Sudan University of Science and Technology

Collage of Graduate Studies

Civil Engineering

Construction Department

Investigating Quality of Concrete Materials in Hot Weauther

تقصى جودة مواد الخرسانة في الطقس الحار

A thesis Submitted in Partial Fulfillment of the Requirement for the Degree of Master of Science in civil Engineering (construction Engineering)

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الآيه

بســم الله الرحمن الرحيــم

قال تعالى:

{لَا يُكَلِّفُ اللَّهُ نَفْسًا إِلَّا وُسْعَهَا ۚ لَهَا مَا كَسَبَتْ وَعَلَيْهَا مَا اكْتَسَبَتْ ۗ رَبَّنَا لَا تُؤَاخِذْنَا إِنْ نَسِينَا أَوْ أَخْطَأْنَا ۚ رَبَّنَا وَلَا تَحْمِلْ عَلَيْنَا إِصْرًا كَمَا حَمَلْتَهُ عَلَى الَّذِينَ مِنْ قَبْلِنَا ۚ رَبَّنَا وَلَا تُحَمِّلْنَا مَا لَا طَاقَةَ لَنَا بِهِ ۖ وَاعْفُ عَنَّا وَاغْفِرْ لَنَا وَارْحَمْنَا ۚ أَنْتَ مَوْلَانَا فَانْصُرْنَا عَلَى الْقَوْمِ الْكَافِرِينَ}

صدق الله العظيــم ،،،

سورة البقرة الآية (286)

Dedication

To the owner of a fragrant biography and an enlightened thought, for he had the first credit in attaining higher education (my beloved father), my god prolong his life

To who set me on the path of life, and took care of me until I became the man I am today (my beloved mother), my god prolong her life

To my brothers…

To everyone who gave me advice and guidance on the path of life

I dedicate this research to you….

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ABSTRACT

Pouring concrete in hot weather has a significant impact on the concrete pouring process, due to the ability of the high temperature to evaporate the water present in the concrete mixture, whose main task is to complete the hydration process of the cement .

In Khartoum city – Sudan, the air temperature is very high during the summer and there is fluctuation in temperature throughout the year, and in hot weather it is difficult to carry out concrete work. The main problem in hot weather is the increased demand for water due to the high temperature , the most important of which is reducing the compressive Strength of concrete.

In this study a questionnaire was made and distributed to engineers , tests were conducted on four concrete mixes designed according to the British code (BS) to know the effect of high temperature of the mix on the compressive strength . In the first mixture coarse aggregate was heated to temperature of (50c^{o}) to simulate the natural conditions in the site , the second mixture sprayed aggregate with water for cooling, the third mixture used cold water for mixing , the fourth mixture aggregate was sprayed with normal water 24c^{o} for cooling and cold water 12.3c^{o} was used for mixing.

The first mixture is considered a standard mixture and the rest of the mixtures are attempts to reduce the temperature of the concrete mix and the compressive strength was measured during (7&28) days.

It was found that use of cold water in concrete mixing leads to a decrease in the temperature of the fresh concrete during mixing and pouring, as in the third and fourth mixture the temperature decreased to 32.9 c^{o} and 27.2 c^{o} compared to the first (standard) mix of 38.5 c^{o}.

The results show that the lowest temperature of mixture 27.2 c^{o} ,was in fourth mixture, has the highest compressive strength at 28 days of 39.99 N/mm^{2}.

The results of the questionnaire that were distributed to the engineers at the construction site showed that 56.76% of the engineers did not care about the weather conditions during the mixing and pouring concrete and 56.76% did not care about the temperature measurement degree of the concrete mix.

مستخلص

صب الخرسانة في الاجواء الحارة لها تأثير كبير علي عملية صب الخرسانة , وذلك بسبب قدره درجة الحرارة العالية على تبخر الماء الموجود في الخلطة الخرسانية و الذي مهمته الاساسية اتمام عملية الاماهة للإسمنت.

في مدينه الخرطوم – السودان تكون درجه حراره الجو مرتفعة للغاية خلال فصل الصيف وهنالك تقلب في درجات الحرارة علي مدار العام ، المشكلة الرئيسية في الطقس الحار هي زياده الطلب علي المياه بسبب ارتفاع درجة الحرارة ، زيادة الماء في الخلطة يؤدي الي مشاكل كثيرة أهمها تقليل مقاومة الخرسانة للضغط.

في هذه الدراسة تم عمل استبيان و توزيعه على المهندسين وأجريت الاختبارات على اربعة خلطات خرسانية مصممة وفقا للمدونة البريطانية لمعرفة تأثير ارتفاع درجة حرارة الخلطة علي مقاومة الانضغاط ، في الخلطة الأولى تم تسخين الركام الخشن لدرجة حرارة (50 درجة مئوية) لمحاكاة الظروف الطبيعية في الموقع ، في الخلطة الثانية تم رش الركام بالماء للتبريد , اما في الخلطة الثالثة تم استخدام الماء البارد في الخلط , وفي الخلطة الرابعة تم رش الركام بالماء العادي درجة الحرارة (24 درجة مئوية) للتبريد واستخدام الماء البارد درجة الحرارة (12.3 درجة مئوية) في الخلط.

تعتبر الخلطة الاولى خلطة قياسية وباقي الخلطات تعتبر محاولات لتقليل درجة حرارة الخلطة، و تم قياس مقاومة الانضغاط خلال (28& 7) يوم .

وجد ان استخدام الماء البارد في خلط الخرسانة الي انخفاض درجة حرارة الخرسانة الطازجة اثناء الخلط و الصب , حيث انخفضت درجة الحرارة في الخليط الثالث و الرابع الي 32.9 درجة مئوية و 27.2 درجة مئوية مقارنة بالمزيج الاول (القياسي) البالغ 38.5 درجة مئوية .

اظهرت النتائج ان اقل درجة حرارة للخليط 27.2 درجة مئوية , كان في الخلطة , وسجلت اعلي مقومة للضغط عند 28 يوم 39.99 نيوتن / مم^2.

اظهرت نتائج الاستبيان الذي وزع علي المهندسين في موقع البناء ان 56.76% من المهندسين لم يهتموا بالظروف الجوية اثناء خلط و صب الخرسانة و 56.76% من المهندسين لم يهتموا بقياس درجة حرارة الخلطة الخرسانية قبل الصب .

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INTRODUCION

CHAPTER ONE

INTRODUCION

1.1 General Introduction:

An overview of concrete as a material is difficult at this stage, because we must refrain from discussing specialized knowledge not yet presented, so that we have to limit ourselves to some selected features of concrete. Concrete in the broadest sense, is any product or mass made by the use of a cementing medium. Generally, this medium is the product of reaction between hydraulic cement and water.

But, these days, even such a definition would cover a wide range of products : concrete is made with several types of cement and also containing pozzolan , fly ash , blast - furnace slag , micro silica , additives , recycled concrete aggregate , admixtures , polymers , fibers , and so on ; and these concretes can be , heated , steam - cured , autoclaved , vacuum - treated , hydraulically pressured shock - vibrated , extruded , and sprayed . This book is restricted to considering no more than a mixture of cement, water, aggregate (fine and coarse) and admixtures This immediately begs the question: what is the relation between the constituents of this mixture?

There are three possibilities. First, one can view the cementing, medium, i.e. the products of hydration of cement as the essential building material with the aggregate fulfilling the role of cheap, or cheaper, dilatant. Second, one can view the coarse aggregate as a sort of mini - masonry which is joined together by mortar, i.e. by a mixture of hydrated cement and fine aggregate. The third possibility : is to recognize that , as a first approximation , concrete consists of two phases hydrated cement paste and aggregate , and , as a result , the properties of concrete are governed by the properties of the two phases and also by the presence of interfaces between them . The second and third view each has some merit and can be used to explain the behavior of concrete. The first view, that of cement paste diluted by aggregate, we should dispose of. Suppose you could buy cement more cheaply than aggregate, should you use a mixture of cement and water alone as a building material? The answer is emphatically no because the so - called volume changes of hydrated cement paste are far too large : shrinkage of neat cement paste is almost ten times larger than shrinkage of concrete with 250 kg of cement per cubic meter . Roughly the same applies to creep. Furthermore, the heat generated by a large amount of hydrating cement, especially in a hot climate, may lead to.

Cracking can also observe that most aggregates are less prone to chemical attack ' than cement paste, even though the latter is, it, fairly resistant so, quite. Independently of cost, the use of aggregate in concrete is beneficial

1.2 Problem Statement:

Concrete is one of the most widely used building materials on the face of the earth as well as in Sudan. The codes stipulate that the appropriate temperature for the mixture when pouring is 32 degrees Celsius.

In Sudan, the average temperature throughout the year in the afternoon reaches 42 degrees Celsius and may increase in the summer.

The weather temperature affects in temperature of the materials used .In mixture, this increases the temperature of the concrete mixture.

1.3 Hypothesis:

The high temperature of the concrete mix can be avoided in hot weather by following:

- Spraying the aggregate with water to cool.
- Using cold water to mix concrete.

1.4 Objectives:

The main objective of this work was to identify the effect of high weather temperature on the compressive strength and workability properties of concrete. The specific objectives are:

1. To know the effect of high weather temperature on concrete by:
    - Making a questionnaire.
    - Experimental work.
2. To Study the methods of treatment for hot weather concrete mixes by:
    - Using cold water.
    - Cooling concrete materials.

1.5 Methodology:

The following steps as a methodology to achieve the research objectives:

- Gathering data and information related to the research topic.
- A review of previous research and studies was also conducted.
- Conducting tests for materials used in mixing concrete, cement, coarse aggregate, fine aggregate.
- Concrete mixtures were designed according to British specifications (BS) and tested fresh and hardened concrete. Use different samples in temperature and knowing the extent of the effect of high temperature on the properties of concrete.
- Distribution of a statistical questionnaire to engineers to know their dealing of concrete in hot weather.

1.6 Research Layout:

This study contains five chapters are following as:

Chapter One contains general introduction, problem statement, objectives, methodology, hypothesis of research and research layout.

Chapter Two presented the literature review of previous research.

Chapter Three contains the experimental work..

Chapter Four presented analysis and discussion results.

Finally contains conclusion and recommendations.

CHAPTER TWO
LITERATURE REVIEW
AND
PREVIOUS STUDIES

CHAPTER TWO

LITERATURE REVIEW AND PREVIOUS STUDIES

2.1 Introduction:

Concrete is one of the most versatile and widely produced construction materials in the world (Penttala, 1997). Its worldwide annual production exceeds 12 billion metric tons, i.e., more than two metric tons of concrete was produced each year for every person on earth in 2007. The ever-increasing population, living standards, and economic development lead to an increasing demand for infrastructure development and hence concrete materials. As a composite material, concrete is composed of different graded aggregates or fillers embedded in a hardened matrix of cementations material. The properties of major constituents of concrete mixtures, such as aggregates, cementations materials, admixtures, and water, should be understood first to better learn the properties and performance of concrete. [2]

2.2 Advantages of Concrete:

(a) Economical: Concrete is the most inexpensive and the most readily available material in the world. The cost of production of concrete is low compared with other engineered construction materials. The three major components in concrete are water, aggregate, and cement. Compared with steels, plastics, and polymers, these components are the most inexpensive, and are available in every corner of the world. This enables concrete to be produced worldwide at very low cost for local markets, thus avoiding the transport expenses necessary for most other materials.

(b) Ambient temperature-hardened material: Because cement isa low-temperature bonded inorganic material and its reaction occurs at room temperature, concrete can gain its strength at ambient temperature. No high temperature is needed.

(c) Ability to be cast: Fresh concrete is towable like a liquid and hence can be poured into various formworks to form different desired shapes and sizes right on a construction site. Hence, concrete can be cast into many different configurations. One good example to show concrete cast ability is the Baha'i Temple located in Wilmette, Illinois, USA, as shown in Figure 1-10. The very complex configurations of the different shapes of flowers in the wall and roof are all cast by concrete.

(d) Energy efficient: Compared with steel, the energy consumption of concrete production is low. The energy required to produce plain concrete is only 450–750kwh/ton and that of reinforced concrete is 800–3200kwh/ton, while structural steel requires 8000kwh/ton or more to make.

(e) Excellent resistance to water: Unlike wood (timber) and steel, concrete can be hardened in water and can withstand the action of water without serious deterioration, which makes concrete an ideal material for building structures to control, store, and transport water, such as pipelines dams, and submarine structures. A typical example of a pipeline application is the Central Arizona Project, which provides water from the Colorado River to central Arizona. The system contains 1560 pipe sections, each 6.7m long, 7.5m outside diameter, and 6.4m inside diameter. Contrary to popular belief, water is not deleterious to concrete, even to reinforced concrete; it is the chemicals dissolved in water, such as chlorides, sulfates, and carbon dioxide that cause deterioration of concrete structures.

(f) High-temperature resistance: Concrete conducts heat slowly and is able to store considerable quantities of heat from the environment. Moreover, the main hydrate that provides binding to aggregates in concrete, calcium silicate hydrate (C–S–H), will not be completely dehydrated until 910oc. Thus, concrete can withstand high temperatures much better than wood and steel. Even in a fire, a concrete structure can withstand heat for 2–6 hours, leaving sufficient time for people to be rescued. This is why concrete is frequently used to build up protective layers for a steel structure.

(g) Ability to consume waste: With the development of industry, more and more by-products or waste has been generated, causing a serious environmental pollution problem. To solve the problem, people have to find a way to consume such wastes. It has been found that many industrial wastes can be recycled as a substitute (replacement) for cement or aggregate, such as fly ash, slag (GGBFS = ground granulated blast-furnaces slag), waste glass, and ground vehicle tires in concrete. Production of concrete with the incorporation of industrial waste not only provides an effective way to protect our environment, but also leads to better performance of a concrete structure. Due to the large amount of concrete produced annually, it is possible to completely consume most of industry waste in the world, provided that suitable techniques for individual waste incorporation are available.

(h) Ability to work withers in forcing steel: Concrete has a similar value to steel for the coefficient of thermal expansion (steel $1.2\times10-5$; concrete $1.0–1.5\times10-5$). Concrete produces a good protection to steel due to existence of CH and other alkalis (this is for normal conditions). Therefore, while steel bars provide the necessary tensile strength, concrete provides a perfect environment for the steel, acting as a physical barrier to the ingress of aggressive species and giving chemical protection in a highly alkaline environment (phvalue is about 13.5), in which black steel is readily passivized.

(i) Less maintenance required: Under normal conditions, concrete structures do not need coating or painting as protection for weathering, while for a steel or wooden structure, it is necessary. Moreover, the coatings and paintings have to be replaced few years. Thus, the maintenance cost for concrete structures is much lower than that for steel or wooden structures. [2]

2.3 Types of Concrete:

Based on unit weight, concrete can be classified into three broad categories. Concrete containing natural sand and gravel or crushed-rock aggregates, generally weighing about 2400 kg/m3 (4000 lb/yd3), is called normal-weight concrete, and it is the most commonly used concrete for structural purposes. For applications where a higher strength-to-weight ratio is desired, it is possible to reduce the unit weight of concrete by using natural or pyro-processed aggregates with lower bulk density. The term lightweight concrete is used for concrete that weighs less than about 1800 kg/m3 (3000 lb/yd3). Heavyweight concrete, used for radiation shielding, is a concrete produced from high-density aggregates and generally weighs more than 3200 kg/m3 (5300 lb/yd3). Strength grading of cements and concrete is prevalent in Europe and many other countries but is not practiced in the United States. However, from standpoint of distinct differences in the microstructure-property relationships, which will be discussed later, it is useful to divide concrete into three general categories based on compressive strength:

■ Low-strength concrete: less than 20 mpa (3000 psi)

■ Moderate-strength concrete: 20 to 40 mpa (3000 to 6000 psi)

■ High-strength concrete: more than 40 mpa (6000 psi).

Moderate-strength concrete also referred to as ordinary or normal concrete is used for most structural work. High-strength concrete is used for special [2]

Table 2.1: Classification of concrete in accordance with unit weight [2]

Classification	Unit weight(kg/m3)
Ultra-lightweight concrete	<1200
Lightweight concrete	1200<UW<1800
Normal-weight concrete	~2400
Heavyweight concrete	>3200

2.4 Concrete Materials:

2.4.1Aggregates:

Aggregates constitute a skeleton of concrete. Approximately three-quarters of the volume of conventional concrete is occupied by aggregate. It is inevitable that a constituent occupying such a large percentage of the mass should contribute important properties to both the fresh and hardened product. Aggregate is usually viewed as an inert dispersion in the cement paste. However, strictly speaking, aggregate is not truly inert because physical, thermal, and, sometimes, chemical properties can influence the performance of concrete. [2]

2.4.1.1 Effects of Aggregates:

(a) Aggregate in fresh and plastic concrete: when concrete is freshly mixed, the aggregates are suspended in the cement–water–air bubble paste. The behavior of fresh concrete, such as fluidity, cohesiveness, and rheological behavior, is largely influenced by the amount, type, surface texture, and size gradation of the aggregate. The selection of aggregate has to meet the requirement of the end use, i.e., what type of structure to be built.

