EFFECTS OF MIXING AND DELIVERY TIME DURATION ON PROPERTIES OF READY MIXED CONCRETE

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ABSTRACT

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Ready mixed concrete is the concrete manufactured for delivery to a purchaser in a plastic and unhardened state. In practice, the concrete is usually mixed at a central mixing plant and loaded on truck mixers for delivery to the job site. Truck mixers operate at an agitation speed.

The slump of the concrete measured at central mixing plant reduces by the time it is delivered due to the effect of various factors, such as the composition of concrete mix, the length of delivery time and ambient temperature. Therefore, it is a common practice to retempering the concrete by adding some water to restore the initial workability in order to facilitate the casting operation. However, increasing the water content of the concrete mixture leads to a reduction in concrete strength.

In this study, the effect of the length of mixing and delivery time on some properties such as concrete temperature, slump loss and strength are investigated. For this reason, three classes of concrete (BS 14, BS 18 and BS 25) are produced and delivered to the University Laboratory. Samples of concretes are taken from the truck mixer at the end of first, second, third and fourth hours, while the agitation in the truck mixer continues until the end of the fourth hour.

After measuring the slump and concrete temperature of each sample concrete, water is added to each sample concrete to raise the slump up to the initial slump value.

Unit weights and air contents of the retempered concrete mixtures are found and standard cylindrical specimens are cast for purpose of determining their compressive strength, modulus of elasticity and tensile strength values.

This first chapter of the text includes general information and objectives and scope of the investigation, Present technology of ready mixed concrete and future prospects are discussed in Chapter 2. Properties and previous studies of ready mixed concrete are given in chapter 4. Test results and discussions, conclusions drawn and recommendations are given in chapters 5,6, and 7 respectively.

Key words: Ready mixed concrete, slump loss, unit weight, air content, concrete temperature, retempering, compressive strength, modulus of elasticity, tensile strength.

ÖZ

KARIŞIM VE TESLİM SÜRESİNİN HAZIR BETON ÖZELLİKLERİ ÜZERİNDEKİ ETKİSİ

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Hazır beton, alıcıya plastik ve sertleşmemiş bir durumda teslim edilmek üzere üretilen betondur. Karılma işlemi, çoğu zaman hazır beton santralındaki merkezi bir mikserde tamamlanmakta ve mikserli kamyonlara yüklenerek teslim yerine taşınmaktadır. Mikserli kamyonlar ağır bir hızda çalıştırılmaktadırlar.

Beton santralındaki merkezi mikserde ölçülen çökme miktarı, teslim süresine beton karışımının bileşimi, teslim süresinin uzunluğu ve ortam sıcaklığı gibi çeşitli faktörlerin etkisiyle azalır. Bundan dolayı, beton dökme işini kolaylaştırmak için ilk işlenebilirliği tekrar sağlamak amacıyla su ilave etmek sıkça rastlanılan bir uygulamadır. Fakat, karışımdaki su miktarının artması beton dayanımının azalmasına neden olur.

Bu çalışmada, karışım ve teslim süresinin beton sıcaklığı, çökme kaybı miktarı ve dayanım gibi özellikler üzerindeki etkisi araştırılmıştır. Bu nedenle, üç çeşit beton sınıfı (BS 14, BS 18 ve BS 25) üretilmiş ve Üniversite Laboratuvarına teslim edilmiştir. Mikserli kamyon dördüncü saatin sonuna kadar karışım işlemine devam ederken kamyondan birinci, ikinci, üçüncü ve dördüncü saatin sonunda beton örnekleri alınmıştır.

Her beton örneğinde çökme miktarı ve beton sıcaklığı ölçüldükten sonra çökme miktarını ilk çökme değerine arttırmak için su ilave edilmiştir.

Su eklenmiş beton karışımlarının birim ağırlıkları ve içerdikleri hava miktarları bulunmuş ve basınç dayanımı, elastik modül ve gerilme dayanımı değerlerini bulmak amacıyla standard silindir numuneler dökülmüştür.

Tezin birinci bölümü yapılan araştırma hakkında genel bilgileri ve çalışmanın amaç ve kapsamını içermektedir. Hazır Betonun bugünkü teknolojisi ve geleceği 2. bölümde tartışılmıştır. Hazır Betonun özellikleri ve daha önce yapılmış çalışmalar 3. bölümde verilmiştir. Deneysel program ve yapılan deneyler 4. bölümde açıklanmıştır. Test sonuçları, çıkarılan sonuçlar ve öneriler sırasıyla 5., 6. ve 7. bölümlerde yer almıştır.

Anahtar Kelimeler: Hazır beton, çökme kaybı, unit weight, hava miktarı, beton sıcaklığı, kıvama getirme, basınç dayanımı, elastik modül, gerilme dayanımı.

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CHAPTER 1

INTRODUCTION

1.1. General

For the past 100 years, cement and concrete have been the basic materials for building and civil engineering and the amounts used are a direct measure of the stage which any country has reached in its economic and social development.

Concrete construction is an intermittent process involving erection of forms, fixing of steel, and concrete production, handling, placing compaction and curing with proper planning, the contractor can interprate ready mixed concrete into his construction programme with considerable savings in costs, site space and construction time.

Ready Mixed Concrete is the fresh concrete which is made to be ready for placing on construction by means of mixing of materials completely and transporting of mixture to the jobsite [22].This enables the places of manufacture and use of concrete being separated and linked by suitable transport operation. The technique is useful in congested sites or at diverse work places and saves the consumer from the botheration of procurement, storage and handling of concrete materials.Ready mixed concrete is produced under factory conditions and permits a close control of all operations of manufacture and transportation of fresh concrete.

Ready mixed concrete is concrete ready for placing on site with additional requirements for delivery. One of the requirement is about period of completion of concrete discharging. It is conceivable that concrete transportations are delayed by traffic jams. Even if trucks arrive early, they can be forced to wait to discharge because of construction-related problems or pump failures leading to delayed unloading. Beside this problems, ready mixed concrete plants in large cities are being gradually driven to the periphery and transportation time to urban areas is increasing. To transport concrete which is generally pumped into place, for a long period make difficulty in flowing smoothly through piping and may impair its quality.

1.2. Object and Scope

Increase in completion period of concrete discharging particularly in hot weather, results in rise of concrete temperature. The increase of concrete temperature causes a more rapid hydration and more rapid evaporation leading to increased rate of slump loss which corresponds tendency to add water at the jobsite. The amount of water required to produce a given slump increases with the extended mixing time. The addition of water without proper adjustments in mix proportions adversely affects the ultimate quality of concrete.

According to ASTM standards, discharge of concrete shall be completed with in 1½ h before the drum has revolved 300 revolutions, which ever comes first, after introduction of the mixing water to the cement and aggregates or the introduction of the cement to the aggregates. This may result from the consideration that the hydration of cement and moisture on aggregate surfaces when the materials are charged to the truck mixer at the plant. On the other hand, TS 11222 standard specifies that ready mixed concrete be transported such that it can be discharged with in 2 h or 300 revolutions after starting mixing, i.e. from the contact of cement and water, on the completion of unloading.

In this study, three class of fresh concrete are mixed for four hour and their slump loss are investigated. Furhermore, the effects of prolonged mixing time by addition of extra water to maintain initial slump on properties of fresh concrete which are Unit Weight and Air Content; and on mechanical poperties, Compressive Strength, Modulus of Elasticity and Split Tensile Strength were tested. It was also aimed to investigate the relation between temperature of concrete which affects slump loss and result in water demand and mechanical properties of hardened concrete.

CHAPTER 2

PRESENT TECHNOLOGY OF READY MIXED CONCRETE AND FUTURE PROSPECTS

2.1 Mixing and Transporting

2.1.1 General

Through mixing is essential for the production of uniform quality concrete. Therefore equipments and methods used should be capable of effectively mixing concrete materials. Sufficient mixing as well as transporting and placing capacity should be provided so that unfinished concrete lifts can be maintained plastic and free from cold joints.

2.1.2 Mixing Equipment

Mixers are either stationary parts of central mix plants or portable equipment. Satisfactory designed mixers have a blade arrangement and drum

shape which insure an end-to-end exchange of materials parallel to axis of rotation or a rolling, folding and spreading movement of the batch over itself as it is being mixed.

The more common types of mixing equipment are:

1) Tilting drum mixer revolving drum mixer that discharges by tilting the axis of the drum. In the mixing mode, the drum axis can be either horizontal or at an angle to the horizontal.

2) Non-tilting drum mixer revolving drum mixer which is charged, mixes and discharges with the axis of the drum horizontal.

3) Vertical shaft mixer called a turbine or pan type mixer offenly. Mixing is done with rotating blades or paddles, mounted on a vertical shaft, in either a stationary pan or one rotating in the opposite

direction to the blades. Rapid mixing and low overall profile are other significant advantages. This mixer does an excellent job of mixing relatively dry concretes and is often used for laboratory mixing and by concrete products manufacturers.

4) Paddle mixer using horizontal blades and suitable for stiff concrete mixtures. It is used primarily in the production of concrete block units.

5) Truck mixers are two types of revolving drum truck mixers. Rear discharge and front discharge. Both utilize fins attached to the drum to mix concrete in the mixing mode and same fins discharge the concrete when drum rotation is reversed [3]. The most common size of truck mixer having 22-26 tones gross weight is the 5-6 cu.m. Many countries have attempted to operate larger sized vehicles, including articulated units up to 10 cu.m. These units are only possible in those countries which have large uses of ready mixed concrete. Statistics supplied by European Ready Mixed Concrete Organisation (ERMCO) indicate that about 70% of the total number of vehicles operated by EMCO Members are in the 5-6 cu.m.range [1].

6) Continous mixing equipment in which mixing is accomplished by a spiral blade rotated at a relatively high speed inside an enclosed through inclined at 15 to 25 deg from the horizontal.

2.1.3 Central Mixed Concrete

Central mixed concrete is mixed completely in a stationary mixer and then transferred to another piece of equipment for delivery. The tendency of concrete to segregate limits the distance it may be hauled in equipment not equipped with an agitator.

Sometimes the central mixer will partially mix the concrete with the final mixing and transporting done in a revolving drum truck mixer. This process is often called "shrink mixing" as it reduces the volume of the as charged mixture. The total volume that a truck can handle is limited to 63 percent of the drum volume.

2.1.4 Truck Mixed Concrete

Truck mixing is a process by which previously proportioned concrete materials from a batch plant are charged into a ready mix truck for mixing and delivery to construction project. To achieve through mixing, total absolute volume of all ingredients batched in a revolving drum truck mixer should not exceed 63 percent of the drum.

2.1.5 Charging and Mixing

The method and sequence of charging mixers is of great importance in determining whether the concrete will be properly mixed.

For central plant mixers obtaining a preblending or ribboning effect as the stream of materials flow into the mixer is essential.

In truck mixers all loading procedures must be designed to avoid packing of material, particularly sand and cement, in the head of the drum during charging. The probability of packing is decreased by placing about 10 percent of the coarse aggregate and water in the mixer drum before the sand and cement.

The handling of water deserves special attention. Generally about one-fourth to one-third of the water should be added to the discharge end of the drum after all other ingredients have been charged. Water charging pipes must be of proper design and sufficient size so that water enters at a point well inside mixer and charging is complete within the first 25 percent of the mixing time.

Chemical admixtures should be charged to the mixer at the same point in the mixing sequence batch after batch. Liquid admixtures should be charged with the water or on damp sand, and powdered admixtures should be ribboned into the mixer with the dry ingredients. When more than one admixture is used, each should be batched separately unless premixing is shown to be permissible and they should be properly diluted before they enter mixer.

2.1.6 Discharge

Mixers must be capable of discharging concrete of the lowest slump suitable for the structure being constructed without segregation. Prior to discharge of concrete transported in truck mixers, the drum should again be rotated at mixing speed for about 30 revolutions to reblend possible stagnant spots near the discharge end into the batch.

2.2.7 Mixer Performance

The performance of mixers is usually determined by serious uniformity tests made on samples taken from two or three locations within the concrete batch after it has been mixed for a given period.

Among the many tests used to check mixer performance, the following are the most common air content, slump, unit weight of air free mortar, coarse aggregate content and compressive strength [3]. According to ASTM standards mixers passing six test items are accepted a given in Table 2.1.

Table 2.1 ASTM Tests For Mixing Efficiency of Mixers [2]

Test Items	Tolerances
1. Variation in unit weight of concrete (excluding air content)	16 kg/m^2
2. Variation in air content	1.0 %
3. Variation in slump	
If slump is 102 mm or less	25 mm
If slump is 102 mm to 152 mm	38 mm
4. Variation in unit coarse aggregate content in concrete	6.0 %
5. Variation in unit weight of mortar in concrete	1.6 %
6. Variation in compressive strength at 7 days	7.5 %

Another important aspect of mixer performance is batch-to-batch uniformity of the concrete which is affected by the uniformity of materials and their measurements as well as by the efficiency of the mixer.

2.1.8 General Considerations for Transporting Concrete

Concrete can be transported by a variety of methods and equipment, such as truck mixers, open top truck bodies with and without agitators, buckets hauled by truck or railroad car, by pipeline, hose conveyor belts. The method of transportation used should efficiently deliver the concrete to the point of placement without significantly altering its desired properties with regard to water-cementt ratio, slump, air content and homogeneity. Each method of transportation has advantages under particular conditions such as: mixture ingredients and proportions, type and accesibility of placement, required delivery capacitiy, location of batch plant, weather conditions and others. These various conditions should be carefully revieved in selecting the type of transportation best suited for economically obtaining quality concrete in place [3].

2.2 Quality Assurance and Quality Control

2.3.1 General

There is often an initial resistance to ready mixed concrete by specifying authorities, who require reassurance concerning the production standards and production standards and product quality. This has been achieved in many countries by the introduction of Approval or Certification Schemes for production and quality control.

Quality assurance planned and systematic actions necessary to assure that the final product will perform its intended function and it is a management tool. On the other hand, quality control related to the physical characteristics of the materials, process, and services which provide a means to measure and control the characteristics to predetermined quantitative criteria and it is production tool. The quality control procedures provide assurance that concrete mixes are subjected to continous quality control and that a specified or characteristic strength will be achieved [1,4,5].

