İZMİR KATİP ÇELEBI UNIVERSITY ★ GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

TECHNICAL INVESTGATION FOR THE USE OF TEXTILE WASTE FIBER TYPES IN NEW GENERATION COMPOSITE PLASTERS

M.Sc. THESIS

Şevket Onur KALKAN

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Thesis Advisor: Prof. Dr. Lütfullah GÜNDÜZ

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İZMİR KÂTİP ÇELEBİ ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

YENİ NESİL KOMPOZİT SIVA HARÇLARINDA TEKSTİL ATIĞI TÜRLERİ KULLANIMININ TEKNİK İNCELENMESİ

YÜKSEK LİSANS TEZİ

Şevket Onur KALKAN
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İnşaat Mühendisliği Ana Bilim Dalı

Tez Danışmanı: Prof. Dr. Lütfullah GÜNDÜZ

TEMMUZ 2017

Şevket Onur KALKAN, a **M.Sc.** student of **IKCU Graduate School of Natural and Applied Sciences** Y140104011, successfully defended the thesis entitled **"TECHNICAL INVESTGATION FOR THE USE OF TEXTILE WASTE FIBER TYPES IN NEW GENERATION COMPOSITE PLASTERS**", which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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To my family,

FOREWORD

Our natural resources are decreasing day by day due to increase of the world population and change of consumption habits. For this reason, it is necessary to use natural resources efficiently by reducing material consumption and increase recycling evaluable wastes. One of the valuable wastes is also textile waste. After textile products put on the market become waste, they are sorted according to their types and sent to the recycling industry. As a result, recycled materials are used as secondary raw materials in the production phase of various products. Thus, eliminating the cost of recreating the product from zero point and providing added value to both the economy and the environment are provided.

With a similar approach in this thesis study, the waste textile fibers were evaluated in cement-based composite mortars. This thesis has an innovative characteristics due to introducing a new type of fiber reinforcing material to the literature as well as researching structural strength properties of mortars and investigating its thermal performance.

I would like to thank my supervisor Prof. Dr. Lütfullah GÜNDÜZ, who endlessly helped me on any issue from the very beginning of my thesis and my two and a half year master degree with his extensive knowledge and experience.

I would like to thank my mother, Nuriye KALKAN, my father, Bektaş KALKAN, my brother, Murat KALKAN, and of course other family members, especially my grandfather, without their continuous support and encouragement I never would have been able to achieve my goals. Thanks for always being there for me, believing in me, and motivating me to set out on my own path.

I am very thankful to BEŞTEPE Family, who helped my family in growing me and my brother over thirty years, for their goodness without expecting anything.

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July 2017 Şevket Onur KALKAN
(Civil Engineer)

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ABBREVIATIONS

ASTM	**:** American Society for Testing and Materials
C	**:** Cotton
CP	**:** Cotton+Polyester
CPA	**:** Cotton+Polyester+Acrylic
P	**:** Polyester
EN	**:** European Norms
ISO	**:** International Organization for Standardization
TS	**:** Turkish Standard

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TECHNICAL INVESTGATION FOR THE USE OF TEXTILE WASTE FIBER TYPES IN NEW GENERATION COMPOSITE PLASTERS

SUMMARY

Garment and textile production industry is one of the main sectors of our country. This sector is a major driving force in our developing economy. According to 2014 data, Turkey is the third country on textile export among the European countries. Besides, Turkey is the world's sixth largest garment exporter. With such a huge production power, in Turkey's textile sector, waste and/or residual textile materials are composed depends on the large scale production, as in most of the other production sectors. Such waste materials in textile industry are the left materials from production stages and/or textile materials that thrown away after use. These waste and/or residual materials could be seen as a recycling material in the internal components of the textile sector. However, also it can be seen that the accumulation of waste textile fiber amount left over from recycling process cannot be underestimated. These textile wastes accumulation also brings up a potential material that may also be regarded as an industrial material. However, today, sufficient level of research on waste materials that shows accumulation characteristics cannot be seen to create added value in the industry.

A comprehensive experimental investigation was carried out to develop especially fiber reinforced composite plaster products for construction sector by using appropriately sized and configured textile waste or residues. In this context, this experimental research includes the assessment of the use of four different types of textile wastes in the building plaster material.

Especially in construction sector, the potential of evaluation of using textile fibers as fiber additive in production of lightweight construction material and production of mortar is being developed in recent years. Technical advantages of fiber additives on building materials are detailed examination subject. But also, it is not found any sufficient level of technical findings on the mechanical and the physical advantages of textile waste fibers. In this context, technical relationship between different types of fibers and mortar combination has been a special examination area by experimental analysis.

In addition, textile wastes are accumulating every day in the factories of textile firms that constitute the mainstay for the Turkish economy. Companies usually under extra financial obligations in order to use, recycle or dispose those textile wastes. This thesis will have a unique value in the context of shed light on companies this seeking, besides contributing the national economy.

Keywords: Plaster, insulation, textile waste fiber, new generation composite mortar, cotton, synthetic, polyester, acrylic

YENİ NESİL KOMPOZİT SIVA HARÇLARINDA TEKSTİL ATIĞI TÜRLERİ KULLANIMININ TEKNİK İNCELENMESİ

ÖZET

Hazır giyim ve tekstil üretim sektörü ülkemizdeki ana endüstri dallarından bir tanesidir. Tekstil sektörü ülkemizin gelişen ekonomisinin ana itici güçlerinden birisidir. 2014 yılının verilerine göre Türkiye, Avrupa ülkeleri arasında tekstil ihracatı bakımından üçüncü sırada yer almıştır. Bunun yanında, Türkiye dünyada altıncı en büyük hazır giyim ihracatçısı konumunda olmuştur. Bu denli büyük bir üretim gücü ile diğer sektörlerde olduğu gibi, Türkiye'nin tekstil sektöründe de atık ve/veya artık malzemeler geniş ölçekli üretime bağlı olarak birikmektedir. Tekstil endüstrisinde bu atık malzemeler üretim aşamalarından geriye kalan malzemeler ve/veya kullanıldıktan sonra atılan tekstil ürünlerdir. Bu atık malzemelerin kısıtlı da olsa tekstil sektörünün iç bileşenlerinde geri dönüşüm malzemesi olarak kullanıldığı görülebilmektedir. Ancak, geri dönüşüm aşamasından geçen tekstil atıklarının da oluşturduğu atık tekstil liflerinin birikimi küçümsenemeyecek kadar azdır. Bu birikim bir endüstriyel malzeme olarak da nitelendirilebilecek bir potansiyel malzemeyi de beraberinde getirmektedir. Ancak, birikim özelliği sergileyen atık malzemelerle ilgili endüstriyel katma değer sağlama bakımından literatürde önemli sayıda araştırma bulunmamaktadır.

Uygun olarak boyutlandırılmış tekstil atık veya artıklarının özellikle inşaat sektöründe kompozit sıva harçlarında lif güçlendirme olarak kullanılması üzerine deneysel bir araştırma yürütülmüştür. Bu bağlamda, bu deneysel araştırma, dört farklı tipte tekstil atık liflerin binalarda sıva harçlarında değerlendirilmesini kapsamaktadır.

Özellikle inşaat sektöründe, tekstil liflerinin lif katkılar olarak hafif yapı malzemeleri ve harç üretiminde değerlendirilme potansiyeli son yıllarda gelişmektedir. Lif katkılarının teknik avantajları detaylı olarak incelenmektedir. Ama aynı zamanda, tekstil atık liflerinin yeterli düzeyde mekanik ve fiziksel avantajlarının teknik incelenmesini bulunmamaktadır. Bu bağlamda, farklı lif türevleri ile harç kombinasyonları arasındaki ilişki özel bir araştırma konusunu gündeme gelmektedir.

Bunlara ek olarak, tekstil atıkları Türk ekonomisi için dayanak teşkil eden tekstil firmalarının fabrikalarında birikerek her gün çoğalmaktadır. Firmalar bu atıkları kullanmak, geri dönüştürmek veya imha etmek için genellikle fazladan mali yükümlülükler altında kalmaktadır. Bu tezin, firmaların bu arayışına farklı bir ışık tutmasının yanında, atıkların değerlendirilmesi ile çevre kirliliğinin önlenmesinde ve ülke ekonomisine katkıda bulunması adına değerli bir çalışma değeri olmaktadır.

Anahtar Kelimeler: Sıva, yalıtım, tekstil atık lif, yeni nesil kompozit harç, pamuk, sentetik, polyester, akrilik

1. INTRODUCTION

The use of waste materials in the construction industry is gaining increasing importance in recent years. These wastes are used in cementitious materials due to their various advantages such as thermal conductivity, sound insulation, structural reinforcement, to lighten composite, etc. One of these waste raw materials is the textile waste fiber. Nowadays, the use of these materials could be investigated more in the cementitious composites, in the economical and sustainable points of views.

One of the most basic human needs is covering and protection of human body. Textile products meet this need of the people for centuries. Raw material of textile, which is produced for covering and protection, is yarn. Techniques such as yarn production, weaving and sewing have been applied since 5000 BC (Güleryüz, 2011; Üçgül and Turak, 2015). Garment, household goods and technical textiles are produced by these techniques (Kozak, 2010).

In recent years, it is seen that fashion sense of the people can be quickly chance and consequently, excessive amount of textile production is done. Textile production in the worldwide scale is reached more than 88.5 million tons per year. A large amount of textile wastes are deposited every day with the great production scale. The production waste cuttings and waste clothes after used occur these wastes. According to EASME (2015), textile industry produces around 12 million tons of waste in a year only in the Europa. In fact, this large amount of textile waste fiber accumulation creates an opportunity for the use of textile wastes in construction materials. Some of the wastes are turned into yarn at the recycling factory. These factories shreds the textile waste cuttings and waste clothes, then turn them into 2 to 5 cm textile fiber. These fibers have a potential to use them in cementitious composites as reinforcement material.

In Uşak Region, Turkey's the most important textile center, textile, fiber and yarn is produced without the use of any chemical substance. Garment waste brought to Uşak after being collected from various parts of the world and Turkey and the firms in the city first classify the waste according to their color and fiber types, then shred the wastes. Then, the cut wastes are gathered into fibers by using rag pulling machine. These fibers are used as what they are or they are taken into yarn production stage. In this thesis work, these fiber types were used.

In this thesis study, different types of textile waste fibers were supplied from textile recycling industrial area in Uşak Region. A series of experimental investigations have been made for these different types of fibers on the use in new generation composite plasters. In this study, the effect of textile waste fibers to technical aspects of the composite materials were examined according to the principals foreseen in the TS EN 998-1 standard.

1.1. Topic

Construction sector is one of the most widely resource of material user industry. Therefore, more effective raw materials should be investigated and used in producing construction materials. The use of recycling materials and/or reusable materials as raw material is an effective way to produce sustainable construction products. One of these raw materials is textile waste fiber.

This experimental investigation was conducted as a master thesis work at Izmir Katip Celebi University Graduate School of Natural and Applied Sciences and it has the subject of the examination of different types of textile waste fiber for the use in composite plaster.

1.2. Aim

This study aims to investigate the utilization of textile waste fiber (TWF) as fiber reinforcement in cementitious composite plasters and the effect of TWF on the plasters' mechanical and physical properties.

Because increasing the use of waste materials in the construction industry, it was foreseen that their advanced engineering properties should be examined deeply. In this thesis, effect of textile waste fiber was carefully examined. In this study, the use of 2-5 cm sized textile waste fibers as an additive in cementitious plasters have been investigated.

1.3. Scope

The work presented in this thesis is an investigation on the behavior of new generation composite plaster produced from blending EN 197-1 CEM I 52.5R white cement with TWF having various ratios. Mechanical properties of the produced samples, such as compressive strength values of samples were obtained from compressive strength tests on cubic samples, splitting tensile strength values of the samples were obtained from Brazilian Test on cylindrical samples, flexural strength values of the samples were obtained from three point bending test. Also, thermal conductivity characteristics of samples were analyzed by a hot box apparatus.

In this study, a total 25 mortar mixtures and 455 samples were casted. For the compressive strength test 50x50x50 mm cubic samples were used. ϕ50x100 mm cylindrical samples were used for the splitting tensile test. 40x40x160 mm prismatic samples were casted for the flexural strength test. 50x200x400 mm plate samples were casted to make hot box test in order to find thermal conductivity of the samples. Besides, it was aimed to have the structural strength parameters, (normal strength, shear strength, cohesion, failure angle and internal friction angle) of the materials produced by combining these two parameters, compressive strength and splitting tensile strength, through the Mohr circles.

Effect of textile fibers on new generation composite plasters is a new research area and there is very limited information about this subject exists in the literature. Furthermore, this investigation can be interesting from technical point of view because any study of the structural strength properties of cement mortar cannot be found in the literature.

2. PREVIOUS STUDIES

A comprehensive review of the literature on the use of textile waste as construction material is made. It has been seen in the few studies, about the assessment of textile wastes in construction industry as a construction material, were studied by the researchers. However, it was observed that there is not enough sufficient work done in the assessment of textile waste as a component of composite plaster mortars. Studies by the researchers on the use of textile wastes in civil engineering application will be given in this section.

2.1. Classification of Composites

The beginning of modern composites industry was in 1937 with the including of fiberglass to the world economy. Development and expansion of composite materials gained momentum with the military operation during the Second World War. In 1970s, with the starting of the use of high-performance fibers, such as, Kevlar and high molecular weight polyethylene, composite materials is provided to reach the peak in the material industry (Aral, N., 2009). New composite materials everyday takes its place in the market. One of these is new generation composite plaster.

Formation options of composite materials are much that can be called infinite. Therefore classification is difficult. However, we shall concentrate on common classifications. Composite materials can be divided into four groups according to the matrix material type, which are metal matrix composite (MMC), ceramic matrix composite (CMK), cement matrix composite and polymer matrix composite (PMK). Composite also can be divided into four groups by its reinforcement element's shape and placement. Table 2.1 shows the types of matrix and reinforcing elements and the type of the resulting composite structure. These are fiber-reinforced composites, particle-reinforced composites, laminar composites and hybrid composites (Callister, W., 2007). Figure 2.1 shows the classification of composites.

Table 2.1 : Matrix, reinforcement element and composite structures types (Ulcay, Y., et al., 2002).

Matrix Material	Reinforcement Element	Type of Composite
Polymers	Fibers	Laminates
Metals	Whiskers	Film
Ceramics	Powder	Honey-Combs
	Chip	Filament Wound Structures
	Granule	Coverings

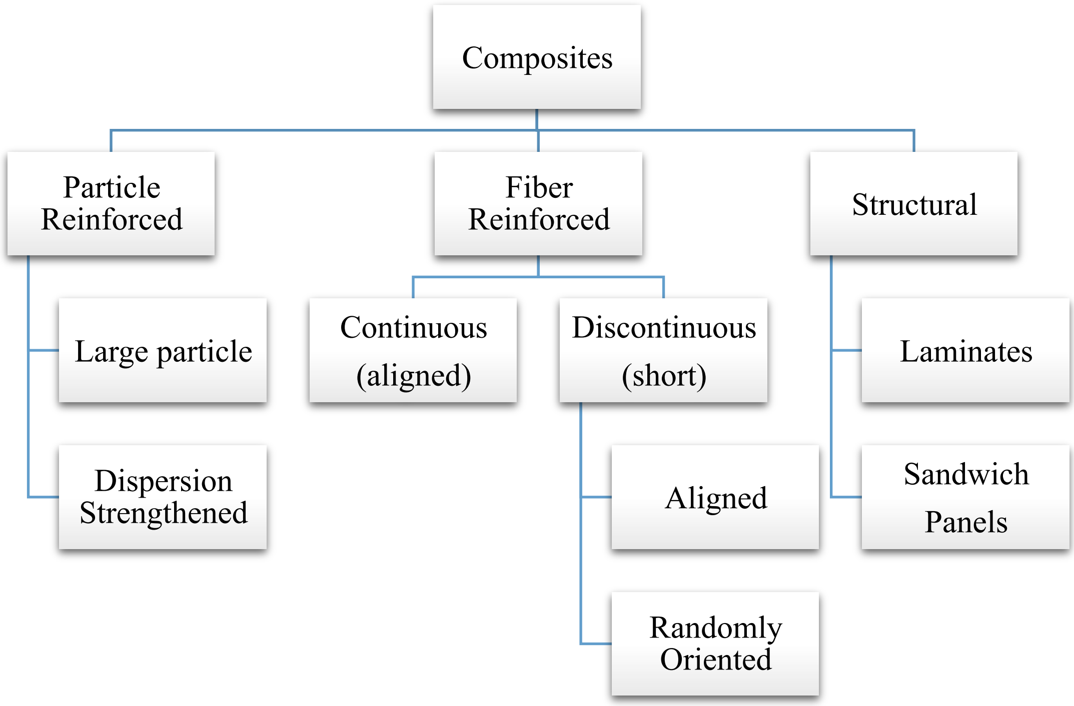

Figure 2.1 : Classification of composites.

2.1.1. Metal matrix composite (MMC)

These materials are formed by the metal matrix as main body and ceramic reinforcement phase as reinforcing element. MMC also can be seen as a combination of aluminum, magnesium or titanium as a metal matrix and fibers, such as carbon and silicon carbide. This material has almost no limit on the choice. Metal matrix composites are the great alternative to traditional materials. In MMC, high abrasion resistance, fracture toughness and high compressive strength are obtained by combining high elasticity modulus of ceramics and plastic deformation capability of metals. Advantageous of MMCs are higher elastic properties, unaffected by humidity, high thermal/electrical conductivity and fatigue and crack resistance. MMCs often used in automobile engines.

2.1.2. Ceramic matrix composite (CMC)

Ceramic materials are very hard and brittle. Furthermore, they have a relatively low density and high temperature strength properties. Ceramic materials have low thermal shock resistance and toughness. These are Al_2O_3, SiC, Si_3N_4, B_4C, cBN, TiC, TiB, TiN and AIN. One or several of these are used according to a purpose and ceramic matrix is created. The advantageous of CMCs can be considered as low density, high strength and high service temperature limits. It can be used in high temperatures that polymer matrix composites and metal matrix composites cannot be used.

2.1.3. Polymer matrix composite (PMC)

PMCs are the most widely used composite materials. The reason of this can be considered as low production cost, high strength and easy production principles. The polymer matrix is widely used as continuous fiber-reinforced and they are divided into two groups as thermosets and thermoplastics. These composites reinforced with continuous fibers of polyester and epoxy resin matrix, which are the most important. The main use of the reinforcing materials are glass fiber, kevlar fiber, boron fiber and carbon fiber. CMCs have wide usage areas, such as airplan industry, wind turbine blades, bicycles and medical tools.

2.1.4. Cement matrix composite

Cement matrix composites are concrete, which is containing coarse and fine aggregates, mortar that is containing fine aggregate but no coarse aggregate, and cement paste, which is containing no aggregate, whether coarse or fine. It also includes steel reinforced concrete, i.e. concrete containing reinforcing steel bars. Other fillers or reinforcements are added to the mix to improve the properties of the cement matrix composite. They can be particles, such as different types of aggregates like limestone, pumice, perlite, vermiculate, diatomite, etc. They can be either short fibers or long fibers, such as polymer, steel, glass, carbon fibers or textile fibers. They can be liquids such as methylcellulose aqueous solution, water ducinagent, defer, etc. (Chung, D.D.L., 2001).

2.1.5. Carbon carbon composite (CCC)

These are composites that carbon fibers or carbon particulates used in carbon matrix. All of the material consists of carbon. They can be used at temperatures up to 3000°C. Some advantageous of carbon carbon composites are resistance to high temperatures, low creep at high temperatures, low density, good tensile and compressive strength and high fatigue strength. Carbon carbon composites generally used in rocket nose cone and plane break systems.

2.1.6. Particle-reinforced composites

In particle-reinforced composites, particles are located in the matrix (Figure 2.2). Particle-reinforced composites are generally isotropic because, particles are randomly distributed. The strength of the structure is generally dependent on the hardness of the particles. They have such advantages as, improved strength, increased operating temperature, oxidation resistance, etc. Particle-reinforced composites can be analyzed as two separate groups. First one is the large particle-reinforced composites. The use of gravel, sand and cement in reinforced concrete construction is an example of large particle-reinforced composites. Second one is the dispersion-strengthened composites. In dispersion-strengthened composites, particles are generally much smaller, with a diameter range between 10 nm and 100 nm. Particle–matrix interactions that lead to strengthening occur on the atomic or molecular level (Callister, W., 2007).

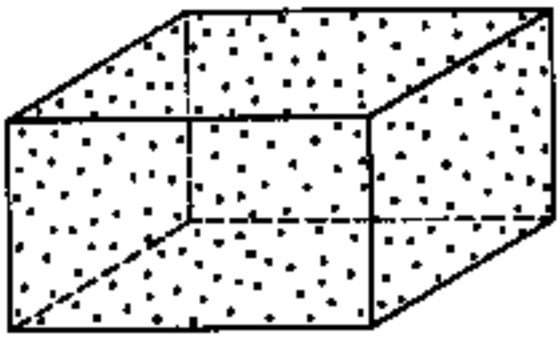

Figure 2.2 : Particle-reinforced composite (Url-1).