(b) Aggregate in hardened concrete: although there is little chemical reaction between the aggregate and cement paste, the aggregate contributes many qualities to the hardened concrete. In addition to reducing the cost, aggregate in concrete can reduce the shrinkage and creep of cement paste. Moreover, aggregates have a big influence on stiffness, unit weight, strength, thermal properties, bond, and wear resistance of concrete.

2.4.1.2 Classification of Aggregates:

- **Coarse Aggregate:**

Aggregates predominately retained on a No. 4 (4.75-mm) sieve are classified as coarse aggregate.

Generally the size of coarse aggregate ranges from 5 to 150 mm. For normal concrete used for structural members such as beams and columns, the maximum size of coarse aggregate is about 25 mm. For mass concrete used for dams or deep foundations, the maximum size can be as large as 150 mm. Figure 2-1 shows some examples of coarse aggregates.

- **Fine Aggregate (Sand):**

Aggregates passing through a No. 4 (4.75 mm) sieve and predominately retained on a No. 200 (75 µm) sieve are classified as fine aggregate. River sand is the most commonly used fine aggregate. In addition, crushed rock fines can be used as fine aggregate. However, the finish of concrete with crushed rock fines is not as good as that with river sand. [2]

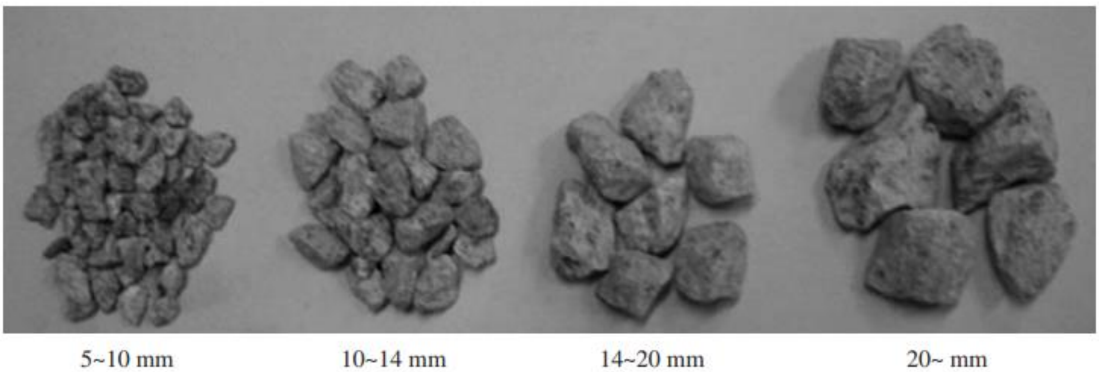


Figure 2.1: Different sizes of coarse aggregates [2]

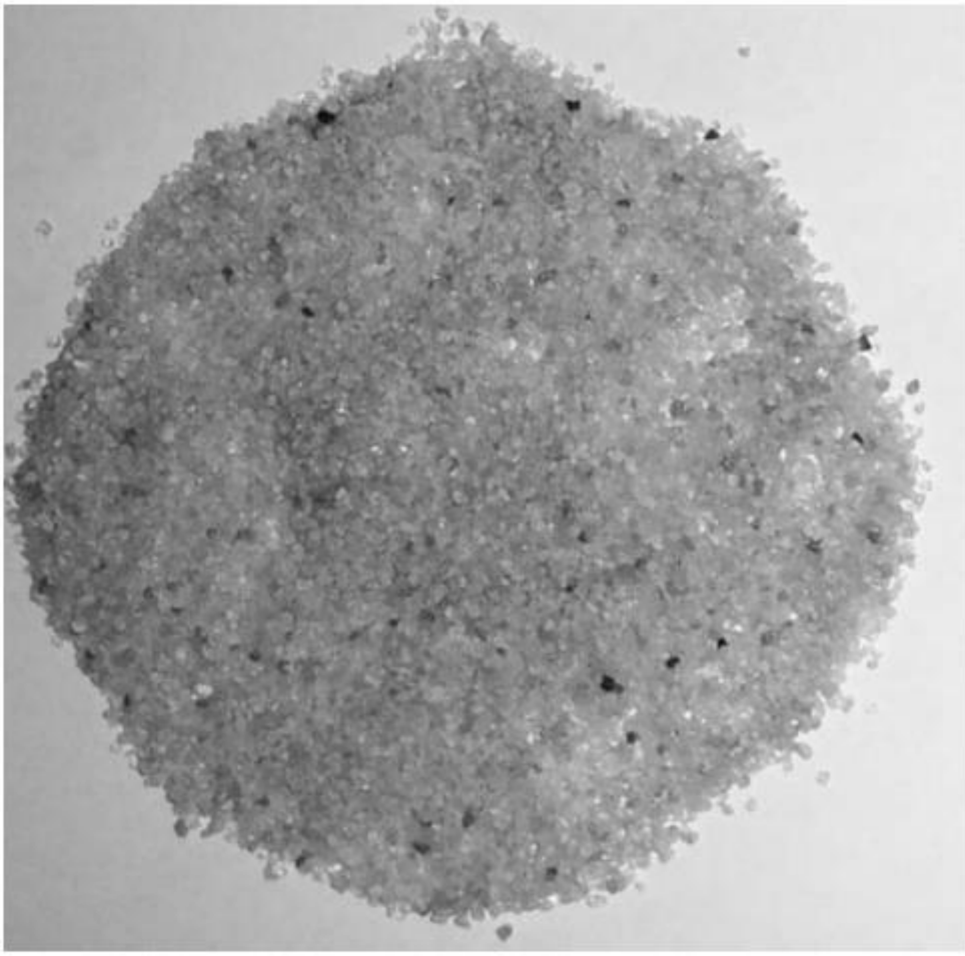


Figure 2.2: Profile of sand [2]

2.4.2.3 Grading and Size Distribution:

The particle size distribution of aggregates is called grading. Grading determines the paste requirement for a workable concrete since the amount of voids among aggregate particles requires the same amount of cement paste to fill out in the concrete mixture. To obtain a grading curve for an aggregate, sieve analysis has to be conducted. The commonly used sieve designation is listed in Table 2-2.

As shown in Figure 2-3, five size distributions are generally recognized: dense, gap graded, well-graded, uniform graded, and open graded. The dense and well-graded types are essentially the wide size ranges with smooth distribution. They are the desired grading for making concrete. The dense graded is for coarse aggregate and well-graded for fine aggregate. Gap grading is a kind of grading that lacks one or more intermediate size; hence, a nearly flat horizontal region appears in the grading curve. For uniform grading, only a few sizes dominate the bulk materials, and the grading curve falls almost vertically at the dominating size. Open grading is defined as being under compact conditions, the voids among the aggregate are still relatively large. In open grading, usually the smaller size of aggregate dominates the bulk and can be easily disturbed by a small cavity. Open-grade material is not suitable to be used for sub grade construction of a road. [2]

Table 2.2: Commonly used sieve designation and the corresponding opening size [2]

Sieve Designation	Nominal Size of Sieve Opening
3 in	75 mm
1.5 in	37.5 mm
3/4 in	19 mm
3/8 in	9.5 mm
No. 4	4.75 mm
No. 8	2.36 mm
No. 16	1.18 mm
No. 30	600 µm
No. 50	300 µm
No. 100	150 µm
No. 200	75 µm

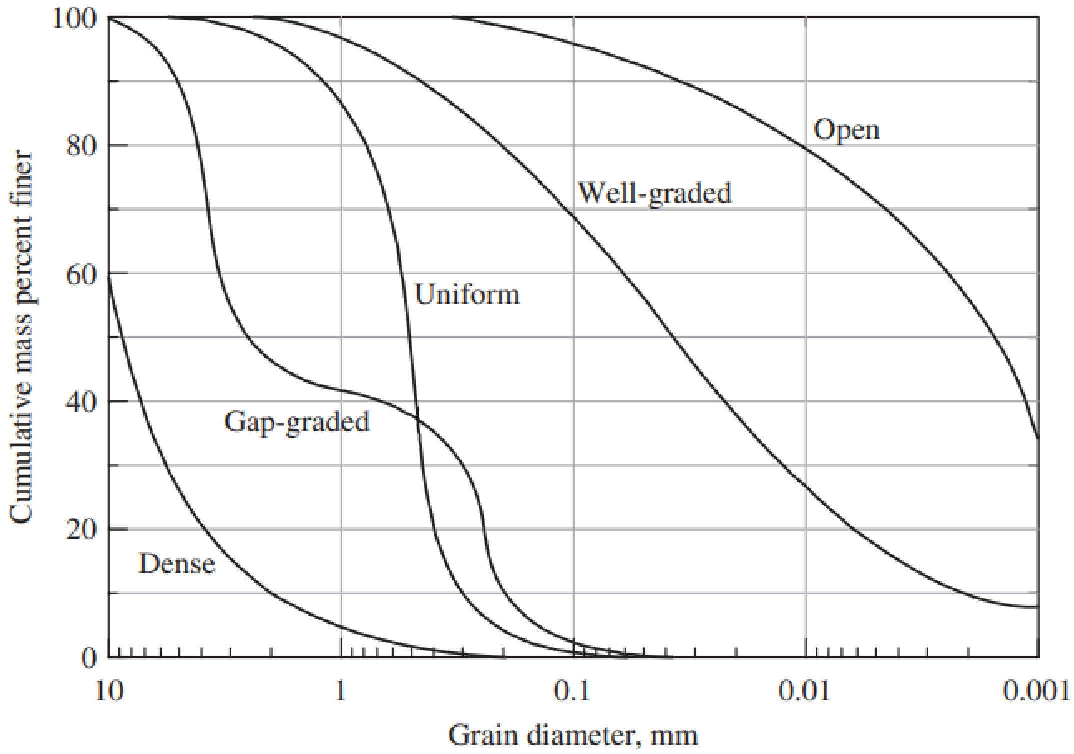


Figure 2.3: Five types of aggregate gradation [2]

It can be seen from the formula that calculation of the fineness modulus requires that the sum of the cumulative percentages retained on a definitely specified set of sieves be determined, and the result divided by 100. The sieves specified to be used in determining the fineness modulus are No. 100, No. 50, No. 30, No. 16, No. 8, No. 4, 3/8", 3/4", 1.5", 3", and 6". It can be seen that the size of the opening in the above sieves has a common factor of 0.5 in any two adjacent ones. They are called full-size sieves. Any sieve size between full-size sieves is called half-size.

2.4.2 Cement:

Cement Ancient Romans were probably the first to use concrete a word of Latin origin - based on hydraulic cement that is a material which hardens under water. This property and the related property of not undergoing chemical change by water in later life are most important and have contributed to the widespread use of concrete as a building material. Roman cement fell into disuse, and it was only in 1824 that the modern cement, known as Portland cement, was patented by Joseph Aspdin, a Leeds builder. Portland cement is the name given to a cement obtained by intimately mixing together calcareous and argillaceous , or other silica- , alumina- , and iron oxide - bearing materials , burning them at a clinkering temperature , and grinding the resulting clinker . The definitions of the original British and new European Standards and of the American Standards are on those lines; no material, other than gypsum, water, and grinding aids may be added after burning. [1]

2.4.2.1 Manufacture of Portland Cement:

From the definition of Portland cement given above, it can be seen that it is made primarily from a combination of a calcareous material, such as limestone or chalk, and of silica and alumina found as clay or shale. The process of manufacture consists essentially of grinding the raw materials into a very fine powder, mixing them intimately in predetermined proper tons and burning in a large rotary kiln at a temperature of about 1400 ° C (2550 ° F) when the material sinters and partially fuses into clinker. The clinker is cooled and ground to a fine powder, with some gypsum added, and the resulting product is the commercial Portland cement used throughout the world. The mixing and grinding of the raw materials can be done either in water or in a dry condition; hence, the names wet and dry process. The mixture is fed into a rotary kiln , sometimes (in the wet process) as large as 7 m (23 ft) in diameter and 230 m (750 ft) long . The kiln is slightly inclined. The mixture is fed at the upper end while pulverized coal (or other source of heat) is blown in by an air blast at the lower. [1]

2.4.2.2 Hydration of Cement:

So far, we have discussed cement in powder form but the material of interest in practice is the set cement paste. This is the product of reaction of cement with water. What happens is that, in the presence of water, the silicates and aluminates (Table2.3) of Portland cement form products of hydration or hydrates, which in time produce a firm and hard mass - the hardened cement paste. As stated earlier, the two calcium silicates (C3 S and C2S) are the main cementations compounds in cement, the former hydrating much more rapidly than the latter. In commercial cements, the calcium silicates contain small impurities from some of the oxides present in the clinker. These impurities have a strong effect on the properties of the hydrated silicates. The ' impure ' C3 S is known as elite and the impure ' C2S as belie. The product of hydration of C3S is the microcrystalline hydrate C3S2H3 with some lime separating out as crystalline Ca $(OH)_2$; C2S behaves Simi early but clearly contains less lime. Nowadays, the calcium silicate hydrates are described as C - S - H (previously referred).

Table 2.3: Main compounds in Portland cement. [1]

Name of compound	Oxide composition	Abbreviation
Tricalcium silicate	3CaO.SiO2	C3S
Dicalcium silicate	2CaO.SiO2	C2S
Tricalcium aluminates	3CaO.Al2O3	C3A
Tetracalciumaluminoferrite	4CaO.Al2O3.Fe2O3	C4AF

2.4.2.3 Types of Portland Cements:

According to the ASTM standard, there are five basic types of Portland cement:

Type I regular cement, general use.

Type II moderate sulfate resistance, moderate heat of hydration

Type III increase C3S, high early strength

Type IV low heat

Type V high sulfate resistance

In BSI, four basic Portland cements are standardized: ordinary Portland cement (OPC), rapid hardening Portland cement (RHPC), low-heat Portland cement (LHPC), and sulfate-resistant Portland cement (SRPC). OPC is equivalent to type LHPC, type IV; SRPC, type V. and I in ASTM, and RHPC, type III There is no Portland cement similar to type II in BSI. The typical chemical compositions of five types of Portland cement in ASTM are given in Table 2.4. Type I is usually used as a reference, which contains 50% C3S, 25% C2S, 12% C3A, 8% C4AF, and 5% gypsum. Compared to type I, type III has more C3S (60%) and less C2S (15%). Moreover, type III has a larger fineness number than type I. As a result, the early strength of type III at 1 day is doubled as compared to that of type I. Meanwhile, the heat released by type III increases to 500 J/g (type I is 330 J/g). On the other hand, type IV has less C3S (25%) and more C2S (50%). Hence, the early strength of type IV at 1 day is only half of that of type I. However, the heat released by type IV greatly decreases to 210 J/g, and thus is called-low heat Portland cement. As for type V, its sum of C3A and C4AF is only 14% and much less than the

20% of type I. Since these two compounds readily react with sulfate, the lower content gives

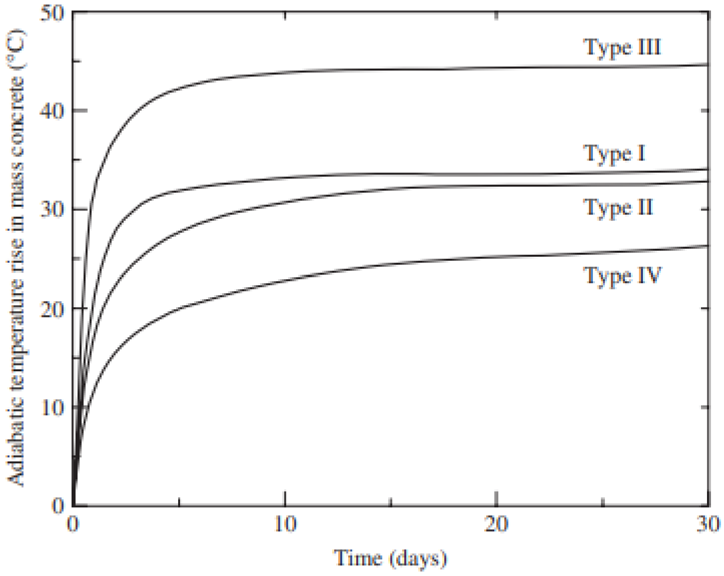


Figure 2.4: Adiabatic temperature rise in mass concretes with different types of cement. [2]