2.2.2 Organizational Responsibilities

The owner and engineer responsible for acceptance inspection and testing. Engineers should provide owners with alternatives and information enabling the owner to recognize and evaluate the quality, cost and maintenance relationships involved in the construction. Owner must understand that field inspection and testing needs to be provided to assure conformance to codes and quality requirements. For the protection of the owner and public, the responsibility for planning and detailing acceptance inspection should be vested in the engineer as continuing function of the design responsibility. Coordination and scheduling of acceptance inspection should be made a function of the contractor. This will provide timely inspections and avoid owner caused construction delays [6].

2.2.3 Control of Design

The design organization should follow established procedures and document its design to the level of detail necessary to permit the design to be developed correctly and to permit qualified person to understand and verify final design documents.

Design basis such as codes, standards, assumptions, and other requirements should be identified. Calculations should be documented, checked and approved. Drawings should be rewiewed and approved for correct incorporation of design calculations, materials, processes and constructibility by the organization originating the design drawings.

2.2.4 Material Control

Controls should be established for concrete constituent materials and other materials integral to the concrete structure to assure that materials within the recognized product variability, meet the requirements of the contract documents prior to use. The implementation of the established controls should be described in a quality program which documents the procedures and instructions to be carried out. Established controls may include supplier evaluation and selection, procurement documents, receiving inspection, storage and handling of material, material qualifications and records.

2.2.5 Inspection

A program for inspection should be established and implemented to assure that concrete construction and materials meet the requirements of the contract documents. The inspection should contain provisions for the specific verification and acceptability of implemented field changes.

2.2.6 Testing and Evaluation

A program or sampling and testing concrete and concrete construction materials and evaluating the results should be established and implemented. All acceptance testing should be performed by qualified personnel other than those who supplied, transported or placed the concrete or concrete materials. The testing should be performed using standard test methods and at frequencies established by the contract documents. The testing should include the qualification of all materials used to produce the concrete, the concrete mix proportioning and physical properties of the plastic and hardened concrete. The evaluation of test results should be performed at the completion of the testing operation by qualified person using acceptance criteria established by the project documents.

2.2.7 Records

Each organization generating records or documents that furnish evidence of the quality of materials, equipment or activities should be responsible for their technical content and accuracy [4].

2.3 Future Prospects

The growth of the ready mixed concrete industry is every developed country in the world confirms that the industry is capable of satisfying the needs of the engineer and contractor by ensuring that there is a continuous delivery service of concrete of high quality. As has been shown, the potential for the industry in any country depends on the stage of economic growth and the corresponding types of construction being carried out, which determine the types of concrete required and corresponding methods of production.

The ready mixed concrete business should consider that the future market position of their product is in question. Already today many producers of building materials and construction systems advertising thir products as "friendly to working conditions". One of the big problems is that fresh concrete is rather stiff substance. The introduction of plasticizing admixtures was substantial improvement but this concept was not able to solve all the problems. For that reason the survey of the concrete-woker's profession concluded in the recommendation to develop a self-levelling concrete with a minimum of physical efforts and without the need vibration, striking off and removing by hand. The application of new concepts in concrete technology offers possibilities to introduce new dimensions where workability of fresh concrete is concerned. The objective is to develop mixes with a slump of approximately 250 to 270 mm without bleeding and segregation [1, 7].

One argument from the prefab industry has been that the owner should choose dry building methods in order to avoid risk of the problems with sick houses ie prefab. The answer is Rapid Drying Concrete or Selfdrying during the hardening process. The Rapid Drying Concrete has a water cement ratio of 0.32-0.38 and Selfdrying Concrete less than 0.32. The contractor have to by a more expensive concrete but as concrete with this low water cement ratio also is extremly rapid hardening he can build much faster and useless form equipment as he can strip the form for the slab the day after the casting. The contractor will save more than he spend on the more expensive concrete. The owner will get a house without risk of the indoor climate and more contentenants and of course the ready mixed concrete supplier will gain somewhat extra on every cubic meter [8].

CHAPTER 3

PROPERTIES AND PREVIOUS STUDIES

OF

READY MIXED CONCRETE

3.1 General

In manufacture and delivery of concrete by the method known as ready mixed, the concrete is continously mixed or agitated for different periods. Although economic and technological considerations dictate minimization of the hauling time, there are not inruent cases in which substantial mixing times cannot be avoided, owing to the distances involved or to delays in placing. Prolonged mixes induces thickening of the mix, that is to say, consistency change or slump loss, which constitutes an early stage of stiffening of the mix, which should clearly distinguished from that of later stiffening-hardening, defined as initial and final set. This change in consistency (slump) may be quite rapid (particularly in hot weather) and cause difficulties in discharging, handling and placing.

Sometimes, in the field, to hold the concrete in trucks for a long time on numerous occasions contractor indiscriminarely add water to the mix during unloading of the trucks to develop and maintain a high slump.

The significant effects of mixing time in ready mixed concrete are on slump loss, compressive strength on which temperature, initial slump and retempering with or without admixture are also important factors.

3.2 Slump Loss

Slump can be defined as the loss of plasticity or workability in fresh concrete with time. The problems during placement and consolidation of concrete due to slump loss after long hauls or delays, especially in warm weather are well known. Field practices, such as starting with a higher water cement ratio and higher initial slump loss in order to compensate for expected slump loss, or concrete retempering are not uncommon. Slump loss is needed in order to maintain concrete uniformity and quality. The factors known or presumed to affect concrete during its plastic period including the following:

- Mixing time
- Temperature of concrete and ambient
- Initial slump value
-Type, addition rate of admixture and time of addition

- Interactions of above [12].

3.2.1 Mixing Time

Prolonged mixing increase slump loss due to the rise in concrete temperature. Figures 3.1 shows concrete slump loss tested up to 4 hour which materials amount of mix are given in Table 3.1. In this test while ambient temperature was 13°C, concrete temperature reached 23.4°C [13].

Table 3.1 Concrete Mix Proportions [13]

Content (kg/m^3)					
Material Cement	Water	Sand	Dust of Crushed Stone	Crushed Stone I	Crushed Stone II
300	180	465	285	460	690

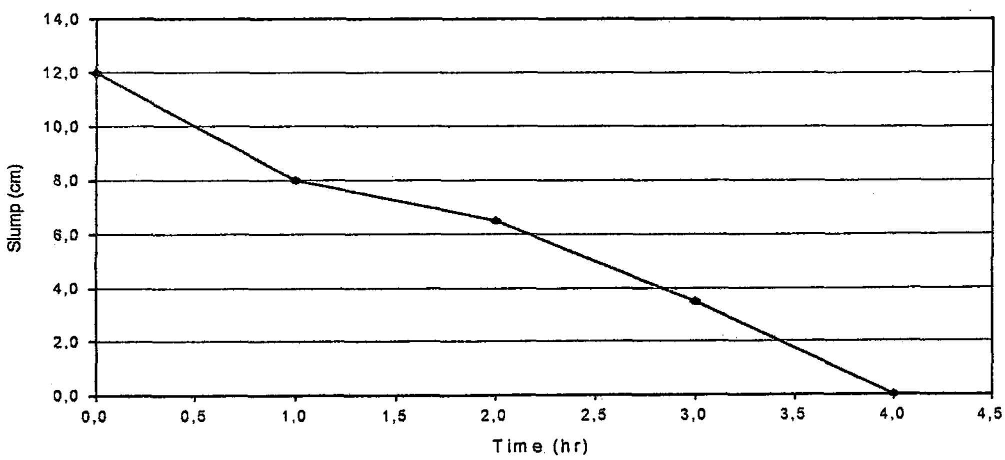

Figure 3.1.Slump depending on time

3.2.2 Temperature

Since high ambient temperature increase the evaporation rate it effects slump loss. The figure 3.2 shows the slump values for the same type of concrete at two different temperature [12]. Beside this, concrete temperature which can increase due to the prolong mixing also effects the slump [12, 14]. The amount of water required to produce a given slump increases with the time since cement is wetted. For a constant mixing time, the amount of water required to produce a given slump also increases with the temperature, as shown Figure 3.3. and Figue 3.4 [5].

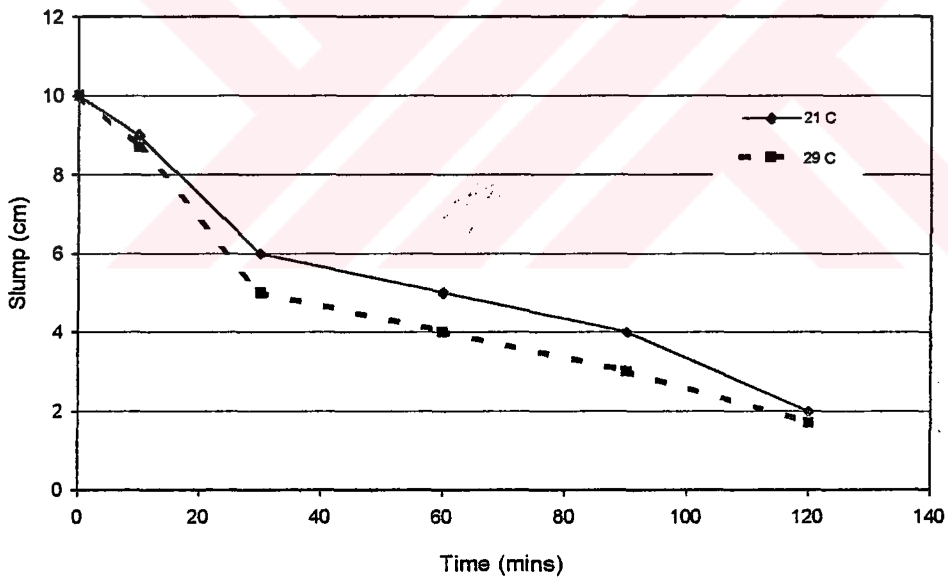

Figure 3.2 Concrete slump loss of same mixes at 21 C and 29 C

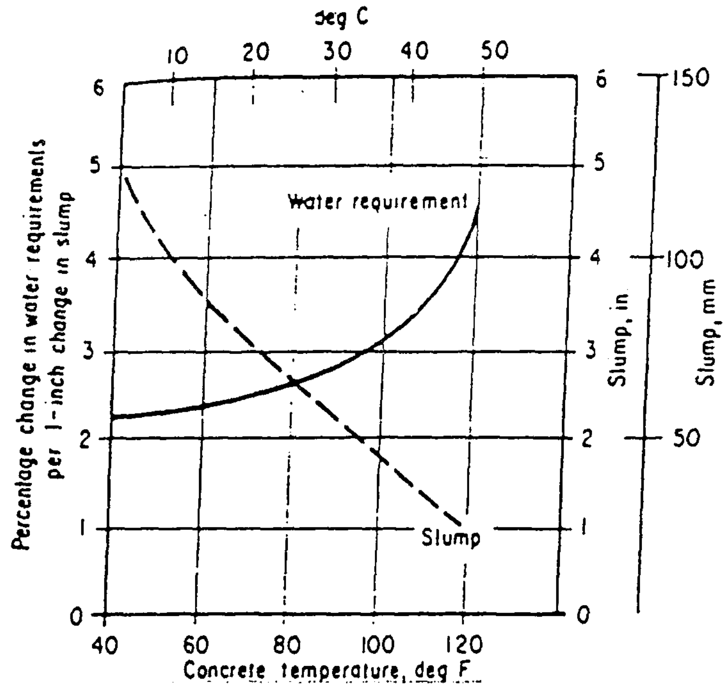

Figure 3.3. Effect of Concrete Temperature on Slump and on Water Required to Change Slump

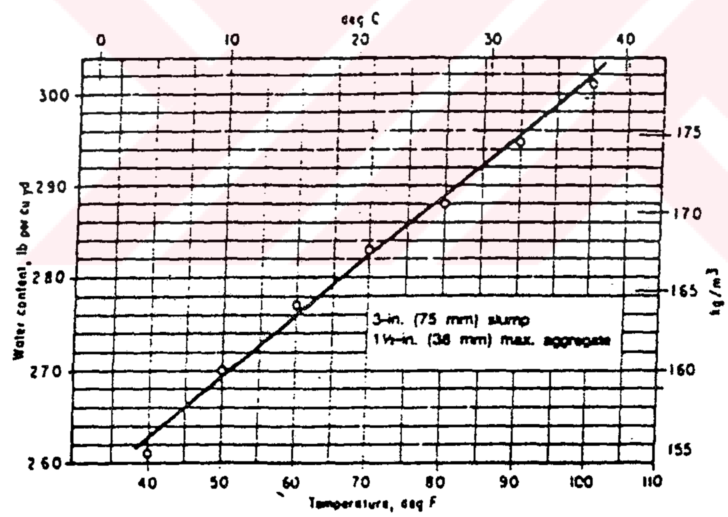

Figure 3.4. Effect of Temperature Increase on the Water Requirement of Concrete

3.2.3 Initial Slump Value

Concrete slump loss is proportional to the initial slump level: the higher initial slump, the higher the slump loss. Concrete containing conventional water reducing admixtures has a slightly, but not significantly higher loss of slump than reference concrete. However, the use of water reducing admixtures allows significant reduction in the total water required after retempering. The extend of this slump loss is proportional to the concrete age. For instance, the difference in slump loss between admixtured and reference concrete is generally less than 1.3 cm. at 30 min. In contrast, at 120 min, the difference is on the average less than 0.6 cm. It is not desirable to compensate for expected slump loss in reference concrete by using a higher initial slump value since retempered concrete will require a higher water cement ratio. Table 3.2 shows the effect of initial slump and temperature on slump loss. Table 3.3 and Table 3.4 indicate the effect of initial water cement ratio retempering at 21 C and at 29 C [12].