2.1.7. Laminar composites

The layered composite structure is a type having the one of the oldest and most widely used composite type. Laminar composite layers are obtained by matrix and fiber. Then with the combination of these multiple layer, laminar composites are obtained (Figure 2.3). In laminar composites, very high strength values can be obtained by a combination of different fiber orientated layers. They have heat and moisture resistant structures.

A sandwich panel consists of two outer sheets, or faces, that are separated by and adhesively bonded to a thicker core. The outer sheets are made of a relatively stiff and strong material. The core material is lightweight, and normally has a low modulus of elasticity.

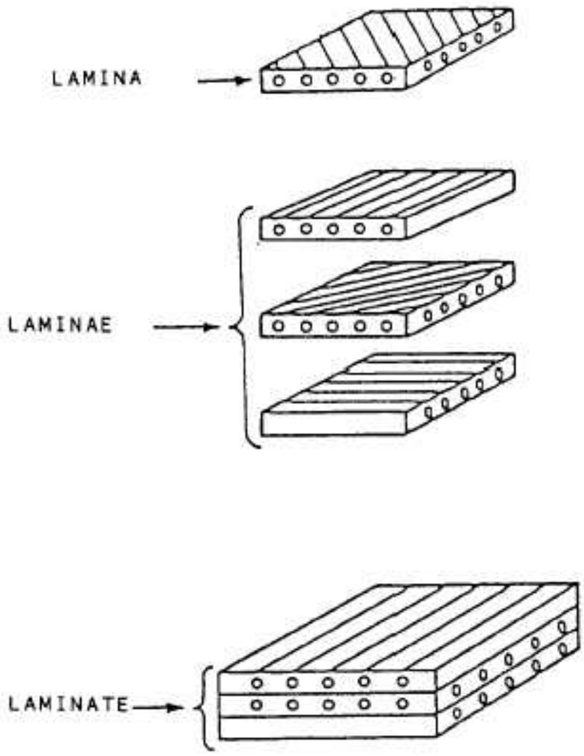

Figure 2.3 : Laminar composite (Url-2).

2.1.8. Hybrid composites

It is possible that the same composite structure of two or more fiber types and/or two or more matrix type. Such composites are called hybrid composites. This area is an area suitable for the development of new types of composite. For example, Kevlar fiber is a cheap and tough, but its compressive strength is low. The graphite has a low toughness and expensive but it is has a good compressive strength. They are sometimes produced together due to these features.

2.1.9. Fiber-reinforced composites

In the technical point of view, the most important composites are those in which the dispersed phase is in the form of a fiber (Callister, W., 2007). Today, most widely used reinforcement materials used in composites are fibers. The mechanical behavior of a fiber-reinforced composite depends on the properties of the fiber, fiber orientation, fiber length and the degree to which an applied load is transmitted to the fibers by the matrix phase. Two type of fiber can be used in composites as reinforcement element. The first one is continuous fibers and the second one is discontinuous (short) fibers.

Continuous fiber reinforcement materials are produced as rope and used (Figure 2.4). Continuous fibers improve the mechanical properties of composites through their longitudinal direction. In transverse direction, there is not reinforcement so that this direction is weaker than the longitudinal direction.

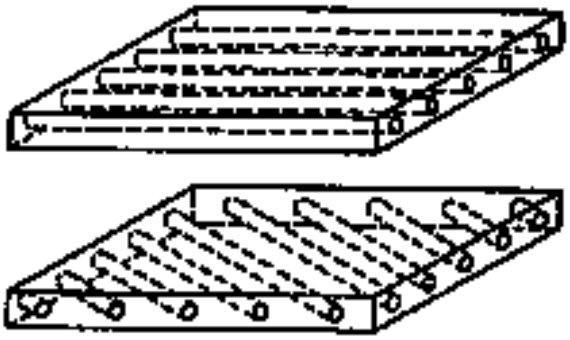

Figure 2.4 : Continuous fiber-reinforced composite (Url-3)

Normally, short and discontinuous fibers are used for randomly oriented fiber reinforced composites (Figure 2.5).

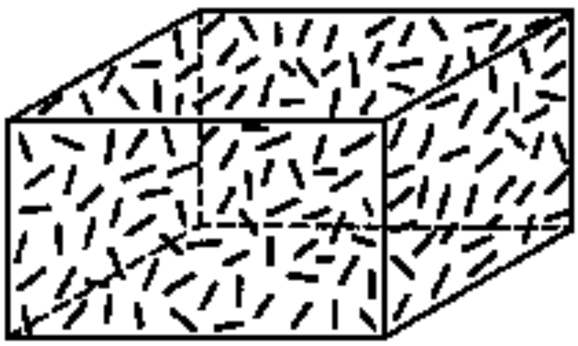

Figure 2.5 : Randomly distributed short fiber-reinforced composite (Url-4)

2.2. Textile Fibers

History of fibers is as old as human civilization. Fiber is a natural or synthetic substance that is significantly longer than it’s wide. Fibers are the smallest component of the textile product. Fibers are often used in the manufacture of other materials. The strongest engineering materials often incorporate fibers. Textile wastes are produced by textile fibers as normal textile products. Textile fibers are classified as natural fibers and chemical fibers. Figure 2.6 shows the classification of fibers.

In recent years, 61% of the fibers used for various purposes is vegetable origin, 5% is animal origin and 34% is chemical origin in the world. Cotton, which is contained in vegetable fibers, has a prominent place in the textile industry, since it covers 54% of the fiber production (MEGEP, 2007). Having the required properties for human health of natural fibers increases the need for these fibers rather than synthetic fibers.

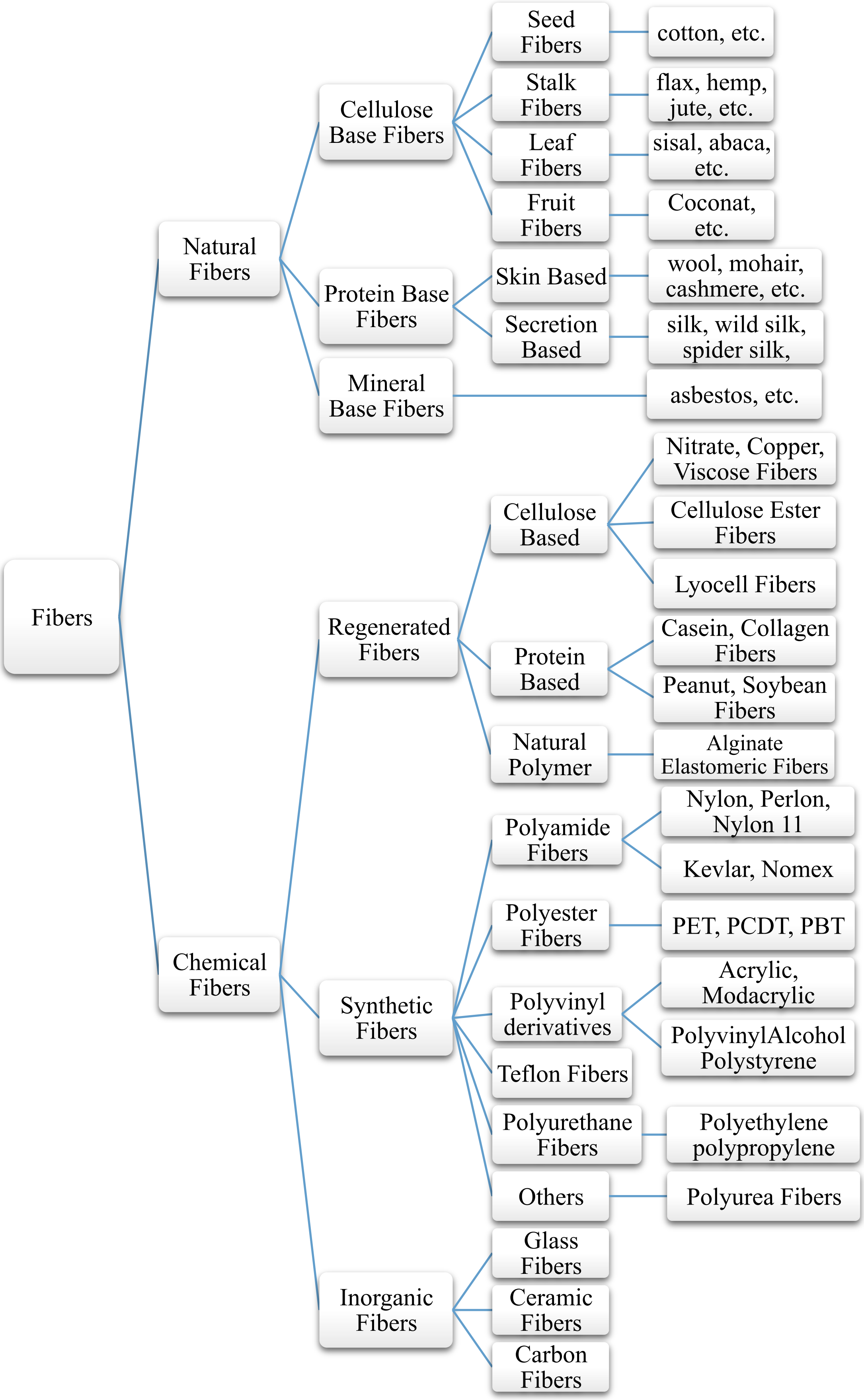

Figure 2.6 : Classification of textile fibers.

2.3. Textile Wastes

Wastes and/or residues are sometimes unwanted or unusable materials. Waste is any substance which is discarded after primary, residual material, or it is worthless, defective and of no use. Wastes are required to be removed by the manufacturer due to lack of direct benefit. Also, wastes are lead to environmental and visual pollution in areas where they are.

A textile is a flexible material consisting of a network of natural or artificial fibers (yarn or thread). Yarn is produced by spinning raw fibers of wool, flax, cotton, or other material to produce long strands. Textiles are formed by weaving, knitting, crocheting, knotting, or felting.

Textile waste is a material that is deemed unusable for its original purpose by the owner. Textile waste can include fashion and textile industry waste, created during fiber, textile and clothing production, and consumer waste, created during consumer use and disposal.

Textile wastes could be examined under two types of production stage which are pre-consumer textile wastes and post-consumer textile wastes (Wang, Y., 2006).

2.3.1. Pre-consumer textile wastes

Textile waste can be grouped under two main headings. First one is production wastes or pre-consumer wastes. Textile pre-consumer waste can be expressed as industrial textile waste in general. The classification of production wastes (Aral, N., 2009) is given in Figure 2.7.

Pre-consumer textile waste is waste generated in the fashion supply chain before the textile reached the consumer (EcoChic, 2013).

These types of materials are re-manufactured for the automotive, aeronautic, home building, furniture, mattress, coarse yarn, home furnishing, paper, apparel and other industries (Wang, Y., 2006).

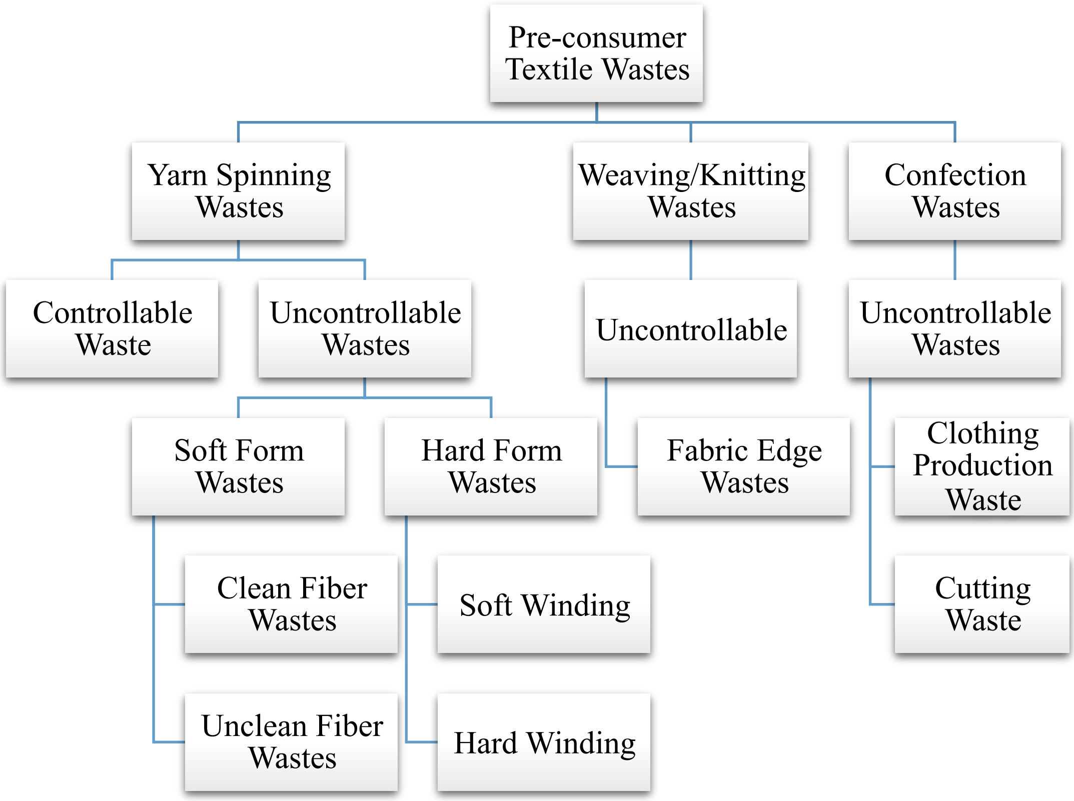

Figure 2.7 : Classification of pre-consumer textile waste.

2.3.2. Post-consumer textile wastes

Second textile waste group is textile wastes which are discarded by consumers after used. There may be several reasons for the formation of post-consumer textile waste. The main reasons are not to require more use of low-quality products, to pass the fashion of used products and completion of service time of textile products, etc. Post-consumer textile waste, ensuring recycling, should participate again in different areas of production. The classification of post-consumer textile waste (Aral, N., 2009) is shown in Figure 2.8.

Post-consumer textile wastes are sometimes given to charities and textile recycling companies, but generally they are disposed into trash and end up in the municipal landfills (Wang, Y., 2006).

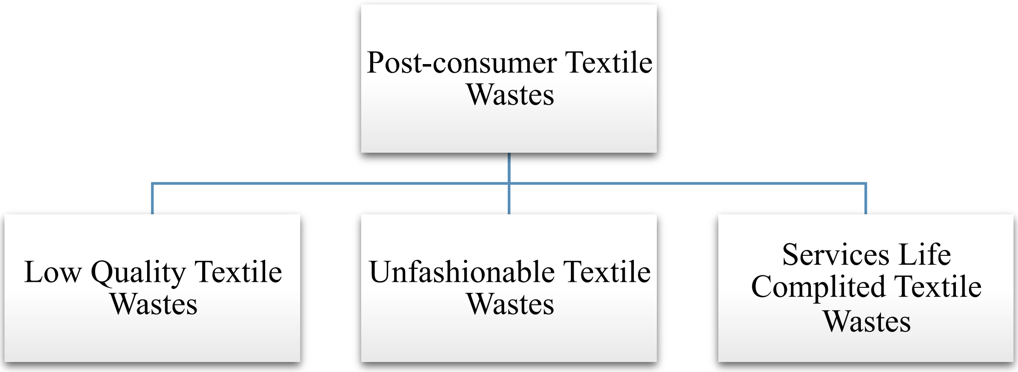

Figure 2.8 : Classification of post-consumer textile waste.

Industrial and post-consumer textile waste products are solid waste generated in various forms and ratios of different processing steps (Aral, N., 2009). Some examples of textile wastes are given in between Figure 2.9 and Figure 2.14.

Figure 2.9 : Textile swatch waste is leftover textile samples (EcoChic, 2013).

Figure 2.10 : Cut-and-sew textile waste is textile scraps generated during garment manufacturing (EcoChic, 2013).

Figure 2.11 : End-of-roll textile waste is factory surplus textile waste leftover on the textile rolls from garment manufacturing (EcoChic, 2013).

Figure 2.12 : Sampling yardage waste is factory surplus sample textiles that have been leftover from textile sample manufacturing (EcoChic, 2013).

Figure 2.13 : Damaged textile waste is unfinished textiles that have been damaged, for example color or print defects (EcoChic, 2013).

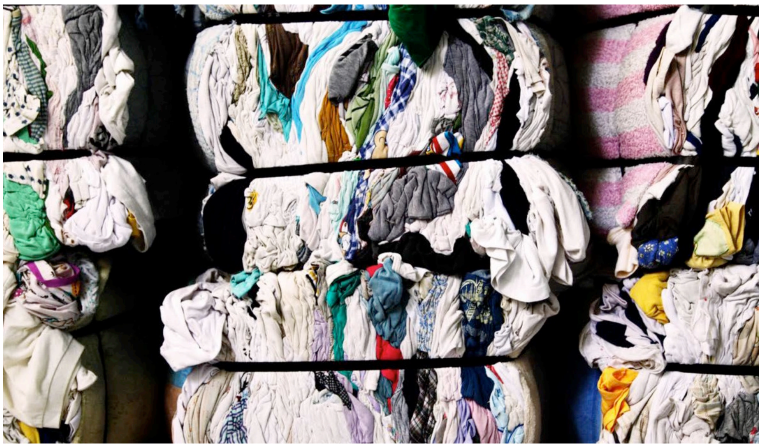

Figure 2.14 : Textile waste at a recycling station (EcoChic, 2013).

2.3.3. Recycling process of textile wastes

The most important factor of waste management is recycling. Recycling is giving worthless materials back as a new and valuable material to the industry. In many applications, such as metals, glasses, polymers, sometimes mineral based materials textile material and synthetic textile wastes can mostly be involved to the recycling process.

Ninety-nine percent of used textiles are recyclable (Gadkari, R., and Burji, M. C. 2015). Thus, the textile recycling industry is one of the oldest and most established recycling industries in the world. However, it is composed of newly awareness about textile recycling in Turkey.

Textile waste recycling can be assessed by four different methods (Figure 2.15). These are mechanical recycling, chemical recycling, thermal recycling and mixed technologies. Thermal recycling generally includes the producing of thermal or electrical energy through incineration of textile wastes. Chemical recycling recovers monomers from waste fibers by polymer decomposition. Mechanical recycling includes transformation of textile wastes to the new textile products or yarns at the mean time combination of these recycled textile waste and PET wastes.

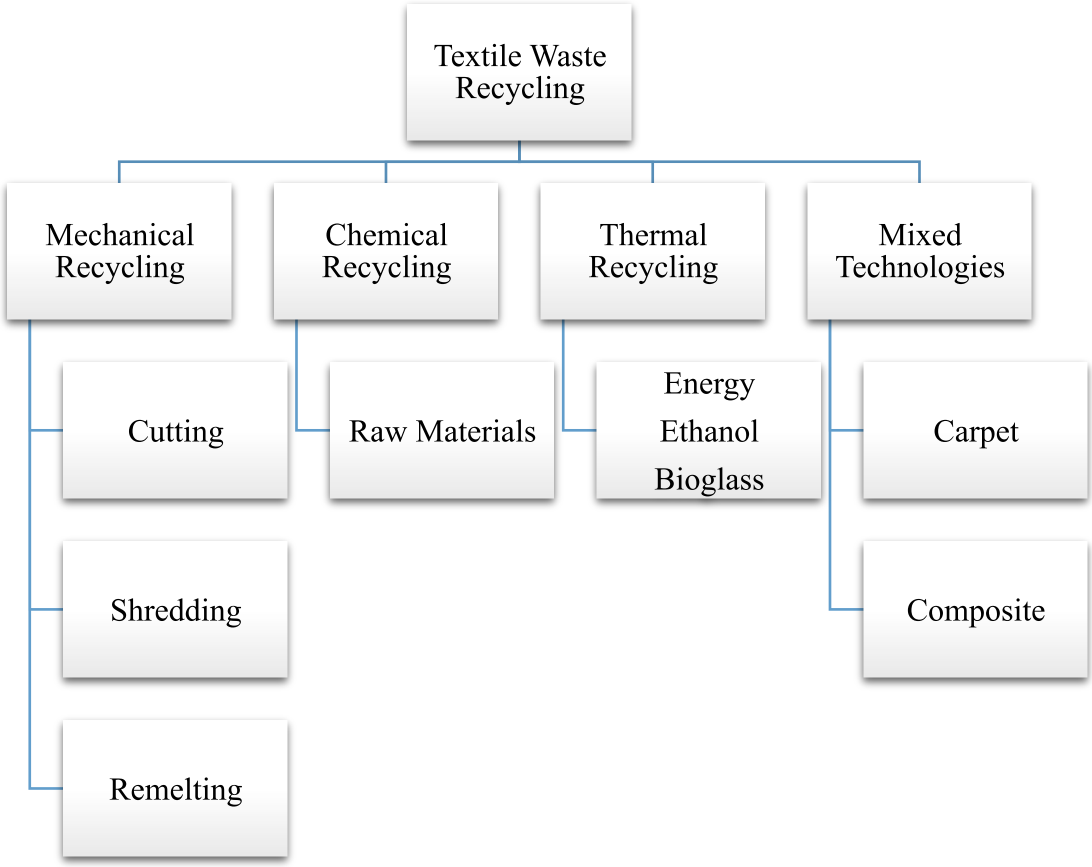

Figure 2.15 : Recycling processes of textile wastes.