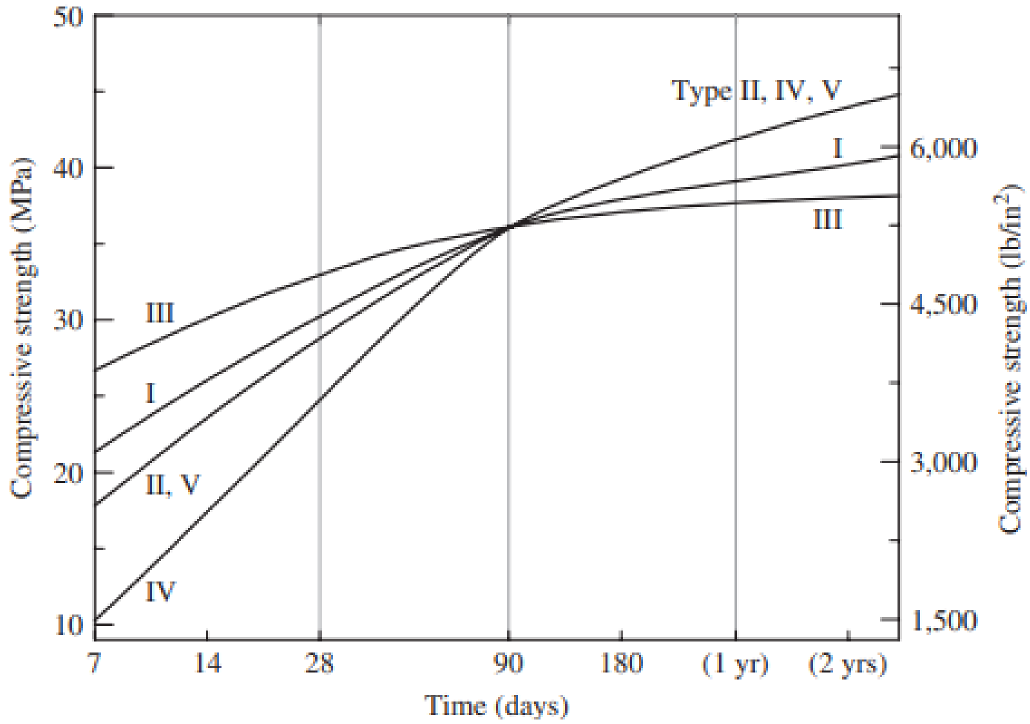


Figure 2.5: Strength development of cement pastes with different types of cement. [2]

Table 2.4: Chemical compositions and physical properties of different Portland cements

Chemical Compositions and Physical Properties	Portland Cement Type				
	I	II	III	IV	V
C3S	50	45	60	25	40
C2S	25	30	15	50	40
C3A	12	7	10	5	4
C4AF	8	12	8	12	10
CSH2	5	5	5	4	4
Fineness (Blaine, m2/kg)	350	350	450	300	350
Compressive strength (1 day, MPa [psi])	7 [1000]	6 [900]	14 [2000]	3 [450]	6 [900]
Heat of hydration (7 days, J/g)	330	250	500	210	250

Because too much heat will cause a larger temperature gradient, thermal stress, and cracking. Hence, type IV cement should be the first candidate and type iii should not be used. For a marine structure, high sulfate resistance and lower ettringite are needed; thus, type v should be selected. If high early strength is needed, type iii will be the best choice. Generally, type I is the most popular cement used in civil engineering. [2]

2.4.3 Admixtures:

Historically, an admixture is almost as old as concrete itself. The Romans used animal fat, milk, and blood to improve their concrete properties. Although these were added to improve workability, blood was a very effective air-entraining agent and might well have improved Roman concrete durability. In more recent times, calcium chloride was often used to accelerate the hydration of cement. The systematic study of admixtures began with the introduction of air-entraining agents in the 1930s, when it was accidentally found that cement ground with beef tallow (grinding aid) had more resistance to freezing and thawing than a cement ground without beef tallow. Nowadays, as we mentioned earlier, admixtures are important and necessary components for modern concrete technology. The concrete properties, both in fresh and hardened states, can be modified or improved

By admixtures. The benefits of admixtures to concrete are listed in Table 2-10. Today, almost all the contemporary concretes contain one or more admixtures. It is thus important for civil engineers to be familiar with commonly used admixtures.

2.4.3.1 Definition and Classifications an Admixture:

Is defined as a material other than water, aggregates, cement, and reinforcing fibers that is used in concrete as an ingredient, and added to the batch immediately before or during mixing.

Admixtures can be roughly divided into the following groups.

- Air-entraining agents (ASTM C260): This kind of admixture is used to improve the frost resistance of concrete.

Table 2.5: Beneficial effects of different kinds of admixtures on concrete properties [2]

Concrete Property	Admixture Type	Category of Admixture
Workability	Water reducers Air-entraining agents Inert mineral powder Pozzolans Polymer latexes	Water reducers Air entraining Mineral Mineral Miscellaneous
Set control	Set accelerators Set retarders	Chemical Chemical
Strength	Pozzolans Polymer latexes	Mineral Miscellaneous
Durability	Air-entraining agents Pozzolans Water reducers Corrosion inhibitors Shrinkage reducer	Air entraining Mineral Chemical Miscellaneous Miscellaneous
Special concrete	Polymer latexes Silica fume Expansive admixtures Color pigments Gas-forming admixtures	Miscellaneous Mineral Miscellaneous Miscellaneous Miscellaneous

- Chemical admixtures (ASTM C494 and BS 5075): A chemical admixture is any chemical additive to the concrete mixture that enhances the properties of concrete in the fresh or hardened state. The general-purpose chemicals include those that reduce the water demand for a given workability (called water reducers), and those chemicals that control the setting time and strength gain rate of concrete (called accelerators and retarders). Apart from these chemicals, there are others for special purposes—viscosity-modifying agents, shrinkage reducing chemicals, and alkali–silica reaction-mitigating admixtures.
- Mineral admixtures: This kind of admixture consists of finely divided solids added to concrete to improve its workability, durability, and strength. Slag and pozzolans are important categories of mineral admixtures.
- Miscellaneous admixtures include all those materials that do not come under the above mentioned categories, such as latexes, corrosion inhibitors, and expansive admixtures. [2]

2.4.4 Water:

When we consider the strength of concrete, the vital influence of the quantity of water in the mix on the strength of the resulting concrete will become clear. At this stage, we are concerned only with the individual ingredients of the concrete mix: cement, aggregate, and water and it is the quality of the latter that is the subject matter of this chapter. The quality of the water is important because impurities in it may interfere with the setting of the cement, may adversely affect the strength of the concrete or cause staining of its surface, and may lead to corrosion of the reinforcement. For these reasons, the suitability of water for mixing and curing purposes should be considered. Clear distinction must be made between the effects of mixing water and the attack on hard ended concrete by aggressive waters because some of the latter type may be harmless or even beneficial when. Used in mixing. [1]

2.4.4.1 Mixing Water:

In many specifications, the quality of water is covered by a clause saying that water should be fit for drinking. Such water very rarely contains dissolved. solids in excess of 2000 parts per million (ppm) , and as a rule less than 1000 ppm For a water / cement ratio of 0.5 by mass , the latter content corresponds to a quantity of solids equal to 0.05 per cent of the mass of cement , and thus any effect of the common solids (considered as aggregate) would be small . If the silt content is higher than 2000 ppm, it is possible to reduce it by allowing the water to stand in a settling basin before use. However, water used to wash out truck mixers is satisfactory as mixing water (because the solids in it are proper concrete ingredients provided of course that it was satisfactory to begin with. ASTM C 94-05 allows, (the use of wash water, but, obviously. different cements and different admixtures should not be involved. The criterion of portability of water is not absolute: drinking water may be unsuitable as mixing water when the water has a high concentration of sodium or potassium and there is a danger of alkali - aggregate reaction. While the use of potable water is generally safe, water not fit for drink in May. Often also, be satisfactorily used in making concrete. As a rule, any water with a pH degree of acidity) of 6.0 to 8.0 which do not taste saline or brackish is suitable) for use, but a dark color or a smell do not necessarily mean that deleterious substances are present. Natural waters that are slightly acidic are harmless, but water containing hemic or other organic acids may adversely affect the hardening of, concrete: such water. As well as highly alkaline water, should be tested. Two somewhat peripheral, comments may be made the presence of algae in mixing water results in air entrainment with a consequent loss of strength. Hardness of water does not affect the efficiency of air - entraining admixtures. Sometimes it may be difficult to obtain sufficient quantities of fresh water and only brackish water is available, which contains chlorides and sulfates. For chloride ion content, a general limit of 500 mg per liter is recommended by BS 3148:1980, but the limits of BS EN. And ASTM C 1602-06 vary according to concrete usage 2002: 1008. [1]

2.4.4.2 Curing Water:

Generally, water satisfactory for mixing is also suitable for curing purposes. However, iron or organic matter may cause staining, particularly if water flows slowly over concrete and evaporates rapidly. In some cases, discoloration is of no significance and any water suitable for mixing, or even slightly inferior in quality, is acceptable for curing. However, it is essential that curing water be free from substances that attack hardened concrete. For example, concrete is attacked by water. Containing free CO3.Flowing pure water, formed by melting ice or by con dentation, and containing little CO3, dissolves CA (OH), and causes surface erosion. This topic is discussed further. Curing with seawater may lead to attack of reinforcement. [1]

2.5 Proportioning Concrete Mixtures:

The proportioning of concrete mixtures is the process of arriving at the right combination of cement, aggregates, water, and admixtures for making concrete according to given specifications. For reasons described below, this process is considered an art rather than a science. Although many engineers do not feel comfortable with matters that cannot be reduced to an exact set of numbers, with an understanding of the underlying principles and, with some practice, the art of proportioning concrete mixtures can be mastered. Given an opportunity, the exercise of this art is very rewarding because the effect of mix proportioning on the cost of concrete and several important properties of both fresh and hardened concrete can be clearly seen.

One purpose of mix proportioning is to obtain a product that will perform according to certain predetermined requirements. Conventionally, the two most essential requirements are the workability of fresh concrete and the strength of hardened concrete at a specified age. Workability, which is discussed in more detail in Chap. 10, is the property that determines the ease with which a concrete mixture can be placed, compacted, and finished. Durability is another important property, but it is generally assumed that under normal exposure conditions durability will be satisfactory if the concrete mixture develops the necessary strength. Of course, under severe conditions, such as freeze-thaw cycles or exposure to sulfate water, the proportioning of concrete mixture will require special attention. Another purpose of mix proportioning is to obtain a concrete mixture satisfying the performance requirements at the lowest possible cost. This involves decisions regarding the selection of ingredients that are not only suitable but also available at reasonable prices. The overall objective of proportioning concrete mixtures can therefore be summarized as selecting the suitable ingredients among the available materials and determining the most economical combination that will produce concrete with certain minimum performance characteristics. The tools available to the engineer to achieve this objective are limited. An obvious constraint in concrete mixture proportioning is that within a fixed volume you cannot alter one component independent of others. For example, in a cubic meter of concrete, if the aggregate component is increased, the cement paste component decreases. With concrete-making materials of given characteristics and with given job conditions (i.e., structural design, and equipment for handling concrete), the variables generally under the control of a mix designer are as follows: the cement paste-aggregate ratio in the mixture, the water-cement ratio in the cement paste, the sand-coarse aggregate ratio in the aggregates, and the use of admixtures. The task of mixture proportioning is complicated by the fact that certain desired properties of concrete may be oppositely affected by changing a specific variable. For example, the addition of water to a stiff concrete mixture with given cement content will improve the flow ability of fresh concrete but at the same time will reduce the strength. In fact, workability itself is composed of two main components [i.e., consistency (ease of flow) and cohesiveness (resistance to segregation)], and both tend to be affected in an opposite manner when water is added to a given concrete mixture. The process of mixture proportioning boils down to the art of balancing various conflicting requirements. [3]

2.5.1 General Considerations:

Before discussing the specific principles underlying the procedures commonly used for mixture proportioning, let us examine some of the general considerations such as cost, workability, strength, and durability of concrete.

2.5.1.1 Cost:

The most obvious consideration when choosing concrete-making materials is that they are technically acceptable and, at the same time, economically attractive. In other words, when a material is available from two or more sources and a significant price differential exists, the least expensive source of supply is usually selected unless there are demonstrable technical reasons that the material will not be suitable for the job at hand. In spite of the usually small differences in the price of aggregates from various local sources, the overall savings for a large project are worthy of consideration. Assume that a concrete mixture composed of 1800 kg/m3 of total aggregate is required for a 6 million cubic meter concrete job, and that the two sources capable of furnishing suitable aggregates have a 10-cent/ton price difference between them. A simple computation will show that a cost saving of over $1 million is possible if the less expensive aggregate is selected. At times, for traditional or other reasons which may no longer be valid, some specifying agencies continue to require materials for concrete that are more expensive and perhaps unnecessary. For example, requiring the use of a low alkali Portland cement when the locally available cements are of high-alkali type and the aggregates are essentially free from alkali-reactive minerals will increase the cost of concrete due to the extra haulage expense for low-alkali cement. Even when the aggregate under consideration contains alkali-reactive minerals, the use of pozzolanic admixtures in combination with high-alkali cement may turn out to be the more cost-effective alternative. A key consideration governing many of the principles behind the procedures for proportioning concrete mixtures is the recognition that cements costs much more than aggregates; therefore, all possible steps should be taken to reduce the cement content of a concrete mixture without sacrificing the desired performance characteristics of concrete, such as strength and durability. For the purpose of illustration, let us refer to the data in Fig. 3-6 (Mixtures No. 1 and 3). A reduction in the cement content from 530 to 460 lb. per cubic yard of concrete at a given water-cement ratio (i.e., without compromising the strength of concrete) made it possible to reduce the cost by $1.55 per cubic yard, because a lower consistency was acceptable for the job. This may well be the case with lightly reinforced or unreinforced concrete structures. The economic implication of reduction in the cement content can be enormous in the projects requiring large amounts of concrete. Further cost reduction is possible, without compromising the essential performance characteristics of a concrete mixture, if cheaper and suitable materials are found to replace a percentage of Portland cement. For instance, under most conditions, substitution of pozzolanic or cementations by-products (such as fly ash or ground granulated iron blast-furnace slag) for Portland cement is likely to produce direct savings in the cost of materials. Furthermore, at some point in the future every nation will have to consider the indirect cost savings resulting from resource preservation and reduced pollution when these industrial by-products are utilized properly, instead of being dumped into the environment. [3]

2.5.1.2 Workability:

Workability of fresh concrete has a direct effect on the pump ability and constructability because it determines the ease with which a concrete mixture can be handled without harmful segregation. In all likelihood, a concrete mixture that is difficult to place and consolidate will not only increase the cost of handling but will also have poor strength, durability, and appearance. Similarly, mixtures prone to segregate and bleed are more expensive to finish and will yield less durable concrete. Thus, workability can affect both the cost and the quality of concrete mixtures. However, there is a problem. The term workability represents many diverse characteristics of fresh concrete that are difficult to measure quantitatively. This is another reason why the proportioning of concrete mixtures for a desirable but not fully definable measure of workability remains an art as well as a science. Clearly, mere knowledge of mixture design procedures is not sufficient without an understanding of the basic principles involved. General considerations guiding the workability of concrete mixtures are as follows:

- The consistency of concrete should be no more than necessary for the ease of placing, compaction, and finishing.
- The water requirement for a given consistency increases with both sand/coarse aggregate ratio and the amount of fines in the sand. Whenever possible, the cohesiveness and finish ability of concrete should be improved by increasing the sand/coarse aggregate ratio alone rather than by increasing the proportion of fine particles in the sand.
- For concrete mixtures requiring high consistency at the time of placement, the use of water-reducing and set-retarding admixtures should be considered rather than the addition of extra water at the job site; water that has not been accounted for in the mixture proportioning is frequently responsible for the failure of concrete to perform according to design specifications. [3]

2.5.1.3 Strength and Durability:

Strength and impermeability of hydrated cement pastes are mutually related through capillary porosity, which is controlled by the water-cement ratio and the degree of hydration (Fig. 2-11). With the exception of frost resistance, the durability of concrete is generally controlled by permeability. Consequently, in routine mix designing operations only the workability and strength of concrete are specified; consideration of durability is ignored unless special environmental exposures require it. With normally available cements and aggregates, structural concretes of consistency and strength adequate for most purposes, that is, 100- to 150-mm slump and 20 to 40 MPs 28-day compressive strength can be produced without any difficulty. When strength or durability considerations require a lower water-cement ratio, this is generally achieved by lowering the water demand at given cement content through control of the aggregate grading and the use of water-reducing admixtures. This approach not only is more economical but also would reduce the chances of cracking due to high thermal shrinkage and high drying shrinkage when the water-cement ratio is lowered by using high cement content. [3]

2.5.1.4 Ideal Aggregate Grading:

Considerations of cost, workability, strength, and durability may lead to the assumption that the densest aggregate packing with a minimum content of voids will be the most economical because it requires the least amount of cement paste. This assumption has led to a number of theoretical studies on the packing density of granular materials, which is defined as the solid volume in a unit total volume. The objective of such studies has been to obtain mathematical expressions or ideal grading curves that help determine the ideal combination of different size fractions of aggregate particles to produce the minimum void space. De Larrard1 provides an excellent review of models to predict the packing density of granular mixtures. Besides being uneconomic, the use of ideal aggregate grading is not prevalent in concrete field practice because often it does not produce the best workability. In the United States, the grading limits specified by ASTM C 33 are usually followed. Not only they are broad and therefore economically attractive, but also are based on practical experience with a large number of concrete mixtures. Using aggregates outside the limits of ASTM C 33 have caused workability problems and produced large voids in concrete. However, using aggregates that meet the requirements of ASTM C 33 may not necessarily produce satisfactory concrete mixtures because the grading limits happen to be too broad to guarantee optimum packing density. Shilstone2 reported that combined mixture containing the course and the fine aggregates is often deficient of particles in the size range 4.75 to 9.5 mm. This can be remedied by substituting a portion (e.g., 15 to 30 percent by mass) of the coarse aggregate with pea-size (4.75 to 9.5 mm) gravel or crushed rock. [3]