3.2.4 Admixture

Concrete slump loss is apparently proportional to the exteny of cement hydration during the plastic period. In the plastic period it is important to differentiate between the rapid initial reactions which occur in the first 5-10 min when water is added to the cement and so called dormant period of low activity

Table 3.2 Effect of Initial Slump and Temperature on Slump Loss [12]

		Slump Loss,cm			
Temperature	Initiall Slump	30 min	60 min	90 min	120 min
21	19.1	1.3	4.8	9.5	13.3
21	12.7	1.6	4.8	7.0	8.9
21	9.2	1.3	2.5	4.5	5.7
29	18.1	4.5	7.0	11.4	13.4
29	14.0	2.5	4.8	7.3	9.8
29	8.9	0	2.5	4.1	6.0

Table 3.3 Effect of Initial Water-cement Ratio on Retempering at 21°C [12]

	Time. Min		
	10	120	126
Slump, cm.	19.1	5.7	9.2
W/C	0.60	0.60	0.63
Slump, cm.	12.7	3.8	9.2
W/C	0.57	0.57	0.62
Slump, cm.	9.5	3.8	9.5
W/C	0.55	0.55	0.64

Table 3.4 Effect of Initial Water Cement Ratio on Retempering at 29°C[12]

	Time. Min		
	10	120	126
Slump, cm.	18.1	4.8	10.2
W/C	0.60	0.60	0.66
Slump, cm.	14.0	4.1	9.8
W/C	0.58	0.58	0.64
Slump, cm.	8.6	2.9	9.5
W/C	0.55	0.55	0.62

which lasts from 1-3 hr. depending on the cement. The setting processes occur during the reactions after the dormant cycle. Water reducing, set retarding admixtures extend the dormant cycle, there by increasing the setting time. Since they do not eliminate or reduce the rapid initial hydration reactions, slump losses not necessarily affected even though the dormant period is lengthened.

The dormant period is indeed only a time of low activity and the term dormant must not be taken literally. The extent of hydration activity during the dormant period is reflected in the water cement ratio needed to retemper reference concrete of comparable slump values having. An age of 10 min versus 120 min. [12]. These data are listed Table 3.5 [12].

Table 3.5 Effect of Concrete Age on Retempering [12]

	Time,min.			
	10	14	120	126
Temperature ,21 C				
Slump, cm	9.5	-	3.8	9.5
W/C	0.55	0.55	0.55	0.61
Slump, cm	4.5	9.8		
W/C	0.53	0.57		
Temperature, 29 C				
Slump, cm	10.5	-	4.1	10.5
W/C	0.58	0.58	0.58	0.64
Slump, cm	3.5	10.5		
W/C	0.54	0.60		

Conventional water reducing admixtures do not have a significant effect on concrete slump loss. They permit a significant reduction in the total ware after retempering. Increased dosages of water reducing or water reducing and retarding admixtures in prolonged mixed concrete have a beneficial effect in reducing the required total mixing water after retempering and consequently improving the compressive strength. That of practical advantage particularly in hot weather, when retempering is done to prolong the permissible interval between batching and placing. Table 3.6 shows effects of some admixtures having different dosages on slump value depending on mixing time. Admixture no 3, 4 and 5 - all based lignincarbohydrates, sulfones. Admixture 4 containing more of the water reducing compound; dosages-single, double and quadruple [10].

Table 3.6 Slump Data for Different Concrete Mixing Times, With Admixtures [10]

			Slump, cm			
Admixture			Mixing time, min			
No	Dosage, % cement		5	45	90	120
3	0.18		10.5	4.0	2.5	1.5
4	0.27	single	10.0	5.7	3.8	3.5
5	0.18		9.5	-	3.0	2.5
3	0.36		10.0	4.5	3.5	3.0
4	0.54	double	11.5	-	2.5	1.0
5	0.36		10.0	5.5	4.0	3.5
3	0.72		11.5	7.0	4.5	3.5
4	1.08	guadruple	19.5	12.0	5.5	4.5
5	0.72		16.0	7.0	4.5	3.0
Reference	Nil		11.0	7.5	5.5	4.5

Table 3.7 [10] shows that after 5 min of batching the required mixing water is reduced. Table 3.8 [10] shows that, except for one case, the total mixing water is reduced, an apperantly unexpected result in view of higher loss of slump

associated with admixtures. Admixture No 1-based on polyhydroxy carbonic acid; dosages- 0.150.15 (low), 0.20 (normal), 0.30 (high), 0.50 (maximum), percent by weight of cement. Admixture No.2-based on modified lignin sulfonate; dosages-0.20, 0.30 and 0.50, percent by weight of cement. Generally, the water reducing effect is weakened by prolonged mixing [10].

Table 3.7 Reduction of Mixing Water After 5 min Mixing [10]

Dosage Percent By weight of Cement	Reduction, percent		Dosage	Reduction, percent		
Admixture	1	2	Admixture	1	2	3
0.15	9					
0.20	15	11	Single	13	13	-2
0.30	15	-	Double	13	-	-
0.50	>15	13	Quadruple	18	>23	>23

Table 3.8 Reduction of Total Mixing Water Admixture After Retempering [10]

Dosage percent by weight of cement	Reduction, percent		Dosage	Reduction, percent		
Admixture	1	2	Admixture	1	2	3
0.15	6					
0.20	6	6	Single	-	-	-6
0.30	6	9	Double	6	6	6
0.50	6	13	Quadruple	17	21	19

3.3 Compressive Strength

Extended mixing does not adversely affect the compressive strength of the concrete until the concrete becomes impossible to work. Retemperring of the concrete mix does have an adverse effect on the strength of concrete. The extra water increases the water-cement ratio or water-cementitious material ratio accordingly will decrease the strength. Concrete strength decreased as water is added, however, mixing appeared to increase the strength some what between periods of adding water. Figure 3.5 indicates the relationship between compressive strength and water cement ratio. Figure 3.6 shows the change in strength for constant slump [11].

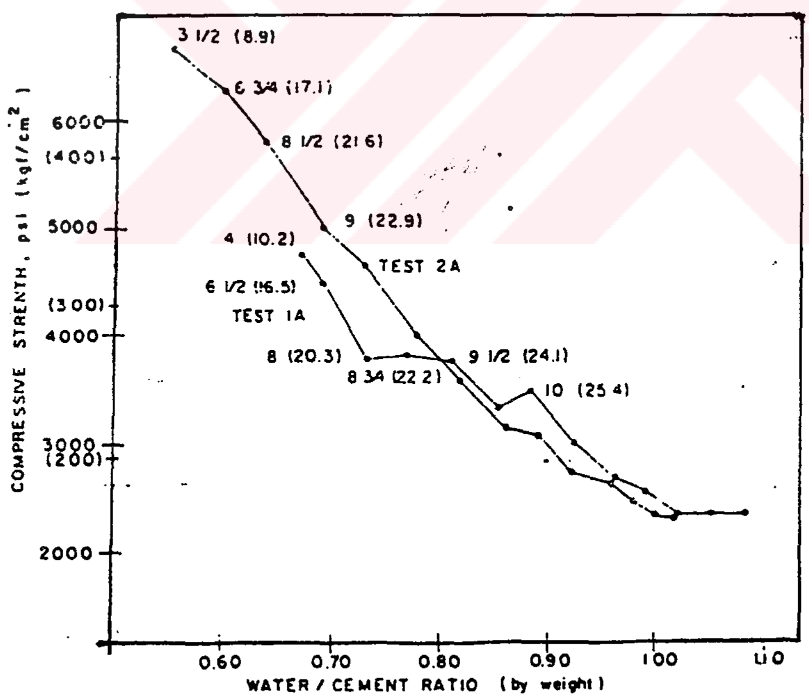

Figure 3.5. Strength depending on water cement ratio

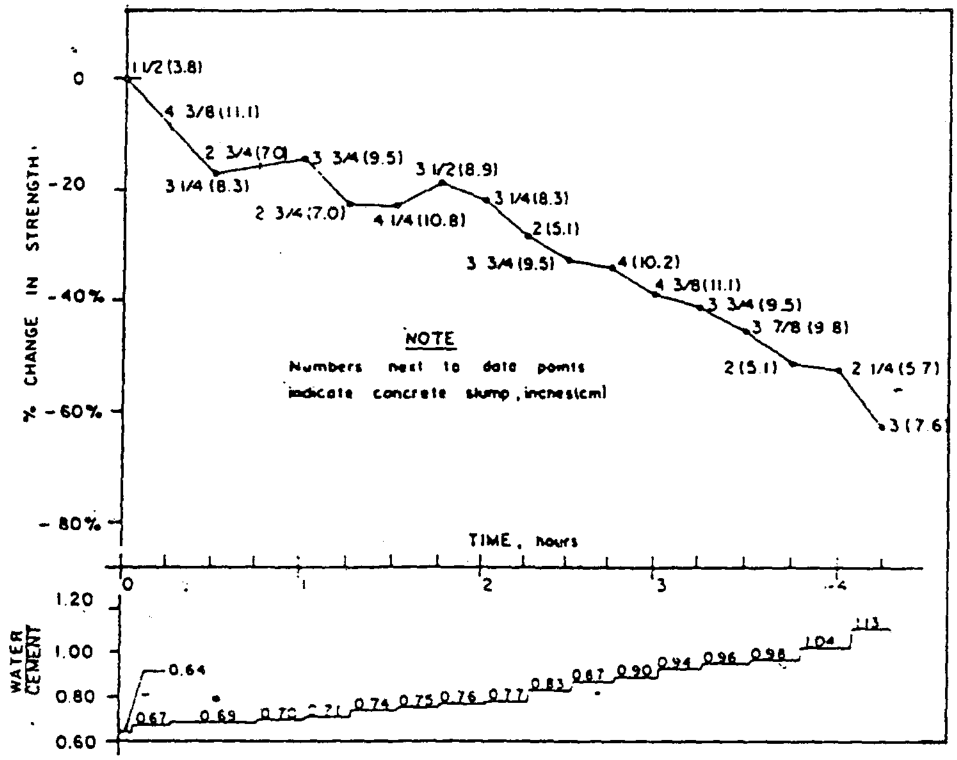

Figure 3.6. Strength depending on time with constant slump

CHAPTER 4

EXPERIMENTAL STUDY

4.1 Experimental Program

Three types of concretes were prepared at a stationary mixer and transported to the point of delivery (Materials of Construction Laboratory of The Middle East Technical University) in truck mixers operating at agitating speed. The three types of concretes were aimed to have minumum 28 day compressive strengths of 14, 18 and 25 MPa that were supposed to belong to BS 14, BS 18 and BS 25 classes of concretes as defined in Turkish Standards TS 500. (BS designates "Beton Sınıfı", meaning "Concrete Class".)

All concretes were designed to have a 15 cm slump as their mixing were completed in the stationary mixer. Thus, the slump of each concrete that was loaded in the truck mixer was 15 cm. Each type of concrete was prepared and transported on a different day.

The concrete that was brought to the University Laboratory in a truck mixer operating at agitation speed was kept in the truck mixer for four hours while the agitation was being continued. However, at the end of first, second, third and fourth hours, samples of concrete mixture were taken out of the truck mixer for determining the concrete temperature and conducting slump tests. Obviously, the slumps of sample mixtures were less than 15 cm especially at the end of second, third and fourth hours.

After determining the temperature and slump value of a concrete sample, that concrete sample was placed into a smaller mixer in the laboratory and some extra water was added to bring the slump value up to 15 cm. Unit weight, air content, compressive strength, modulus of elasticity and tensile strength tests were conducted on sample specimens obtained from the large sample mixture which now had a 15 cm slump that was achieved by adding extra water.

The chart shown in Figure 4.1 indicates the steps followed for conducting the tests.

All tests were conducted according to ASTM Standards. Table 4.1 [16], [17], [18], and Table 4.2 give the types of tests and relevant ASTM Standards for fresh concrete and hardened concrete [19], [20], [21], respectively.

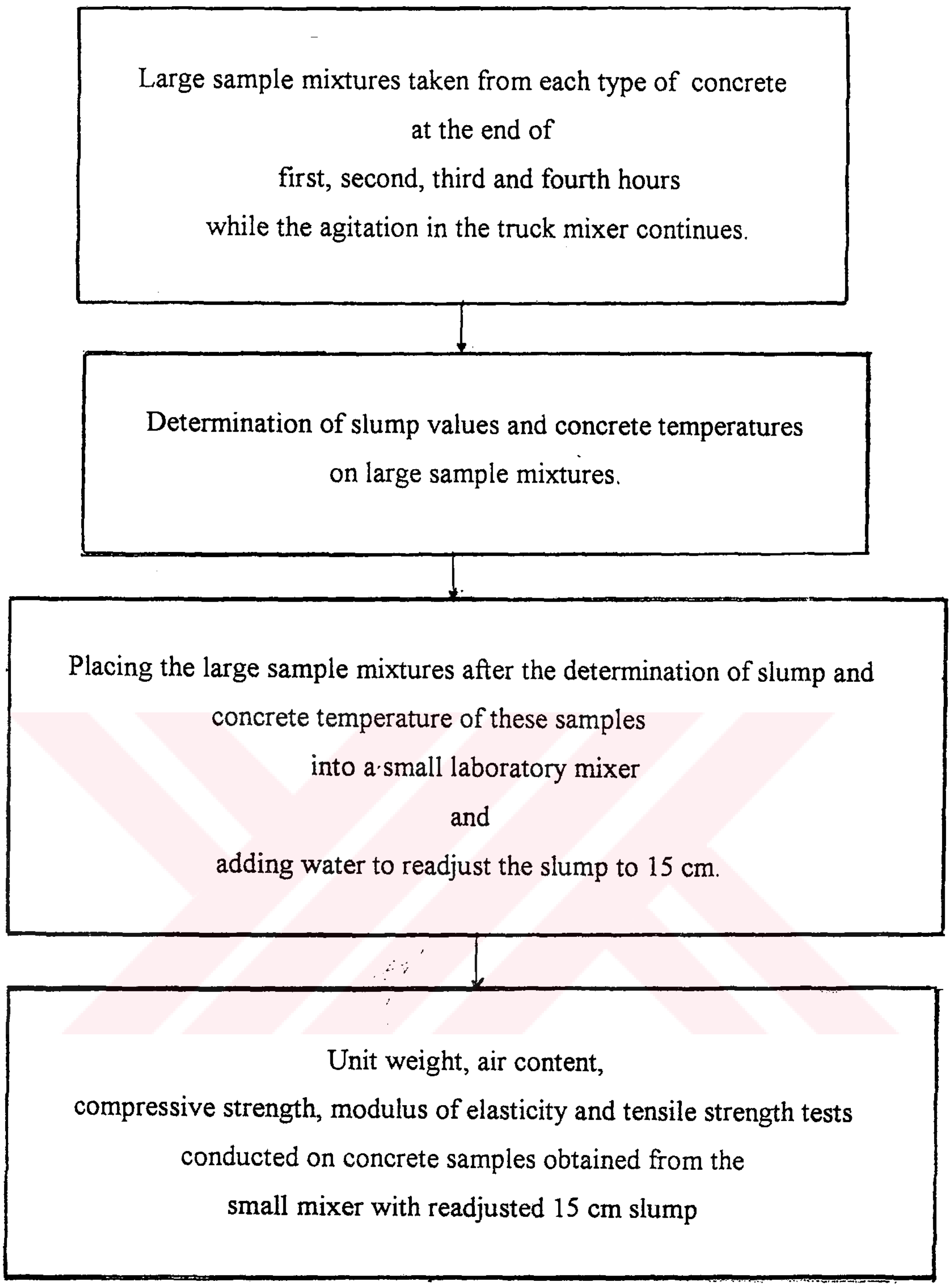

Figure 4.1 Steps Followed for Conducting the Tests

Table 4.1 Tests Performed on Fresh Concrete

Tests Performed on	Relevant ASTM Standards
Slump Tests	ASTM C 143
Air Content	ASTM C 231
Unit Weight	ASTM C 138 and ASTM C 231

Table 4.2 Tests Performed on Hardened Concrete

Tests Performed on	Relevant ASTM Standards
Compressive Strength Tests	ASTM C 39
Elastic Modulus Tests	ASTM C 469
Splitting Tensile Strength Tests	ASTM C 496

4.2 Materials

4.2.1 Cement

An ordinary portland cement (PÇ 42.5) was used for preparation of all concrete mixes. Chemical composition of this cement is shown in Table 4.3.

