695	7000	2.385

The unit weight of concrete can be primarily affected by the unit weight of aggregates. The unit weight also affects the compressive strength of concrete, so it is essential to know the unit weight of concrete. The allowed standard density of the concrete is from 2400 to 2300 kg/m^3. [12.] The results show that the density of fresh concrete from the three trial mixes satisfy the criteria of the standards.

8.6 Casting of fresh concrete in mould

The fresh concrete was cast in 8 moulds. Although the test was carried out in 3 specimens at 7th and 28th days after casting, two other specimens were cast to avoid possible disputes. The size of mould was 15*15*15 cm3. The cube specimens were cast. After casting of the cube, the curing of specimens was necessary. The cube was allowed to set for 24 hours and demould without damaging the cube. The numbers were given to each cube and kept immediately in the curing tank at room temperature. The curing of concrete was done up to the time of testing.

8.7 The compressive strength of Trial Mixes

The compressive strength test of the trial mixes was carried out in Bahuni pati Central laboratory. The strength test was carried out using a compressive strength tester on the 7^{th} and 28^{th} day after the manufacturing of the concrete cube specimens. Before performing the compressive strength test, the weight, volume and density of all cubes were measured. Three different concrete specimens were used on the 7^{th} and 28^{th} day to test the compressive resistance of the concrete. The test results of the three specimens for the trials are summarised in the tables below.

Tables 13, 14 and 15 in appendix 2 show the compressive strength of the three different concrete specimens on the 7th and 28th day after casting. It is necessary to perform strength test on the 7th day even though the concrete only gets, its near to final strength on the 28th day after casting because the user can already estimate if the concrete will be able to achieve the targeted strength on the 28th day. The readings also show that trial 3 was unable to achieve the target strength, but was still valid as it had the characteristic strength of C25 concrete. This is also the reason why of trial can be acceptable for use, but not the best option for construction purposes because the work site might have different conditions than the lab where trial mix is carried out.

8.8 Compressive strength VS water/cement ratio

The result of the three trial mixes was plotted in a graph. Figure 11, the graph shows the relationship between the compressive strength of the concrete compared to the water-cement ratio on the 7th and 28th day. From the three trials three different W/C ratios and their compressive strength on the 7th and 28th days were established.

Table 8. Water-Cement Ratio vs compressive Strength of Concrete.

SN	W/C	Seven days comp. strength(MPa)	28th days comp. strength(MPa)
1	0.461	24.7	38
2	0.486	21.1	35.7
3	0.515	19.8	33.2

The graph in figure 11 can be used to find out the correlation between the compressive strength of concrete and its water-cement ratio. For example, if the water/cement ratio of 0.5 is used for preparing concrete mix then its corresponding compressive strength ratio on the 28th day can be predicted as 34.5 MPa for C25 concrete.

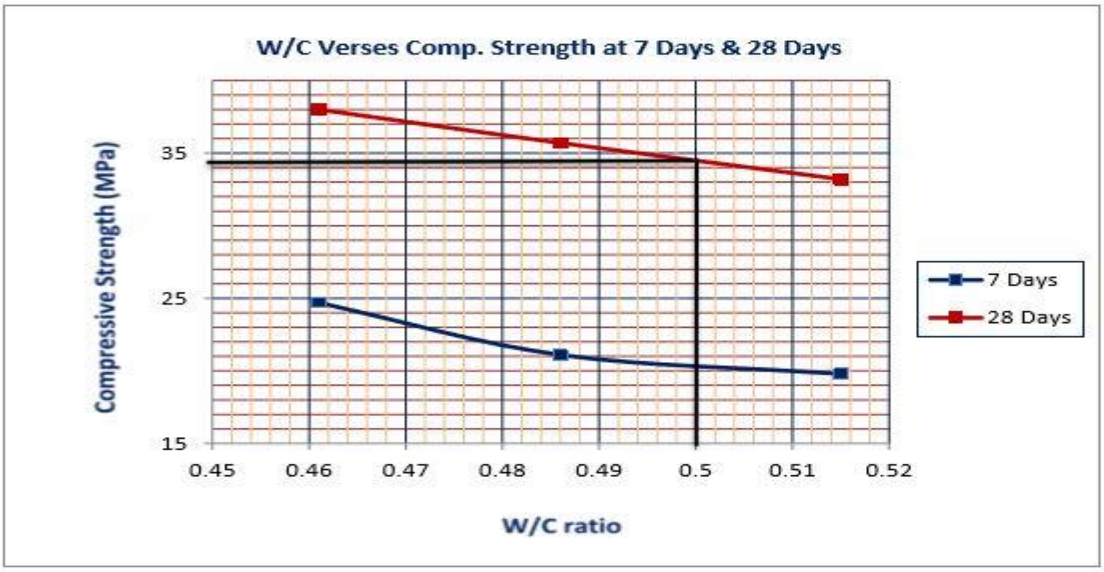


Figure 11. Compressive strength vs Water – Cement ratio.