2.6 Concrete at Early Age:

Selection of proper materials and mixture proportions are important steps in producing a concrete meeting the requirements of strength and durability in a structural member. However, this goal will remain elusive if adequate attention is not paid to the processing operations to which concrete is subjected at early age. The term early age covers only an insignificant amount of time (e.g., first 2 days after production) in the total life of concrete but during this period numerous operations are performed such as mixing, transport to the job site, placement in the forms, consolidation, finishing, curing, and removal of formwork. These operations are affected by the characteristics of fresh concrete, like workability and setting time. Obviously, the control of both early-age operations and properties of fresh concrete is essential to ensure that the finished element is structurally adequate for the purpose for which it was designed. A detailed description of the operations and equipment used for batching, mixing, conveying, placing, consolidation, and finishing operations for fresh concrete is beyond the scope of this book. Only the basic methods and their significance are described in this chapter. The significance and control of properties of fresh concrete, such as workability, slump loss, segregation and bleeding, plastic shrinkage, setting time, and temperature of fresh concrete are discussed. Finally, as effective and economical tools of modern quality assurance programs, the accelerated strength testing procedures and statistical quality control charts are briefly discussed. [3]

2.6.1 Placing, Compacting, and Finishing:

After arrival at the job site, the ready-mixed concrete should be placed as near as possible to its final position. Belt conveyers, truck-mounted chutes, and mobile-boom pumps are among the most commonly used today for concrete placement (Fig. 2.6). To minimize segregation, concrete should not be moved over too long a distance during the placement into forms. In general, the concrete mixture is deposited in horizontal layers of uniform thickness, and each layer is thoroughly compacted before the next is placed. The rate of placement**.**

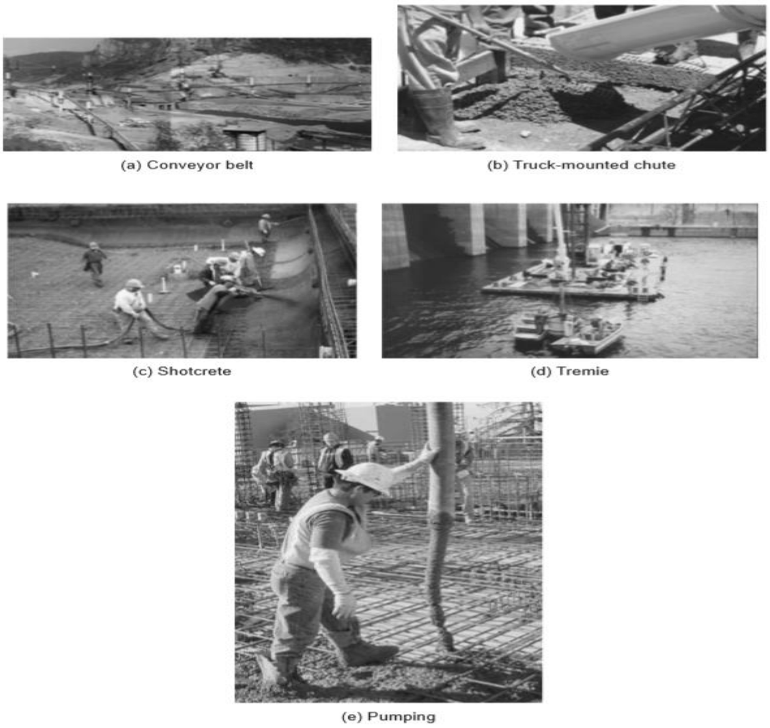


Figure 2.6: Placement of concrete as near as possible to its final position prevents segregation [3]

Is kept rapid enough so that the layer immediately below is still plastic when a new layer is deposited This prevents cold joints, flow lines, and planes of weakness that occur when fresh concrete is placed on hardened concrete. Consolidation or compaction is the process of molding concrete within the forms and around embedded items and reinforcing steel to eliminate pockets of empty space and entrapped air. This operation can be carried out by hand rodding and tamping. However, now it is carried out by mechanical methods such as power tampers and vibrators that make it possible to place stiff mixtures with low water-cement ratio or high content of coarse aggregate. High-consistency mixtures should be consolidated with care because they are likely to segregate when intensely worked. Vibrators should only be used to compact concrete and not to move it horizontally, as this would cause segregation. Vibration, whether internal or external, is the most widely used method for compacting concrete. The internal friction between the coarse aggregate particles is greatly reduced on vibration; consequently, the mixture behaves like a liquid and begins to flow into the empty space. One purpose of using internal vibrators (described below) is to force entrapped air out of the concrete by plunging the vibrator rapidly into the mixture and removing it slowly with an up-and down motion. The rapid penetration forces the concrete upward and outward, thereby helping the air to escape. Internal or immersion-type vibrators, also called spud or poker vibrators, are commonly used for compacting concrete in beams, columns, walls, and slabs. Flexible-shaft vibrators usually consist of a cylindrical vibrating head, 19 to 175 mm in diameter and connected to a driving motor by a flexible shaft. Inside the head an unbalanced weight rotates at high speed, causing the head to revolve in a circular orbit. Small vibrators have frequencies ranging from 10,000 to 15,000 vibrations per minute and low amplitude, between 0.4 and 0.8 mm (deviation from the point of rest); as the diameter increases, the frequency decreases and the amplitude increases. An idealized representation of the sequence of actions during the consolidation of concrete by a high-frequency immersion-type vibrator is shown in fig. 2.7. External or form vibrators can be securely clamped to the outside of the forms. They are commonly used for compacting thin or heavily reinforced concrete members. While the concrete mixture is still mobile, vibration of a member congested with reinforcement helps to remove air and water that may be entrapped underneath the reinforcing bars thus improving the bond between the bars and concrete. Precutting plants generally use vibrating tables equipped with suitable controls so that the frequency and amplitude can be varied according to the size of the member and the consistency of concrete. Surface vibrators such as vibrating screeds are used to consolidate concrete in floors and slabs up to 150 mm thick. Reverberation of concrete an hour or two after the initial consolidation but before setting is sometimes needed in order to weld successive castings together. This helps to remove any cracks, voids, or weak areas created by settlement or bleeding, particularly around the reinforcing steel or other embedded items. [3]

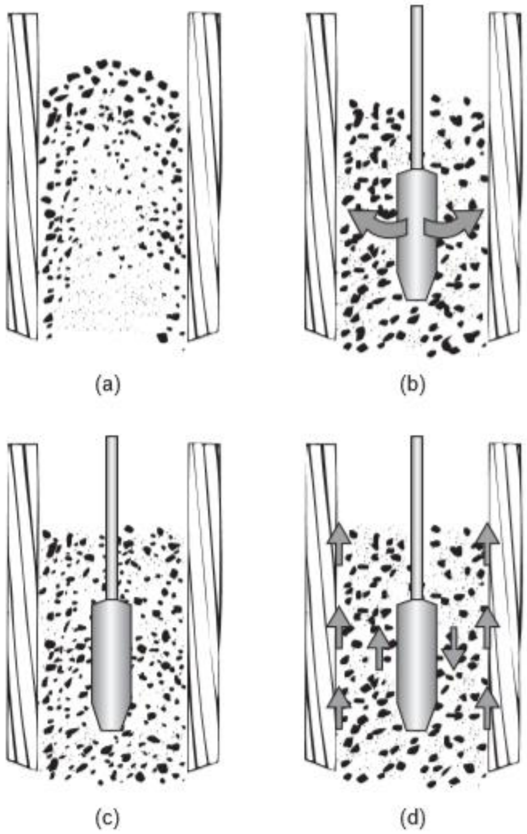


Figure 2.7: Idealized representation of the impudence of a high frequency vibrator on concrete consolidation. [3]

Flatwork such as slabs and pavements require proper finishing producing dense surfaces that will remain maintenance-free. Depending on the intended use, some surfaces require only strike-off and screening, whereas others may need finishing operations consisting of a sequence of steps described below, which must be carefully coordinated with the setting and hardening of the concrete mixture. Screening is the process of striking off excess concrete to bring the top surface to the desired grade. With a sawing motion a straight edge is moved across the surface with a surplus of concrete against the front face of the straight edge to fill in low areas. A Darby or bull-float is used immediately after screening to

Firmly embed large aggregate particles and to remove any remaining high and low spots. Bull-floating must be completed before any excess bleed water accumulates on the surface because this is one of the principal causes of surface defects such as dusting or scaling in concrete slabs. When the bleed-water sheen has evaporated and concrete is able to sustain foot pressure with only slight indentation, the surface is ready for floating and final finishing operations. Floating is an operation carried out with flat wood or metal blades for the purposes of firmly embedding the aggregate, compacting the surface, and removing any remaining imperfections. Floating tends to bring the cement paste to the surface; therefore, floating too early or for too long can weaken the surface. After floating, the surface may be steel toweled if a very smooth and highly wear resistant surface is desired. Toweling should not be done on a surface that has not been floated. For producing a skid-resistant surface, brooding or scoring with a rake or a steel-wire broom is done before the concrete has fully hardened (but has become sufficiently hard to retain the scoring). Photographs of various finishing operations are shown in Fig. 2.8. For additional durability and wear resistance, a special surface treatment after the concrete has fully hardened may be considered. [3]

Figure 2.8: Placement and finishing of concrete slabs. [3]

2.6.2 Concrete Curing and Formwork:

Removal concrete curing deserves special attention in the construction practice because inadequate curing frequently causes the lack of proper strength and durability. The two objectives of curing are to prevent the loss of moisture and to control the temperature of concrete for a period sufficient to achieve a desired strength level. When the ambient temperature is sufficiently well above freezing, the curing of pavements and slabs can be accomplished by ponding or immersion; other structures can be cured by spraying or fogging, or moisture-retaining coverings saturated with water, such as burlap or cotton. These methods afford some cooling through evaporation, which is beneficial in hot-weather concreting. Another group of methods are based on prevention of moisture loss from concrete by sealing the surface through the application of waterproof curing paper, polyethylene sheets, or membrane-forming curing compounds. The use of curing compounds is preferred for speedy construction. To achieve satisfactory results the selection of materials and the method of application must be carefully performed. When the ambient temperature is low, concrete must be protected from freezing with the help of insulating blankets. In cold weather, the rate of strength gain can be accelerated by curing concrete with live steam, heating coils, or electrically heated forms or pads. Formwork removal is generally the last operation carried out during the "early-age" period of concrete. The operation has economic implication because, on the one hand, early removal of formwork keeps the construction cost low, while on the other hand, concrete structures have failed when forms were stripped before concrete had attained sufficient strength. Formwork should not be removed until the concrete is strong enough to carry the stresses from both the dead load and the imposed construction load. Also, concrete should be sufficiently hard so that the surface is not injured in any way during the formwork removal or other construction activities. As the strength of a freshly hydrated cement paste depends on the ambient temperature and availability of moisture, it is better to rely on a direct measure of the concrete strength rather than an arbitrarily selected time for the formwork removal. Under normal moist-curing and temperature conditions, conventional concrete mixtures made with ordinary Portland cement may gain adequate strength for formwork removal, for example, 6- to 7-MPa compressive strength, in 24 h; with a high early strength Portland cement in 12 to 15 h, and those containing high volume of slag or fly ash in 48 h. For safety of structures in cold weather, designers often specify a minimum compressive strength before concrete is exposed to freezing. In hot weather, moisture from unprotected concrete may be lost by evaporation, causing interruption in the normal rate of cement hydration and strength gain. [3]

2.7 Temperature of Concrete:

Among other problems, as will be discussed below, in hot weather, unprotected concrete is subject to plastic shrinkage cracking. On the other hand, in cold weather the low temperature of concrete curing may seriously impede the rate of strength development. Premature removal of formwork (i.e., before the concrete acquires sufficient maturity or strength) has led to disastrous consequences in terms of both human and economic losses. The problem usually arises when the construction scheduling decisions are based on laboratory cured cylinders whereas the actual curing history of the in-place field concrete happens to be very different. Construction engineers should have a general understanding of the possible effects of both lower- and higher-than-normal curing temperatures on properties of concrete at early ages, and the methods of evaluating and controlling them. [3]

2.7.1 Cold-Weather Concreting:

In the event of little cement hydration, no strength gain occurs when the concrete is frozen and is kept frozen below −10°C. Therefore, fresh concrete must be protected from freezing until adequate strength has been gained. Expansion is also prevented when the degree of saturation of concrete has been sufficiently reduced by some progress in the hydration process. Without an external heat source, the heat of cement hydration in large and well-insulated concrete members may be adequate to maintain satisfactory curing temperatures provided that the concrete has been delivered at a proper temperature, and the temperatures of frozen ground, formwork, and reinforcing bars have been taken into consideration. ACI Committee 306R recommendation for cold-weather concreting on placement temperatures for normal-weight concrete is shown in Table 10-3. It may be noted that lower concrete temperatures are permitted for massive sections because with these the heat generated during hydration is dissipated less rapidly than from flatwork. Also, as more heat is lost from the concrete during transport and placement at lower air temperatures, the recommended concrete temperatures are higher for colder weather (see lines 1, 2, and 3 in Table 2.6). Insufficient curing of concrete can also be detrimental to properties other than strength. Most of the decision making is based on strength because form stripping, prestressing, and other such operations in concrete construction are guided by the strength of concrete on hand. Usually, strength is also the criterion when durability of concrete in early exposure to aggressive waters is of concern. The traditional method for determining safe stripping times is to test laboratory-cured concrete cylinders and strip the forms when the cylinders reach the specified strength. As already stated, this procedure has led to problems when the curing history of the cylinder in the laboratory is considerably different from the curing history of the in-place concrete. In case of weather. [3]

Table 2.6: Recommended Concrete Temperature for Cold-Weather Construction: Air-entrained Concrete. [3]

Line	Condition		Sections less than 12 in. (300 mm) thick		Sections 12–36 in. (300 mm–0.9 m) thick		Sections 36–72 in. (0.9–1.8 m) thick		Sections over 72 in. (1.8 m) thick	
			°F	°C	°F	°C	°F	°C	°F	°C
1	Minimum temperature fresh concrete as *mixed* in weather indicated, °F (°C)	Above 30°F (−1°C)	60	16	55	13	50	10	45	7
2		0°F to 30°F	65	18	60	16	55	13	50	10
3		Below 0°F (−18°C)	70	21	65	18	60	16	55	13
4	Minimum temperature fresh concrete *as placed* and *maintained*		55	13	50	10	45	7	40	5
5	Maximum allowable *gradual* drop in temperature in first 24 h after end of protection		50	28	40	22	30	17	20	11

*For durability and safe stripping strength of *lightly stressed* members. ACI 306 recommends 1 to 3 day's duration of the temperatures shown in the table, depending on whether the concrete is conventional or the high-early-strength type. For *moderately and fully stressed* members, longer durations are recommended. Also, for the concrete that is *not air-entrained* it is recommended that protection for durability should be at least twice the number of days required for air-entrained concrete.

SOURCE: Adapted from ACI 306–78.

2.7.2 Control of Concrete Temperature:

For cold-weather concreting (Table 2.6), making fresh concrete mixtures at temperatures 21°C (70°F) is not recommended. The higher temperatures do not necessarily offer better protection: first, because at higher temperatures the rate of heat loss is greater, and second, the water requirement for the same consistency is more. Depending on the ambient temperature and transport time form the production site to the job site, the temperature of concrete as mixed is maintained at not more than 5.6°C (10°F) above the minimum recommended in . As discussed further, the temperature of fresh concrete is usually controlled by adjusting the temperatures of mixing water and aggregates. Of all the concrete-making components, mixing water is the easiest to heat. Also, it makes more practical sense to do so because water can store five times as much heat as can the same mass of cement or aggregate. Compared to a specific heat of 1.0 for water, the average specific heat for cement and aggregates is 0.22. At temperatures above freezing, it is rarely necessary to heat the coarse aggregates. At temperatures below freezing, often only the fine aggregate needs to be heated to keep the freshly produced concrete at the required temperature. This is generally accomplished by circulating hot air or steam through pipes embedded in the aggregate stockpile. Concrete temperature can be measured directly by a mercury thermometer or a bimetallic thermometer. It can also be estimated using the expression. [3]

$$T = \frac{0.22(T_a W_a + T_c W_c) + T_w W_w + T_{wa} W_a}{0.22(W_a + W_c) + W_w + W_{wa}}$$

where T = temperature of the fresh concrete in °F

T_a, T_c, T_w, and T_{wa} = temperatures of aggregates, cement, mixing water, and free moisture in aggregates, respectively

W_a, W_c, W_w, and W_{wa} = weights (in pounds) of aggregates, cement, mixing water, and free moisture in aggregates, respectively

The formula remains the same in SI units except that °F is changed to °C and pounds to kilograms.