Mechanical textile recycling is a process which aims to produce a near fibrous product form from textile wastes. First step of this process is collection of pre-consumer and post-consumer textile wastes. Then the textile wastes are usually sorted before recycling. All collected textile wastes are sorted according to their fiber type and color by skilled labor, which are able to easily recognize the raw material of the textile. Last step of the mechanical recycling is shredding. Shredding process is the shape changing of the piece of textile waste (Gordon, S. and Hsieh, Y., 2007). In this stage, textile wastes are reformed as very small fibers about 2 to 5 cm length. Figure 2.16 shows an example of the shredded textile wastes with a length range of 2 to 5 cm.

Figure 2.16 : Shredded textile wastes.

2.4. Use of Textile Wastes in Construction Sector

Waste material is defined as any material occurring as a result of human activity and does not serve the producer any longer. After the formation of wastes, control is required not to cause environmental problems. For this purpose, one of the most frequently used methods is the reuse of waste materials and evaluation of them in several areas. In this way, waste materials that considered as worthless could be used as a raw material or by-products in another material production. Thus, it provides major environmental and economic benefits. In order to evaluate the waste materials as a raw material or by-product, there is a need for new product ideas and designs. In this stage, developing various composite materials is could be evaluated as one of the most beneficial methods.

As in Turkey, the textile industry is one of the world's leading manufacturing sectors. Because of large production scale of textile sector, it generates a large scale of solid wastes. These solid wastes can be seen as both piece of textile and as fiber. Limited number of studies that have tried to evaluate textile pieces and fibers in construction sector and composite material production are listed:

Aspiras and Manalo (1995) have produced a composite lightweight masonry block formed from a combination of water, cement and textile waste fibers. They have tested their samples in accordance with standard ASTM procedures for testing concrete products. They have found high energy-absorbing capacity in their samples.

The result of their study indicate a sturdy lighter-than-concrete building material with various potential uses such as for ceilings, walls, wooden board substitute, or as an economical alternative concrete block.

Hejazi et al. (2012) have investigated the use of natural and synthetic fibers on soil reinforcement applications. They have discussed that why, how, when; and which fibers have been used in soil reinforcement projects, in their study. They have made a comprehensive literature review and results shows that using natural and/or synthetic fibers in geotechnical engineering is feasible in six fields including pavement layers, retaining walls, railway embankments, protection of slopes, earthquake and soil-foundation engineering.

Binici et al. (2014) have developed thermal insulation material from sunflower stalk, textile waste and stubble fibers. Their purpose is to produce board blocks on wall covering applications. They have composed sunflower stalk, textile waste and stubble fibers epoxy binder under different pressures. The results obtained satisfied the Turkish Standard TS 805 EN 601. Thus, their method proposed solves two industrial problems at the same time; on of them is developing thermal insulation material and the other one is using waste materials causing environmental problems.

Aghaee and Foroughi (2012) have produced lightweight concrete using textile waste and perlite. They used textile waste as a core material in their concrete. They have tested their lightweight concrete blocks as bending test. They found that textile wastes as a core fiber in central part of lightweight panels has proven to be beneficial not only for saving a raw materials and obvious environmental benefit, but also due to experiments a light-weighing insulated panel is achieved.

Algin and Turgut (2007) have aimed to produce cotton wastes and limestone powder wastes combination for producing new low cost and lightweight composite as a building masonry material. They have tested compressive strength, flexural strength, ultrasonic pulse velocity, unit weight and water absorption values and they found that these values satisfy the relevant international standards.

Raut et al. (2011) worked on producing waste-create bricks. Various waste materials in different compositions that were added to the raw material at different levels to develop waste-create bricks in their work. One of these additives to raw material is cotton waste. They have studied on Water absorption, compressive strength, flexural strength, UPV test for this new material.

Binici et al. (2012) have examined the usage of cotton waste, fly ash and epoxy resin on production of chip- boards. They have tested thermal conductivities, sound insulations and bending strengths of chip-boards with different thickness. They have investigated radioactive properties of samples containing barite. They have found that usage of cotton waste and fly ash had a positive effect on the engineering properties of chipboards and lightweight construction materials produced with cotton waste, fly ash and epoxy resin could be used for getting better thermal and sound insulation results.

Anurag et al. (2009) have investigated tensile strength of hot mix asphalt with polyester waste additive. Their results of the experiments states that, in general, the addition of the polyester fiber was beneficial in improving the wet tensile strength and tensile strength ratio of the modified mixture, increasing the toughness value in both dry and wet conditions, and increasing the void content, the asphalt content, the unit weight.

Oliveira and Castro-Gomes (2011) have investigated the utilization of polyethylene terephthalate (PET) bottle fiber recycled as fiber reinforced renders mortar. Their investigation was carried out on cement-lime mortar samples. Their results indicate that the incorporation of PET fibers significantly improve the flexural strength of mortars with a major improvement in mortar toughness.

Rajput et al. (2012) have produced mixture of recycle paper mills waste and cotton waste to make waste crete bricks. They used Portland cement as a binder material. They have investigated engineering properties of this new material. They found that their waste crete bricks can be potentially used in the production of lighter and economical brick material which can be used as internal partition wall.

Kozak (2010) has been investigated the areas of textile waste as construction material. He studied materials such as, cotton, jute waste and short asbestos fibers, cotton linter, etc. where and for what purpose can be used in the construction industry.

Üçgül ve Turak (2015) studied the recycling of textile waste as construction material. They produced block member by mixing cement and textile waste. They produced thermal insulation block. They evaluated thermal performance, fire resistance and sound insulation parameters of the manufactured block.

Briga-Sá et al. (2013) have studies on thermal insulation with filling walls with textile wastes for building external walls. They have done their experimental work by using an external double wall, with the air-box filled with textile waste, to determine their thermal characteristics. The thermal conductivity values of their experiments are similar to expanded polystyrene (EPS), extruded polystyrene (XPS).

Hadded et al. (2016) have investigated thermal properties of textile wastes in their study. They divide textile waste as waste linter and tablecloth. They found their thermal conductivity, density and Thermal diffusivity values and compare them with traditional thermal insulation materials.

Murathan et al. (2014) have examined the availability of production of high-density polypropylene textile waste in composite materials. They considered this application, which they used cement, lime and vinyl acrylic binder, to be useful in the practice of commercial repair and bonding applications.

2.5. New Generation Composite Plasters

In ancient buildings, mortars and plasters were used to hold the building materials, such as stone, brick and wood together. Also, they were used to protect the building materials against external influences. Today, plasters are often used for similar purposes.

Generally, mortars include Portland cement, sand and sometimes hydrated lime. These types of mortars are chiefly used in masonry works. As another definition, mortars are generally consisting of binder (cement, lime, and gypsum), aggregates (sand), additives and water.

The composite materials are chiefly made from a matrix and one or more filling materials. In general, reinforcing material takes over bearing task and the matrix phase serves to support and hold it together. Today, one of the most commonly used composite is concrete. The matrix material consisting of cement and sand is supported by steel rods. Composite components do not affect chemically each other.

Composite material is a new, physically different and with better properties material than its original state that obtained by mixing two or more materials having different characteristics. The purpose of composite production is to gathering advance properties to main material, which are not exist originally, such as, lightweight, strength, flexibility, etc. The properties and volumetric ratios of the phases that create composite material determine the properties of the composite material (Karcı, 2011).

Composite plasters or composite masonry mortars are construction material which are produced by the mixing of binder materials, aggregates and sufficient amount of water and if necessary, polymer additive that to change the properties of the main material (Gündüz et al., 2007).

The production of the composite material aims to improve one or a few of the following features:

- High strength
- Fatigue strength
- Abrasion resistance
- Corrosion resistance
- Fracture toughness
- Thermal insulation
- Sound insulation
- Electrical conductivity or insulation
- Stiffness
- Lightweight
- Economy
- Aesthetic

Plastering mortar is a type of mortar used to protect and to smooth the masonry and ceiling surfaces. In another definition, plaster is called as a continuous coating material that is applied to internal and external wall surfaces and ceilings with a certain thicknesses (Babadağ, Y., 2009). A plaster mainly consists of binder, aggregate and water. There are six types of plasters according to TS EN 998-1 standard. The schematic view of plaster types is given in Figure 2.17.

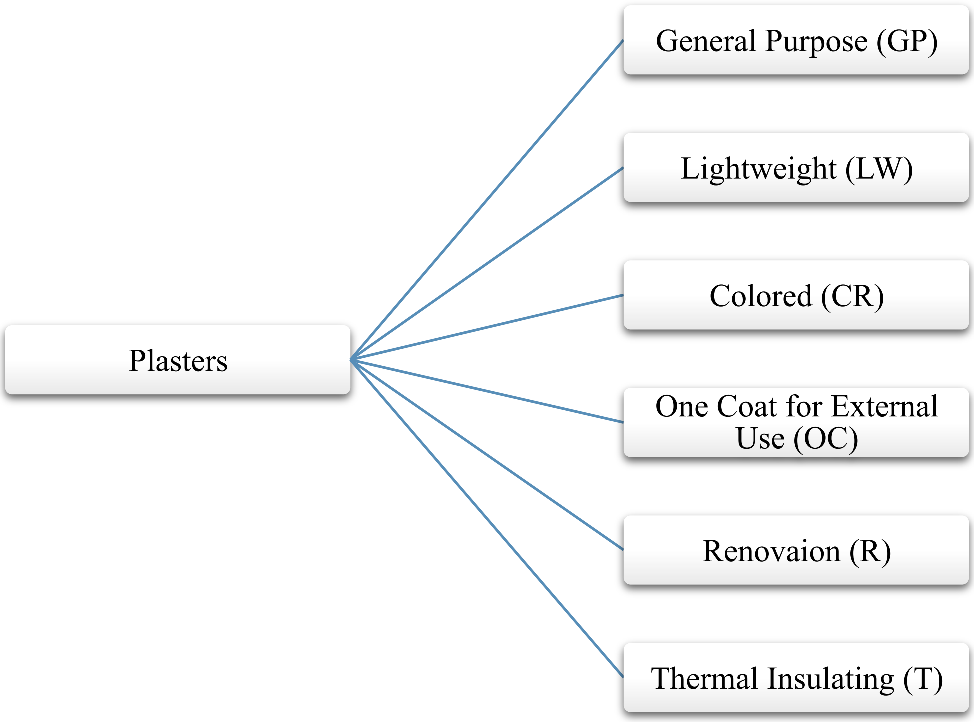

Figure 2.17 : Classification of plasters.

New generation composite plastering mortars are generally produced at plants and sold in bags. These composite plasters are used to give superior abilities to the building walls or to the complete building. Some of these abilities are:

- Thermal insulation
- Sound insulation
- Fire resistance
- Lightweight
- Bulletproof
- Radiation resistance
- High compressive strength
- High flexural strength
- High tensile strength
- Flexibility

- Water resistance
- Aesthetic etc.

The influence of site practice and procedures on the final properties of mortar is profound. All of these properties, the appearance, mechanical properties and durability are all affected by site operations and labor actions. Thus, correct practice is needed through all construction stages (Ahmed, A. and Sturges, J., 2015) in order to achieve these properties of new generation composite plasters.

2.6. New Generation Fiber-Reinforced Cementitious Composite Mortars

In many years, fibers have been used to reinforce the cement matrix composites. The physical and the mechanical performance of the cement based composite is mainly depended on the amount of fibers, the physical and the chemical properties of the fibers and the matrix, and the bond between the fiber and the cement matrix. In order to evaluate the physical and the mechanical behavior of fiber reinforced cementitious composites, many different types of fibers are used in the cementitious compound. Some of those are, steel fibers, plastic fibers, glass fibers, mineral based fibers and natural fibers.

The use of fiber in concrete in developed countries began in the early 1960s and the use of fiber-reinforced concrete applications has been increased (Aghaee K. and Foroughi M., 2012). It can be seen that in the literature, various types of fibers are used as reinforcement element in cementitious composites. Various studies about fiber reinforcement in concretes according to different advantages of the fibers as follows:

Yin, S. et al. (2016) investigated the alkali resistance and performance of recycled polypropylene (PP) fibers in the 25 MPa and 40 MPa concretes for footpaths and precast panels. They found that PP fibers had very good alkali resistance in the concrete. Excellent post-cracking performance of PP fibers was found by them.

Grabois, T. M., et al., (2016) investigated the characterization on the fresh and hardened state of self-compacting lightweight concrete (SCLC) reinforced with steel fibers. They found the mechanical behavior of test samples by means of compression, tensile and flexural strengths. They made specific heat, thermal diffusivity and conductivity tests. They found that fiber reinforcement has increased the mechanical properties under direct tensile and bending tests.

Pogorelov, S.N., and Semenyak, G.S., (2016) studied the frost resistance of steel fiber reinforced concrete with the use of active mineral additives. They picked the steel fiber reinforced concrete because of its high durability in road construction. They found that the dispersed reinforcement improves the pore structure of the concrete matrix and the combination of fiber reinforcement with the cement matrix having enhanced crack resistance allows improving the performance of the composite material.

Wang, Y., et al., (1994) studied the evaluation of recycled fibers from carpet industrial waste for reinforcement of concrete at 1 and 2 vol. % fractions. They performed some mechanical and physical tests on the test samples, such as compressive, flexural, splitting tensile and shrinkage tests. They found that recycled carpet wastes improved shatter resistance, energy absorption and ductility.

Shah S.P., et al. (1988) tested long-term weathering of glass fiber reinforced panels (GFRC). They experienced the long term flexural strength and flexural toughness of GFRC. In spite of the improved alkali resistance, long term tensile strength and ductility reduced with aging.

Asbestos is a naturally occurring mineral that once was lauded for its versatility, recognized for its heat resistance, tensile strength and insulating properties, and used for everything from fire-proof vests to home and commercial construction. It was woven into fabric, and mixed with cement. Asbestos cement has used during the past 100 years because of its very low cost and excellent durability. The reason of its long term use is the great durability of asbestos fibers. However, once it is determined to be carcinogenic, its use has been decreased since 1980 (Illston, J. and Domone, P., 2001).

Glass fiber reinforced cement matrix composites are normally made with alkali-resistant glass fiber bundles combined with a Portland cement matrix and if necessary inorganic fillers. Fiber length, fiber amount and fiber orientation in the composite are the parameters that affect the performance of the composite. Cladding panels are a general application for glass-reinforced cement (Illston, J. and Domone, P., 2001). Various studies about glass fiber reinforcement in cementitious composites according to different advantages of the fibers as follows:

Marikunte, S. et al., (1997) studied the durability characteristics of glass fiber reinforced cementitious composites with the effect of silica fume and metakaolin. They compared the flexural, tensile and hot-water durability performance of AR-glass fiber reinforced composites in blended cement matrix. They investigated three different matrices as only cement, cement and metakaolin, and cement and silica fume. They found from hot-water durability tests that cement and metakaolin matrix was more durable than the others.

Another fiber type used in the composites is wood cellulose fibers produced from trees. Wood fibers are produced by pulping the wood to separate fibers. Wood fibers could be used in conjunction with polyvinyl alcohol fibers in a matrix of Portland cement, and if fillers are used, the composite can provide tough and durable fiber cement. This type of composite is applicable for the production of corrugated sheeting and pressed tiles on traditional slurry dewatered systems (Illston, J. and Domone, P., 2001).

In recent years, the use of vegetable fibers produced from seed, stalk, leaf and fruit of some plants are generally aimed to produce cheap but labour-intensive, locally constructed cement-based composites. Long fibers which are indigenous to the locality are used, such as akwara, banana, bamboo, coir, elephant grass, flax, henequen, jute, malva, musamba, palm, plantan, pineapple leaf, sisal, sugar cane and water reed (Illston, J. and Domone, P., 2001). Several studies carried out about vegitable fiber reinforcement in cementitious composites as follows:

Savastano, H. and Agopyan, V. (1999) compared composites with vegetable fibers (malva, sisal and coir), chrysotile asbestos and polypropylene fibers. They tested the tensile strength and ductility of the composites. They tried to investigate the transition zone of short filament fibers randomly dispersed in a paste of ordinary Portland cement. They found that mainly for vegetable fiber composites the transition zone of composites porous, cracked and rich in calcium hydroxide macrocrystals.

Silva, F.A. et al. (2010) tried to characterize the physical and mechanical behavior of the cement composites reinforced with long and unidirectional aligned sisal fibers.

They produced flat and corrugated sheets. They carried out direct tensile and bending tests to determine the first crack, post-peak strength and toughness of the composites. Also, they tested the drying shrinkage, capillary water absorption and water tightness of the samples.

Savastano, H. et al. (1999) studied about reinforcement cement based composites with plant fibers, such as eucalyptus pulp, coir fibers and with a mixture of sisal fiber and eucalyptus pulp. They produced cement based and vegitable reinforced roof tiles. They tested the compressive strength and modulus of rupture of the composites. They found the performance of tiles made with these composites was in accordance with international requirements.

It is seen in the literature that the synthetic fibers commonly used in cementitious composite mortars. Synthetic fibers are used very commonly because of the general acceptance of low cost and to improve the mechanical properties of the composite mortars. Various studies about synthetic fiber reinforcement in cementitious composites according to different advantages of the fibers as follows:

Zhang, H., et al., (2016) investigated the dynamic characteristics and the constitutive relationship of polypropylene fiber reinforced mortar (PFRM) materials under compressive impact loading. They carried out the impact tests by using improved Split Hopkinson Pressure Bar (SHPB) equipment installed with confining pressure device. They analyzed the compressive strength, the dynamic elastic modulus, the toughness and the ductility parameters. They found that the dynamic performance of PFRM materials is significantly affected by strain rates. Also, they have found that polypropylene fibers are able to improve the impact toughness.

Bezerra, E.M., et al. (2006) investigated the different amounts of synthetic fiber on physical and mechanical performance of asbestos free fiber cement. They test Polyvinyl alcohol (PVA) fiber as reinforcement in their research. They found that synthetic fiber contents higher than 2% by mass (from 4% to 5% by volume of the composite) were unable to promote any further improvement in the mechanical performance of the composites at the age of 28 days.

Habib, A., et al., (2013) carried out an investigation about the effect of different types of synthetic fibers, such as, glass, nylon, and polypropylene fibers on the mechanical properties of cementitious composite mortar. They found that addition of fibers in to the mortars increased the compressive strength of mortar composites except glass fiber, tensile and flexural strength had little influence with the addition of fibers.

Pakravan, H.R., et al. (2012) compared he adhesion strength between three polymeric fibers (polypropylene (PP), nylon66 (N66) and polyacrylonitrile (PAN)) embedded in a cement paste in their research. They used scanning electron micrographs in order to characterize the fibers' surface before and after the Pullout tests. They found that pull-out behavior of all tested fibers was almost the same for 7 and 14 days cured specimens. An increase was found in pull-out load for all tested fibers for 28 days cured specimens by the researchers.

Cristel et al. (2010) examined the thermal properties of cement composites reinforced with vegetable bagasse fibers. They found that the vegetable fibers produced a slight decrease in the thermal conductivity. Contrarily, the mechanical strength of the composites increased. Also, they pointed out that the use of more fiber composites might reduce the unit volume weight and the thermal conductivity.

Textile waste fiber reinforced cement matrix composites is a new research area, because not much work done on this topic. A very limited number of studies are found in the literature about the textile waste fiber reinforced cementitious composites. Some of which are given below:

Ucar, M. and Wang, Y. (2011) carried out an experimental investigation about utilization of recycled carpet waste fibers as reinforcement in lightweight cementitious composites. In their study, lightweight cementitious composites were fabricated that were reinforced with recycled carpet fibers at up to 20 per cent fiber to cement weight ratios. They tested flexural, toughness, and impact properties of the lightweight cementitious composites. They found that the density of the composites decreases with the increase of fiber content. In the three-point bending test, lightweight cementitious composites exhibited a ductile behavior.