9 The Result of the Case Study

The principal aim of a trial mix is to establish, per cubic meter of concrete, an optimum amount of each concrete ingredient. The result has well satisfied the strength criteria as well as workability of the concrete. Three different trials were carried out by taking a fixed amount of water, i.e. 175 kg/m3 with different water-cement ratios. A water reducing agent at 0.5% by the weight of cement was used to make concrete compatible with the suitable concrete pump. In the three trials, the slump after 30 minutes was in the range of 130-170 mm, an acceptable limit for the concrete pump. It was necessary as the results show the concrete has excellent workability and can give the user enough time for the placing and casting of concrete.

Table 9. C25 concrete at 0.5 water-cement ratio.

W/C	Weight of ingredients in kg for cubic meter of concrete					
	Water kg/m^3	Cement kg/m^3	Natural sand kg/m^3	5-10MM aggregates kg/m3	10-20mm aggregates kg/m^3	Admixture kg/m^3
0.5	175	350	715	540	540	1.75

Table 15 shows the amounts of the ingredients that are used when 0.5 water cement ratio is used for concrete mix to achieve 34.5MPa strength on 28th day. The ingredient amounts for 0.5 water-cement ratio are calculated from the trial mix sheet and shown in table 15 above.

10 Conclusion

Concrete is an essential material for infrastructure because of its versatility and economic efficiency. Identifying the critical issues and factors that affect concrete and its strength is necessary. The study has pointed the most important aspects of concrete ingredients and their use when making concrete. The thesis shows the importance of common procedure that is essential in order to achieve quality concrete with the least possible number of trial mixes to allow the consumer to save time and money.

The research and laboratory mix also show that the admixtures are critical ingredients for proper concrete mixing. The study has also shown how the use of an admixture enhances the workability of fresh concrete. The use of a water reducing admixture for a fixed water quantity can increase the workability of concrete.

The graph in figure 9 in chapter 8.1 was obtained from three different trials of compressive strength versus water/cement ratio. The graph shows that at constant water amount, one can use the graph to select a water/cement ratio for the trial mix of C25 concrete and achieve strengths.The recommendations of the thesis address the importance of proper concrete mixing, the test of cement, aggregates, and concrete itself to minimize the failure in making quality concrete. The thesis also recommends the most important factor that affects the strength of concrete when performing the concrete mix, because it can already map the progress on the mixing of concrete. The 7th day test can already give a glimpse if the concrete composition is in the correct order or whether it will achieve the targeted strength in 28th days of time. This prevents the time loss in case of failure. The thesis can be used as possible guideline for proper concrete mixes of C25 concrete.

References

1 Daily Civil. 2017. Grades of Concrete - Daily Civil. Online. < Http: //www.dailycivil.com/grades-of-concrete/.> Accessed 8 Jan 2019.

2 Silica Fume for Sale, Microsilica Supplier in China. 2019. Conventional grade C20, C25 and C30 concrete mix ratio - Silica Fume for Sale, Microsilica Supplier in China. Online <http: //www.microsilica-fume.com/conventional-grade-c20-c25-c30-concrete-mix-ratio.html.>. Accessed 8 Jan 2019.

3 Construction technology. Online. <https://www.youtube.com/watch?v=cSN8B16lqOQ>. Accessed 8 Jan 2019.

4 Adewole; K; Olabanji Ajagbe; W. & Ademola Arasi. 2015.82. Online. <Http: //lejpt.academicdirect.org/A26/079_088.pdf.>. Accessed 8 Jan 2019.

5 Concrete, B. 2019. Different Types of Concrete Grades and their uses | Base Concrete. Online. Baseconcrete.co.uk. <https://www.baseconcrete.co.uk/different-types-of-concrete-grades-and-their-uses> Accessed 8 Jan 2019.