2.7.3 Hot-Weather Concreting:

For the purposes of construction problems with structural concrete, ACI Committee 305 defines hot weather as any combination of high air temperature, low relative humidity, and wind velocity tending to impair the quality of fresh or hardened concrete or otherwise resulting in abnormal properties. In addition to the increase in slump loss and plastic-shrinkage cracking, and the decrease of setting time in fresh concrete (already described), hot weather increases the mixing water requirement for a given consistency and creates difficulty in holding the air in an air-entrained concrete mixture. Retendering of fresh concrete is frequently necessary in hot weather. At times, this causes adverse effects on strength, durability, dimensional stability, and appearance of the hardened concrete. Also, concrete placed and cured at higher than moderate ambient temperatures normally develops high early strength but at 28 days and later ages the strength is usually lower than the same concrete placed and cured at a relatively lower temperature.

Control of concrete temperature. As explained earlier, because the mixing water has the greatest effect per unit weight of any of the ingredients on the temperature of concrete, the use of cooled mixing water and/or ice offers the best way of lowering the temperature of concrete. The expression used for determining the temperature of concrete in cold weather by using hot water can be employed for calculating how much cold water will be needed to lower the temperature of a concrete by a given amount. [3]

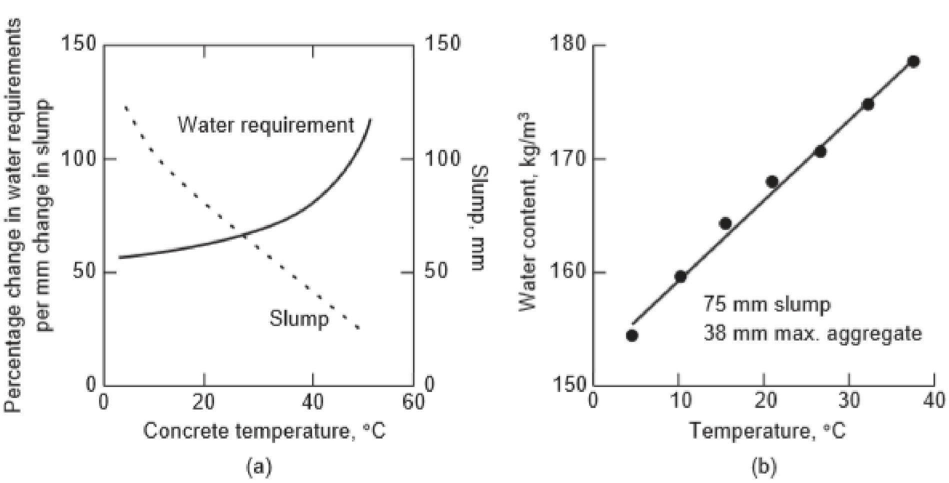


Figure 2.9: (a) Effect of concrete temperature on the slump and the water requirement to the change slump; (b) Effect of ambient temperature on the water requirement of concrete [3]

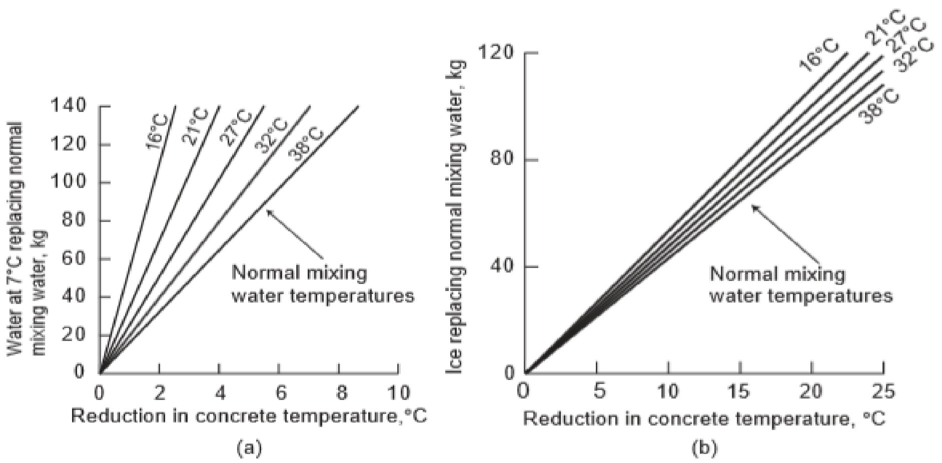


Figure 2.10: Determination of reduction in concrete temperature: (a) by adding cooled water; (b) by adding ice [3]

The use of shaved or chipped ice as a substitute for all or part of the required mixing water is the most effective way of reducing the concrete temperature because ice absorbs 80 cal/g (144 Btu/lb) on melting. Figure 10-12b illustrates the possible reductions in concrete temperature by substitution of varying amounts of ice at 0°C for mixing water at the temperature shown. Figure 10-12 demonstrates that, with normal mixing water at 38°C, there will be a 3.3°C temperature reduction when 54 kg (120 lb) of water at 7°C, replaces the mixing water; the same amount of ice replacing the mixing water would have reduced the temperature of the concrete by 13°C. [3]

2.8 Previous Studies:

In this paragraph presented a comprehensive literature review of related previous researches:

Sheng SzuPeng 2013: In study, the 50°C warm water is applied to accelerate curing of concrete and to increase the design strength to 210kgf/cm2 (3000psi), 280kgf/cm2 (4000psi), and 490kgf/cm2 (7000psi) by using water/cement (w/c) ratio of 0.6, 0.5, and 0.35 respectively. The result shows that it takes only 2~5 days to reach the design strength with warm water curing instead of 28 days by standard curing. Three type of specimens may reach 1.0~1.05 times of target strength. As a result, a modified coefficient factor for design of concrete strength can be predicted more accurately and much earlier during curing process of the concrete. [4]

A.F. Abbasi 1982: Hot weather creates problems for concrete construction. Present codes of practice specify costly precautions to be taken to counteract the effects of hot weather. This paper presents the results of compressive strength tests at different ages of the specimens of different sizes and mix proportions prepared and cured both in the laboratory conditions under varying temperatures and in natural atmosphere in hot weather. Results have shown that the costly precautions would not be necessary for hot weather if the concrete mix is properly designed and curing done properly. [5]

Martin Alexa 2020: Concreting in hot weather is usually very demanding. One of the most important aspects is correct curing of the concrete. The crucial factor is not only quality but also the time of curing. Insufficient curing of concrete may result in a decrease in its basic parameters, a decrease in the quality of the surface layer or a massive development of shrinkage cracks. All this may have a very negative impact on the durability of the concrete structure. This paper is about the influence of the concrete curing time on its compressive strength and on the modulus of elasticity. To determine the modulus of elasticity, two non-destructive methods were used – ultrasonic pulse velocity test and resonance method – and also a static test. The results presented show that the concrete curing time has a clear impact on its quality and it is, therefore, not advisable to underestimate this aspect of summer concreting. [6]

MD. ROBIUL AWALL 2019: In the city of Rajshahi, Bangladesh the temperature of atmosphere is very high during the summer season and there is a fluctuation of temperature throughout the year. In hot weather, it is very difficult to carry out the concrete work. The main problem in hot weather is the increased demand of water. Due to increased temperature, high initial rate of hydration occurs which retards the subsequent hydration and there is non-uniform distribution of products of hydration which effects strength. In this study, the potential effect of high atmospheric temperature on concrete compressive strength is evaluated. To carry out these work, total 96 concrete cylinders were prepared in which 80 cylinders were cast in high environment temperature (summer seasons) and another 16 cylinders were cast in comparatively low temperature (winter season). From the experimental results it is found that the hot weather has an adverse effect on the compressive strength of concrete i.e. compressive strength decreases with the increment of temperature. ASTM type D admixture is suitable for hot weather in 0.60 and 0.65 water cement ratio. [7]

Merbouh M'hammed 2017: Coal produces large amount of waste during the mining and processing stages, which is the residue of French colonialism of Algeria in the region of Bechar. This waste is dumped on to open land which creates a lot of environmental problems. The main objective of this study was utilization of Coal waste (CW) as a replacement for conventional natural fine aggregate in concrete. Conventional natural fine aggregate was replaced by coal waste aggregate in different percentages 0–6% by weight. This paper presents the results of a series of experiments conducted to investigate the effect of high temperature curing on concrete made with coal waste (CW). The curing temperatures adopted were 25 and 50°C.The experimental results suggest that high temperature cured CW concrete normally has a greater compressive strength than similarly cured control concrete. The concrete formulations were prepared with a constant water–cement ratio 0.51. It was observed in hot weather that the workability of concrete mixes containing coal waste aggregate and control concrete was 35-65% less than normal climate. The average compressive strength of all the concrete mixes containing coal waste (CW) aggregate increased by 6% and 5% at 7 and 28 days, respectively. Keywords: Waste concrete, Hot weather, Workability, Compressive strength. [8]

Abdullah M. Zeyad 2019: The properties of high-strength concrete (HSC) are significantly influenced by environmental conditions and the duration of the curing method. This paper presents an experimental study that investigated the influence of three types of curing methods during hot weather on the properties of hardened HSC reinforced with 0.0% or 0.22% (by volume fraction) polypropylene fibers (PFs). HSC samples were cured via water immersion under indoor laboratory conditions; wet-coverage with a wet gunny under outdoor conditions; and spraying with water twice day for one week under outdoor conditions. The concrete mixture was designed to achieve compressive strength beyond 60 MPa after 28 days of curing via water immersion. Various tests were conducted to determine HSC properties, including slump, compressive, indirect tensile and flexural strengths. Cubes, cylinders, and prisms were cast with each concrete mixture to measure strength at 7, 14, 28, and 90 days of curing. Compressive strength under all curing conditions with and without PF reinforcement exceeded 60 MPa at 28 days. PF-reinforced concrete cured via water immersion exhibited the best concrete strength. [9]

Mennatallah Amr Assal 2017: Environmental factors and hot weather conditions can drastically impact the properties, strength and durability of concrete structures. Whereby, higher slump loss rate, faster hydration with accelerated setting, reduced long term compressive strength and plastic shrinkage are more common. Literature review on the impact of hot weather on concrete is not sufficiently elaborated and at the same time majority of studies focused on curing temperature on overall concrete quality, however sufficient research on the effect of casting temperature on the concrete itself and its materials is lacking.

This study is carried out to investigate the direct impact of mixing water temperature and concrete temperature on the concrete properties serving in hot weather conditions, with special emphasis to the Egyptian hot climate throughout the year. Thus, the scope of this work is to study mixing water temperature's impact on concrete properties being a key ingredient to the concrete mix, with direct impact on workability, strength and durability. The feasibility of cooling water as a remedial action in hot climate is covered for various project sizes. To achieve the work objective, four categories of concrete mixtures with various cement contents and admixtures were studied while changing the mixing water temperature at 5, 25 and 45˚C to yield a total 12 different test sets. All other concrete ingredients were heated to 45˚C ahead of mixing to simulate hot weather conditions. Two sets of results were analyzed starting with fresh concrete tests of slump, unit weight and concrete temperature; in addition to hardened concrete tests of compressive and flexural strengths. Results showed an average 15% increase in the 28 days concrete compressive strength and enhanced workability in 5 ˚C temperature water Vs. 45 ˚C suggesting the strong impact of water temperature on concrete properties and need to add cool mixing water to concrete cast in hot weather conditions. Recommendations are provided towards the incorporation of cold water in concrete with a market feasibility conducted to study the technical and economic aspects resulting in up to 9% reduction in concrete cost with cold mixing water incorporated. [10]

Nikolay Aniskin 2021: This article proposes a formula to determine the required amount of ice to partially replace the water in the concrete mix to control the initial temperature of the concrete mix and reduce possible cracking.

The formula was created based on the principle of energy balance in the

heat transfer process.

At the same time, the obtained results were compared with the other methods. Besides, an example of the calculation for a concrete block during the construction was performed.

The maximum temperature and temperature difference in mass concrete obtained depend significantly on the initial temperature of the concrete mixture.

The research results and the proposed techniques can be used in the practical design of mass concrete structures. [11]

Suyun Ham 2013: Portland cement concrete exposed to high temperatures during mixing, transporting, casting, finishing, and curing can develop undesirable characteristics. Applicable requirements for such the hot weather concrete differ from country to country and government agencies. The current study is an attempt at evaluating the hardened properties of the concrete exposed to hot weather in fresh state. First of all, this study reviews the current state of understanding and practice for hot weather concrete placement in US and then roadway sites with suspected hot weather concrete problems were investigated. Core samples were obtained from the field locations and were analyzed by standard resonance frequency analysis and the boil test. Based on the results, there does not appear to be systematic evidence of frequent cracking problems related to high temperature placement. Thus, the suspicious deteriorations which are referable to hot weather concreting would be due to other factors. [12]

Hisham K. Ahmed 2018: The aim of this investigation is to produce high performance lightweight aggregate concrete in actual hot- dry weather conditions, and then study the combined effect of hot-dry weather conditions on the fresh properties of high performance lightweight aggregate concrete such as workability, initial and final setting time, measuring concrete temperature, and hardened concrete properties (compressive strength, splitting tensile strength and flexural strength, modulus of elasticity). The experimental program including the use of fixed mix proportions and was carried out in a typical Iraqi summer days (under actual conditions) of different times during the day, where the mean maximum temperature in shadow in July and August usually is more than 44° C and relative humidity of about 24 %, the results were compared with the specimens prepared and casted in laboratory and others in shadow site. The results indicate that as temperature rises, and relative humidity falls, the initial and final setting time were reduced, beside that actual drop in slump. The results also show that rising placing temperatures more than allowable concrete temperature that recommended in ACI 305 does not, as a rule, lead to lower strengths. The strength performance of concrete can remain unaffected by higher placing temperatures, or it can even improve over that at lower temperatures. Using pre-soaked lightweight aggregates (pumice) as internal water reservoirs for producing this type of concrete under actual hot-dry weather condition played positive role in improvement of concrete properties by compensate the evaporation of water due to the rising temperature and decreasing relative humidity, and provide additional moisture in concrete for a more effective hydration of the cement. [13]

CHAPTER THREE

METHODOLOGY
AND
EXPERIMENTAL WORK

CHAPTER THREE

METHODOLOGY AND EXPERIMENTAL WORK

3.1 Methodology And Experimental Work:

While designing a structure, engineer assumes contain value of strength for each of material being used therein. When the structure is being constructed, it is the bounden duty of the field engineers to get the same validated by regular testing of material. The quality of materials used in any infrastructure does play a vital role with regard to its ultimate strength and durability in the long run hence; the materials need to be tested according to certain standard procedures. Developed by ASTM, BIS, and RDSO to give a clear picture of material strength there are so many tests available for testing different qualities of concrete Different tests give results for their respective quality of concrete. Thus it is no possible to conduct all the tests as it involves cost and time thus it is very important to sure about purpose of quality tests for concrete . The most important test for quality check of concrete is to detect the variation of concrete quality with given specification and mix design during concrete mixing and place mentis will ensure that right quality of concrete is being place at site and with check for concrete placement in place , the . Quality of constructed concrete members will be as desire.

3.2 Questionnaire:

A questionnaire is a scientific research tool that helps the researcher to collect accurate information about the subject of his research, by asking many questions to the study sample. The questionnaire is one of the most widespread scientific research tools, due to its ease of use, the accuracy of its results, the shortening of a lot of time, and its low material cost.

A closed questionnaire was prepared and distributed to engineers with different experiences , with 37 copies. The results were analyzed and a conclusion was extracted from them.

3.3 Tests of Cement:

3.3.1 Field Tests on Cement:

Field tests on cements are carried to know the quality of cement supplied at site. It gives some idea about cement quality based on color, touch and feel and other tests.

The following are the field tests on cement:

(a) The color of the cement should be uniform. It should be grey color with a light greenish shade.

(b) The cement should be free from any hard lumps. Such lumps are formed by the absorption of moisture from the atmosphere. Any bag of cement containing such lumps should be rejected.

(c) The cement should feel smooth when touched or rubbed in between fingers. If it is felt rough, it indicates adulteration with sand.

(d) If hand is inserted in a bag of cement or heap of cement, it should feel cool and not warm.

(e) If a small quantity of cement is thrown in a bucket of water, the particles should float for some time before it sinks.

(f) A thick paste of cement with water is made on a piece of glass plate and it is kept under water for 24 hours. It should set and not crack.

(g) A block of cement 25 mm ×25 mm and 200 mm long is prepared and it is immersed for 7 days in water. It is then placed on supports 15cm apart and it is loaded with a weight of about 34 kg. The block should not show signs of failure.

(h) The briquettes of a lean mortar (1:6) are made. The size of briquette may be about 75 mm ×25 mm ×12 mm. They are immersed in water for a period of 3 days after drying. If the cement is of sound quality, the briquettes will not be broken easily.