Pinto, J., et al., (2013) investigated the reinforcement of the render with textile threat. They used 30% wool and 70% acrylic composition thread textile waste considered as a reinforcement fiber in their paper. Also, they compared two different sizes (2 cm and 4 cm) of threats. They mainly studied the applicability, the durability and the mechanical behavior of the proposed reinforced render. They found that the mechanical behavior of the render may increase according to the increase of the short size fiber content. In contrast, this tendency does not seem to occur when the fiber length increases. Also, they found that high fiber lengths may reduce the workability of the mortar.

2.7. Mohr-Coulomb Failure Criterion

Mohr Coulomb Failure Criterion is generally used in rock mechanics to understand the relationships between stress, failure, and frictional faulting and to use this relationship to predict rock behavior. Also, The Mohr-Coulomb criterion is the most common failure criterion encountered in geotechnical engineering. Many geotechnical analysis methods and programs require use of this strength model. The Mohr-Coulomb criterion describes a linear relationship between normal and shear stresses (or maximum and minimum principal stresses) at failure. The Mohr Coulomb Failure Criterion is rarely encountered in some investigations based on concrete researches:

Öztekin, et al. (2016) were investigated experimentally the parameters which define Drucker-Prager yield criterion for both normal strength concrete (NSC) and high strength concrete (HSC) by triaxial compression tests. They found the values of cohesion between 5 MPa and 13 MPa for NSC and 13 MPa and 19 MPa for HSC and the values of internal friction angle between 27° and 34° for NSC, 34° and 39° for HSC through drawing the Mohr circles.

Mahboubi, A. and Ajorloo, A. (2005) investigated the extensive experimental parametric study of the mechanical responses of various types of plastic concrete in unconfined and triaxial compression tests. They used Mohr Circle in their study. According to Mohr circle parameters, they investigated the effect of specimen age, cement factor, bentonite content and confining pressure on shear strength and permeability of plastic concrete.

In this thesis, Mohr Coulomb Failure Criterion was tried to use to determine the structural strength properties of the samples. Mohr Coulomb Failure Criterion could be estimated by some mechanical properties of cement matrix composites based on the tension and compression strengths. Although a few Mohr Coulomb failure criterion practices related with concrete can be seen in the literature (Mahboubi and

Ajorloo, 2005; Öztekin et al., 2016). There are no such studies related to cementitious mortars.

2.8. Literature Evaluation

In this study, a comprehensive literature research was conducted. Majority of existing literature shows that fibers have been used in the cement matrix composites for a long time. Recently, with the concern of sustainability and environmental protection, the use of waste fibers and natural fibers has gained an importance in the composites. The literature review shows that the use of natural and/or vegetable fibers rapidly increasing besides the traditional fibers. However, there is a very limited research work at the point of evaluation for textile waste fibers as a reinforcement element in the cementitious composites in construction sector. The evaluation of textile wastes in composite materials is mostly focused on carpet wastes. But in this study, any type of textile material is included in the research, as the textile fibers was supplied from textile recycling plants and this plants could process any type of textile wastes.

In this thesis, the use of textile waste fibers as a reinforcement element in cement matrix composites was examined deeply. In this context, mechanical, physical and structural behavior of textile waste fibers on the composites were analyzed in detail.

Also, no work was encountered about the internal strength characteristics of fiber-reinforced mortars. Internal strength characteristic was meant as structural strength parameters (internal friction angle, failure angle, normal strength, shear strength and cohesion) of the mortars. Structural strength analysis of a material provides more comprehensive information about the material. Also, it can be obtained from structural strength parameters better understanding about what happens inside the material before it reaches failure.

In this thesis, the use of textile waste fiber materials as reinforcement in cementitious composite mortars was investigated. The effect of textile waste fibers on cement matrix composite mortar is a new research topic and there is a very limited information about this subject in the literature. Furthermore, this thesis can be interesting from technical point of view, because any study of the structural strength properties of cement based composite mortar cannot be found in the literature.

3. MATERIALS AND METHODS

3.1. Materials

In this thesis, white ordinary Portland cement (WOPC) was used as a main binder material. Hydrated powder lime (HPL) was used in the batches as the aim of pH stabilizing additive. Pumice was used as a main aggregate and expanded perlite aggregate was also used in order to reduce the weight of the composite samples. The calcite material was as a powder calcite filler (PCF) material in mixture combinations. Cellulose ethers were added to control the large extend the rheology of the mortar. Also, a commercial water repellent additive material was used in powder form (white color) throughout the research. In this experimental investigation, four different types of textile waste fibers were used as fiber-reinforcement element in the cement-matrix composites.

3.1.1. Cement

In this thesis, white ordinary Portland cement (WOPC) conforming to EN 197-1:2011 CEM I 52.5 R (52.5 N/mm^2) was used as a binder material. WOPC is a cement type produced with the combination of such raw materials as white clay, limestone and marble dust. Due to the small amount of iron oxide (Fe_2O_3) (generally less than 0.3%) and manganese, this type of cement appears as white colored. WOPC is chiefly used in projects where architectural and aesthetics visibility is important (Figure 3.1). The chemical composition and Bogue composition of the white ordinary Portland cement is shown in Table 3.1. The mechanical and the physical properties of WOPC is given in Table 3.2.The WOPC was analyzed for its mineral composition and the loss on ignition by using the X-ray Fluorescence (XRF) analysis. The average particle size distribution was detected by laser particle analyzer. The specific gravity of the white cement was determined as foreseen in British Standard (BS 1377:Part 2) by using the small pycnometer method. The fineness of the cement was determined by conducting the Blaine surface area test according to ASTM C 204-94a and shown in Table 3.2.

Figure 3.1 : A view of the WOPC.

Table 3.1 : Chemical composition of the WOPC.

Major Element	%
SiO_2	21.60
Al_2O_3	4.05
Fe_2O_3	0.26
CaO	65.70
MgO	1.30
SO_3	3.30
Na_2O	0.30
K_2O	0.35
Bogue composition	
C_3S	66.31
C_2S	11.90
C_3A	10.29
C_4AF	0.79

Table 3.2 : Mechanical and physical properties of WOPC.

Major Element	%
Specific gravity (g/cm^3)	3.06
Blaine specific surface (cm^2/g)	4600
Initial setting time (min)	100
Final setting time (min)	130
Volume expansion (mm/m)	1
Compressive strength (MPa)	
7 days	37.0
14 days	50.0
28 days	60.0

3.1.2. Hydrated powder lime

Lime is known as one of the oldest binders. Lime has been an important component of mortars for over 2000 years. Limestone or calcium carbonate ($CaCO_3$) is the raw material of lime. To produce commercial lime, firstly the limestone is burned and CaO occurs. Then, CaO is reacted with water, this process is called as hydration, and $Ca(OH)_2$ occurs. This new material is called as Hydrated Lime. The characteristics of hydrated lime could provide unique benefits to mortars, such as flexural bond strength, water leakage, durability, compressive strength, uniformity, etc.

Hydrated Powder Lime (HPL) used in this work was a commercial product in Turkey. The hydrated lime in powder form belongs to the class of CL80 according to EN 459-1. HPL additive (Figure 3.2) was used in the mixture combinations in order to stabilize pH balance. Hydrated lime is a soft, white, crystalline, very slightly water-soluble powder as $Ca(OH)_2$, obtained by the action of water on lime. It is generally used in mortars, plasters, and cements. The chemical composition of HPL is given in Table 3.3.

Figure 3.2 : A view of the HPL.

Table 3.3 : Chemical composition of the HPL.

Major Element	%
SiO_2	< 1.3
Al_2O_3	0.4-0.8
Fe_2O_3	< 0.3
CaO	80.0
MgO	< 2.0
SO_3	< 2.0
Na_2O	< 0.8

3.1.3. Pumice

Pumice was evaluated as the main aggregate in this thesis. Also, due to low unit volume weight of pumice, it was used as lightweight aggregate in this experimental investigation. Pumice is a natural and volcanic material and it has spongy and porous structure. Pumice contains numerous pores, because during the formation, gases in the structure in the pumice rapidly leave the body and then sudden cooling takes place. Thus, the porous structure occurs. Disconnected hollows generally form these pores. Therefore, pumice has low permeability and it has very high thermal and sound insulation. Because of these characteristics, pumice is widely used as a lightweight aggregate in lightweight concrete designs. Besides, pumice is used in production of lightweight building elements such as bricks, masonry blocks, panels and boards, etc. (Gündüz, L. 2005).

Pumice aggregate used in this experimental study was supplied from the location of a pumice mining quarry in Nevşehir Region, Centre of Turkey (Figure 3.3). The specific gravity of the pumice used in the experimental work is 2.35 g/cm^3 and its bulk dry density value was 435 kg/m^3 for coarse NPA and 530 kg/m^3 for fine NPA. Nevşehir pumice aggregate (NPA) obtained from the quarry was crushed by a primer crusher and then screened into 63-250 μm and 1-2 mm as fine and coarse aggregate form in this thesis. Then, pumice aggregates were visually analyzed by a microscope and the pumice particulates were observed as mostly rounded shape in an acceptable scale. This situation could help to mortar strength.

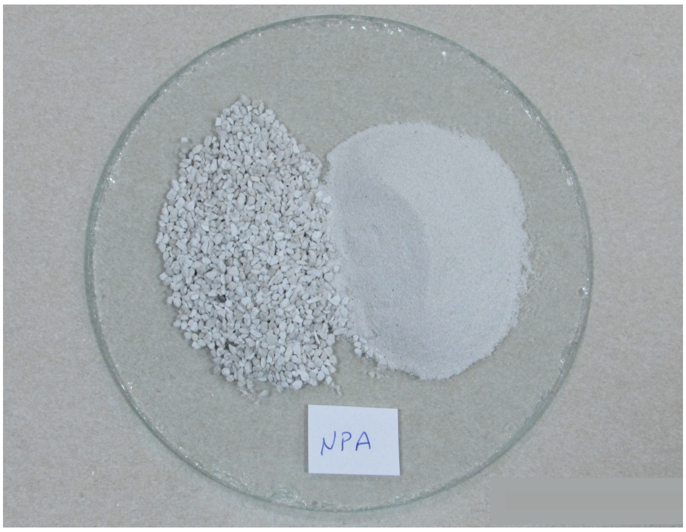

Figure 3.3 : A view of the fine and coarse NPA.

In order to determine organic material content in the NPA, NaOH solution at a concentration of 3% was prepared. As a result of this experiment, no organic material was found in the pumice. Analysis of sulfur compounds in lightweight aggregates is done in terms of SO_3. It is foreseen that the SO_3 composition is maximum 1% by weight in lightweight aggregates. SO_3 content of NPA was determined as 0.23% by weight. In this respect, Nevşehir pumice aggregates could be used for cement based mortars in terms of sulphate content. Pumice aggregates are also very resistant to the effects of freezing and thawing (Gündüz, L. 2005). Chemical composition of the NPA is shown in Table 3.4.

Table 3.4 : Chemical composition of the NPA.

Major Element	%
SiO_2	70.50
Al_2O_3	13.00
Fe_2O_3	1.20
Na_2O	3.75
MgO	0.20
K_2O	4.55
CaO	1.35
TiO_2	0.09

3.1.4. Expanded perlite

Perlite is a glassy and volcanic originated rock type. When perlite granules are heated in the temperature range between 900°C and 1100°C, its volume increases about 20 times and it becomes a porous structure. Resulting new material after heat-treating is called Expanded Perlite (EP). This formal transformation or expansion makes expanded perlite a very light material and very efficient insulator. Expanded perlite aggregate is often used for these features when thermal insulation and lightness required cases are needed. The chemical composition of the EPA is given in Table 3.5.

Table 3.5 : Chemical composition of the EPA.

Major Element	%
SiO_2	70.50
Al_2O_3	13.00
Fe_2O_3	1.20
Na_2O	3.75
MgO	0.20
K_2O	4.55
CaO	1.35
TiO_2	0.09

Expanded perlite aggregate (EPA) was used in this experimental work as a lightweight aggregate. Expanded perlite aggregate (Figure 3.4) as a commercial product used in this study was supplied from İzmir Region in a size of 0-2 mm. Any procedure was not applied to the material and was directly used in the cement matrix composite mortar combinations.

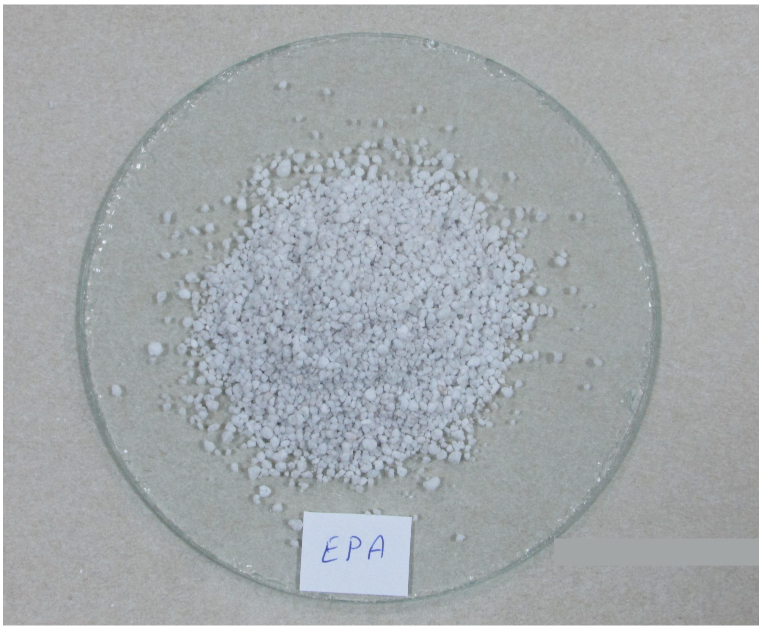

Figure 3.4 : A view of the EPA.

EP is usually white colored. pH of EP is between 6.6 and 8. Water absorption of EPA is between 40 and 60% (Gündüz, L. et al., 2006). The specific gravity of the expanded perlite used in the experimental work is 2.30 g/cm3 and its bulk dry density value was also 80 kg/m^3. SO_3 content of EPA was determined as 0.34% by weight.

3.1.5. Calcite

Calcite is a carbonate mineral and it is known as the most stable polymorph of calcium carbonate ($CaCO_3$). Calcite is very common and can be found throughout the world in sedimentary, metamorphic and igneous types of rocks. The calcite used in the composition of mortars was also a commercial product in Turkey. The calcite used in this experimental program was a white powder form obtained by grinding from calcite minerals. The calcite material was as a powder calcite filler (PCF) material in mixture combinations. Its maximum particle size was 500 µm and its bulk dry density value was also 900 kg/m^3. The chemical composition of PCF (Figure 3.5) is given in Table 3.6.

Figure 3.5 : A view of the CPF.

Table 3.6 : Chemical composition of the PCF.

Major Element	%
SiO_2	0.05
Al_2O_3	0.10
Fe_2O_3	0.04
Na_2O	0.03
MgO	0.55
K_2O	0.02
CaO	55.20

3.1.6. Cellulose

Cellulose ethers are additives which control to a large extend the rheology of a cement mortar. In a complex matrix of this multiphase blend they have an impact on the yield point and the shear thinning behavior (Baumann, R. et al., 2009). Cellulose ether is an indispensible component of a cement mortar formulation. This highly functional additive helps to adjust the performance profile of the mortar at various levels. The solubilized cellulose ether in the mortar matrix determines to a large extend its rheological properties and subsequently the workability of the mortar. The cellulose ethers preferred in dry-mix mortar application are hydroxypropyl methyl cellulose (HPMC) or hydroxyethyl methyl cellulose (HEMC). In this research program, a commercially available HEMC (Figure 3.6) in Turkey was used for all mixtures to provide sufficient water retention to the mortar so that the cement can set and develop strength before it dries out. It was a non-ionic cellulose ether that provides many of the same benefits as other methylcellulose derivatives, such as the ability to efficiently thicken and provide water retention. It was a white powder form as a very fine size; its etherification property was very high. Its level of viscosity was 150000 mPa.s according to Höppler. The water solution appears strong pseudoplastic and provides excellent shear viscosity. It is mainly used for binders, protective colloid, thickeners, stabilizers, and emulsifier. It is also dissolved readily in cold water, not the hot.

Figure 3.6 : A view of the cellulose ether.

3.1.7. Wetting agent

A polymer powder was also additionally used as a wetting agent in this research work. The wetting agent used in the composition of cement based composite mortars was also a commercial product. It is actually a copolymer of propylene oxide and ethylene oxide, containing 80% by weight of ethylene oxide. It is generally used as a wetting agent for solid admixtures in the construction industry and is applied for plasters and mortars based on cement, gypsum or lime. In this research work, this wetting agent additive (Figure 3.7) was actually used to improve the wetting of fine particles of dry mortar. Workability and plasticity characteristics of the mortar mixtures were tried to improve by using the polymer wetting agent powder additive.

Figure 3.7 : A view of the wetting agent additive.

3.1.8. Textile waste fiber

Recycled textile fiber as a new type of reinforcement element is proposed in this study. Recycled textile fibers used in cement matrix composite mortar combinations were collected from textile recycling factories in Uşak Region, textile recycling center of Turkey. In these factories, the fabrics are shredded and separated into 2 to 5 cm length fibers. Generally, these fibers are then used for yarn production. In this thesis, cement based composite mortars were produced by using four different types of these fibers as fiber reinforcement.

Four types of recycling waste fibers were supplied from Uşak Region. First one is cotton waste fibers from recycling of cotton based textile products. Cotton fiber is the most important vegetable textile fiber. Cotton is almost pure cellulose. The main component of cotton fiber is cellulose with a ratio of 94%. The remaining of cotton fibers consists of hemicellulose, pectin and inorganic substances. Cotton is one of the dense fibers and its specific gravity is 1.54 g/cm^3. Water absorption capacity of cotton is varies between 25-30%. Cotton is very resistant to alkalies. Concentrated alkali solutions swell cotton, but the fiber is not damaged. While diluted bases minimal effect on cotton fiber, cotton fiber shows degradation with concentrated and strong acids. Cotton has excellent heat resistance and cotton fibers do not exhibit degradation up to 150°C (MEB, 2011; Saçak, M., 1994; Needles, H. 1986). Microscopic view of cotton fibers is given in Figure 3.8.

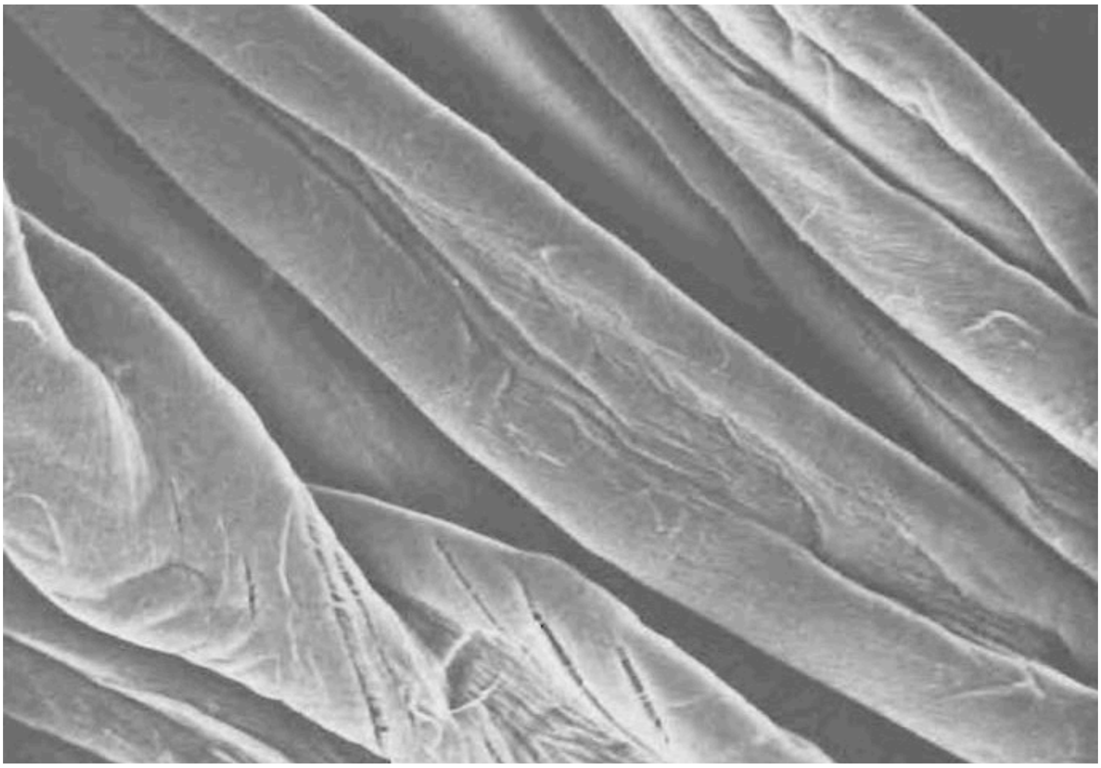

Figure 3.8 : A view of the cotton fibers (Needles, H. 1986).