6 Aguado a; C.galvez J; Fernadez D; De la Fuente A. Online. Core.ac.uk. 2018. <https://core.ac.uk/download/pdf/46111757.pdf>. Accessed 15 Jan 2019.

7 The History of Concrete - InterNACHI. Online. Nachi.org. 2018. <https://www.nachi.org/history-of-concrete.htm> Accessed 8 Jan 2019.

8 Pepin R. The History of Concrete. Giatec Scientific Inc. Online. Giatec Scientific Inc. 2018.<https://www.giatecscientific.com/education/the-history-of-concrete/>

9 Steel Structures Vs Concrete Structures | Complete Comparison of Steel & Concrete. Online. < https://civildigital.com/steel-structures-vs-concrete-structures-complete-comparison-of-steel-concrete/> Accessed 8 Jan 2019.

10 Kozul R, Darwin D. Effects of Aggregate Type, Size and Content on Concrete Strength and Fracture Energy. Online. Lawrence, Kansas: http://www2.ku.edu; 1997. <http://www2.ku.edu/~iri/publications/sm43.pdf>. Accessed 8 Jan 2019.

11 Concrete in Practice. Nrmca.org. Online. <https: //www.nrmca.org/aboutconcrete/cips/11p.pdf.> Accessed 8 Jan 2019.

12 Jerzy Z; Zemajtis. Role of Concrete Curing. Online. < https://www.cement.org/learn/concrete-technology/concrete-construction/curing-in-construction> Accessed 8 Jan 2019.

13 Density- Related Properties of Concrete Masonry. Online. 1st ed. Building Construction and Design Viewpoint; < https://masonryadvisorycouncil.org/wp-content/uploads/2015/11/Density-of-Concrete-Masonry.pdf. > Accessed 23 November 2018.

14 Soundness test of cement. Online <http: //civilsutra.in/soundness-test-of-cement/.> Accessed 8 Jan 2019.

15 Wihardi Tjarong M; Djamaluddin R; Sampebulu V. Compressive Strength and Slump flow of Self Compacting Concrete Uses Fresh Water and Sea Water. Online. Arpnjournals.com. 2018. <http://www.arpnjournals.com/jeas/research_papers/rp_2015/jeas_0415_1770.pdf>. Accessed 10 Jan 2019.

16 Concrete Slump Test Procedure, Applications & Types of Slump. Online. <https://www.aboutcivil.org/concrete-slump-test.html> Accessed 11 Jan 2019.

17 What are the difference between shear slump and collapse slump in slump test? Online. <https://www.engineeringcivil.com/what-are-the-differences-between-shear-slump-and-collapse-slump-in-slump-test.html> Accessed 12 Jan 2019.

18 Concrete Technology Today Cement.org. 2018. Online. <https://www.cement.org/docs/default-source/fc_concrete_technology/pl981.pdf?sfvrsn=2&sfvrsn=2>. Accessed 13 Jan 2019.

19 Control of Air Content in Concrete. Volume19/Number 1. April 1998.<https://www.cement.org/docs/default-source/fc_concrete_technology/pl981.pdf>

20 What are the different grades of Cement? - General Knowledge Today Gktoday.in. 2018. Online. <https://www.gktoday.in/gk/cement/>. Accessed 15 Jan 2019.

21 Akhtar N. Strength of Concrete vs Grades of Cement. Online. Nbmcw.com. 2018. <https://www.nbmcw.com/tech-articles/concrete/25796-strength-of-concrete-vs-grades-of-cement.html>. Accessed 16 Jan 2019.

22 S.Patil C. Lab Manual of 1 Concrete Technology. Lecture presented at Sanjay Ghodawat Group of institutions. <http://www.sginstitute.in/Downloads/Civil_Downloads/Manual_ConcreteTech.pdf>.

23 Pranav; K; and kushwaha; P. 2019. Fineness test of Cement and its Significance | Tests on Cement. Online. <https://civilread.com/fineness-test-cement>. Accessed 8 Jan. 2019.>. Accessed 20 Jan 2019.

24 Cement Consistency Test - Standard Consistency of Cement by Vicat Apparatus. Online <http://www.civilology.com/consistency-test-of-cement/ Accessed 8 Jan 2019.

25 Soundness test of cement. Online. <http: //civilsutra.in/soundness-test-of-cement/.>. Accessed 8 Jan 2019.

26 Concrete Technology. Mycourses.aalto.fi. 2019. 3. <https: //mycourses.aalto.fi/pluginfile.php/403893/mod_label/intro/Lec02_Binders_v07.pdf.>. Accessed 8 Jan 2019.