3.3.2 Laboratory Tests on Cement:

3.3.2.1 Consistence of Standard Paste:

For the determination of the initial setting time, the final setting time, and for Le Chatelier soundness tests, neat cement paste of a standard con sistence has to be used. Therefore, it is necessary to determine for any given cement the water content which will produce a paste of standard con sistence. Consistence is determined by the Vicat apparatus, which measures the depth of penetration of a 10 mm (in.) diameter plunger under its own weight. When the depth of penetration reaches a certain value, the water content required gives the standard consistence of between 26 and 33 (expressed as a percentage by mass of dry cement).

3.3.2.2 Setting Time:

This is the term used to describe the stiffening of the cement paste. Broadly speaking, setting refers to a change from a fluid to a rigid state. Setting is mainly caused by a selective hydration of C, A and C, S and is accompanied by temperature rises in the cement paste; initial set corresponds to a rapid rise and final set corresponds to the peak temperature. Initial and final sets should be distinguished from false set which sometimes occurs within a few minutes of mixing with water (ASTM C 451-05). No heat is evolved in a false set and the concrete can be re - mixed without adding water. Flash set has previously been mentioned and is characterized by the liberation of heat. For the determination of initial set, the Vicat apparatus is again used. This time with a 1 mm (0.04 in.) diameter needle, acting under a prescribed weight on a paste of standard consistence. When the needle penetrates to a point 5 mm (0.2 in.) from the bottom of a special mound, initial set is said to occur (time being measured from adding the mixing water to the cement). A minimum time of 45 min is prescribed by BS EN 197-1 for cements of strength classes 52.5 N and 62.5 N whereas 60 minutes applies .to strength classes of 32.5 N and R and 42.5 N and R. A similar procedure is specified by ASTM C 191-04b except that a smaller depth of penetration is required; a minimum setting time of 60 min is prescribed for Portland cements (ASTM C 150-05). Final set is determined by a needle with a metal attachment hollowed out so as to leave a circular cutting edge 5 mm (0.2 in .) in diameter and set 0.5 mm (0.02 in .) behind the tip of the needle . Final set is said to have occurred when the needle makes an impression on the paste surface but the cutting edge fails to do so. British Standards prescribe the final setting time as a maximum of 10 hours for Portland cements, which is the same as that of the American Standards. An alternative method is that of the Gilmore test, as prescribed by ASTM C 266-04. The initial and final setting times are approximately related: final time (min.) = 90+ 1.2 [initial time (min.)] (except for high alumina cement). Since temperature affects the setting times , BS EN 196-3 : 1995 specifies that the mixing has to be undertaken at a temperature of 20 ± 2 °

C (68 ± 4 ° F) and minimum relative humidity of 65 per cent , and the cement paste stored at 20 ± 1 ° C (68 ± 2 ° F) and maximum relative humidity of 90 per cent.

Figure 3.1: Vicat Apparatus

3.3.2.3 Strength:

Strength tests are not made on neat cement paste because of difficulties in obtaining good specimens and in testing with a consequent large variable of test results. Cement - sand mortar and, in some cases, concrete of prescribed proportions, made with specified materials under strictly controlled conditions, are used for the purpose of determining the strength of cement. There are several forms of strength tests: direct tension, compression. And flexure. In recent years, the tension test has been gradually superseded by the compression test and therefore will not be discussed here. The British Standard method for testing the compressive strength of cement BS EN 196 1: 2005 specifies a mortar prism test. The cements are described by strength classes, with N denoting normal, and R rapid hardening properties. ASTM C 109-05 prescribes a cement - sand mix with proportions of 1 : 2.75 and a water / cement ratio of 0.485 , using a standard sand (ASTM C 778-06) for making 51 mm (2 in .) cubes . The mixing and casting price due is similar to that of BS EN 196 but the cubes are cured in saturated lime water at 23 ° C (73 ° F) until they are tested. An alternative compression test is the modified cube method (ASTM C 349-02) which utilizes the sections of failed flexural prisms (see below). The minimum strength requirements of the British and ASTM standards for the different cements. It should be noted that the strengths listed by BS EN and ASTM are characteristic strengths and mean strengths, respectively. The flexural text , prescribed in ASTM C 348-02 , uses simply - supported 40 x 40 x 160 mm mortar prisms loaded at mid - span ; the mix proportions , storage , and curing procedures are the same as for the compression test . As stated earlier, an advantage of this test is that the modified cube test can be undertaken as well. [1]

Table 3.1: BS EN 197-1: 2000 for minimum strength of cement (MPa) [1]

Age (day)	BS EN 197-1: 2000(mortar prism) , strength class					
-	32.5N	32.5R	42.5N	42.5R	52.5N	52.5R
2	- -	10 (1450)	10 (1450)	20 (2900)	20 (2900)	20 (2900)
7	16 (2300)	- -	- -	- -	- -	- -
28	32.5* (4700)	32.5* (4700)	42.5* (6200)	42.5** (6200)	52.5 (7600)	62.5 (9100)

3.4 Tests on Aggregate:

Aggregate:

1. Coarse aggregate:

Coarse aggregate shall be obtained from breaking hard durable rock or gravel, first class bricks or Picked Bricks. Coarse aggregate shall be clean, free from dust and other materials. The grading of the coarse aggregate shall be such that when combined with the approved fine aggregates, its hall produce a workable mixture of maximum density.

Aggregates, which are larger than ASTM #4 sieve OR 4.75 mm, are Coarse aggregate

2. Fine aggregates:

Fine aggregates shall be angular (gritty to touch), hard and durable, free from clay, mica and soft flaky pieces.

- **Sand:**

Sand is a granular material composed of finely divided rock and mineral particles. Sand shall be clean and free from organic impurities.

Aggregate which are passes 4.75 mm and retain on 0.0075 mm (ASTM # 200 sieves) are fine aggregate.

3.4.1 Sieve Analysis Test:

The process of dividing a sample of aggregate into fractions of same particle size is known as a sieve analysis, and its purpose is to determine the grading or size distribution of the aggregate. A sample of air - dried .aggregate is graded by shaking or vibrating a nest of stacked sieves, with the largest sieve at the top. For a specified time so that the material retained on each sieve represents the fraction coarser than the sieve in question but finer than the sieve above. Table lists the sieve sizes normally used for grading purposes according to BS 812-103.1:1985, BS EN 933.2: 1996. Also shown are the previous designations of the nearest size. It should be remembered that 4 to 5 mm, No. 4 ASTM) is the dividing line between the fine and coarse aggregate.

Table 3.2: Sieve commonly used for sieve analysis for fine aggregate

Sieve Size (mm)	% Passing by weigh
25	100
19	90-100
9.50	20-55
4.75	0-10
2.36	0-5

1. Fine aggregates:

Sand shall be well graded from coarse to fine within the limits given below:

Table 3.3: Sieve commonly used for sieve analysis for coarse aggregate

Sieve Size (mm)	% Passing by weigh
9.5	100
4.75	95-100
2.36	80-100
1.18	50-85
600	25-60
300	10-30
150	2-10

Figure 3.2: Photo of sieve

3.4.1.1 Fineness Modulus:

- The sum of cumulative %weight retain on the following sieve 80mm, 40mm, 20mm, 10mm, #4, #8, #16,#30,#50&#100dividedby100
- Fineness modulus = ΣCumulative % retained up to sieve #100/100

Fineness Modulus:

Table 3.4: Fineness modulus

Very Fine Sand	<2.2
Fine Sand	2.2-2.6
Medium Sand	2.6-2.9
Coarse Sand	2.9-3.2

3.4.2 Specific Gravity:

The specific gravity of a substance is the ratio of the unit weight of the substance to the unit weight of water. A representative aggregate sample in SSD (Saturated surface dry) condition is obtained by quartering and the following weights are used in the tests for the various sizes of aggregates.

Less than 4.75 mm - 500 to 700 gm.
4.75 mm to 10 mm - 1000 to 1500 gm.
10 mm to 20 mm - 1500 to 2000 gm.
20 mm to 40 mm - more than 2000 gm.

Figure 3.3: Specific Gravity Test Tool

Procedure:

- Take a suitable size jar, the top open side of which have flange, so that a glass plate may be put on it.
- The jar should be filled with clean water up to the flange and slide on it the glass plate. If there is any air bubble, which can be seen from top of glass plate, then the jar top should be filled with more water. There should not be any air bubble. Take the weight of jar fully filled with water and upon it glass plate (weight A).
- About half empty the jar fill it with known weight of SSD aggregate sample weight (B). As mentioned at b, fill the jar up to the top and putt glass plate on it. There should not be any air bubble. Take its weigh (weight C).

3.5 Fresh Concrete Testing:

3.5.1 Slump Test:

This test is performed to check the consistency of freshly made concrete. The slump test is done to make sure a concrete mix is workable. The measured slump must be within a set range, or tolerance, from the target slump.

Tools and apparatus used for slump test (equipment):

- Standard slump cone (100 mm top diameter x 200 mm bottom diameter x 300 mm high)
- Small scoop - Bullet-nosed rod (600 mm long x 16 mm diameter)

- Rule - Slump plate (500 mm x 500 mm)

Procedure of slump test for concrete:

1 Clean the cone. Dampen with water and place on the slump plate. The slump plate should be clean, firm, level and non-absorbent. Collect a sample of concrete to perform the slum test.
2 Stand firmly on the foot pieces and fill 1/3 the volume of the cone with the sample. Compact the concrete by 'rodding' 25 times. Rodding means to push a steel rod in and out of the concrete to compact it into the cylinder, or slump cone. Always rod in a definite pattern, working from outside into the middle.
3 Now fill to 2/3 and again rod 25 times, just into the top of the first layer.
4 Fill to overflowing, rodding again this time just into the top of the second layer. Top up the cone till it overflows.
5 Level off the surface with the steel rod using a rolling action. Clean any concrete from around the base and top of the cone, push down on the handles and step off the foot pieces.
6 Carefully lift the cone straight up making sure not to move the sample.
7 Turn the cone upside down and place the rod across the up-turned cone.
8 Take several measurements and report the average distance to the top of the sample. If the sample fails by being outside the tolerance (is the slump is too high or too low), another must be taken. If this also fails the remainder of the batch should be rejected.

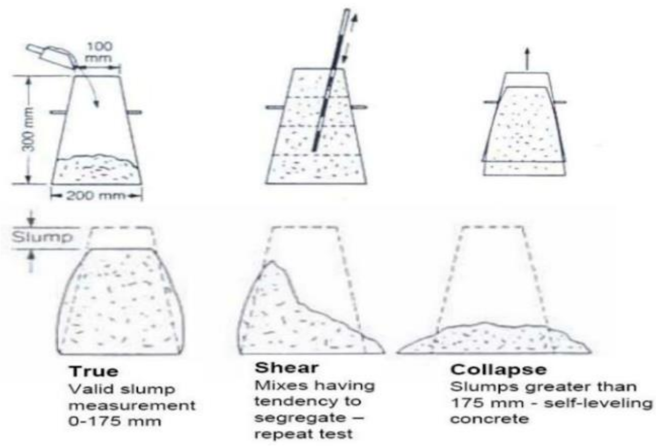


Figure 3.4: Forms of collapse in Slump Test

Figure 3.5: Slump Test Mold

3.5.2 Fresh Concrete Temperature Test:

This test method covers the determination of temperature of freshly mixed.

True represents the temperature at the time of testing and may not be an indication of the temperature of the freshly mixed concrete at later time. It may be used to verify conformance to a specified requirement for temperature of concrete. Concrete containing aggregate of a nominal maximum size greater than 75 mm [3 in.] may require up to 20 min for the transfer of heat from aggregate to mortar.

Figure 3.6: Fresh Concrete Temperature Test

3.6 Hardened Concrete Testing:

3.6.1 Compressive Strength Test on Concrete:

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. For cube test two types of specimens either cubes of 15 cm X 15 cm X 15 cm or 10cm X 10 cm x 10 cm depending upon the size of aggregate are used. For most of the works cubical mounds of size 15 cm x 15cm x 15 cm are commonly used. This concrete is poured in the mound and tempered properly so as not to have any voids. After 24 hours these mounds are removed and test specimens are put in water for curing. The top surface of these specimens should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen.

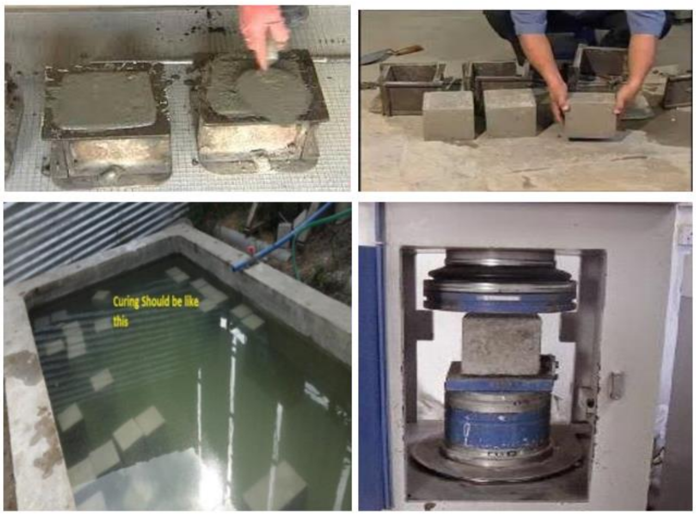


Figure 3.7: Steps to prepare and crush cubes

These specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete. The apparatus in this test is a Compression testing machine The proportion and material for making these test specimens are from the same concrete used in the field. The specimen used for testing is 6 cubes of 15 cm size Mix. M15 or above. The mixing can be done manually.

3.7 Hand mixing:

- Mix the cement and fine aggregate on a water tight none-absorbent platform until the mixture is thoroughly blended and is of uniform color.
- Add the coarse aggregate and mix with cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch.
- Add water and mix it until the concrete appears to be homogeneous and of the desired consistency.

3.8 Sampling:

- Clean the mounds and apply oil.
- Fill the concrete in the molds in layers approximately 5cm thick.
- Compact each layer with not less than 35strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet pointed at lower end).
- Level the top surface and smoothen it with a trowel.

3.9 Curing:

The test specimens are stored in moist air for 24hours and after this period the specimens are marked and removed from the molds and kept submerged in clear fresh water until taken out prior to test. The water for curing should be tested every 7days and the temperature of water must be at 27±2oC.

Figure 3.8: Concrete Cubes

CHAPTER FOUR
ANALYSIS AND DISCUSSION RESULTS

CHAPTER FOUR
ANALYSIS AND DISCUSSION RESULTS

4.1 Introduction:

Laboratory tests were conducted on each of the concrete materials (aggregate cement - fresh concrete and hard concrete).

The aggregate was heated to a temperature of 50 degrees Celsius to find out the effect of high temperature of the materials on fresh and hardened concrete and study its effect on the mixed concrete .and then the results obtained in this Part into fresh and hardened concrete.

4.2 Questionnaire:

This questionnaire was made to identify the extent of interest of engineers in Sudan on the impact of weather and the temperature of the concrete mixture on quality of concrete.

A closed questionnaire was prepared and distributed to engineers with different experiences , with 37 copies. The results were analyzed and a conclusion was extracted from them.

1. Educational level:

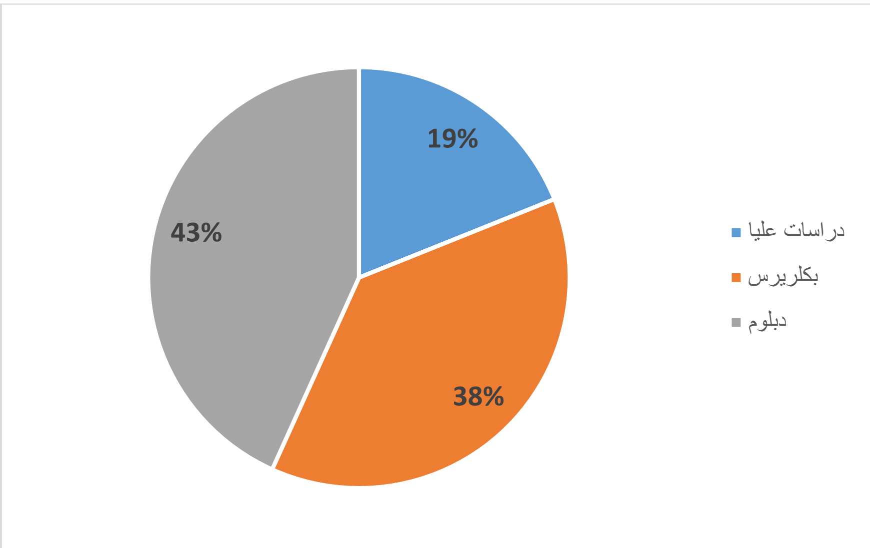


Figure 4.1: Educational level

Figure 4.1: shown that 18.92% of those who participated in the questionnaire have graduate studies, 37.84% from a bachelor's degree, and 43.24% from diploma degree.