Compound composition of this cement calculated by using Bogue's Equations was as follows :

C_3S	52.33 %
C2S	17.66 %
C_3A	8.24 %
C_4AF	10.55 %

Table 4.3 Chemical Composition of the Cement

Oxides	(%)	ASTM C 150 Limits Requirements
CaO	61.88	-
SiO_2	19.83	-
Al_2O_3	5.32	-
Fe_2O_3	3.47	-
MgO	1.78	max. 6.0%
SO_3	2.84	max. 3.5%
K_2O	0.82	-
Na_2O	0.20	-
LOI	3.06	max. 3.0%

Table 4.4 Physical and Mechanical Properties of the Cement

Property		ASTM C 150 Requirements
Density, (gr/ cm^3)	3.10	-
Blain Specific Surface, (cm^2 /g)	3170	min 2800
Vicat Setting Time, (minutes)		
- Initial-	100	min 45
- Final-	175	max 375
Compressive Strength, (MPa)		
- 7 days-	34.4	min 19.3
- 28 days-	49.3	-
Flexural Strength, (Mpa)		
- 7 days-	7.2	-
- 28 days	8.1	-

4.2.2 Aggregates

Natural river sand and limestone based crushed sand were used as fine aggregate. Natural sand constituted 18.36 % of the total amount of fine aggregate.

Three size groups of crushed limestone (designated as Type I, II and III in this study) were used as coarse aggregate.

The physical properties of the fine aggregate and each coarse aggregate are given in Table 4.5.

Gradation of natural sand, crushed sand and the three groups of crushed coarse aggregate are given in Table 4.6.

Table 4.5 Some Properties of Aggregates

	Fine Aggregate	Crushed Stone I	Crushed Stone II	Crushed Stone III
Specific Gravity, (g/cm^3)	2.57	2.70	2.70	2.70
Abrasion, (%)		25	25	25
Unit Weight, (kg/m^3)				
Dense	1914	1626	1614	1587
Loose	1673	1492	1484	1416

Table 4.6 The Percentage of Passing Through Standard Sieves

	TS sieve size, (mm)							
	31.5	16	8	4	2	1	0.5	0.25
Natural Sand	100	100	100	97	78	60	32	11
Crushed Sand	100	100	100	93	52	36	26	24
Crushed Stone I	100	100	98	12				
Crushed Stone II	100	100	21					
Crushed Stone III	100	33						

A suitable gradation for the total groups of aggregate was prepared. The maximum aggregate was prepared. The maximum aggregate size of the combined aggregate was 31.5 mm. Figure 4.2 shows the gradation curve obtained. (The solid lines A and B represents the limits given in Turkish Standard TS 706 for a maximum aggregate size of 31.5 mm. The solid line C represents the optimum gradation. The dotted line represents the results of aggregate combination used in this investigation.)

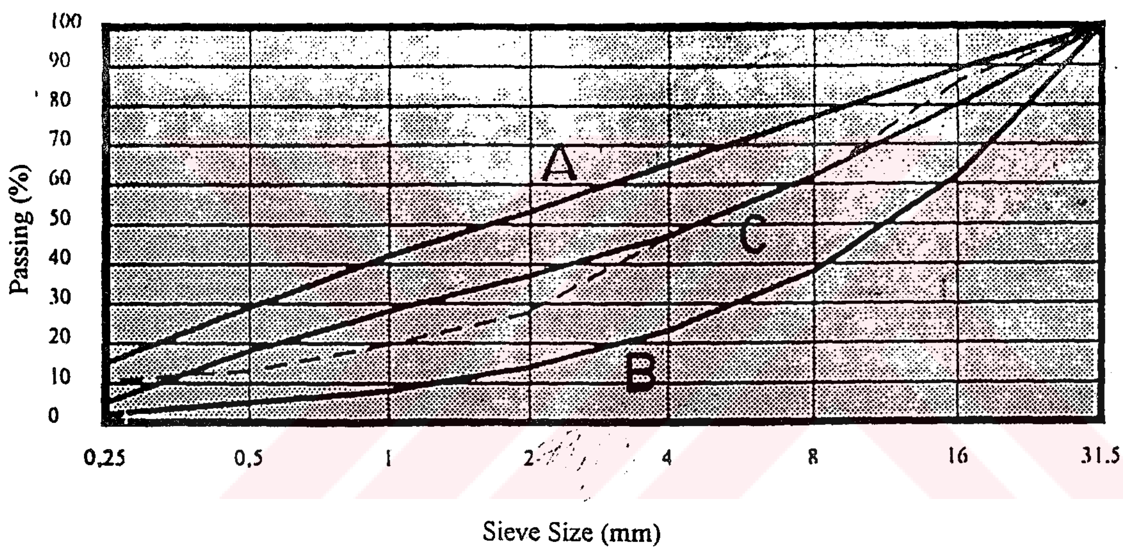

Figure 4.2 Combined Aggregate Gradation

The proportions of each size group of aggregates used in this investigation are given in Table 4.7.

Table 4.7 The Size Groups Used To Consist Combined Aggregate Gradation

Aggregates	Percentages
Sand	9
Crushed Sand	40
Crushed Stone I	8
Crushed Stone II	22
Crushed Stone III	21

4.2.3 Mixing Water

Normal, drinkable tap water which was assumed to be free from oil, organic matter and alkalies, was used as mixing water without admixture.

4.3 Concrete Mixture

Three different concrete mixtures were designed with the purpose of obtaining minumum 28 day compressive strengths of 14, 18 and 25 MPa and a slump value of 15 cm.

The proportioning method given in ACI 211 was followed. In all mixes, the same gradation was used for combined aggregate.

Table 4.8 , Table 4.9 and Table 4.10 show the amounts materials used for proportioning BS 14, BS 18 and BS 25 concrete mixes.

Table 4.8 Concrete Mix Proportions for BS 14

Materials	Content, (kg/m^3)
Cement	250
Water	202
Sand	164
Crushed Sand	733
Crushed Stone I	154
Crushed Stone II	423
Crushed Stone III	404

Table 4.9 Concrete Mix Proportions for BS 18

Materials	Content, (kg/m^3)
Cement	257
Water	207
Sand	162
Crushed Sand	725
Crushed Stone I	152
Crushed Stone II	419
Crushed Stone III	400

Table 4.10 Concrete Mix Proportions for BS 25

Materials	Content (kg/m^3)
Cement	343
Water	213
Sand	155
Crushed Sand	690
Crushed Stone I	145
Crushed Stone II	399
Crushed Stone III	381

4.4. Tests Conducted on Fresh Concrete

Concrete samples were taken for each type of concrete at the end of first, second, third and fouth hours following the concrete loading on the truck mixer.

The temperature of the concrete samples were found by inserting thermometer into samples. Besides,the slump value was found for each mixture by conducting the slump test.

After the determination of the slump value (which was somewhat lower than the initial 15 cm slump), the sample of concrete was placed in a small laboratory mixer. Water was added while the small mixer was in operation, until a readjustment was obtained in the slump by adding water and the slump being raised to 15 cm. Then, the unit weight and air content of the water added samples were determined.

4.5. Tests Conducted on Hardened Concrete

Since concrete samples were taken at the end of first, second, third and fourth hours from a certain concrete type such as BS 14, and since the slumps of these samples were readjusted to 15 cm by adding water, four different groups of concrete were obtained from a certain concrete type. Thus, 12 different groups of concretes were available for BS 14 , BS 18 and BS 25 types of concretes in total.

18 standard cylindrical specimens were made for each group of concrete sample. Thus, 216 cylinder specimens were prepared.

108 standard cylindrical were subjected to compressive strength tests while 108 cylinders were subjected split tension test. Modulus of elasticity tests were carried on the same samples used for compressive strength.

Tests for compressive strengths and tensile strengths were conducted at the ages of 7, 28 and 90 days. Three specimens were tested for each age.
Table 4.11 shows the number of cylindrical specimens prepared for strength tests.

All specimens were cured in the curing room at a temperature of 21 °C and 95 % relative humidity.

Those specimens to be subjected to compressive strength tests capped before testing.

Table 4.11 The number of Standard Cylindrical Specimens Prepared for Strength Tests

	For Compressive Strength			For Tensile Strength		
	7 day	28 day	90 day	7 day	28 day	90 day
BS 14 at						
1st hour	3	3	3	3	3	3
2st hour	3	3	3	3	3	3
3st hour	3	3	3	3	3	3
4st hour	3	3	3	3	3	3
BS 18 at						
1st hour	3	3	3	3	3	3
2st hour	3	3	3	3	3	3
3st hour	3	3	3	3	3	3
4st hour	3	3	3	3	3	3
BS 25 at						
1st hour	3	3	3	3	3	3
2st hour	3	3	3	3	3	3
3st hour	3	3	3	3	3	3
4st hour	3	3	3	3	3	3

CHAPTER 5

TESTS RESULTS AND DISCUSSIONS

5.1 Results of Tests Performed on Fresh Concrete

5.1.1 Concrete Temperatures

Concrete temperature is an important factor affecting the rate of hydration reactions and evaporation rate, both of which affect slump loss significantly. For that reason the effect of prolonged mixing on concrete temperature was determined on the three classes of fresh concrete.

The dates tests performed on fresh concrete had been chosen as the days in July due to hot weather effect on the concrete temperature, hydration reactions and evaporation rate.

Table 5.1 shows the concrete temperatures of the three different concretes subjected to one to four hours mixing. The numbers in paranthesis are the ambient temperatures during the testing time. Figure 5.1 shows the increase of concrete temperatures grafically.

Table 5.1 Concrete Temperatures Depending on Mixing Time

	Concrete Temperatures°C (Ambient Temperatures)			
	1.hr.	2.hr.	3.hr.	4.hr.
BS 14	29(38)	30(38)	30(36)	31(34)
BS 18	32(42)	34(42)	36(41)	38(38)
BS 25	33(46)	34(46)	36.5(44)	40(43)

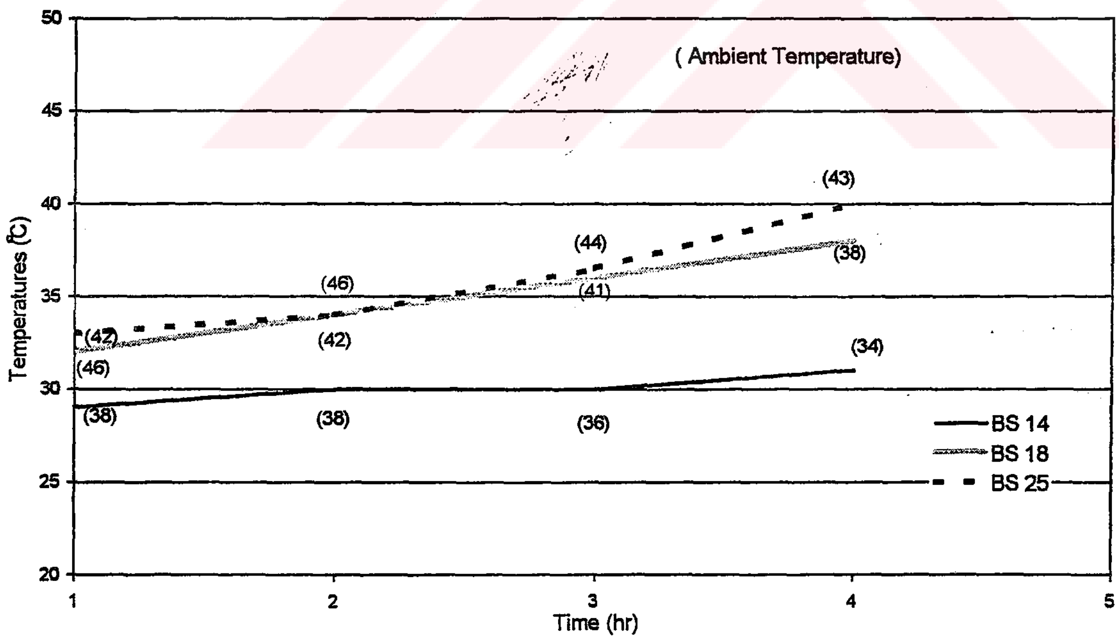

Figure 5.1 Concrete Temperatures Depending on Time

The following comments can be made on the results given in table and the figure.

1. Temperatures increases in all concrete mixes as the time that the concretes are mixed increases.

2. The temperatures of BS 25 type of concrete at the end of 1-4 hours mixing were slightly higher than the BS 14 and BS 18 type of concrete. This was probably due to the presence of higher cement content in BS 25 type of concrete.

5.1.2 Slump Tests

Slumps were tested to determine the effect of prolonged mixing on the slump loss of three different classes of concrete. At every hour, a large sample of concrete was taken out of the transmixer that was continuing its mixing process at agitation speed. After measuring the slump of this large sample of concrete, it was placed in a smaller mixer of 0.2 m^3 capacity and water was added until the slump value was raised to 15 cm.