The second type of recycled textile waste fiber consists of polyester fibers. Polyester fibers are chemical fibers with synthetic raw materials. In this thesis, polyester fibers obtained by recycling of PET (Polyethylene terephthalate) bottles were used in mortar mixtures. PET has usage areas such as soft drink, food and beverage containers, and polyester fibers. Polyethylene terephthalate polyester is the most commonly used man-made fiber and owes its popularity to its versatility alone or as a blended fiber in textile structures (Needles, H. 1986). The polyester fiber has a specific gravity of 1.38 g/cm^3. PET fibers are quite hydrophobic with a water absorption capacity of between 0.2-0.8% by weight. Polyester fibers are resistant to weak acids even at the boiling point. They have good resistance to strong acids at room temperature while poor resistance to strong bases. Melting point of polyester fibers is 250 °C (MEB, 2011; Saçak, M., 1994; Needles, H. 1986). Microscopic view of cotton fibers is given in Figure 3.9.

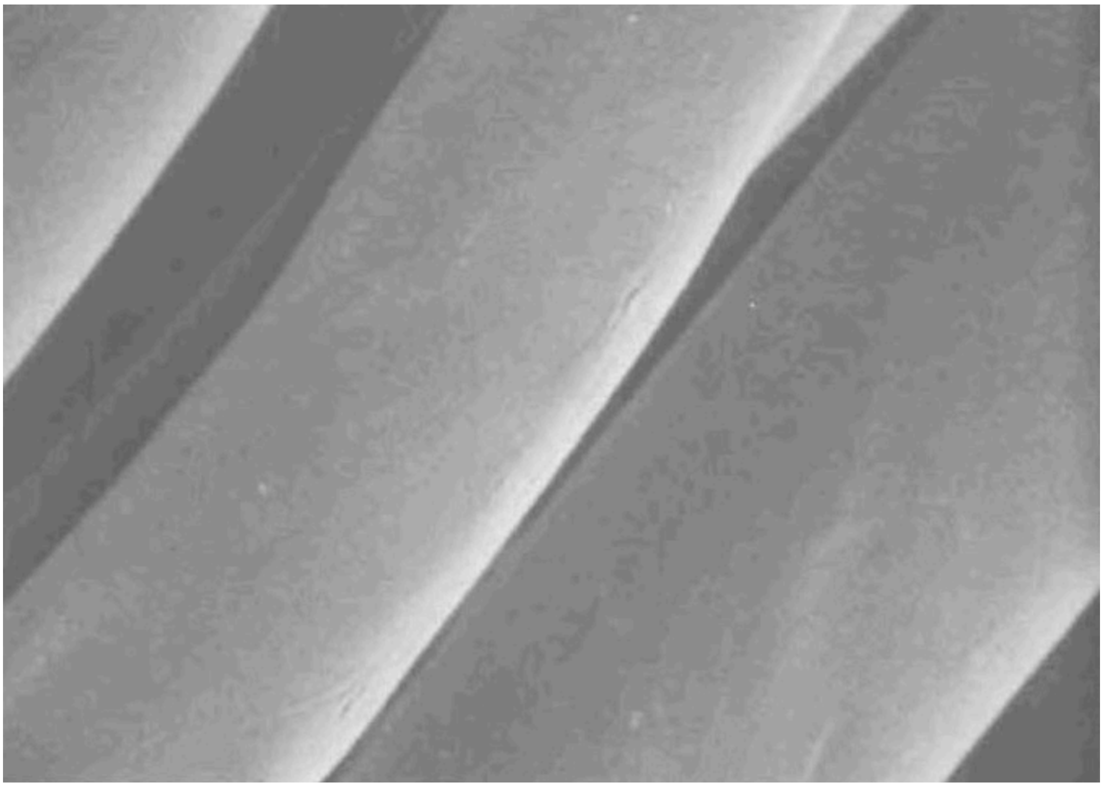

Figure 3.9 : A view of the polyester fibers (Needles, H. 1986).

The third type of textile waste used in this study is the mixture of cotton fibers and polyester fibers. These fibers are fibers obtained by recycling products sewn from cotton and polyester yarns together.

The last type of recycling textile waste fiber is the mixture of cotton waste fiber, polyester waste fiber and acrylic waste fiber, which is the remaining waste from the recycling stage of the acrylic products were made from synthetic fibers. Acrylic fibers are obtained by mixing ratio of 85% acrylonitrile polymers and more than one monomers with a ratio of 15%. The acrylic fibers have low specific gravities of between 1.16-1.18 g/cm^3. Acrylic fibers are quite hydrophobic with a water absorption capacity of between 0.3-1.3% by weight. Acrylic fibers are resistant to other acids except nitric acid. Especially dense and hot state alkali damages the fibers. There is not a certain melting point of the acrylic fibers. Melting point of them ranges from 215 to 255 ° C (MEB, 2011; Saçak, M., 1994; Needles, H. 1986). Microscopic view of cotton fibers is given in Figure 3.10.

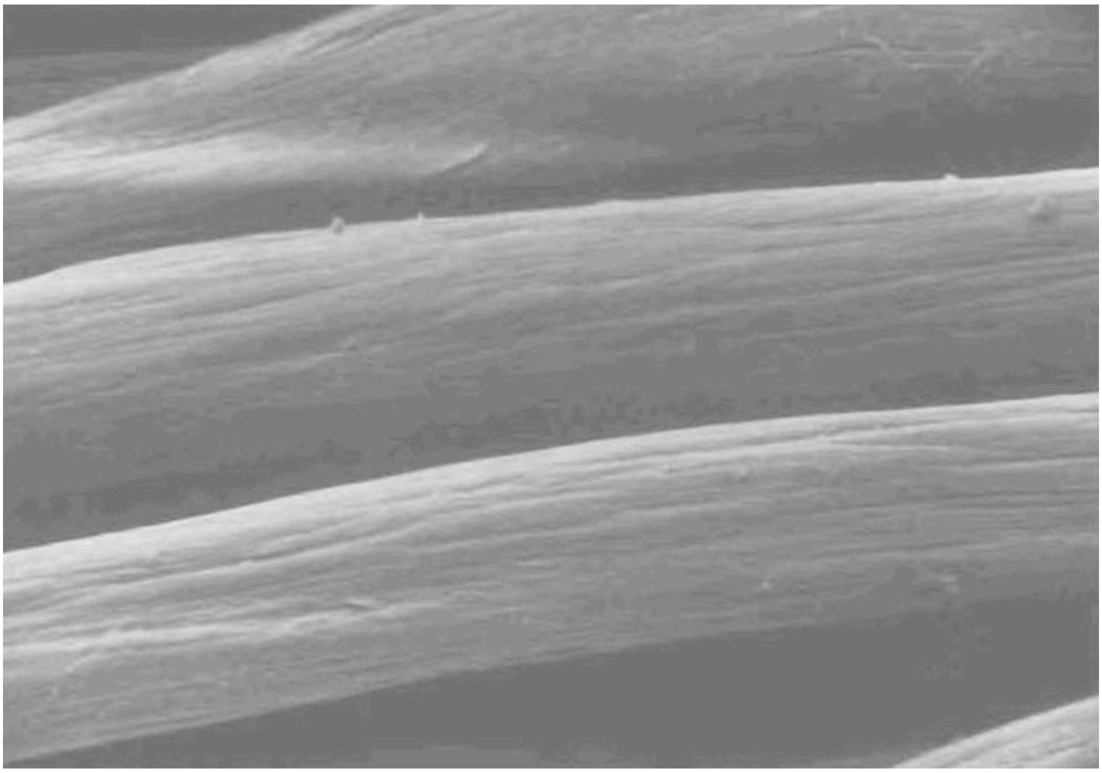

Figure 3.10 : A view of the acrylic fibers (Needles, H. 1986).

Four different types of recycled textile waste fiber were used in this study to understand the effects of them on mortar's physical and mechanical properties. Any pretreatment was not applied to the textile waste fibers used.

3.1.9. Water

Water used in mortar production has two important functions. The first of which is to make the dry matter mortar into a workable mass and the second is to make the plastic mass harden by chemical reaction with cement (Karcı, M., 2011). Water should be used in the production of mortar in a clean and non-negative impact manner. Drinking water can be used in the production of cement based mortars (Emekyapar and Örüng, 1993).

To provide the hydration of cement based composite mortars prepared in this thesis, tap water in İzmir Katip Çelebi University Construction Materials Laboratory was used.

3.2. Mix Design

Recycling has become a sector of considerable importance to developed countries. With developing technology, new materials and/or raw material can be obtained as a result of recycling of many materials. Textile wastes are also one of these materials. Textile waste fabrics are shredded and turned into fiber in the recycling plants. The scope of this study is to evaluate these shredded different types of textile fibers in cement based composite mortars. For this purpose, the methods described below were followed.

- First of all, fibers of different types but similar lengths were obtained from Uşak Region, the center of textile recycling industry in Turkey. No further treatment was made to these fibers and they were used directly in the mortar mixture.
- After the fibers were supplied, suitable aggregates and filler materials were selected.
- Various cement ratios were tried and the most suitable ratio was found.
- The most ideal batch formulas had been established for the use of textile waste fibers.
- The lowest and highest ratios of the amount of fiber in the mortar were determined.
- In the last stage, a series of experimental studies have been carried out in accordance with the TS EN, ASTM and TS standards for the investigation of the evaluation of different fiber types in the new generation cementitious composite mortars. The results of these experimental works will be examined in detail in the test results section.

Every stage of this thesis study was experimentally performed in the laboratory environment. Pictures of the mixture of the raw materials before the addition of water, the plastic phase of mixture of the raw materials after the addition of water, molding of the plastic mixture and demolding and hardened state of the plasters are given in between Figure 3.11 and Figure 3.14.

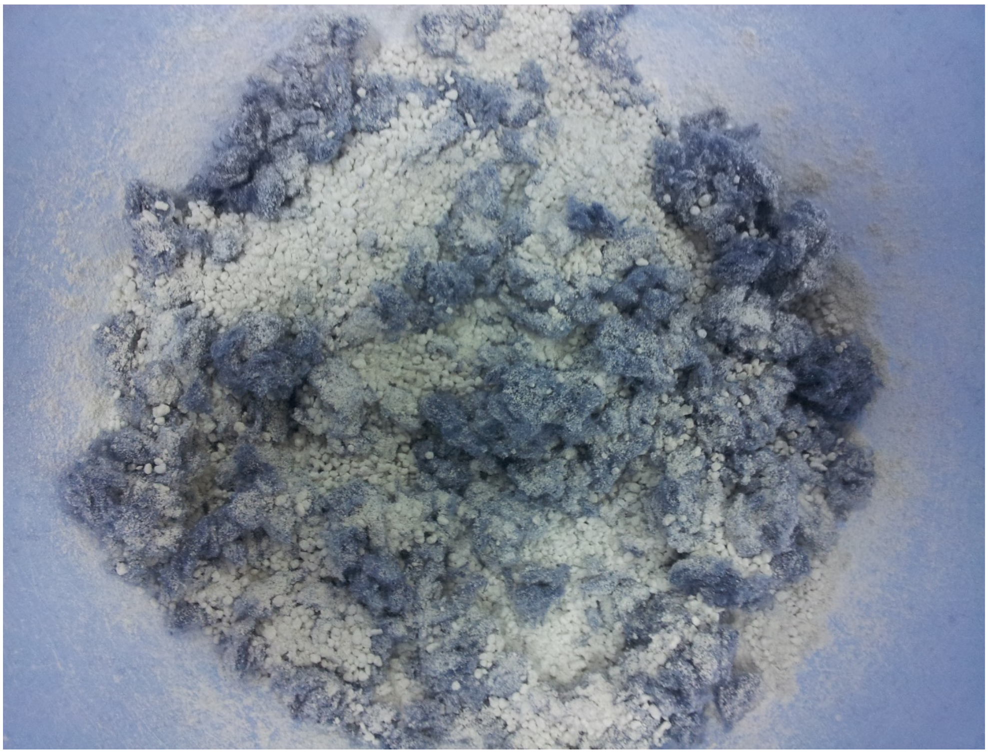

Figure 3.11 : Mixture before the addition of water.

Figure 3.12 : Mixture after the addition of water.

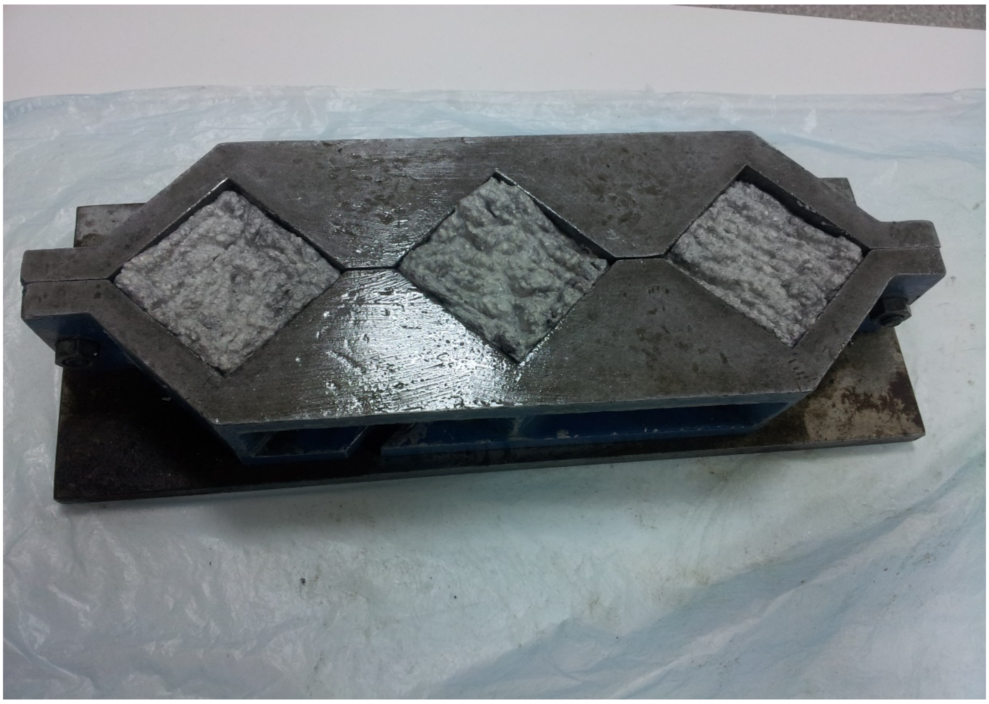

Figure 3.13 : Molding of the plastic mixture.

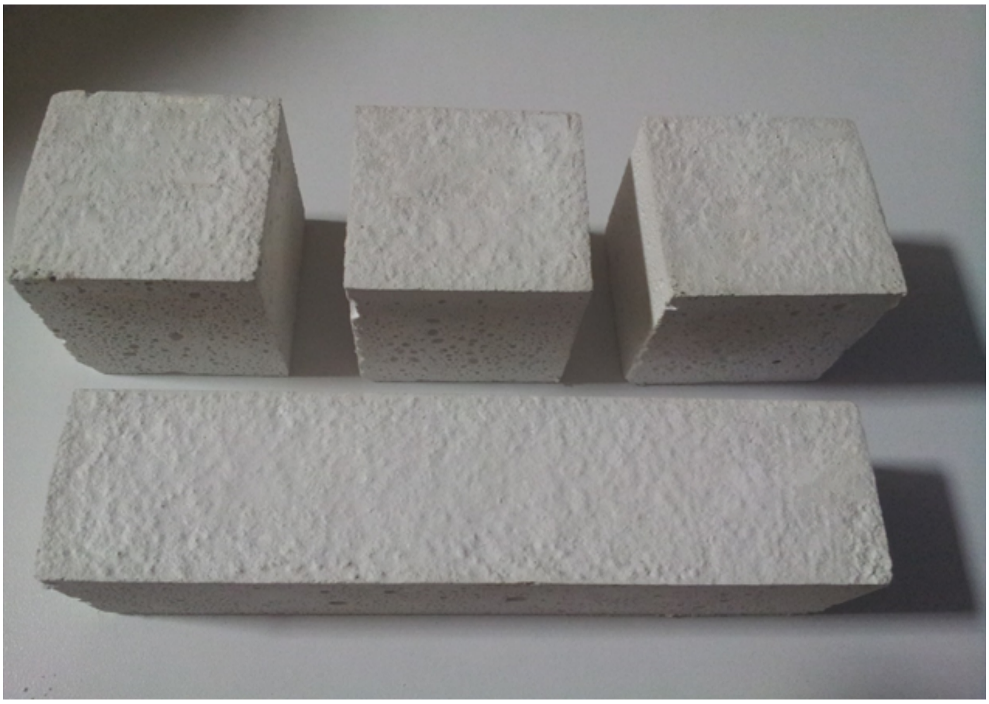

Figure 3.14 : Hardened state of the plasters.

Mixture design of the lightweight cement matrix composite mortar combinations for this experimental study is given in Table 3.7. Mixture proportioning was carried out according to the mix design methodology currently prescribed in TS EN 998-1 and the relevant standards. Twenty-five different cementitious composite mortar combinations were prepared and analyzed in order to evaluate the potential interest of using 2 to 5 cm sized textile waste fibers on cement based lightweight composite mortars.

Table 3.7 : Mixture constituents and designation for testing mortar.

Mix	WOPC (wt%)	Fine and Coarse NPA (wt%)	EPA (wt%)	Calcite (wt%)	HPL (wt%)	Fiber (wt%)
CM	29.0	45.0	8.5	10.9	5.5	0.0
075C	29.0	45.0	8.5	10.15	5.5	0.75
15C	29.0	45.0	8.5	9.4	5.5	1.5
2C	29.0	45.0	8.5	8.9	5.5	2.0
3C	29.0	45.0	8.5	7.9	5.5	3.0
4C	29.0	45.0	8.5	6.9	5.5	4.0
5C	29.0	45.0	8.5	5.9	5.5	5.0
075CP	29.0	45.0	8.5	10.15	5.5	0.75
15CP	29.0	45.0	8.5	9.4	5.5	1.5
2CP	29.0	45.0	8.5	8.9	5.5	2.0
3CP	29.0	45.0	8.5	7.9	5.5	3.0
4CP	29.0	45.0	8.5	6.9	5.5	4.0
5CP	29.0	45.0	8.5	5.9	5.5	5.0
075P	29.0	45.0	8.5	10.15	5.5	0.75
15P	29.0	45.0	8.5	9.4	5.5	1.5
2P	29.0	45.0	8.5	8.9	5.5	2.0
3P	29.0	45.0	8.5	7.9	5.5	3.0
4P	29.0	45.0	8.5	6.9	5.5	4.0
5P	29.0	45.0	8.5	5.9	5.5	5.0
075CPA	29.0	45.0	8.5	10.15	5.5	0.75
15CPA	29.0	45.0	8.5	9.4	5.5	1.5
2CPA	29.0	45.0	8.5	8.9	5.5	2.0
3CPA	29.0	45.0	8.5	7.9	5.5	3.0
4CPA	29.0	45.0	8.5	6.9	5.5	4.0
5CPA	29.0	45.0	8.5	5.9	5.5	5.0

According to the Table 3.7, the amount of cement ratio was kept constant as 29% by weight throughout the study for all mixtures. Again, the amounts of the NPA, EPA and HPL in the mixtures were also kept constant as 45%, 8.5% and 5.5%, respectively by weight throughout the experimental research. As can be seen in the table, the increase in fiber ratio is achieved by reducing the ratio of calcite filler.

First mortar mixture, which is named as CM (Control Mix), was analyzed as a reference mortar and this mixture does not contain any textile recycling fiber additive. This batch actually was undertaken to understand impact of textile recycling fiber to the mortar's properties by comparing this batch with the other samples and to determine mean compressive strength, flexural strength, splitting tensile strength, thermal conductivity value and unit weight values of mortar mixtures by the effect without fiber additive.

In order to examine the physical and mechanical properties of cement based composite mortars reinforced with various types of fibers, four different types of textile waste fiber were studied in this research. First six mixtures after control sample (075C, 15C, 2C, 3C, 4C, 5C) were mixed with cotton fibers and this group was named as Type 1 textile waste fiber, second six mixtures (075CP, 15CP, 2CP, 3CP, 4CP, 5CP) were mixed with a combination of cotton and polyester fibers and this group was named as Type 2 textile waste fiber, the third six mixtures (075P, 15P, 2P, 3P, 4P, 5P) were mixed with only polyester fibers and this group was named as Type 3 textile waste fiber and the last six mixtures group (075CPA, 15CPA, 2CPA, 3CPA, 4CPA, 5CPA) were mixed with a combination of cotton, polyester and acrylic fibers and this group was named as Type 4 textile waste fiber in this study. In mixture coding, the numbers at the beginning of the codes are represents the percent fiber content by weight in the mixture and the letters came after numbers represent the first letters of fiber types.