2. Practical experience:

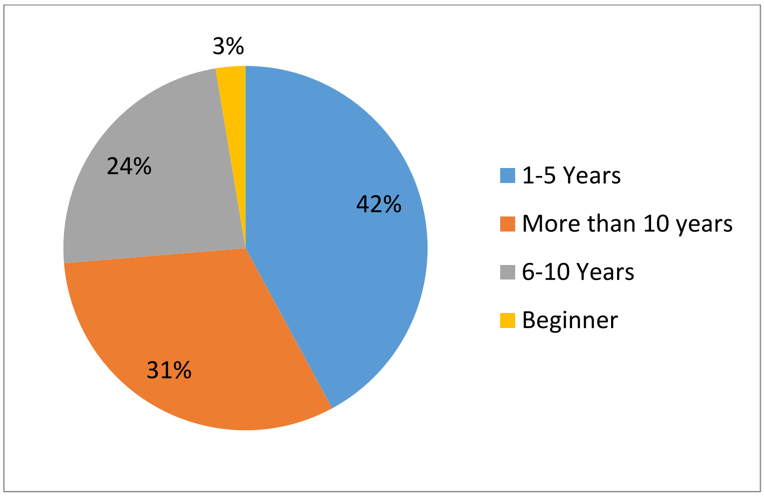


Figure 4.2: Practical experience

Figure 4.2 show the Practical experience of the engineers who filled out the questionnaire have shown 2.70% of them had a beginner, and 40.54% had an experience of (1-5) years, 24.33% had an experience of (6-10) years, and 32.43% had an experience more than 10 years.

3. The effect of high and low weather temperature on quality of concrete.

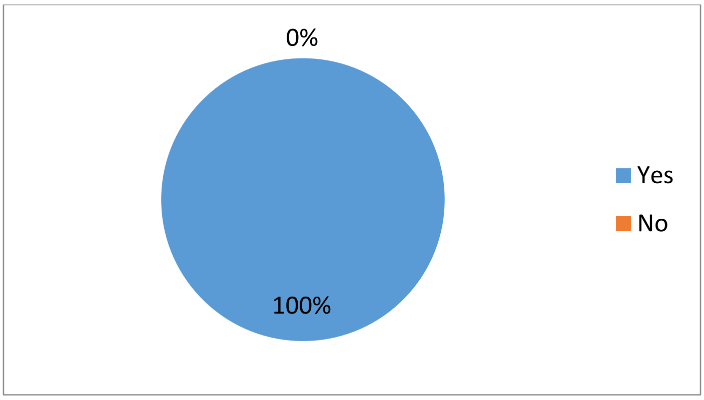
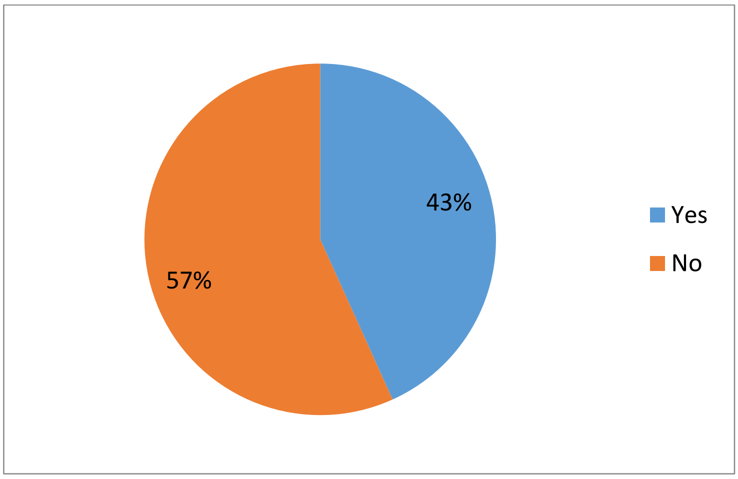


Figure 4.3: Explains engineers answers to The effect of high and low weather temperature on quality of concrete.

Finger 4.3: Show that all engineers agree that the weather is effects in the quality of concrete.

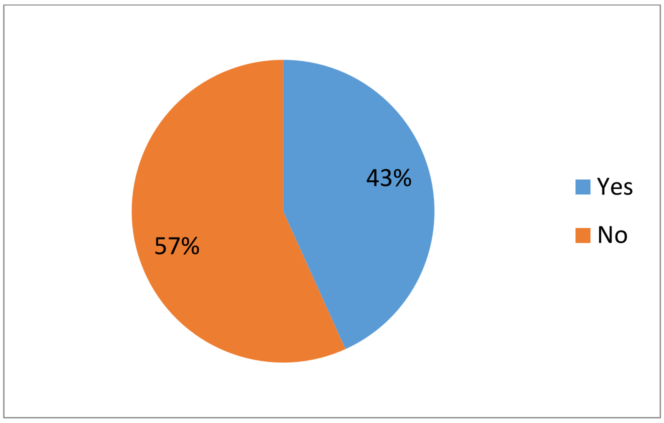
4. Does care about weather conditions and their impact when mixing and casting in Sudan.



Finger 4.4: Show engineers answers about attention to weather conditions when mix and cast.

Figure 4.4: Show that 43.24% of the engineers who filled out the questionnaire were interested in the weather conditions when casting and 56.76% of them did not.

5. Measuring the concrete temperature during mixing and before casting.



Finger 4.5: Show engineers answers about attention measuring the concrete temperature during mixing and before casting.

Finger 4.5: Show that 43.24% of the engineers who filled out the questionnaire care about measuring the concrete temperature during mixing and 56.76% of them did not.

6. Rejecting the mix if the temperature is high (in Sudan).

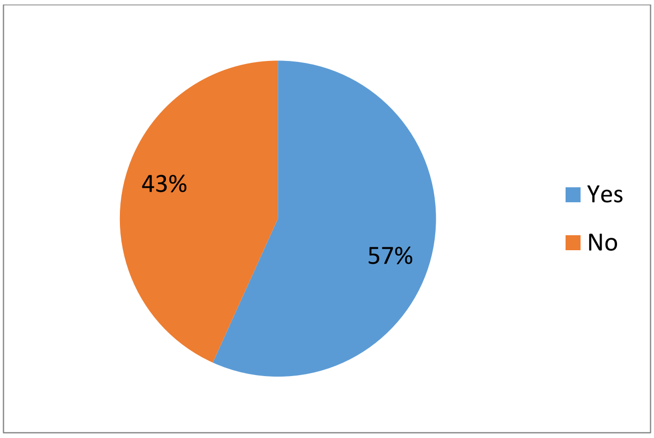


Figure 4.6: Show engineers act when the temperature rises**.**

Finger 4.6: Show that 56.76% of the engineers they reject the mix, if the temperature of concrete mix is high and 43.24% of them did not.

7. Spraying aggregate with water before mix is considered an effective solution to reduce the temperature of the concrete mixture.

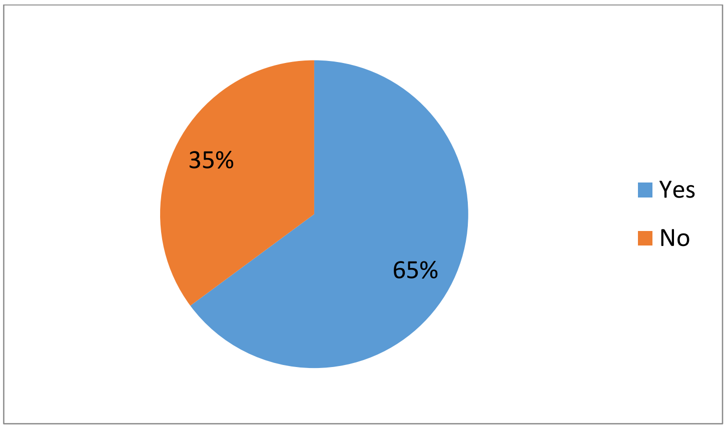


Figure 4.7: Explains engineers answers to spraying aggregate with water to cooling.

64.86% of the engineers agree that the spraying aggregate is solution to reduce the temperature of the concrete mixture and 35.14% of them did not agree as show in figure 4.7

8. Use cold water and ice in mixing concrete.

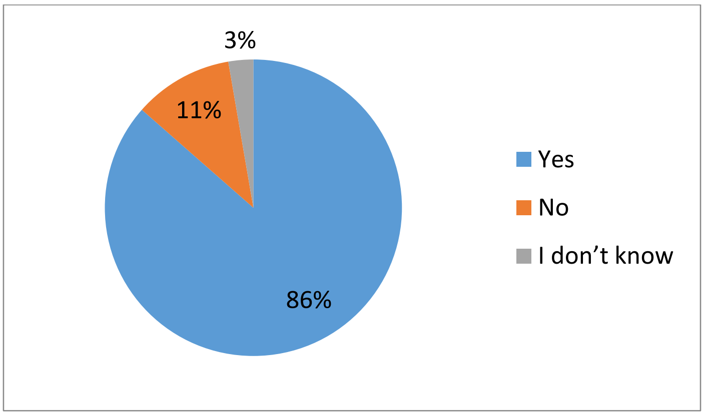


Figure 4.8: Explains engineers answers about use cold water in mix.

86.49% of the engineers use cold water and ice in mixing concrete gives acceptable results and 10.8% of them say no.

4.3 Experimental Methodology:

In this study, we study the effect of heat on fresh, hardened concrete the focus was, on the temperature of the aggregate, because it constitutes the majority of concrete. about 70 to 80% of the weight of the concrete mixture The aggregate was heated to a building temperature during the summer of about 50 degrees Celsius and four mixtures were made to know the effect of possible: treatments on the temperature of the aggregates.

1. Distribution of a statistical questionnaire to engineers to know their dealing of concrete in hot weather
2. Use hot aggregate in the mixture as normal.
3. Sprinkle the aggregate with water to cool it.
4. Mixing concrete with cold water.
5. Sprinkle the rubble with water to cool and use water.

4.4 Results of Materials:

4.4.1 Results of Cement Tests:

Cement used in testing is Ordinary Portland Cement (ASTM C150), manufactured by Atbara Cement company in compliance with international standards (EN 197/1-2011) and Sudanese standards (SDS 164 / 2013 N 42.5). The Portland cement used has specific gravity of 3.15 and a Blain fineness of 312 m2/kg, with the below composition 55% (C_3S), 19% (C_2S), 10% (C_3A), 7% (C_4AF), 2.8% MgO, 2.9% (SO_3), 1.0% ignition loss, and 1.0% free CaO. Further test results are summarized in Table 4.1.

Table 4.1: Results of cement tests

Test No	Test Conducted	Results	Requirements of SSMO 164:2002
1	Fineness	97%	-
2	Consistency	29.5%	26%-33%
3	Soundness	-	Not more than 10mm
4	Setting times (min)		

	A .Initial B. Final	97min 172min	Not less than 60 min Not less than 390 min
5	Compressive Strength (N/mm2) a- 2Days 1st Sample 2nd Sample 3rd Sample	 26.5 N/mm2 26.6 N/mm2 26.7 N/mm2	Equal or greater than 10N/mm2

4.4.2 Results of Aggregate Tests:

4.4.2.1 Results of Sieve Analysis:

Coarse Aggregate:

The fractions from 20 mm to 4.75 mm are used. As coarse aggregate.

The Coarse Aggregates from uncrushed stone. The sieves test result of course: aggregate presented in Table (4.2) and Figure (4.9)

Table 4.2: Sieve Analysis of Coarse Aggregate

Sample	1	3
Sample total weight (g)	2282	2128

Sieve	Retained					% age Passing
	Sample 1		Sample 2		Average	
(mm)	Wt (g)	%	Wt (g)	%	%	
37.5	0	0	0	0	0	
25	519	22.7	781	36.7	29.7	70.3
19.0	996	43.6	588	27.6	35.8	34.7
12.5	664	29.1	634	29.8	29.5	5.2
9.50	95	4.2	116	5.5	4.9	0.3
4.75	8	0.4	9	0.4	0.4	
2.36	0	0	0	0	0	
1.180	0	0	0	0	0	
0.600	0	0	0	0	0	
Pan	0	0	0	0	0	

Fine Modulus = ∑ Cumulative percentage Retained / 100

= (29.7+35.8+29.5+4.9+0.4) / 100 = 1.003

Fine aggregate:

The fractions from 4.75mm to75mic are used; the fine aggregate used in the experimental program was natural river sand. Impurities proportion 1 the gradient of the test, the sieves test result of fine aggregate presented in table :(4.3) and figure (4.10) below:

Table 4.3: Sieve Analysis of Fine Aggregate

Sample	1	2
Sample total weight (g)	542.8	519.3

Sieve	Retained					% age Passing
	Sample 1		Sample 2		Average	
(mm)	Wt (g)	%	Wt (g)	%	%	
4.75	7.9	1.5	7.4	1.4	1.5	98.5
2.36	13.3	2.5	14.3	2.8	2.7	95.8
1.180	92.3	17.0	94.2	18.1	17.6	78.2
0.600	153.6	28.3	149.4	28.8	28.6	49.6
0.300	177.1	32.6	166.3	32.0	32.3	17.3
0.150	42.1	7.8	37.7	7.3	7.6	9.7
0.075	21.5	4.0	19.1	3.7	3.9	5.8
Pan	35	6.4	30.9	6.0	6.2	

Figure 4.9 : Photo of Sieve Analysis test of Sand

4.4.2.2 Results of Specific Gravity:

Description of sample: **Aggregate**

Table4.4: Results of Specific Gravity & Absorption for Aggregate

NO	Description of sample	Test Number		Average
		1	2	-
A	Weight of over – dry sample in air (g)	2532	2518	-
B	Weight of saturated surface - dry sample in air (g)	2554	2527	-
C	Weight of saturated sample in water (g)	1583	1567	-
	Bulk specific gravity A/(B-C)	2.608	2.623	2.616
	Bulk specific gravity (saturated surface – dry basis) B/(B-C)	2.630	2.632	2.631
	Apparent specific gravity A/(A-C)	2.668	2.648	2.658
	Water absorption 100*(B-A)/A	0.869	0.357	0.613

The specifications recommend that the specific Gravity of coarse aggregate ranges from 2.60 -2.90 and that the absorption ratio for it does not exceed 0.6 %. And through experiments, it was found that:

specific Gravity of coarse aggregate = 2.616 ok

water absorption = 0.613 ok

Description of sample: **Sand**

Table4.5: Results of Specific Gravity & Absorption for Sand

NO	Description of sample	Test Number		Average
-	-	1	2	-
A	Weight of over – dry sample in air (g)	492.8	494.0	-
B	Weight of pycnometer filled water (g)	686.4	686.4	-
C	Weight of pycnometer sample & water (g)	998.9	999.0	-
S	Weight of saturated surface dry sample (g)	500.0	500.0	-
	Bulk specific gravity A/(B+C+S)	2.628	2.636	2.632
	Bulk specific gravity (saturated surface – dry basis) S/(B+500-C)	2.773	2.756	2.765
	Apparent specific gravity A/(B+A-C)	2.733	2.723	2.728
	Water absorption 100*(S-A)/A	1.461	1.215	1.338

The specifications recommend that the specific gravity of fine aggregates range from 2.60 to 2.65, and that the absorption ratio for it does not exceed 2.5 %. Through experiments, it was found that:

specific gravity of fine aggregates = 2.632 ok

water absorption = 1.338 ok

Figure 4.10: Photo of Specific Gravity Test

4.5 Result of Fresh Concrete Test:

In this study four samples were used, the first mixture, the mixing was carried out according to the hot weather conditions in Khartoum. The second mixture the aggregate sprayed with water for cooling, the third mixture the cold water used for mixing. The fourth and last aggregate sprayed with water for cooling and cold water was used for mixing.

Table 4.6: Result of temperature mix

Mix concrete	Temperature of mix
first mixture	**38.5**
second mixture	**33.7**
third mixture	**32.9**
fourth mixture	**27.2**

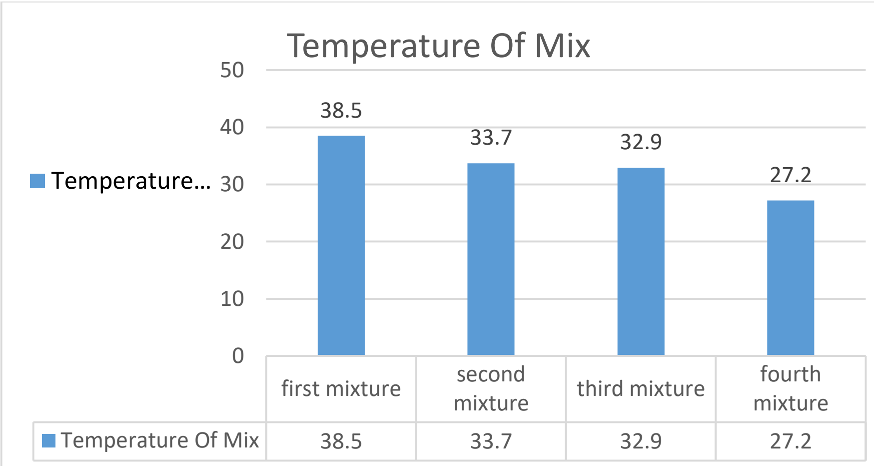


Figure4.11: Result of temperature mix

Figure 4.13 and Table4.6 show the temperature of the concrete mixtures. We notice a gradual decrease in temperatures. The first mixture recorded the highest temperature and the temperature of the mixtures gradually decreased.