Table 5.2 shows the slumps of the three classes of fresh concretes subjected to four hour mixing without adding extra water

Table 5.2 Slumps of Concretes Without Adding Water Depending on Mixing Time

	Slump of Concretes (cm)			
	1.hr.	2.hr.	3.hr.	4.hr.
BS 14	15	14.5	12	7.5
BS 18	15	13	8	5
BS 25	10	3	0	0

Table 5.3 indicates the amount of water added for 1 m^3 of concrete to raise the slump to 15 cm. The figures in paranthesis show the new water-cement ratios obtained with the addition of extra water. The amount of water that was evaporated by the time that the concrete samples were taken out of the transmixer was ignored in calculating the water-cement ratios.

Note : Water-cement ratios of BS 14 , BS 18 and BS 25 types of concretes prepared at the central mixing plant without addition of any extra water were 0.81, 0.81 and 0.62 , respectively.

Table 5.3 Amount of Water Addition to the Concrete and Water Cement Ratio Depending on the Mixing Time

Amount of Water Addition for 1 m³ of concrete, kg (Water Cement Ratio)				
	1.hr.	2.hr.	3.hr.	4.hr.
BS 14	0(0.81)	2(0.82)	8(0.84)	23(0.90)
BS 18	0(0.81)	4(0.82)	18(0.87)	38(0.95)
BS 25	10(0.65)	34(0.72)	64(0.81)	94(0.89)

Figure 5.2 shows the slumps of concretes without adding extra water and Figure 5.3 indicates the new water-cement ratios obtained with addition of extra water.

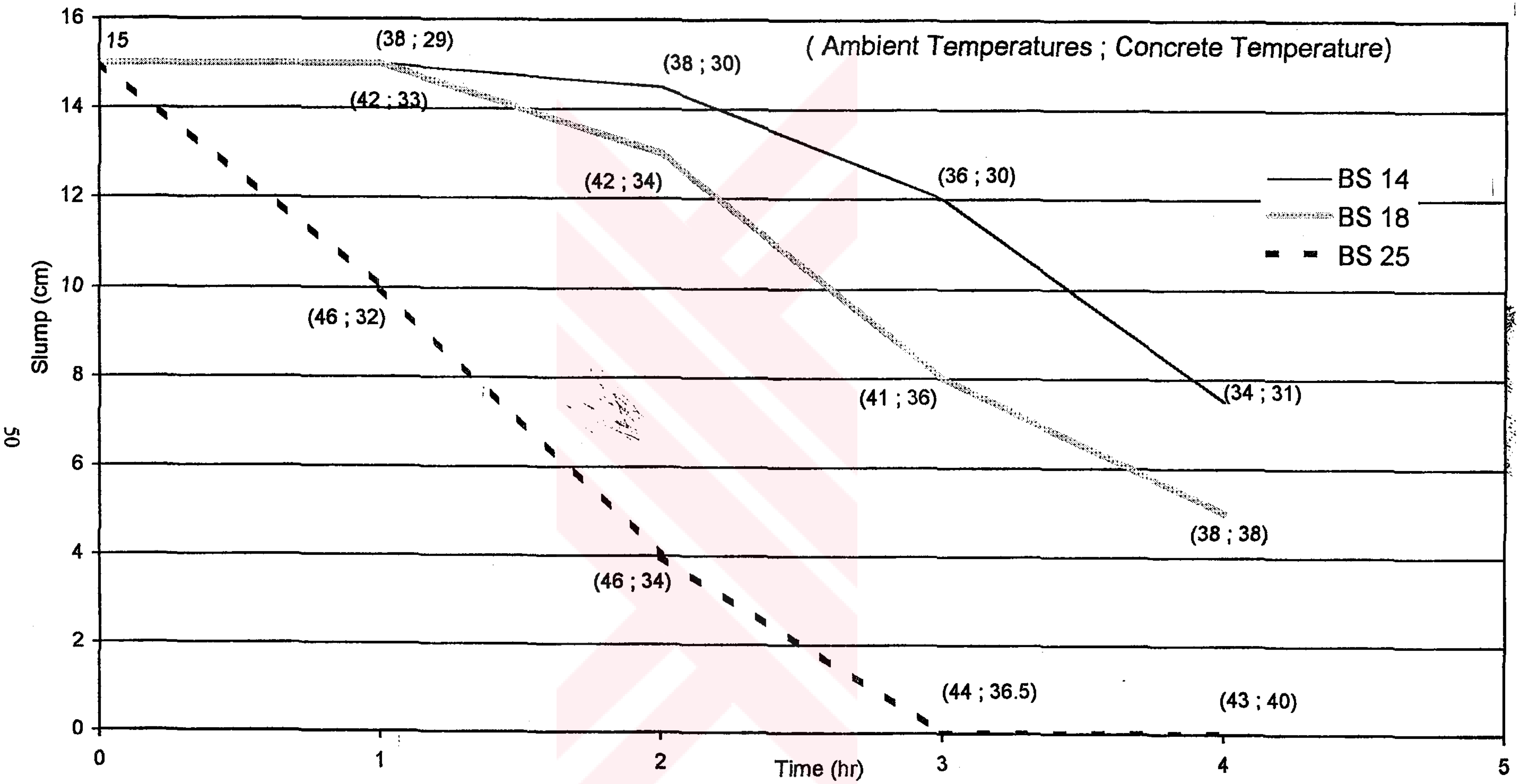

Figure 5.2 Slumps of Concretes without Adding Water Depending on Mixing Time

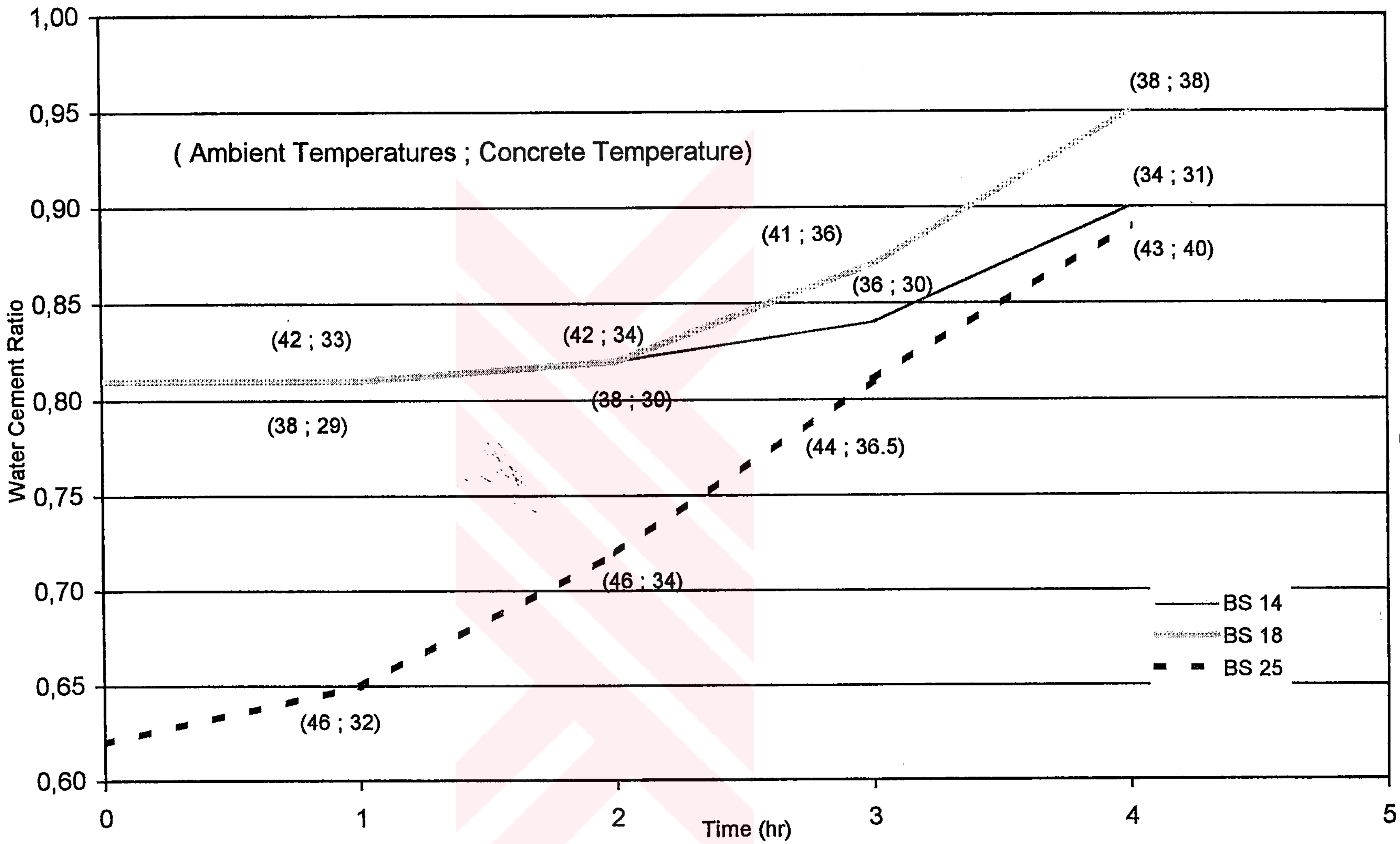

Figure 5.3 Water Cement Ratios of Concrete Samples Whose Slumps were Raised to 15 cm.

Following comments can be made on the slump loss and rearranged water-cement ratios obtained for bringing the concrete samples to a 15 cm slump value.

1. BS 14 and BS 18 types of concretes did not show slump losses at the end of first hour following their production. However, there were slump losses at the end of second, third and fourth hours. The amounts of slump losses increased as the mixing time incresed.

2. BS 25 type of concrete showed a slump loss at the end of first hour and the amount of slump loss increased as the mixing time increased.

3. Mixing time, concrete temperature and the amount of cement that takes part in the concrete are the main factors that influence the amount of slump loss. The large amounts of slump losses for BS 25 type of concrete may be attributed to the higher cement content of this concrete.

4. Water-cement ratios of all concrete mixtures that show slump loss obviously raises after the addition of extra water to bring the slump back to 15 cm. Therefore, there was an increase in the water-cement ratios of all concretes as the time of mixing was prolonged.

5. Since BS 25 type of concrete had the higest content of cement and since the slump loss of this concrete was higher than the others, a greater amount of extra water was needed to raise its slump to 15 cm. Therefore, there was a greate increase in the water-cement ratios of these concrete samples taken from BS 25 type of concrete.

5.1.3 Unit Weight Tests

Unit weights of those samples whose slumps were raised to 15 cm by adding extra water are given in Table 5.4 and Figure 5.4.

Table 5.4 Unit Weights of Concretes whose slumps were raised to 15 cm by addition of extra water.

	Unit Weights, kg/m^3			
	1.hr.	2.hr.	3.hr.	4.hr.
BS 14	2.346	2.341	2.332	2.325
BS 18	2.340	2.335	2.324	2.312
BS 25	2.327	2.323	2.313	2.295

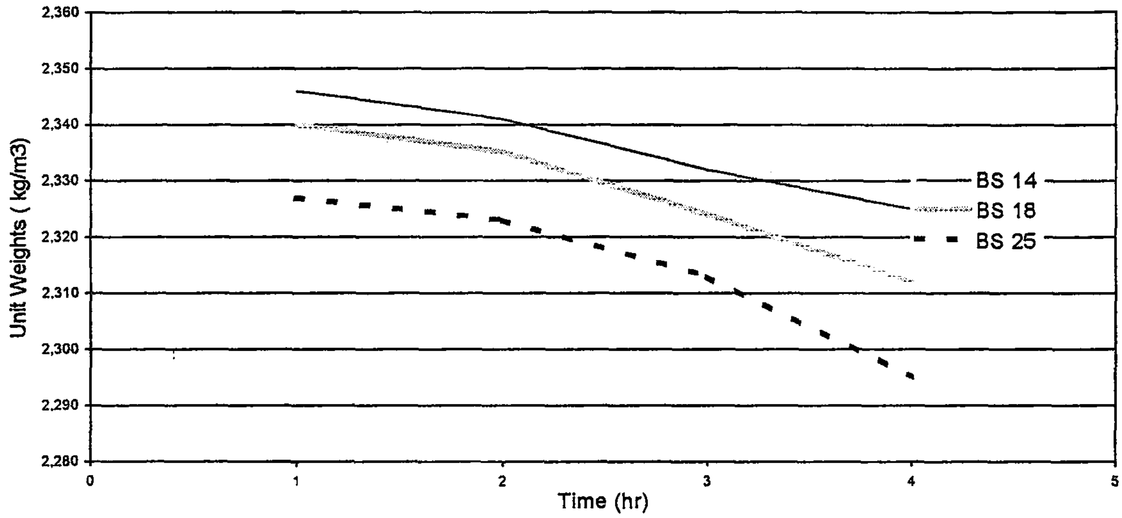

Figure 5.4 Unit Weights of Concretes Depending on Mixing Time

From these results ,the following comments can be made.

1. Unit weights of all classes of concrete show a decrease as the mixing time increase. This is due to the increased water content that was necessary to obtain 15 cm slump.

2. Since BS 25 had the highest slump loss and needed the greatest amount of water to bring it to a 15 cm slump, the decrease in the unit weight of this concrete was higher than the others.

5.1.4 Air Content Tests

After the addition of extra water to the concrete samples to raise their slump to 15 cm, air contents of these reproportioned samples were measured. Table 5.5 and Figure 5.5 shows the air content values.