27 Design and Control of Concrete Mixtures. 16th ed. 5420 Old Orchard Road: Portland Cement Association; <http://www.ce.memphis.edu/1101/notes/concrete/PCA_manual/Chap05.pdf>

28 Gradation of Aggregates and its Effects on Properties of Concrete. 2019. Volume 3(2). Online <https: //www.researchgate.net/publication/301957055_Gradation_of_Aggregates_and_its_Effects_on_Properties_of_Concrete.>. Accessed 8 Jan. 2019.

29 Aggregates. 2019. Online. <http://civil.emu.edu.tr/courses/civl284/4%20Aggregates.pdf>. Accessed 8 Jan 2019.

30 Exp 3 & 4 specific gravity & water absorption – Civil Engineers PK. Online. <https://civilengineerspk.com/transportation-engineering-experiments/exp-3-4-specific-gravity-water-absorption/#comment-91105>. Accessed 8 Jan 2019.

31 Design and Control of Concrete Mixtures. 16th ed. 5420 Old Orchard Road: Portland cement Association.

32 Materials Selection Guide: Water Reducing Admixtures. Concreteconstruction.net. 2006. Online. <https://www.concreteconstruction.net/how-to/materials/materials-selection-guide-water-reducing-admixtures_o>. Accessed 15 Jan .2019.

33 Mix Design Manual. Prabhat Road, Erandwane: Durocrete Engineering Services Pvt. Ltd.<https://mesbai.com/download/dwl26.pdf>

34 Concrete for Sustainable Construction. 2018. Online. <https: //www.researchgate.net/publication/280864905_Concrete_for_sustainable_construction.>. Accessed 8 Jan 2019.

35 Comparison of IS, BS AND ACI Methods Of Concrete Mix Design and Proposing Function Equation Based Design. Online <https://www.researchgate.net/publica-

tion/271585894_Comparison_of_IS_BS_and_ACI_Methods_of_Concrete_Mix_Design_and_Proposing_Function_Equations_Based_Design>. Accessed 8 Jan. 2019.

36 Vimmrova A, Vyborny J, vysoke C. Building materials 10. Materials and Testing Methods. 1st ed. Praha: Vydavatelství ČVUT, 2002. 2018.

37 Concrete Mix Design. Online. <Https: //civilhack.blogspot.com/2016/07/is-method-for-concrete-mix-design.html.>. Accessed 11.03.2019

38 Afsar J. Water to Cement Ratio | Relation | Graph | Engineering Intro. Online. Engineering Intro. 2018. <http://www.engineeringintro.com/concrete/concrete-strength/water-to-cement-ratio/>

39 What is workability of concrete? Tyes, Mechanism. Online < https://civiltoday.com/civil-engineering-materials/concrete/93-workability-of-concrete-definition-types-details>. Accessed 15 Jan. 2019.

40 Guthrie, W. and Sebesta, S. n.d. Selecting Optimum Cement Contents for Stabilizing Aggregate Base Materials. The Texas A&M University System. Pp.1-49. <https: //static.tti.tamu.edu/tti.tamu.edu/documents/7-4920-2.pdf.>

41 Pavement Interactive. n.d. ACI Mix Design Example - Pavement Interactive. Online. <https://www.pavementinteractive.org/reference-desk/design/mix-design/aci-mix-design-example/>. Accessed 20 Jan .2019.

42 Indian Standard Methods of Tests for Strength of Concrete 2018. 18th Ed. New Delhi. <http://www.iitk.ac.in/ce/test/IS-codes/is.516.1959.pdf>

43 Dennis Vandegrift, Jr. Anton K. Schindler.The Effect of Test Cylinder Size on the Compressive Strength of Sulfur Capped Concrete Specimens. Eng.auburn.edu. n.d. Online. <http://www.eng.auburn.edu/files/file806.pdf>. Accessed 20 Jan. 2019.

44 Concrete in Practice. Online. <https://www.nrmca.org/aboutconcrete/cips/35p.pdf>. Accessed 8 Jan 2019.

45 Navlakha; Indore; Madhya Pradesh. Cement Testing Laboratories. Online. <https://www.indiamart.com/indexlab/cement-testing-laboratories.html>. Accessed 9 Jan 20

Specific Gravity and water Absorption properties

Table 10. Specific gravity and water absorption properties of natural sand.