Figure4.12: Temperature of fresh concrete

4.5.2 Result Slump Test:

Table 4.7: Result of amount Slump

Mix concrete	Amount of slump
first mixture	**15.5**
second mixture	**17**
third mixture	**13**
fourth mixture	**16**

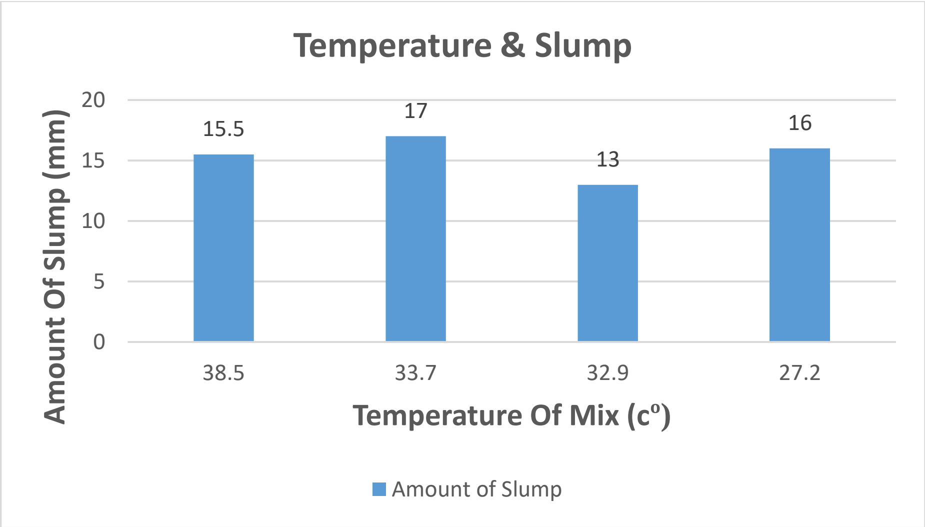


Figure4.13: The relationship between temperature of the mixture and slump.

Figure 4.15 and Table 4.7 illustrate the relationship between the temperature of the mixture and the slump test. In the second and the fourth mixture, we notice a high slump in value, which are the mixtures spray the aggregate with water, and the third mixture in which cold water was used for mixing had the lowest slump value.

Figure 3.14: Slump Test

4.6 Result of Hardened Concrete Testing:

The concrete was poured under the standard conditions and the cubes were immersed in water and the fracture was completed within **7** days and **28** days and the results were as follows:

- **First** mixture: (Temperature of mix**38.5)**

Table 4.8: Result of compression strength of first mixture:

7 DAY			28 DAY		
W(g)	Kg/cm²	N/mm²	W(g)	Kg/cm²	N/mm²
8321	666	31.08	8352	813	37.94
8256	692	32.29	8224	859	40.09
8181	615	28.7	8260	744	34.72
Average	30.69		Average	37.58	

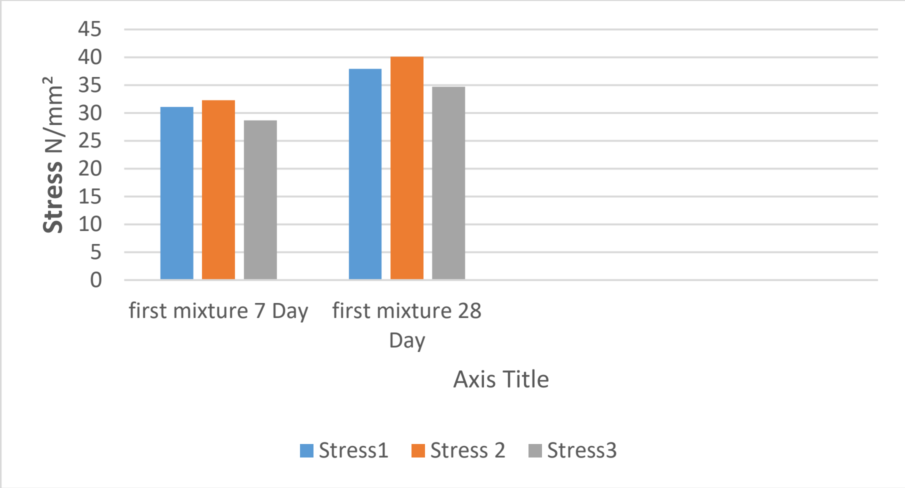


Figure 4.15: Result of compression strength of first mixture.

Figure 4.17 and Table 4.8 show the results of the mixture compression resistance in hot climate conditions. We note that there is a discrepancy in the values of the three samples taken and the results were acceptable according to the design the compression strength in 7 days and 28 days 30.69 N/mm² and37.58 N/mm² respectively.

- **Second** mixture: (Temperature of mix **33.7)**

Table 4.9: Result of compression strength of second mixture:

7 Day			28 Day		
W (g)	Kg/cm²	N/mm²	W (g)	Kg/cm²	N/mm²
8159	613	28.6	8182	800	37.33
8276	644	30.05	8208	795	37.1
8233	603	28.14	8201	773	36.07
Average		28.93	Average		36.83

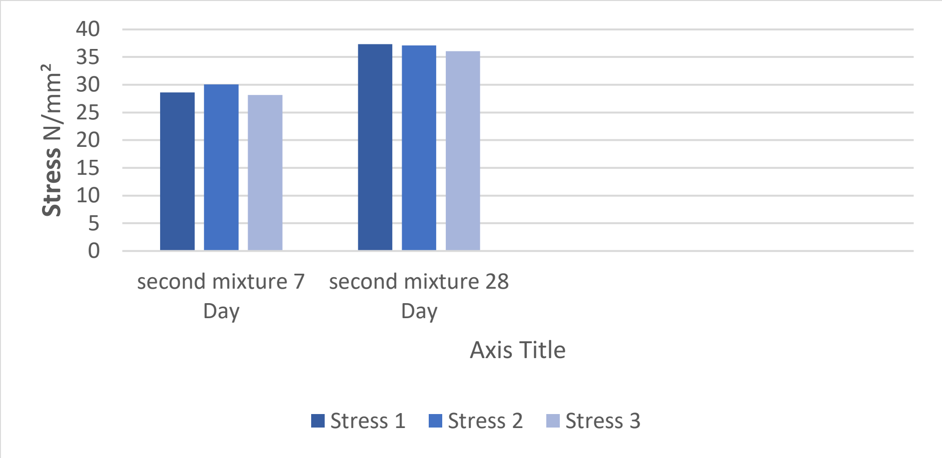


Figure 4.16: Result of compression strength of second mixture.

Figure 4.18 and Table4.9 show the results of the compression resistance for the second mixture, in which the aggregate was sprayed with water for cooling, and the results in 7 days were less than 30 N/mm² view in figure (4.18) the average of results the three samples in7and 28 days is 28.93 N/mm² and 36.83 N/mm² respectively.

- **Third** mixture: (Temperature of mix **32.9)**

Table 4.10: Result of compression strength of third mixture

7 Day			28 Day		
W (g)	Kg/cm²	N/mm²	W (g)	Kg/cm²	N/mm²
8183	607	28.33	8171	801	37.38
8189	619	28.88	8229	736	34.35
8210	598	27.90	8229	811	37.85
Average		28.37	Average		36.53

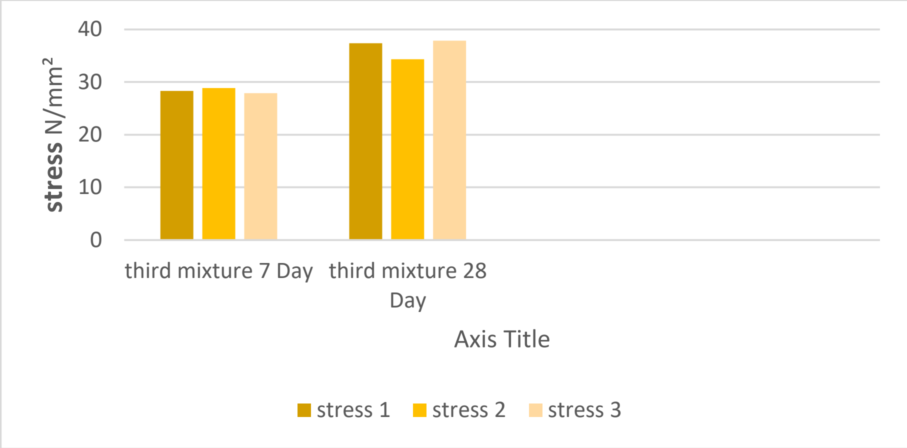


Figure 4.17: Result of compression strength of third mixture.

The results of the compression resistance for the third mix, in which cold water was used for mixing. The results during 7 days were similar and varied in days28 as show in figure 4.19 and table 4.10.

- **Fourth** mixture: (Temperature of mix **27.2)**

Table 4.11: Result of compression strength of fourth mixture

7 Day			28 Day		
W (g)	Kg/cm²	N/mm²	W (g)	Kg/cm²	N/mm²
8364	685	31.96	8409	853	39.80
8291	690	32.20	8281	846	39.48
8235	671	31.31	8225	872	40.69
Average		31.82	Average		39.99

Figure 4.18: Result of compression strength of fourth mixture.

Figure 4.20 and Table 4.11 show the results of the compression resistance for the fourth and final mixture, in which cold water was used for mixing and the aggregate was sprayed with water for cooling. This mixture recorded greatest compression strength which are 31.82 N/mm² and 39.99 N/mm² at 7 and 28 days respectively.

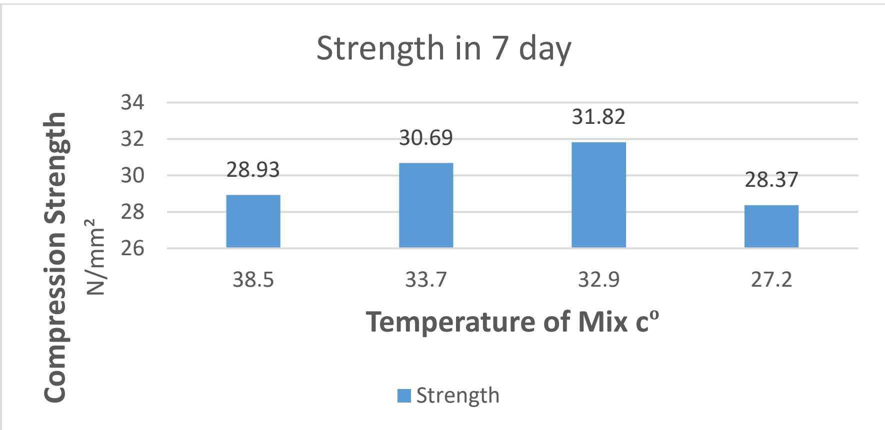


Figure 4.19: Relationship between Compression Strength and Temperature of Mix in 7 days

Figure 4.21 shows their ration ship between the temperature of concrete mixtures and the average compressive strength during 7 days. The best result was for the mixture in which cold water was used for mixing 31.82 N/mm², and the lowest result was for the mixture in which the coarse aggregate was sprayed with water for cooling and the use of cold water for mixing 28.37 N/mm².

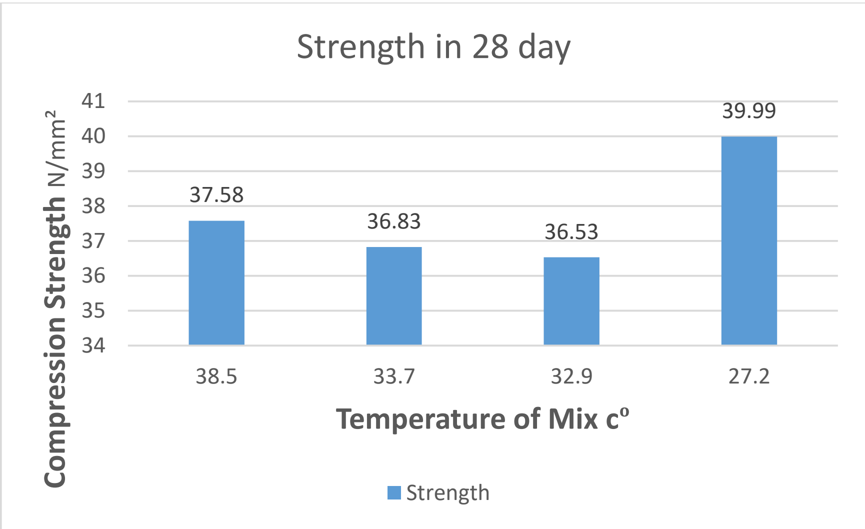


Figure4.20: Relationship between Compression Strength and Temperature of Mix in 28 days.

In figure 4.22 the Relationship between Compression Strength and Temperature of Mix in 28 days was shown. The best result for mixture in which the coarse aggregate was sprayed with water for cooling and the use of cold water for mixing 39.99 N/mm² the lowest compression strength was mixture in which cold water was used for mixing 36.53 N/mm².

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

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5.1 Conclusion:

High weather temperatures affect the temperature of the concrete materials used in the concrete mix and thus increase the temperature of the mix, affecting the strength of the concrete. in this study, solutions were made to avoid the high temperature of the mixture and the following conclusions were drawn:

1. Fresh concrete mixes in which the aggregate is sprayed to cool show a relative increase in slump testing. This increase in slump in reflects an overall improvement in workability of concrete mix.
2. The use of cold water in concrete mixing leads to a decrease in the temperature of the fresh concrete during mixing and pouring, as in the third and fourth mixture the temperature decreased to 32.9 c^{o} and 27.2 c^{o} compared to the first (standard) mix of 38.5 c^{o}, which makes it a major factor in influencing the temperature of the concrete mixture, especially in hot weather conditions.
3. The initial 7-day compressive strength in the mixture with water sprayed aggregate was 30.69 N/mm^2, and in the cold water mixture use for mixing was 30.82 N/mm^2.
4. The results show that the mixture with the lowest temperature of 27.2 c^{o} ,which is the aggregate sprayed with water for cool and used cold water for mixture, has the highest compressive strength at 28 days of 39.99 N/mm^2.
5. Heating the aggregate to a temperature of 50 c^{o} does now no longer have an effect on the compressive strength of concrete.
6. The results of the questionnaire that were distributed to the engineers at the construction site showed that 56.76% of the engineers did not care about the weather conditions during the mixing and pouring concrete and 56.76% did not care about the temperature measurement degree of the concrete mix.

5.2 Recommendations :

5.2.1 Recommendations for the study:

1. Use cooling water when pouring concrete in hot weather in addition to meeting the technical requirements for cool concrete mix temperature.
2. Working on mixing and pouring at night, if possible, to avoid high temperatures of the concrete mix.
3. Integrate methods to lower mixing temperature of constituent materials of the concrete.
4. Consultants to mandate concrete temperature measurement in the job sites ensuring mix is within limits and avoiding the negative impacts of hot weather on concrete structures.
5. Keep the concrete mix components in the shade, away from the sunlight and heat.
6. Spray and moisten the concrete base and formwork used before pouring in hot weather.

5.2.2 Recommendations for future study:

This experimental work carried out within the scope of this work identified a number of recommendations and areas for further research, including:

i. Increase the temperature variability of aggregates for a sensitivity analysis to achieve optimal mixing temperatures that can then be used as benchmark for hot weather conditions fabrication.

ii. Using more controlled temperature simulation during test work, it is possible to construct a climate chamber to mimic concretes exposure to heat and sunshine during high temperatures casting and harsh summer conditions.

iii. Monitor concrete strength over a longer period (90 days) to further study the structural behavioral and durability of the analyzed concrete structure.

iv. Add ash or sugar to the concrete mix and know its effect in reducing the temperature of the mixture.

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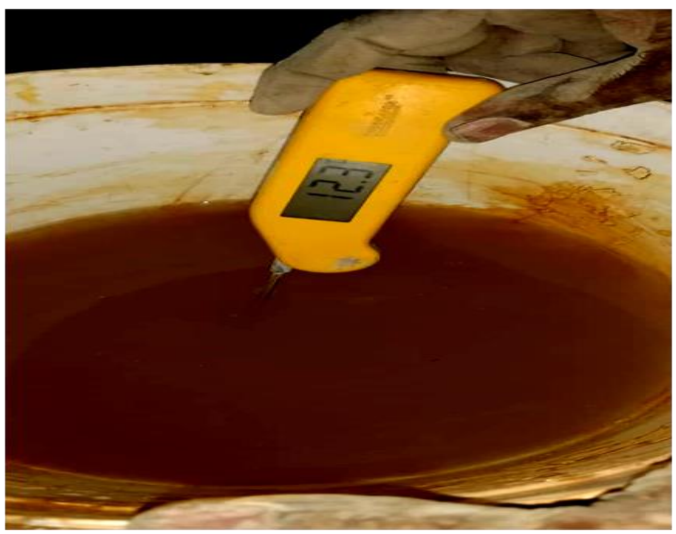
Sieves Analysis Test

Specific Gravity Test

Heating the aggregate to a temperature 50 c°



Using cold water for mix concrete

a temperature of fresh concrete

Slump test

Concrete cubes

Curing cubes

Compressive test