Table 5.5 Air Contents of Concretes Depending on Mixing Time

	Air Contents, %			
	1.hr.	2.hr.	3.hr.	4.hr.
BS 14	0.9	1.00	1.1	1.2
BS 18	1.2	1.2	1.3	1.4
BS 25	1.3	1.4	1.5	1.7

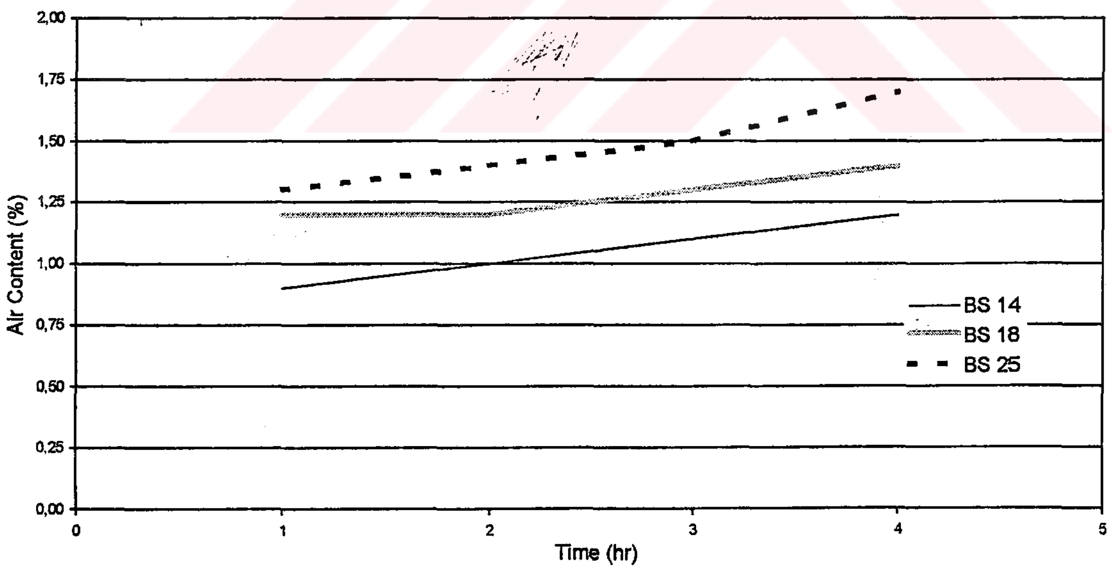

Figure 5.5 Air Contents of Concretes Depending on Mixing Time

5.2 Results of Tests Performed on Hardened Concrete

5.2.1 Compressive Strength Tests

Standard cylinder specimens (15x30 cm) were cast from the concrete mixture samples that were taken out of the transmixer at the end of 1-4 hours of mixing and after their slump values were raised to 15 cm by adding extra water. 9 cylinders were prepared for each concrete sample. 3 cylinders were subjected to 7-day comppressive strength test while 3 cylinders being subjected to 28-day and remaining 3 cylinders being tested at 90 days. days. Table 5.6, 5.7 and 5.8 give the compressive strengths of the cylinders tested at 7, 28 and 90 days, respectively. Figures 5.6, 5.7 and 5.8 show compressive strengths at 7, 28 and 90 days, respectively.

Table 5.6 Compressive Strengths of Concretes at 7 Days (MPa)

	1.hr.	2.hr.	3.hr.	4.hr.
BS 14	12.7	11.9	11.5	10.6
BS 18	15.2	14.5	13.1	11.4
BS 25	22.0	17.6	13.5	9.8

Table 5.7 Compressive Strengths of Concretes at 28 Days (MPa)

	1.hr.	2.hr.	3.hr.	4.hr.
BS 14	15.9	15.3	14.5	13.5
BS 18	20.1	19.0	17.4	14.3
BS 25	24.7	20.2	18.5	13.2

Table 5.8 Compressive Strengths of Concretes at 90 Days (MPa)

	1.hr.	2.hr.	3.hr.	4.hr.
BS 14	16.4	15.9	15.2	14.5
BS 18	21.5	20.7	19.4	16.8
BS 25	28.0	23.1	20.2	15.3

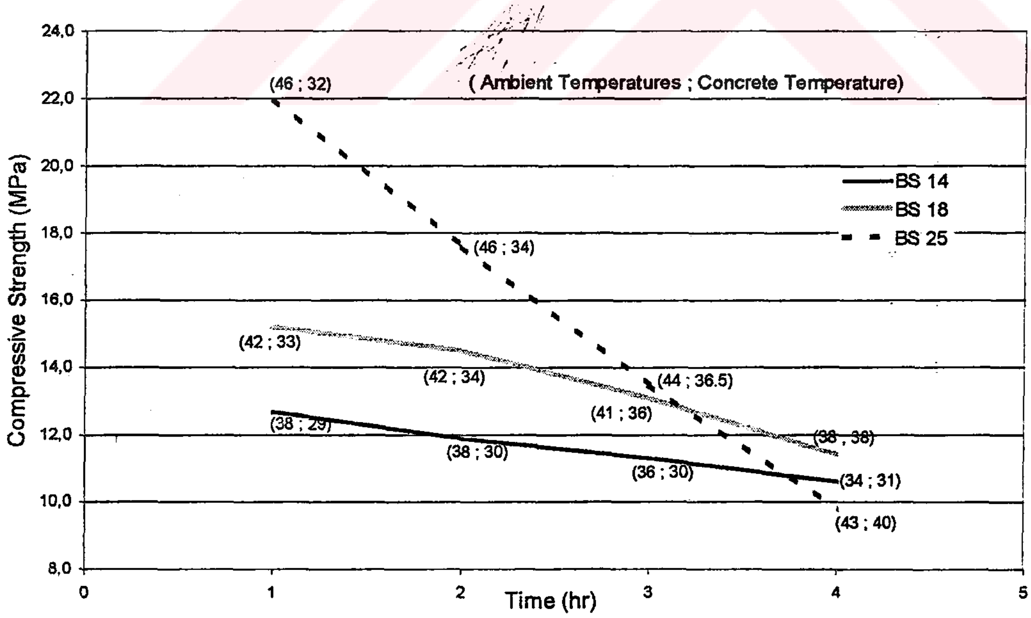

Figure 5.6 Compressive Strengths at 7 Days Depending on Mixing Time

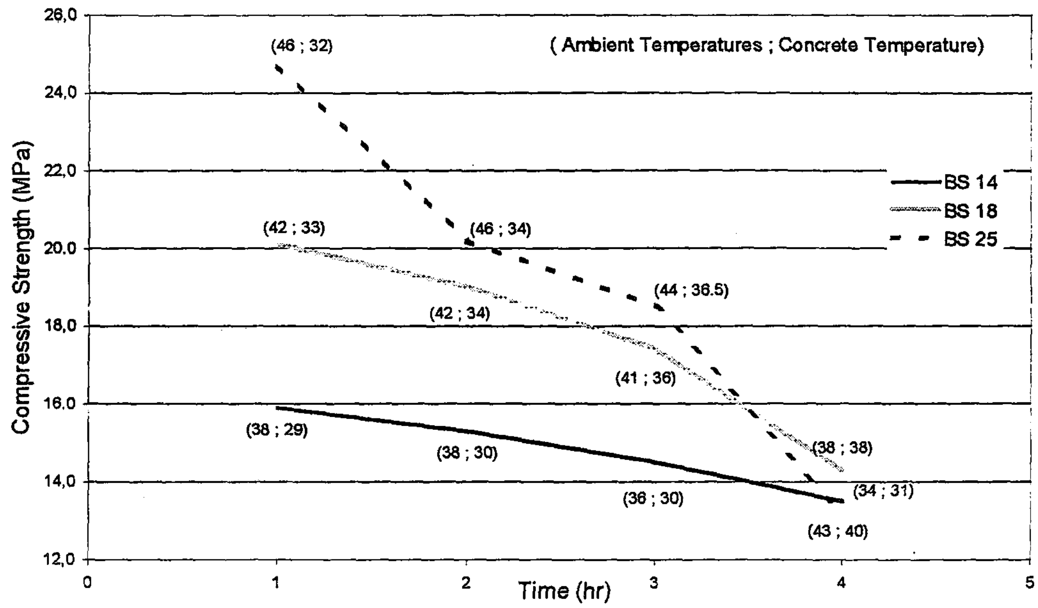

Figure 5.7 Compressive Strengths at 28 Days Depending on Mixing Time

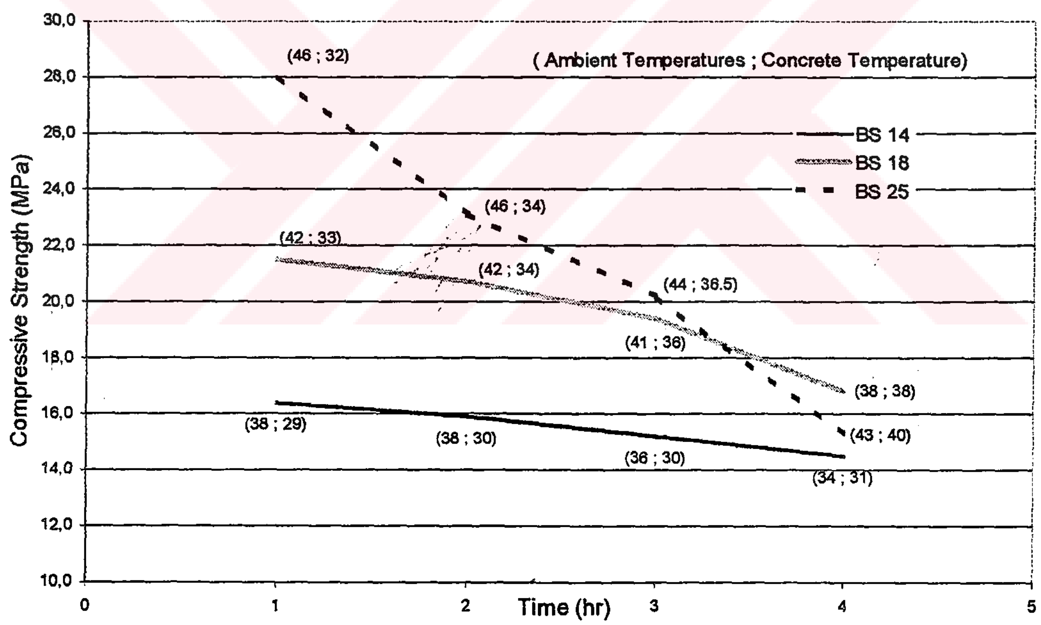

Figure 5.8 Compressive Strengths at 90 Days Depending on Mixing Time

Figures 5.9, 5.10 and 5.11 shows the difference between compressive strengths of BS 14, BS 18 and BS 25 types of concretes tested at the ages of 7, 28 and 90 days, respectively.

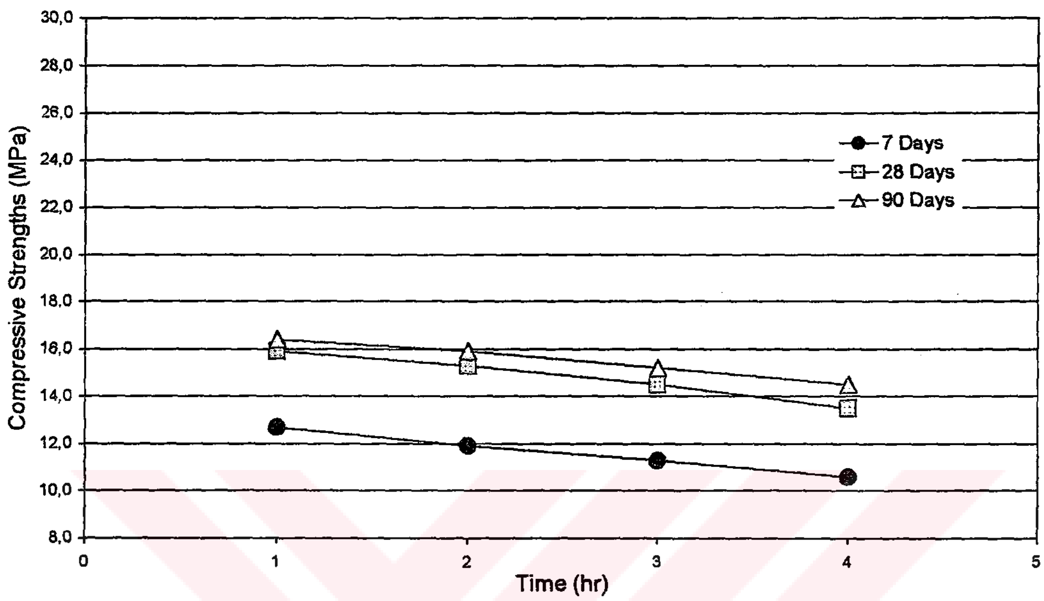

Figure 5.9 Compressive Strengths of BS 14 at 7, 28, 90 Days

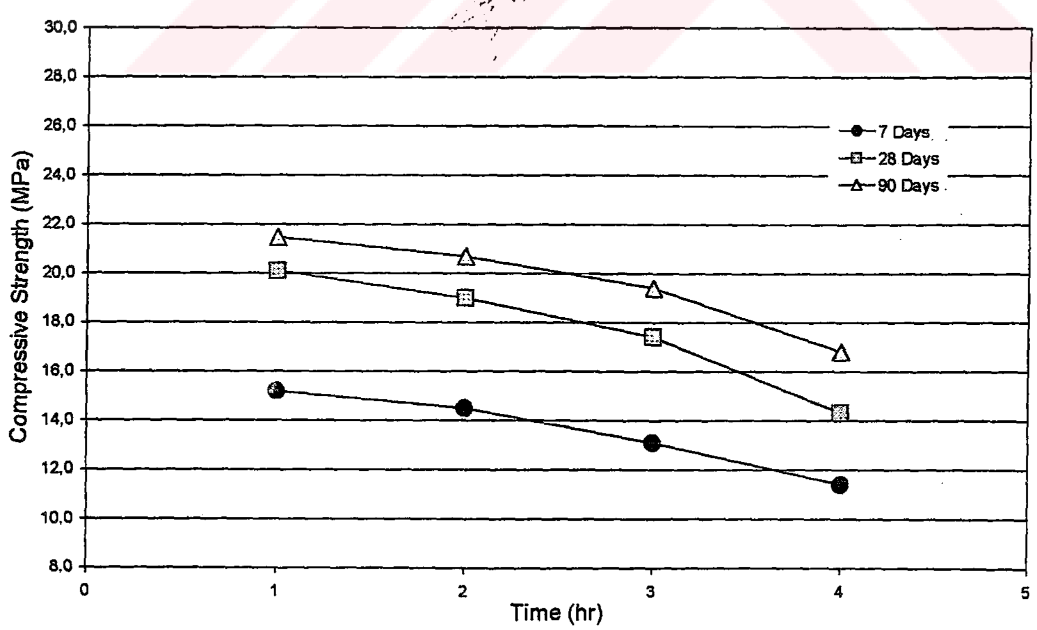

Figure 5.10 Compressive Strengths of BS 18 at 7, 28, 90 Days

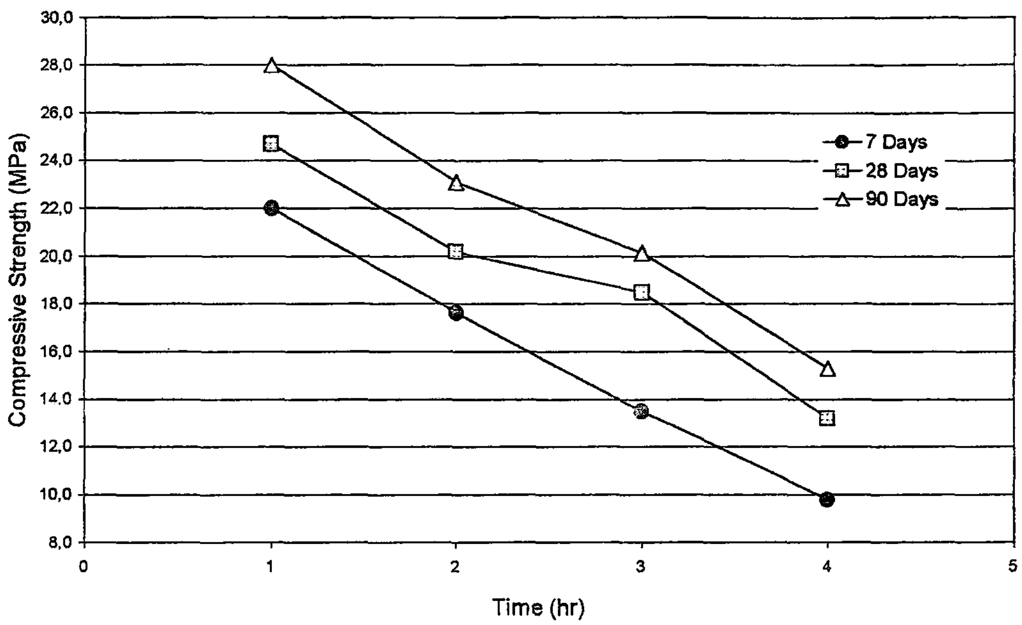

Figure 5.11 Compressive Strengths of BS 25 at 7, 28, 90 Days

Following comments can be made from the results obtained from compressive strength tests.