Mixing was carried out by a mortar mixer then the plastic state samples were casted and left for 24 hours. After that, samples were removed from the molds and placed in wet surface curing condition up to first 3 days and then left drying in a normal room condition until the testing times.

In this work, the influence of four different types of textile waste fiber was investigated in the usage of 0.75, 1.5, 2, 3, 4 and 5%, respectively. The properties of fresh mortar samples, i.e. fresh and plastic set density were studied; then, the compressive strength and flexural strength at the age of 7 and 28 days were investigated, too. Also, splitting tensile strength of hardened mortars was tested on 14 and 28 days curing time. In order to evaluate the mechanical properties of the mortar samples, compressive strength test was carried out on cubic specimens, flexural strength test was carried out on prismatic samples and splitting tensile strength test was carried out on cylindrical specimens. Samples after preparation molded and left in the casting room for 24 hours then they were remolded and moved into the wet surface curing condition up to first 3 days in a guarded moisture cup. Then all specimens were moved into an open and dry cup for curing in normal room conditions until the testing time. Compressive, flexural and splitting tensile strength tests were conducted on 50x50x50 mm cubic test samples, 40x40x160 mm prismatic test samples and Ø50x100 mm cylindrical test samples, respectively. Compressive, flexural and splitting tensile strength of all samples were determined as the average value taken from 3 specimens as per the relevant standards. Structural strength values of the cement matrix composite mortars have been achieved through splitting tensile and compressive strength tests by using Mohr Circles.

3.3. Methods

In this section, the experimental studies performed within the scope of the thesis and the devices used in these studies are going to be explained. Experimental methods used for study on the evaluation of textile waste fibers in cement based composite mortars and related standards used for these methods are given in the Table 3.8.

Table 3.8 : Methods used in experimental works and related standards.

Name of Analysis	Experimental Method
Dry bulk density analysis	TS EN 1015-10 : Determination of dry bulk density of hardened mortar
Dry unit volume weight of hardened mortar analysis	TS EN 1015-10 : Determination of dry bulk density of hardened mortar
Compressive strength analysis of hardened mortar	TS EN 1015-11 : Determination of flexural and compressive strength of hardened mortar
Flexural strength analysis of hardened mortar	TS EN 1015-11 : Determination of flexural and compressive strength of hardened mortar
Splitting tensile strength anaysis for hardened mortar	ASTM C496 : Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens
Thermal conductivity analysisi for hardened mortar	TS EN 1745 : Methods for determining thermal properties TS EN ISO 8990 : Determination of steady-State thermal transmission properties-Calibrated and guarded hot box TS EN ISO 6946 : Thermal resistance and thermal transmittance - Calculation method

3.3.1. Compressive strength test

Compressive strength is the ability of the material to resist the break under axial load impact. The compressive strength tests were conducted according to EN 1015-11 standard. In the compressive strength tests, cubic samples were used for each batch. The samples, after removal from the molds and cured at 3 days and then dried at room temperature until the testing time, were taken directly on the compressive strength test without any further action. The compressive strength tests were done at 7 and 28 days curing times for all batches. For the compressive strength test, 50x50x50 mm cubic samples were used.

According to TS EN 998-1 standard, the mortars must have a certain compressive strength characteristic. This characteristic is determined by calculating the amount of load per unit area via the compressive strength device. The 303 kN capacity compressive strength test device used in the study is shown in Figure 3.15. The left part of the device shown in the figure is used for compressive strength.

Figure 3.15 : Automatic test press for compression and flexure (Url-5).

Compressive strength values of cement based mortar samples are divided by 4 different groups in TS EN 998-1 standard at 28 days curing time. Table 3.9 shows the compressive strength ranges according to the relevant standard.

Table 3.9 : Classification of compressive strength values according to the TS EN 998-1 standard.

Curing Time	Classes	Values
28 days	CS I	0.4 – 2.5 N/mm^2
	CS II	1.5 – 5.0 N/mm^2
	CS III	3.5 – 7.5 N/mm^2
	CS IV	≥ 6 N/mm^2

As an image of the samples used in the compressive strength test is given in Figure 3.16.

Figure 3.16 : 50x50x50 mm cubic samples for compressive strength test.

3.3.2. Flexural strength test

Flexural strength is a measure of cement based materials to resist failure in bending. The flexural strength of hardened composite mortars is determined by three point loading of the prism specimens. Size of prismatic samples was 40x40x160 mm. For flexural strength, prismatic samples were tested by a 30 kN capacity flexural strength test device shown in Figure 3.17. The right part of the device shown in the figure is used for flexural strength. The automatic test device is not sufficient alone for the bending test. Bending Test Apparatus is required to perform bending test. The testing apparatus has two supporting rollers; there is 100 mm span between two supports, and a third roller, which is the loading roller, located above the test specimen and midway between the supporting rollers. Figure 3.18 shows the three-point flexural strength apparatus.

The flexural strength is calculated from the equation below:

$$\sigma_f = \frac{3PL}{2bd^2} \tag{3.1}$$

In the formula 3.1, P is the axial load at the fracture point, L is the span between two support, b is the width of the sample, d is the depth of the material.

Figure 3.17 : Automatic test press for compression and flexure (Url-6).

Figure 3.18 : Three point flexural testing apparatus (Url-7).

As an image of the samples used in the flexural strength test is given in Figure 3.19.

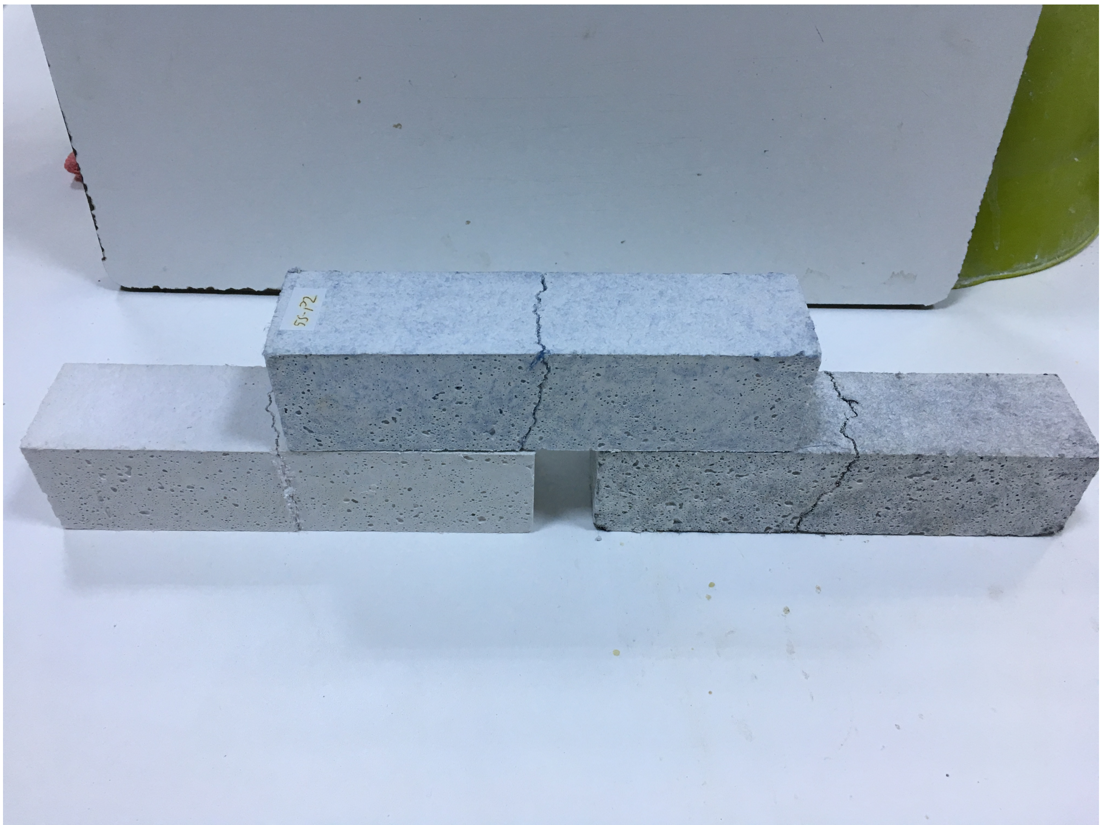

Figure 3.19 : 40x40x160 mm prismatic samples for flexural strength test.

3.3.3. Splitting tensile test

Within the scope of this study, splitting tensile strength test was performed. The simplest and most frequently applied method used to determine the tensile strength of concrete is splitting tensile test also known as the Brazillian Test. This test provides a lower coefficient of variation. In splitting tensile test, same materials and equipment are used with compression test. This test is performed by applying a diametric compressive force along the length of a cylindrical specimen between two plates (Arıoğlu, N., et al. 2006; Hannant, D., et al., 1973; Kadleček, V., et al. 2002).

Cylindrical specimens were used in the splitting tensile strength test. The dimensions of all the samples used in this experiment were Ø50x100 mm. The samples, after removal from the molds, they cured at 3 days in a wet surface condition and then dried at room temperature until the testing time. They were taken directly on the test without any further action after 28 days curing time. The system applied to break the sample is given in the Figure 3.20. As an image of the samples used in the compressive strength test is given in Figure 3.21.

The flexural strength is calculated from the equation below:

$$\sigma_{sp} = \frac{2P}{\pi D L} \tag{3.2}$$

In the formula 3.2, P is the axial load at the fracture point, L is the length of the sample and D is diameter of the sample.

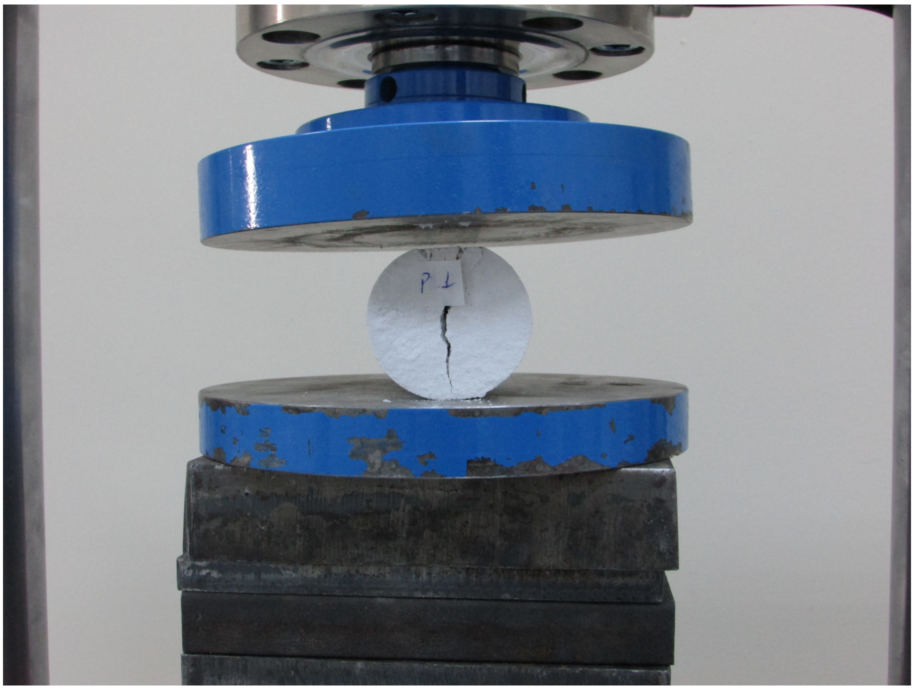

Figure 3.20 : Splitting tensile test.

Figure 3.21 : Ø50x100 mm cylindrical samples for splitting tensile strength test.

3.3.4. Thermal conductivity test

The thermal conductivity values of the samples produced in plate form were found by hot box experiment. This experiment was performed according to the prescribed rules in the “TS EN ISO 8990 - Determination of steady-state thermal transmission properties-calibrated and guarded hot box” standard.

Figure 3.22 shows the hot box device. The hot box used for this experiment is a well-insulated device and it consists of three parts. Left part of the device is hot room, middle part is sample room and the right part is cold room. The sample is divided the device into two parts when it is placed the middle part. Between hot room and the sample room remains open, but the samples close the front of the cold room. A heater and a ventilator are in continuous operation in the hot room. Thus, the air efficiency in this section is maintained. The sample in the middle part cuts the expected heat flow from the hot room to the cold. So that the cold room is expected to be remain colder than the hot room. During the test, the temperatures of the hot room and the cold room are measured with thermocouples. Also, the temperature of hot face and cold face of the sample is measured during the experiment. The temperatures are measured in degrees centigrade and sensitivity of the thermocouples is 0.1°C.

Figure 3.22 : Hot Box device.

4. TEST RESULTS AND DISCUSSIONS

Some analyses were carried out on samples produced, such as, dry unit volume weight analysis, compressive, flexural and splitting tensile strength analysis, within the scope of this thesis study. Four types of fibers, cotton, polyester, cotton-polyester mix and cotton-polyester-acrylic mix fibers, were used in the composite mortars. For each fiber type, 0.75, 1.5, 2.0, 3.0, 4.0 and 5.0% textile waste fiber consumption by weight is achieved. The analysis of the materials mentioned above indexed to the amount of fiber used has been examined in detail in this section. General characteristics of the samples are given in Table 4.1 and Table 4.2.

Table 4.1 : General mechanical characteristics of samples.

Mix	Water/Solid Ratio	Compressive Strength at 28 days (N/mm^2)	Flexural Strength at 28 days (N/mm^2)	Splitting Tensile Strength at 28 days (N/mm^2)
CM	0.73	2.19	1.88	0.46
075C	0.78	2.59	1.71	0.44
15C	0.82	2.26	1.61	0.39
2C	0.93	1.59	1.57	0.35
3C	1.02	1.54	1.29	0.31
4C	1.10	1.46	1.22	0.29
5C	1.25	1.23	0.96	0.26
075CP	0.70	3.53	2.25	0.60
15CP	0.74	3.37	2.12	0.52
2CP	0.78	2.80	2.06	0.48
3CP	0.86	2.33	1.57	0.43
4CP	0.93	1.98	1.36	0.33
5CP	1.03	1.38	1.17	0.30
075P	0.75	2.54	1.78	0.55
15P	0.87	2.25	1.48	0.45
2P	0.88	1.99	1.41	0.43
3P	0.93	1.77	1.24	0.38
4P	1.01	1.29	1.06	0.35
5P	1.04	1.22	0.96	0.32
075CPA	0.74	3.37	2.23	0.62
15CPA	0.84	2.60	1.85	0.44
2CPA	0.91	2.14	1.59	0.38
3CPA	0.96	2.07	1.55	0.35
4CPA	1.04	1.72	1.29	0.31
5CPA	1.21	1.23	1.01	0.25

Table 4.2 : General physical characteristics of the samples and their relation.

Mix	Dry Unit Volume Weight (kg/m^3)	Compressive Strength at 28 days (N/mm^2)	Flexural Strength at 28 days (N/mm^2)	Splitting Tensile Strength at 28 days (N/mm^2)	Thermal Conductivity (λ)
CM	654	2.19	1.88	0.46	0.121
075C	666	2.59	1.71	0.44	0.126
15C	664	2.26	1.61	0.39	0.126
2C	622	1.59	1.57	0.35	0.108
3C	607	1.54	1.29	0.31	0.102
4C	600	1.46	1.22	0.29	0.100
5C	556	1.23	0.96	0.26	0.085
075CP	730	3.53	2.25	0.60	0.157
15CP	728	3.37	2.12	0.52	0.156
2CP	725	2.80	2.06	0.48	0.155
3CP	700	2.33	1.57	0.43	0.142
4CP	678	1.98	1.36	0.33	0.132
5CP	606	1.38	1.17	0.30	0.102
075P	662	2.54	1.78	0.55	0.125
15P	632	2.25	1.48	0.45	0.112
2P	629	1.99	1.41	0.43	0.111
3P	619	1.77	1.24	0.38	0.107
4P	590	1.29	1.06	0.35	0.096
5P	576	1.22	0.96	0.32	0.091
075CPA	712	3.37	2.23	0.62	0.148
15CPA	656	2.60	1.85	0.44	0.122
2CPA	623	2.14	1.59	0.38	0.109
3CPA	620	2.07	1.55	0.35	0.107
4CPA	614	1.72	1.29	0.31	0.105
5CPA	563	1.23	1.01	0.25	0.087

4.1. Analysis of Dry Unit Volume Weight of Hardened Composite Plasters

Dry unit volume weight of hardened new generation composite plasters were analyzed according to the “TS EN 1015-10 Methods of test for mortar for masonry-Part 10: Determination of dry bulk density of hardened mortar” standard. This experiment was carried out on 6 samples for each mixture.

Usually heat insulation characteristic is directly proportional to the dry unit volume weight of materials. The material's thermal insulation value develops as the unit volume weight drops. In this respect, the low unit volume weight value is very important in terms of heat insulation.

The tested specimens were dried in oven. The unit volume weights of each series were examined comparatively. Dry unit volume weights of the samples are given in Table 4.3.

Table 4.3 : Unit volume weight of plasters.

Mix	Water/Solid Ratio	Wet Unit Volume Weight (kg/m^3)	Dry Unit Volume Weight (kg/m^3)	Water Loss Rate (%)
CM	0.73	927	654	29
075C	0.78	969	666	31
15C	0.82	995	664	33
2C	0.93	984	622	37
3C	1.02	998	607	40
4C	1.10	1030	600	42
5C	1.25	1019	556	45
075CP	0.70	1022	720	30
15CP	0.74	1052	728	31
2CP	0.78	1071	725	32
3CP	0.86	1074	700	35
4CP	0.93	1073	678	37
5CP	1.03	1024	606	41
075P	0.75	958	662	31
15P	0.87	954	622	35
2P	0.88	944	629	33
3P	0.93	978	619	37
4P	1.01	967	590	39
5P	1.04	963	576	40
075CPA	0.74	1028	712	31
15CPA	0.84	989	656	34
2CPA	0.91	962	613	36
3CPA	0.96	1008	630	38
4CPA	1.04	1026	614	40
5CPA	1.21	1003	563	44

According to Table 4.3, samples loose water between 30% and 45% by weight during drying. As the amount of fiber in the mixture increases, the water requirement also increases to obtain a workable sample. The increase in the amount of water also increased the wet unit volume weights. Generally, unit volume weights were found higher than the control samples up to 1.5% fiber use in almost all batches. This means that up to this usage rate, the fiber addition settles the wet material. Conversely, the samples gain volume over 1.5% fiber usages in the mixtures. So that the weight of fiber-based materials over this ratio was found to be lower than the control sample. Hardened unit volume weight of plasters was found between 728 – 556 kg/m^3.

Unit volume weights (UVW) of composite plasters are analyzed in this section. Graphs showing the drying characteristics of the samples are given in Figure 4.1 – Figure 4.25, respectively.

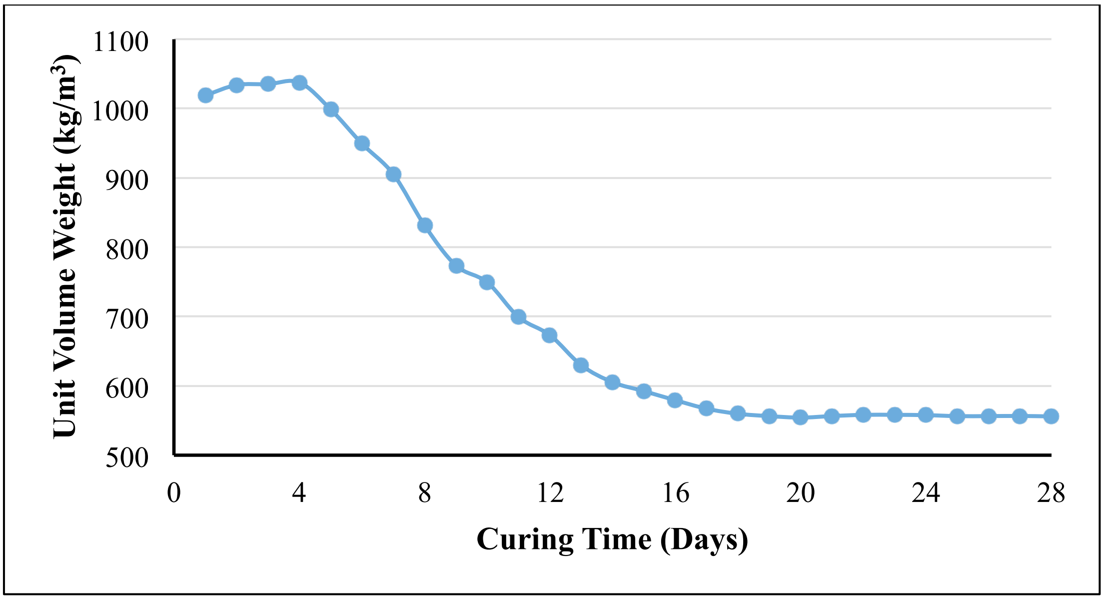

Figure 4.1 : UVW vs curing time for control mix.