Test	0-5 mm	Aggregates
	1	2
Weight of dry sample S	500	500
Weight of Flask + Water up to calibration Mark, B	703.1	679.0
Weight Flask + SSD AGG + Water up to mark, C	1014.7	1007.5
A volume of flask V	500	500
Weight of oven dried material A	491.9	491.9
Specific gravity (oven dried) A / (B+S-C)	2.611	2.596
Specific gravity (SSD) S / (B+S-C)	2.654	2.639
Apparent SP.GR A / (B+A-C)	2.728	2.712
Absorption % (S-A) / A* 100	1.647	1.647
Specific Gravity (AVG) Oven dried	2.603	
Specific Gravity (AVG) SSD	2.646	
AVG Apparent Specific Gravity	2.720	
AVG Absorption	1.65	

Table 11. Specific gravity and water absorption properties of 10 mm aggregates.

Test	10 mm	AGG
	1	2
Weight of saturated surface dry sample B	1674.9	1769.7
Weight of sample + container in water S	1314.6	1376.2
Weight of the container in water D	268.3	271.1
Weight of the sample in water C = S – D	1046.3	1105.1
Weight of oven dried material A	1660.1	1754.3
Specific gravity (oven dried) A / (B-C)	2.641	2.663
Specific gravity (SSD) B / (B-C)	2.664	2.663
Apparent SP.GR A / (A-C)	2.705	2.702
Absorption %	0.892	0.878
Specific Gravity (AVG) Oven dried	2.640	
Specific Gravity (AVG) SSD	2.664	
AVG Apparent Specific Gravity	2.703	
AVG Absorption	0.885	

Table 12. Specific gravity and water absorption properties of 20mm aggregates.

Test	20 mm	AGG
	1	2
Weight. of saturated surface dry sample B	4001.0	4120.0
Weight of sample + container in water S	3221.0	3296.0
Weight of the container in water D	714.7	726.5
Weight of the sample in water C = S – D	2506.3	2569.5
Weight of oven dried material A	3961.0	4070.2
Specific gravity (oven dried) A / (B-C)	2.650	2.625
Specific gravity (SSD) B / (B-C)	2.677	2.657
Apparent SP.GR A / (A-C)	2.723	2.712
Absorption % {(B-A) / A}*100	1.010	1.224
Specific Gravity (AVG) Oven dried	2.638	
Specific Gravity (AVG) SSD	2.667	
AVG Apparent Specific Gravity	2.718	
AVG Absorption	1.117	

Compressive Test Result

Table 13. Compressive test result of trial 1.

Sample #	Day 7	Day 7	Day 7	Day 28	Day 28	Day 28
Area			225			
Volume of cube cm^3	3375	3375	3375	3375	3375	3375
Weight of cube (gm)	7968	7940	7967	8057	7932	7968
Density of cube (gm/cc)	2.361	2.353	2.361	2.387	2.350	2.361
Failure load (KN)	571.0	528.0	568.0	800.8	857.7	903.4
Compressive strength (MPa)	25.4	23.5	25.2	35.6	38.1	40.2
Average compressive strength (Mpa)		24.7			38.0	

Table 14. Compressive test result of trial 2.

Sample #	Day 7	Day 7	Day 7	Day 28	Day 28	Day 28
Area			225			
Volume of cube cm^3	3375	3375	3375	3375	3375	3375
Weight of cube (gm)	8069	7984	7982	8077	8046	8099
Density of cube (gm/cc)	2.391	2.366	2.365	2.393	2.384	2.400
Failure load (KN)	445.5	478.9	496.8	783.3	794.5	831.0
Compressive strength (MPa)	19.8	21.3	22.1	34.8	35.3	36.9
Average compressive strength (Mpa)		21.1			35.7	

Table 15. Compressive test result of trial 3.

Sample #	Day 7	Day 7	Day 7	Day 28	Day 28	Day 28
Area			225			
Volume of cube cm^3	3375	3375	3375	3375	3375	3375
Weight of cube (gm)	8128	8141	8126	8123	8066	8123
Density of cube (gm/cc)	2.408	2.412	2.408	2.407	2.390	2.407
Failure load (KN)	449.8	455.6	428.2	760.2	701.8	776.1
Compressive strength (MPa)	20.0	20.2	19.0	33.8	31.5	34.5
Average compressive strength (Mpa)		19.8			33.2	