1. Due to the fact that there were slump losses in concretes at the end of 1-4 hours of mixing time and extra water was needed to raise the slump values of the concrete samples to 15 cm, there were changes in the original water-cement ratios of the concretes. Since the slump losses increased as the mixing time of the concretes increased, water-cement ratios were also increased as the mixing time increased.. Increased in the water-cement ratios of a certain type of concrete resulted to lower compressive strengths. Thus, the strengths of all

classes of concrete that were retempered got lower values as the time of mixing time got longer.

2. Although all classes of the concretes showed decreases in compressive strengths as the duration of mixing increased, the most striking decrease was seen for BS 25 type of concrete. This was due to the fact that BS 25 type of concrete had the highest rate of slump loss and thus, highest rate of increase in its water-cement ratios

5.2.2 Modulus of Elasticity

Modulus of elasticities of the retempered concrete samples obtained from the three classes of concretes at the end of 1-4 hours of mixing are given in Tables 5.9, 5.10 and 5.11. The results are graphically shown in Figures 5.11, 5.12 and 5.13.

Table 5.9 Modulus of Elasticities of Concretes at 7 Days (MPa)

	1.hr.	2.hr.	3.hr.	4.hr.
BS 14	18320	17225	15956	14967
BS 18	18433	17785	16680	15457
BS 25	19927	18319	16099	14715

Table 5.10 Modulus of Elasticities of Concretes at 28 Days (MPa)

	1.hr.	2.hr.	3.hr.	4.hr.
BS 14	19505	18772	17812	16708
BS 18	21245	19993	18675	17112
BS 25	23791	20762	18613	16788

Table 5.11 Modulus of Elasticities of Concretes at 90 Days (MPa)

	1.hr.	2.hr.	3.hr.	4.hr.
BS 14	20145	19451	18467	17237
BS 18	21657	20841	19755	17897
BS 25	24658	22576	19339	17155

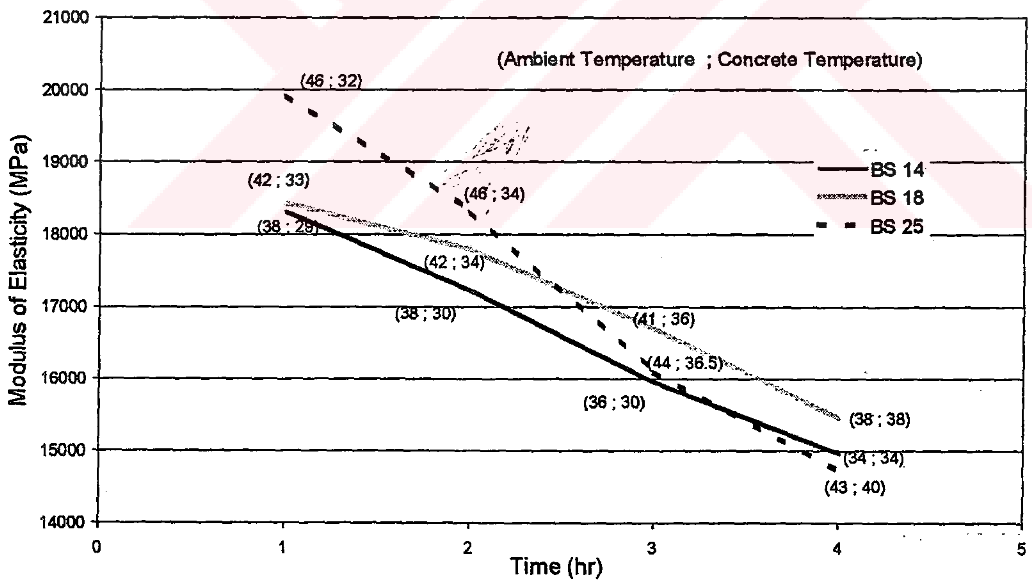

Figure 5.12 Modulus of Elasticity at 7 Days Depending on Mixing Time

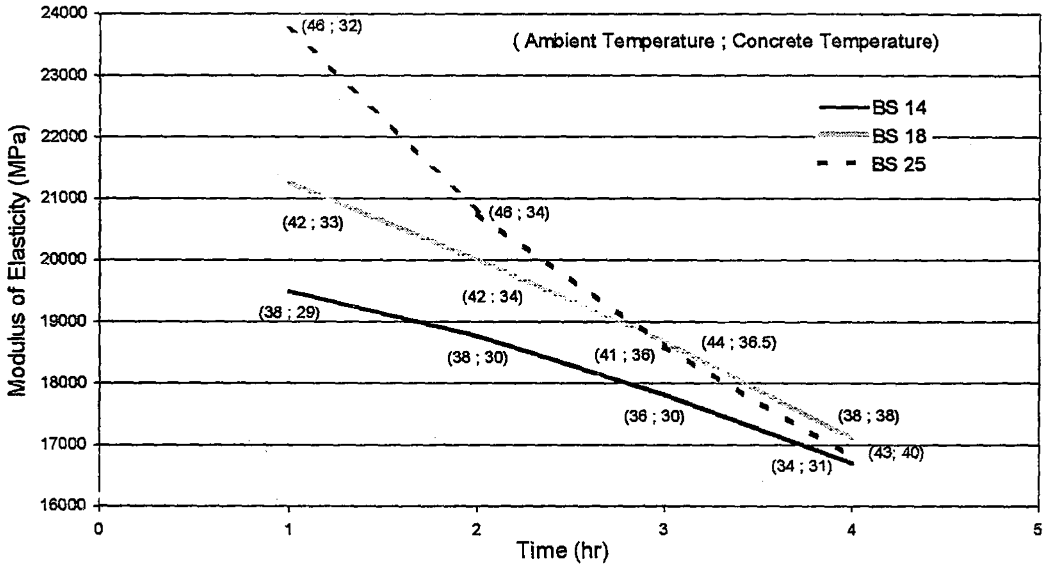

Figure 5.13 Modulus of Elasticity at 28 days Depending on Mixing Time

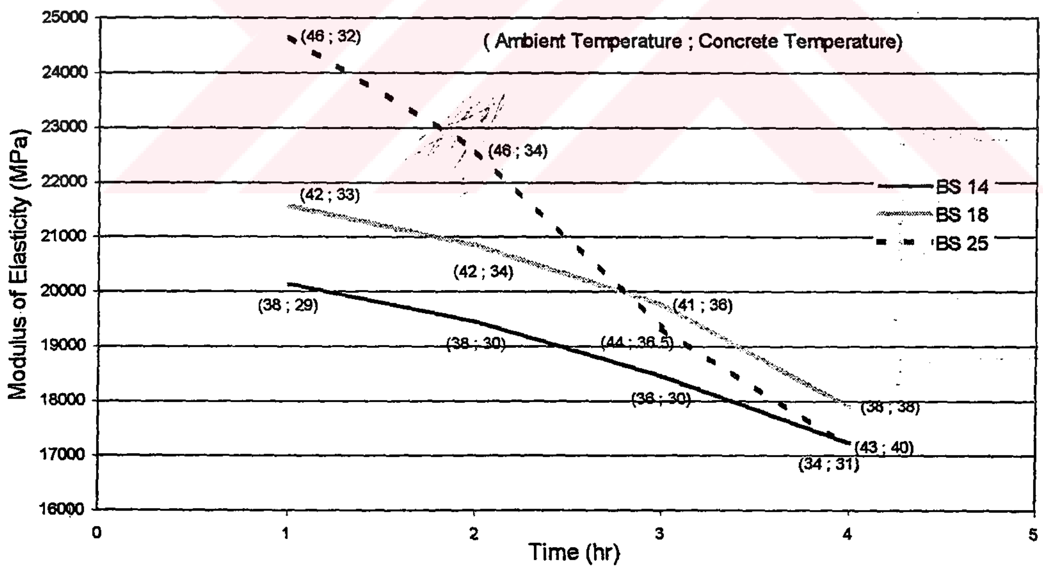

Figure 5.14 Modulus of Elasticity at 90 Days Depending on Mixing Time

Figures 5.15, 5.16 and 5.17 shows the difference between modulus of elasticities at the ages of 7 , 28 and 90 days for the same class of concrete depending on mixing time .