According to the Figure 4.1, the UVW of CM sample, prepared with 0.73 Water/Solid (W/S) ratio, was not change after 19th day of curing. CM sample lose the water in the body at 19th day.

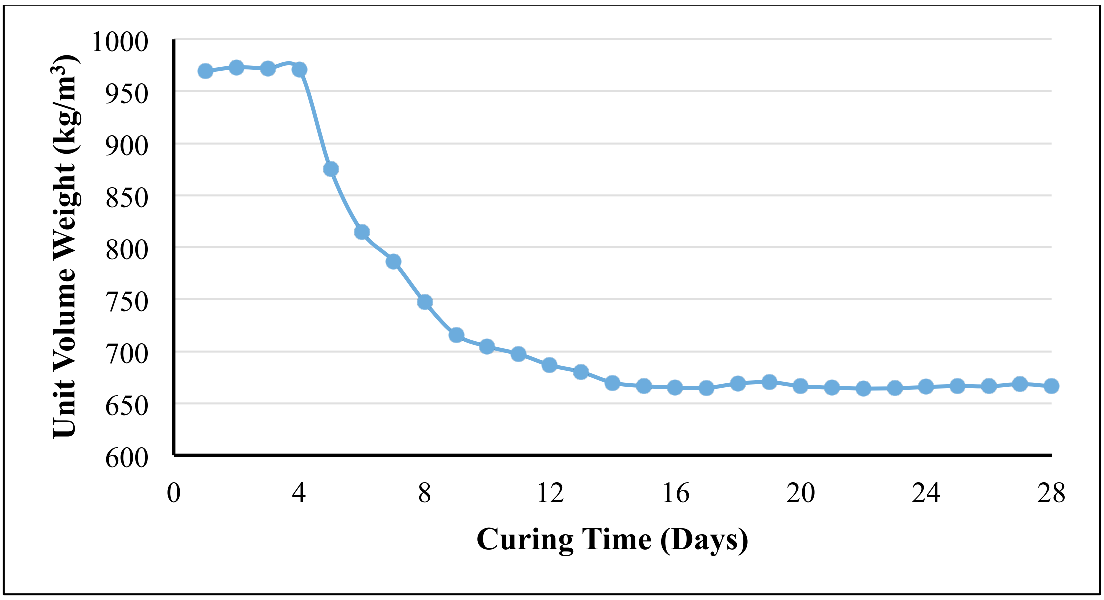

Figure 4.2 : UVW vs curing time for plaster containing 0.75% cotton fiber.

According to the Figure 4.2, the UVW of 075C sample, prepared with 0.78 W/S ratio, was not change after 16th day of curing. 075C sample lose the water in the body at 16th day.

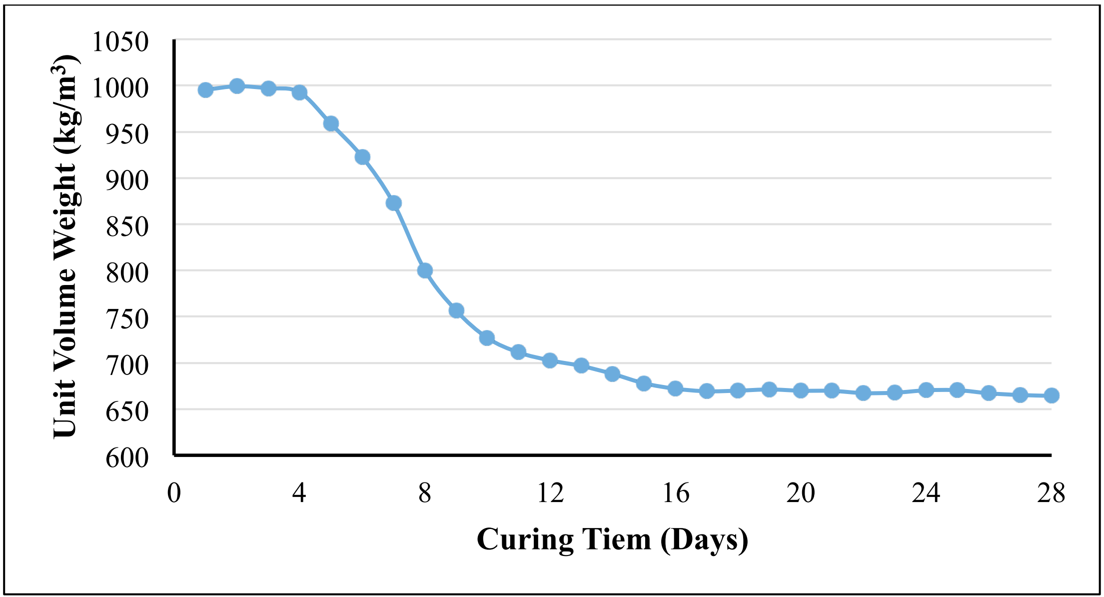

Figure 4.3 : UVW vs curing time for plaster containing 1.5% cotton fiber.

According to the Figure 4.3, the UVW of 15C sample, prepared with 0.82 W/S ratio, was not change after 16th day of curing. 15C sample lose the water in the body at 16th day.

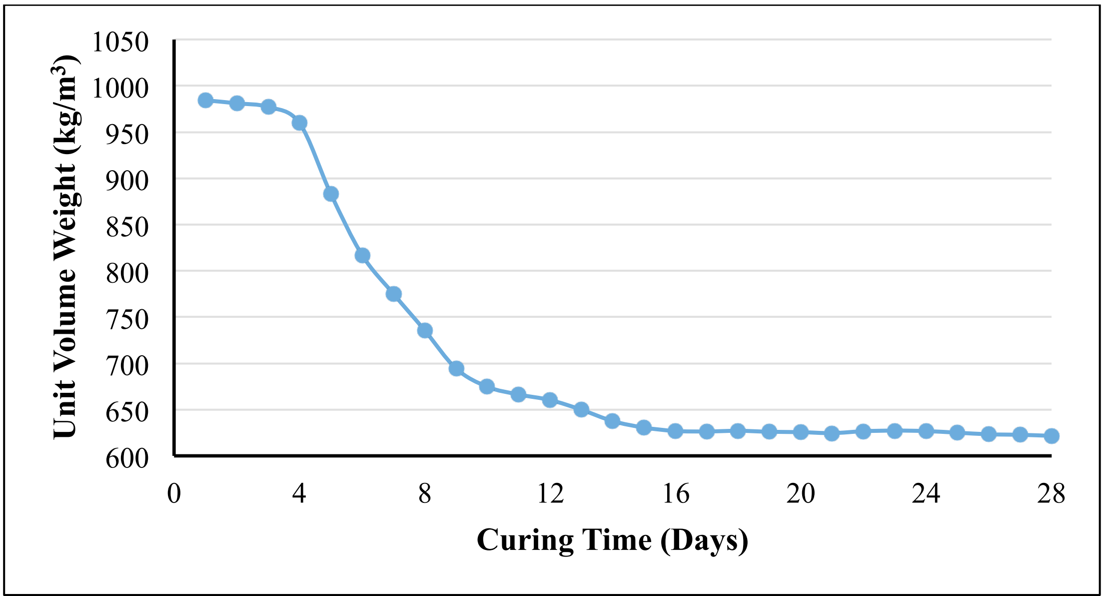

Figure 4.4 : UVW vs curing time for plaster containing 2.0% cotton fiber.

According to the Figure 4.4, the UVW of 2C sample, prepared with 0.93 W/S ratio, was not change after 16th day of curing. 2C sample lose the water in the body at 16th day.

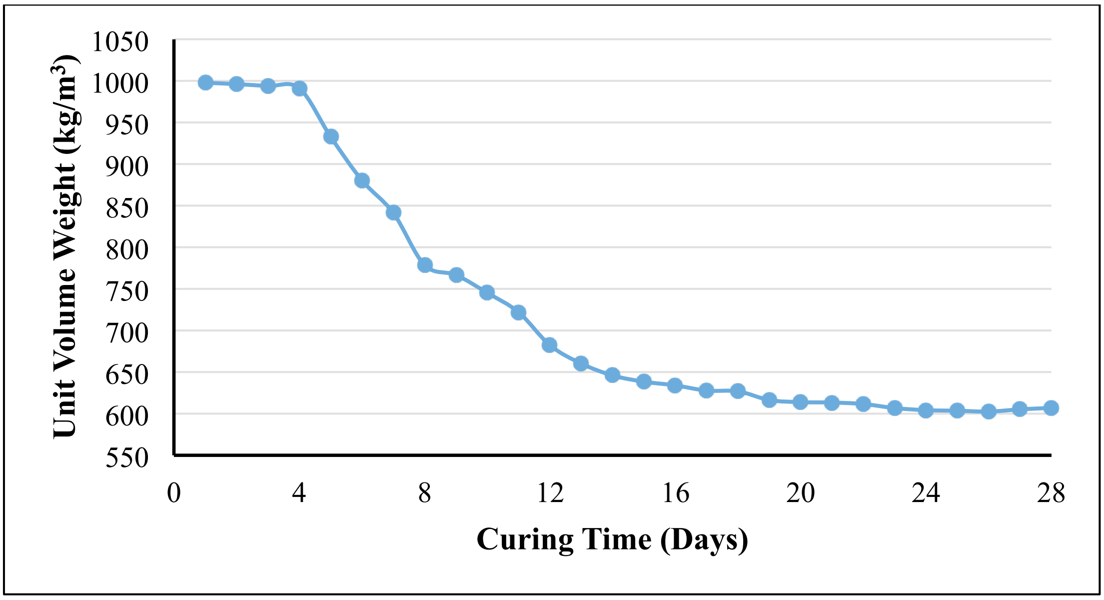

Figure 4.5 : UVW vs curing time for plaster containing 3.0% cotton fiber.

According to the Figure 4.5, the UVW of 3C sample, prepared with 1.02 W/S ratio, was not change after 24th day of curing. 3C sample lose the water in the body at 24th day.

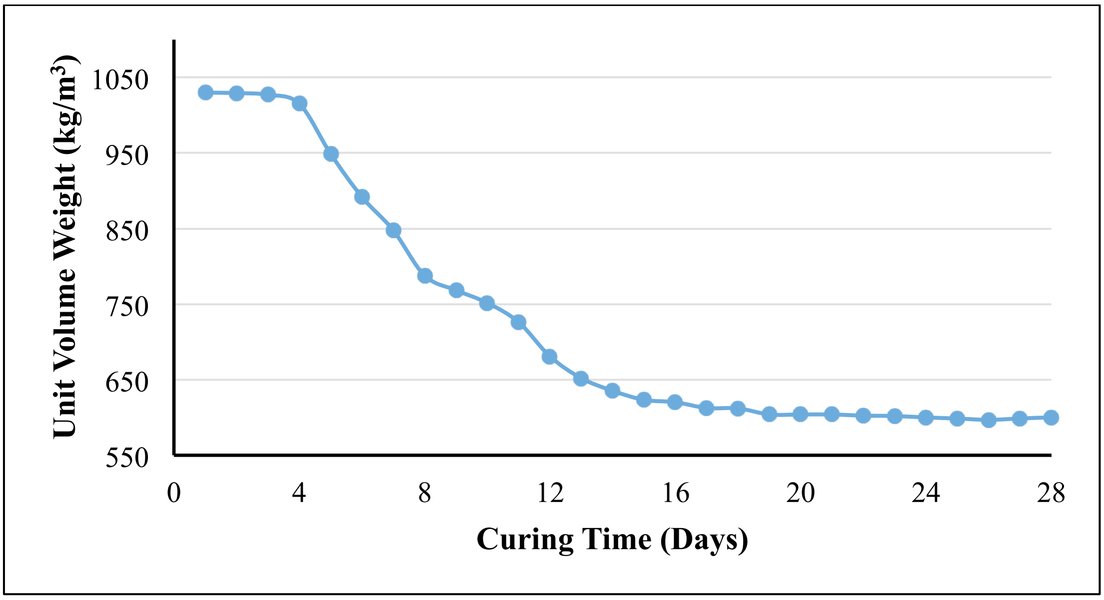

Figure 4.6 : UVW vs curing time for plaster containing 4.0% cotton fiber.

According to the Figure 4.6, the UVW of 4C sample, prepared with 1.10 W/S ratio, was not change after 19th day of curing. 4C sample lose the water in the body at 19th day.

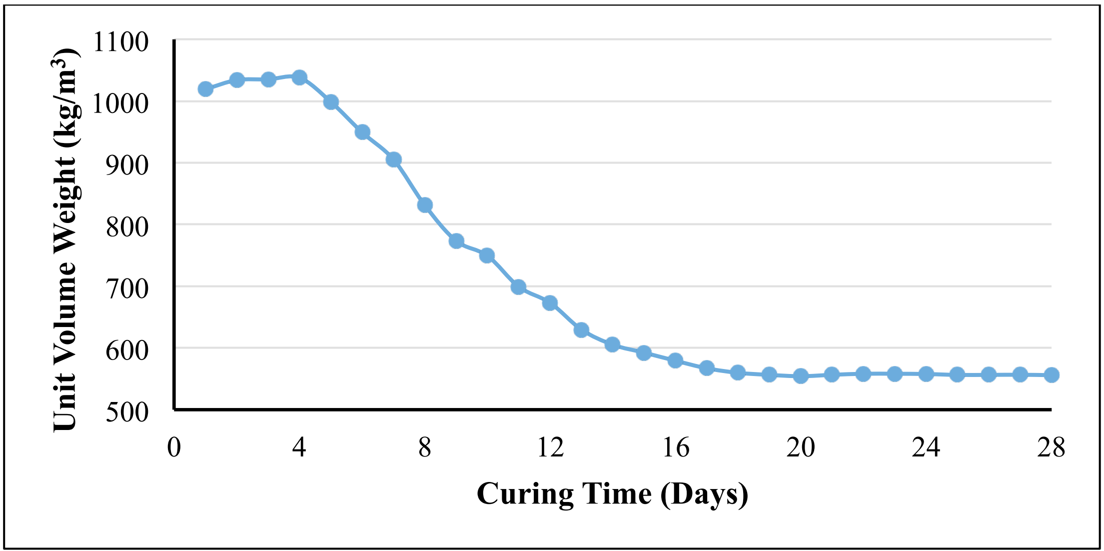

Figure 4.7 : UVW vs curing time for plaster containing 5.0% cotton fiber.

According to the Figure 4.7, the UVW of 5C sample, prepared with 1.25 W/S ratio, was not change after 19th day of curing. 5C sample lose the water in the body at 19th day.

It was analyzed that the composite plasters containing cotton waste fiber dried on average in 19-20 days. That corresponds to the time which the any treatment can be carried out on the applied plaster surface after such periods.

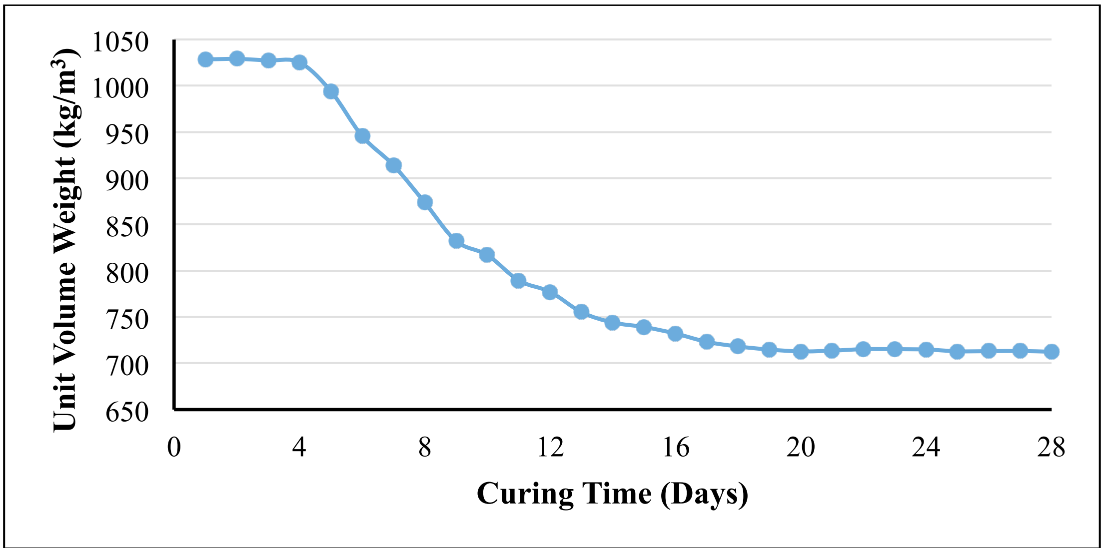

Figure 4.8 : UVW vs curing time for plaster containing 0.75% cotton+polyester+acrylic fiber.

According to the Figure 4.8, the UVW of 075CPA sample, prepared with 0.74 W/S ratio, was not change after 20th day of curing. 075CPA sample lose the water in the body at 20th day.

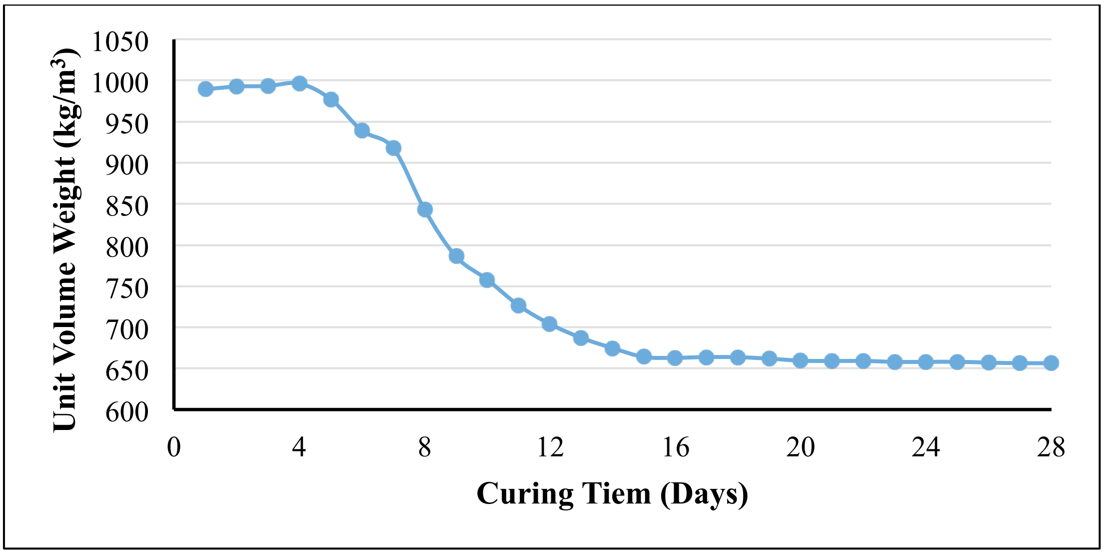

Figure 4.9 : UVW vs curing time for plaster containing 1.5% cotton+polyester+acrylic fiber.

According to the Figure 4.9, the UVW of 15CPA sample, prepared with 0.84 W/S ratio, was not change after 16th day of curing. 15CPA sample lose the water in the body at 16th day.

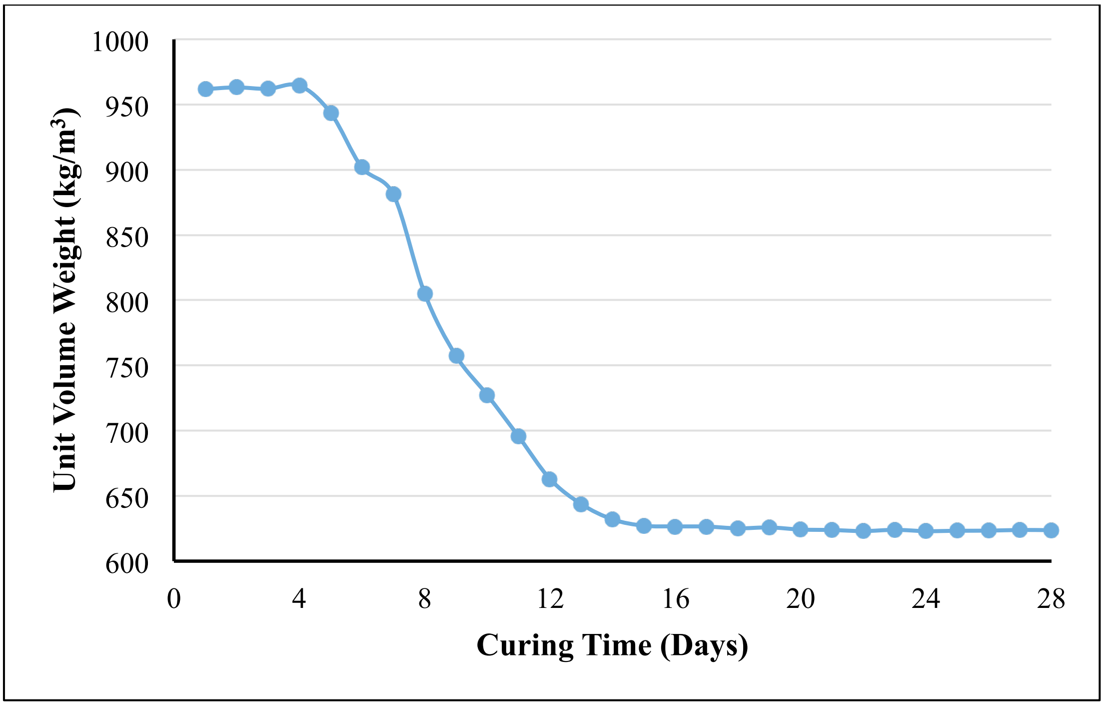

Figure 4.10 : UVW vs curing time for plaster containing 2.0% cotton+polyester+acrylic fiber.