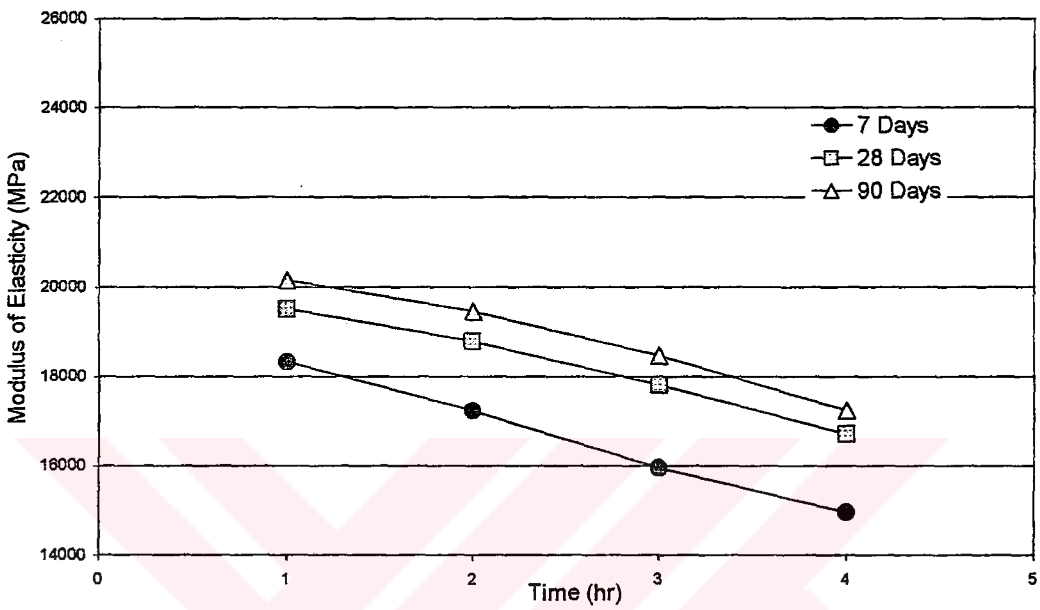

Figure 5.15 Modulus of Elasticity of BS 14 at 7, 28, 90 Days

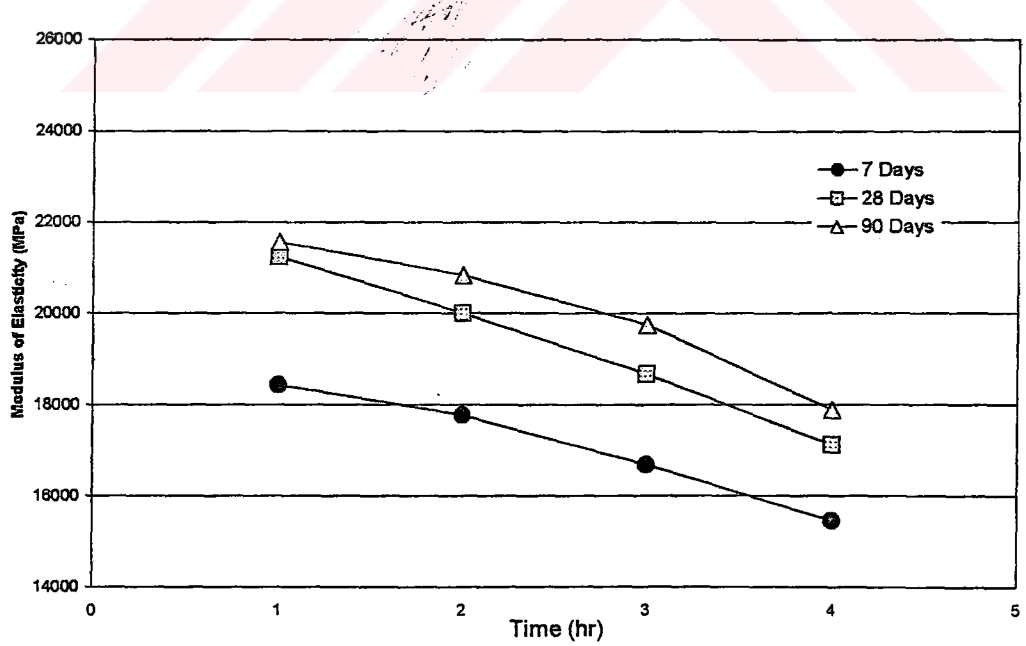

Figure 5.16 Modulus of Elasticity of BS 18 at 7, 28, 90 Days

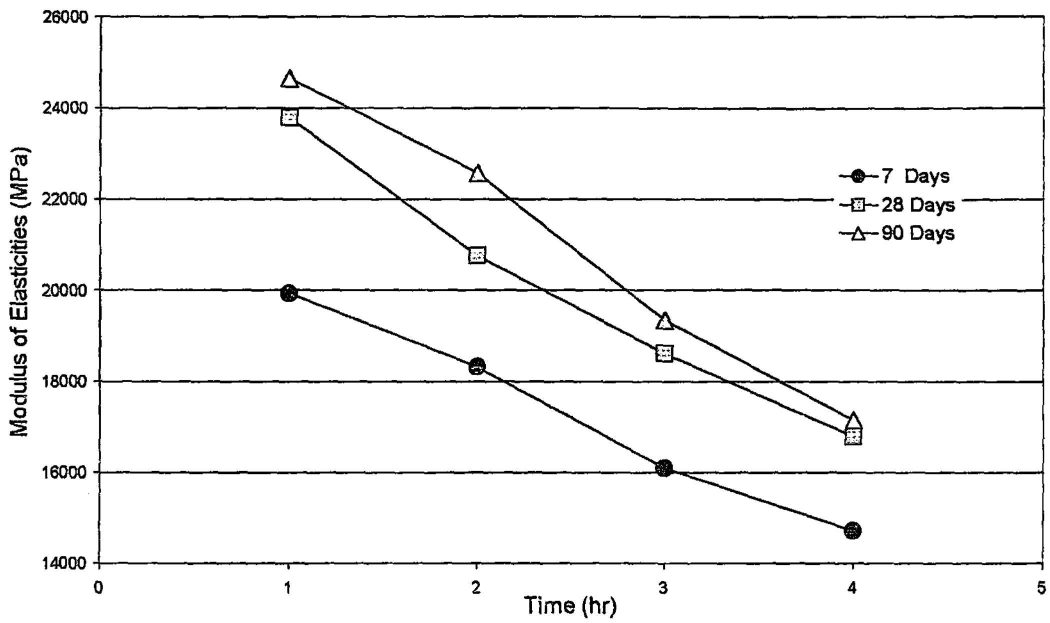

Figure 5.17 Modulus of Elasticity of BS 25 at 7, 28, 90 Days

Following comments can be made from the results.

1. Modulus of elasticity values of the retempered concrete samples got lower as the mixing time got longer. This was due to the increase in water-cement ratios as the mixing time was increased.

2. The trend of change in the modulus of elasticity values were similar to the trend of change in compressive strength values.

5.2.3 Splitting Tensile Tests

The results of splitting tension tests conducted at ages of 7, 28 and 90 days are given in Table 5.12, Table 5.13 and Table 5.14, respectively. These results are also shown in Figures 5.18, 5.19 and 5.20.

Table 5.12 Splitting Tensile Strengths of Concretes at 7 Days (MPa)

	1.hr.	2.hr.	3.hr.	4.hr.
BS 14	1.30	1.25	1.20	1.13
BS 18	1.47	1.37	1.29	1.20
BS 25	2.11	1.76	1.46	1.17

Table 5.13 Splitting Tensile Strengths of Concretes at 28 Days (MPa)

	1.hr.	2.hr.	3.hr.	4.hr.
BS 14	1.95	1.81	1.70	1.45
BS 18	2.21	2.15	1.86	1.52
BS 25	2.51	2.34	1.92	1.36

Table 5.14 Splitting Tensile Strengths of Concretes at 90 Days (MPa)

	1.hr.	2.hr.	3.hr.	4.hr.
BS 14	2.12	2.03	1.95	1.85
BS 18	2.25	2.15	2.06	1.95
BS 25	2.94	2.50	2.04	1.73

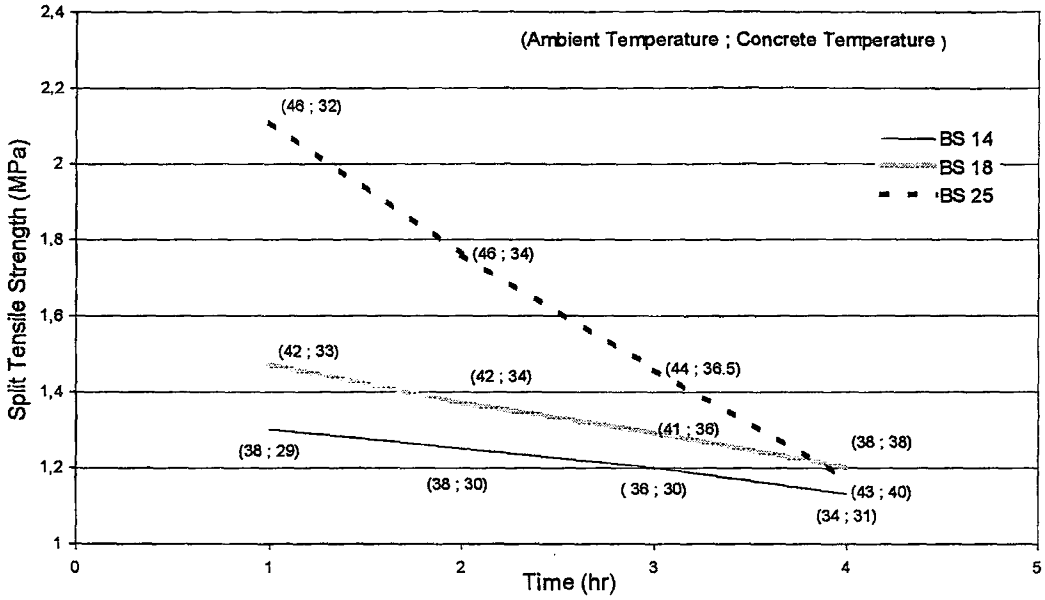

Figure 5.18 Split Tensile Strengths at 7 Days Depending on Mixing Time

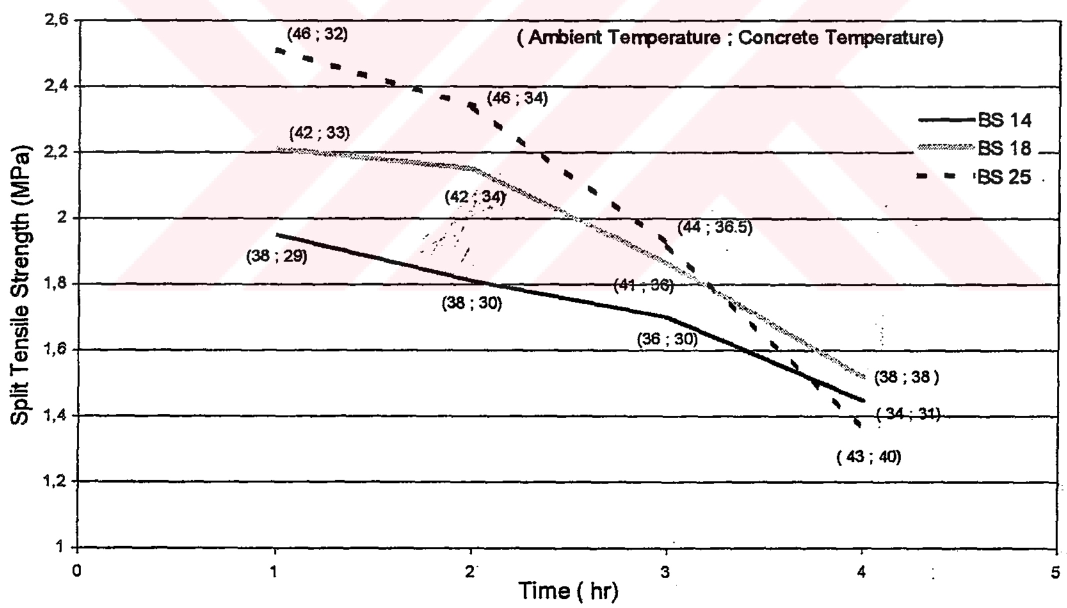

Figure 5.19 Split Tensile Strengths at 28 Days Depending on Mixing Time

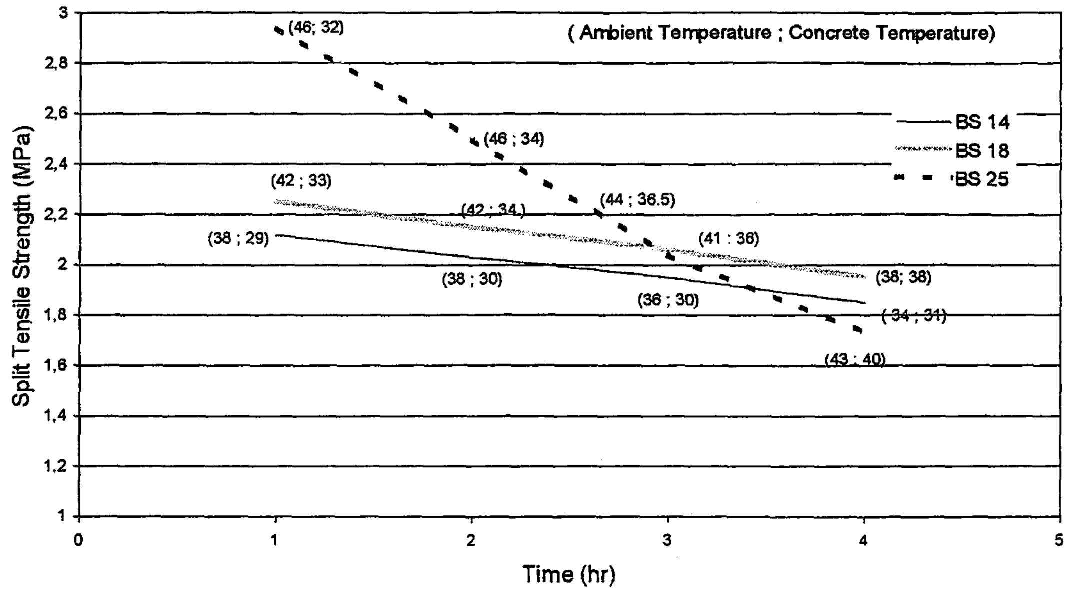

Figure 5.20 Split Tensile Strengths at 90 Days Depending on Mixing Time

According to these results it can be observed the followings.

1. The splitting tensile strength of the retempered BS 14 decreases slightly as the mixing time increase. It is seen that splitting tensile strength of this concrete decreases 7.2 %, 12.8 % and 25.7 % at the end of second, third and fourth hours.

2. These of the retempered BS 18 shows a decreasing trend similar to that of the retempered BS 14. It is observed from the table that splitting tensile strength of this concrete decreases 2.7 %, 15.8 % and 31.2 % at the end of second, third and fourth hours.

3. The split tension strength trend of the retempered BS 25 is deeper than the other classes for 7, 28 and 90 days. It is observed from the table that splitting tensile strength of this concrete decreases 6.8 %, 18 % and 46 % at the end of second, third and fourth hours.

4. Splitting Tensile Strength of concretes shows approximately the same trend as for compressive strength and modulus of elasticity.

CHAPTER 6

CONCLUSIONS

In ready mixed concrete transportation, extended agitation time can be experienced if there is a heavy traffic or breaking down of a ready mixed truck. Even if trucks arrive early, they can be forced to wait to discharge because of construction related problems or pump failures, leading to delayed unloading.

As a result of the experimental work, the following conclusions are derived.

1. Concrete temperature is affected by the length of the mixing time, ambient temperature and amount of cement content in concrete. Prolonged mixing and high ambient temperature result in an increase in concrete temperature leading to high rate of hydration reactions and thus to high rate of hydration heat. High cement content is the another factor that increases the rate of hydration reactions and rate of hydration heat evoluation.

2. Since high ambient temperatures and high concrete temperatures increase the evaporation rate of the moisture inside the fresh concrete, slump loss is inevitable under such conditions. High cement content is the another factor leading to a high slump loss.

3. A change in the consistency of fresh concrete causes difficulties in discharging, handling and placing. Therefore, some extra water is usually added to the fresh concrete to bring it to the desired workability. However, addition of extra water leads to lower compressive and tensile strengths in concrete. Modulus of elasticity gets lower as the strength decreases. The addition of water without proper adjustments in mix proportions adversely affects the quality of concrete. Retempering of a concrete exposured to prolonged mixing decreases strength of concrete much more, when the cement content is high. When this types of fresh concrete is mixed for a long time, it shows a high slump loss and needs more water to reach acceptable value of slump.As the cement content decrease in concrete , extend of mixing by adding water to the mix become less effective on the strength of concrete.

4. According to ASTM C 94, discharge of concrete shall be completed within 90 minutes, or before the drum of the transmixer has revolved 300 revolutions, whichever comes first, after the introduction of the mixing water to the cement and aggregates or introduction of cement to aggregates. Maximum

temperature of concrete produced shall at no time during its production or transportation exceed 32 °C. On the other hand TS 11222 (Turkish Standard for Ready- Mixed Concrete) allows the discharge of concrete within 120 minutes.

Temperatures of the concretes used in this investigation were already 32 °C at the end of first hour following the production. The temperatures of BS 18 and BS 25 types of concretes were 34 °C at the end of second hour following their production. Therefore it can be concluded that a discharge time of 120 minutes given in the Turkish Standard might be too long for rich concretes that are produced and transported at high ambient temperatures existing during the summer time.

CHAPTER 7

RECOMMENDATIONS

Fresh concrete is subject to slump loss with time whether it is used in moderate or hot weather. Two or three types of ready mixed concrete classes with different cement content can be subjected to prolonged mixing on the same day in order to maintain same ambient temperature if it is provided. Thus, it can be obtained the same effect of ambient temperature on the temperatures of different types of concretes and cement content effect can be tested effectively.

While specimens are cast from the concrete mixture readdjusted to initial slump by adding extra water in the smaller mixer, specimens can be cast from the concrete mixture without adding extra water in the transmixer. So, the properties of concretes not to readjusted to initial slump by adding water can also be investigated depending on mixing time.

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