According to the Figure 4.10, the UVW of 2CPA sample, prepared with 0.91 W/S ratio, was not change after 16th day of curing. 2CPA sample lose the water in the body at 16th day.

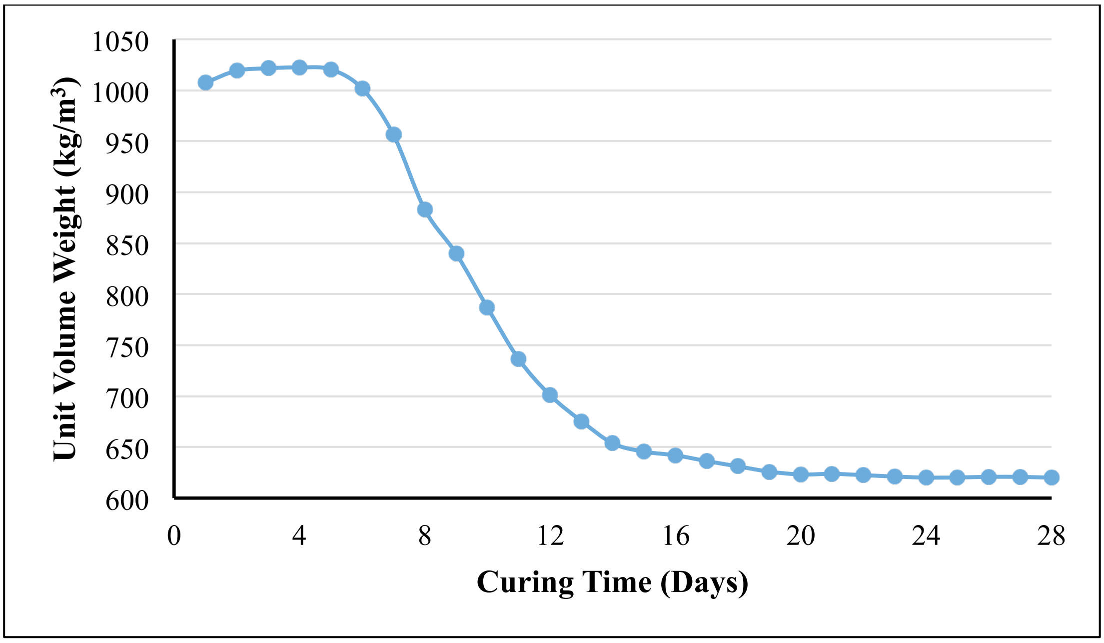

Figure 4.11 : UVW vs curing time for plaster containing 3.0% cotton+polyester+acrylic fiber.

According to the Figure 4.11, the UVW of 3CPA sample, prepared with 0.96 W/S ratio, was not change after 20th day of curing. 3CPA sample lose the water in the body at 20th day.

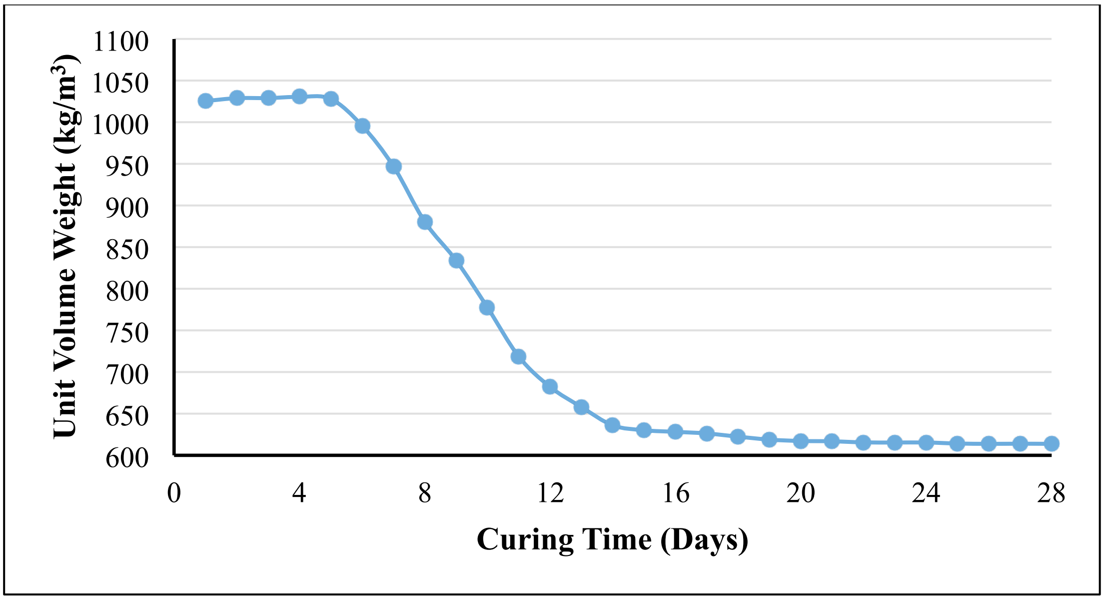

Figure 4.12 : UVW vs curing time for plaster containing 4.0% cotton+polyester+acrylic fiber.

According to the Figure 4.12, the UVW of 4CPA sample, prepared with 1.04 W/S ratio, was not change after 20th day of curing. 4CPA sample lose the water in the body at 20th day.

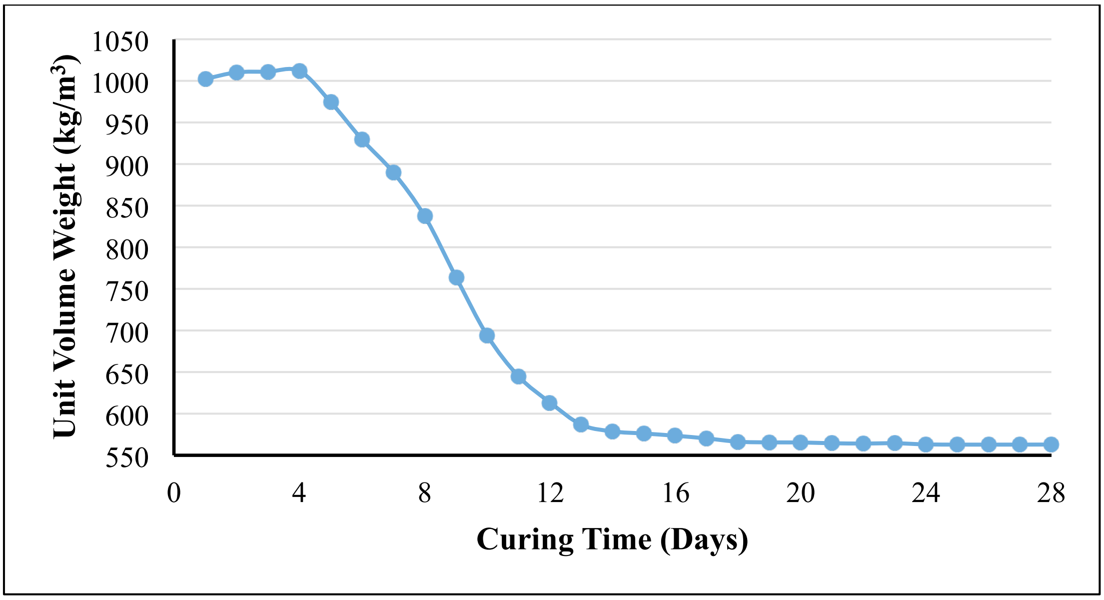

Figure 4.13 : UVW vs curing time for plaster containing 5.0% cotton+polyester+acrylic fiber.

According to the Figure 4.13, the UVW of 5CPA sample, prepared with 1.21 W/S ratio, was not change after 20th day of curing. 5CPA sample lose the water in the body at 20th day.

It seems that at the 15-16 days drying is slowing down. It was analyzed that the composite plasters containing mixture of cotton+polyester+acrylic waste fiber dried on average in 19-20 days. That corresponds to the time which the any treatment can be carried out on the applied plaster surface after such periods.

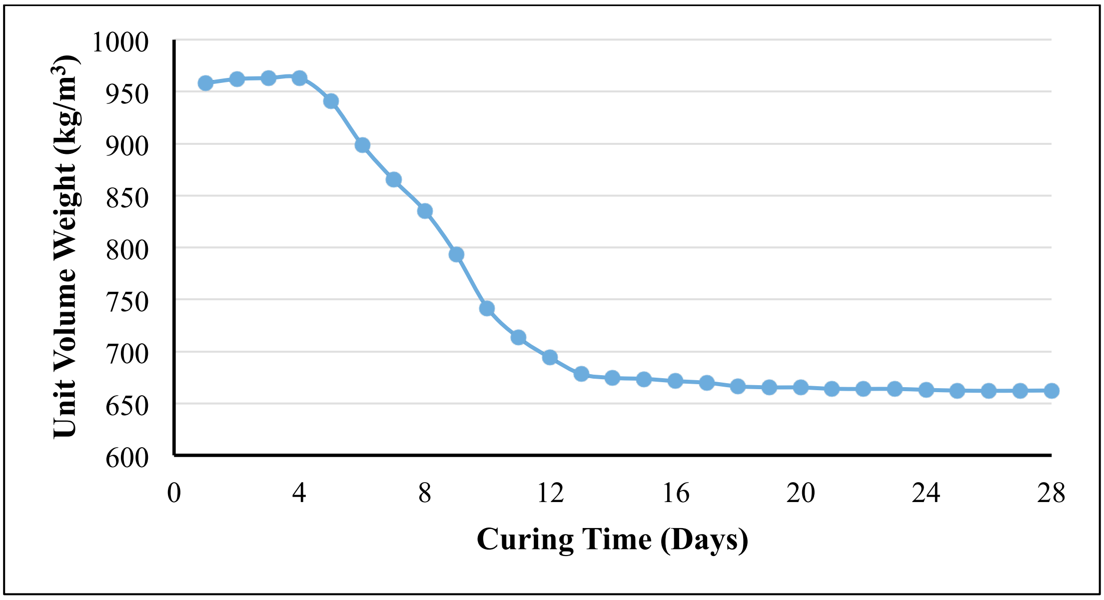

Figure 4.14 : UVW vs curing time for plaster containing 0.75% polyester fiber.

According to the Figure 4.14, the UVW of 075P sample, prepared with 0.75 W/S ratio, was not change after 19th day of curing. 075P sample lose the water in the body at 19th day.

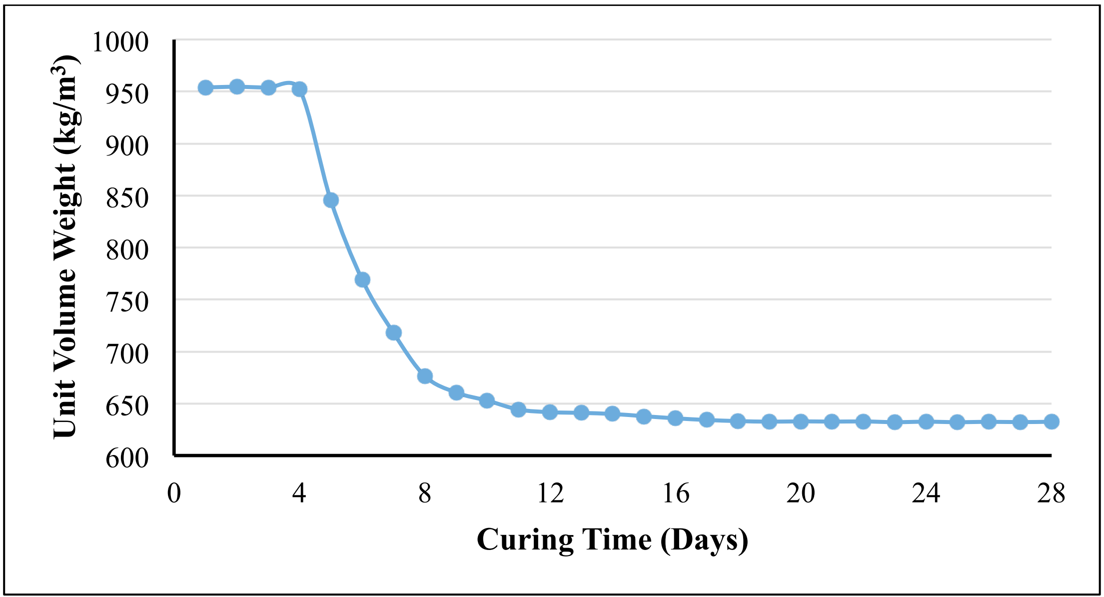

Figure 4.15 : UVW vs curing time for plaster containing 1.5% polyester fiber.

According to the Figure 4.15, the UVW of 15P sample, prepared with 0.87 W/S ratio, was not change after 16th day of curing. 15P sample lose the water in the body at 16th day.

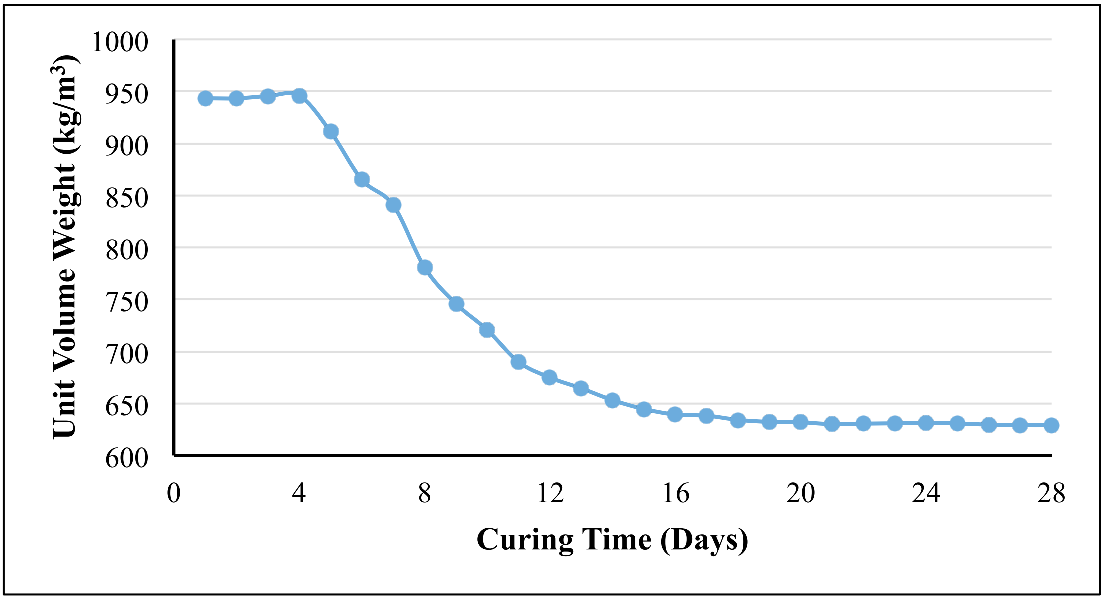

Figure 4.16 : UVW vs curing time for plaster containing 2.0% polyester fiber.

According to the Figure 4.16, the UVW of 2P sample, prepared with 0.88 W/S ratio, was not change after 20th day of curing. 2P sample lose the water in the body at 20th day.

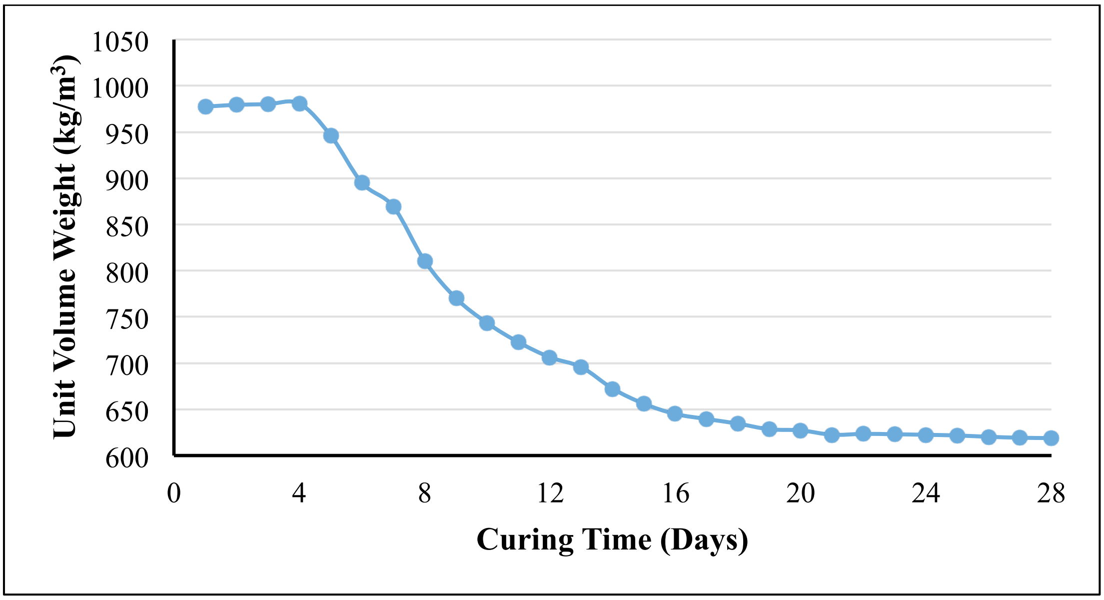

Figure 4.17 : UVW vs curing time for plaster containing 3.0% polyester fiber.

According to the Figure 4.17, the UVW of 3P sample, prepared with 0.93 W/S ratio, was not change after 21th day of curing. 3P sample lose the water in the body at 21th day.

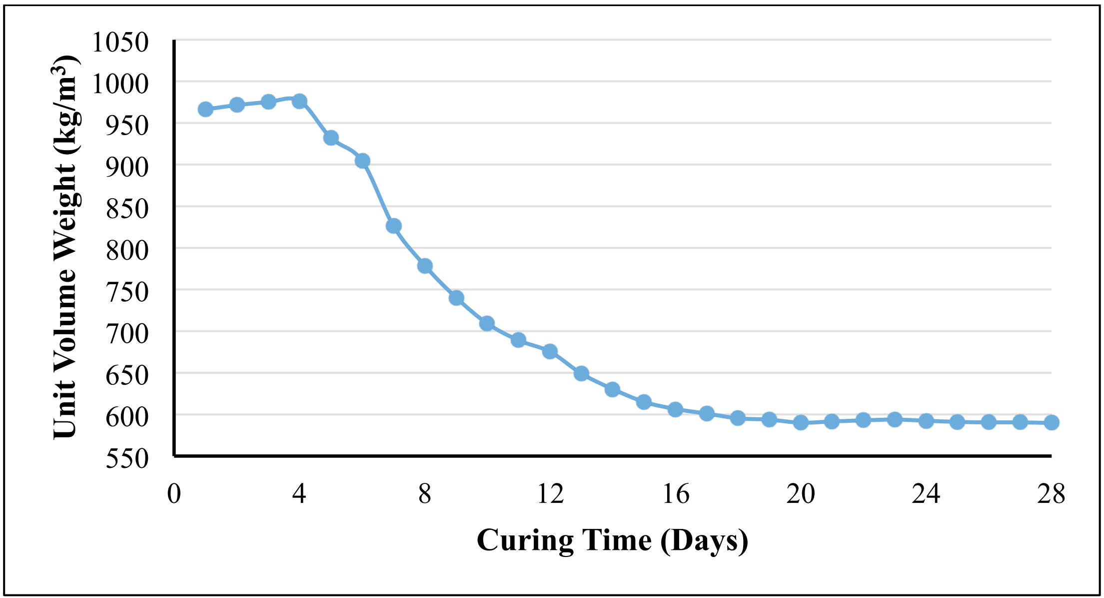

Figure 4.18 : UVW vs curing time for plaster containing 4.0% polyester fiber.

According to the Figure 4.18, the UVW of 4P sample, prepared with 1.01 W/S ratio, was not change after 21th day of curing. 4P sample lose the water in the body at 21th day.

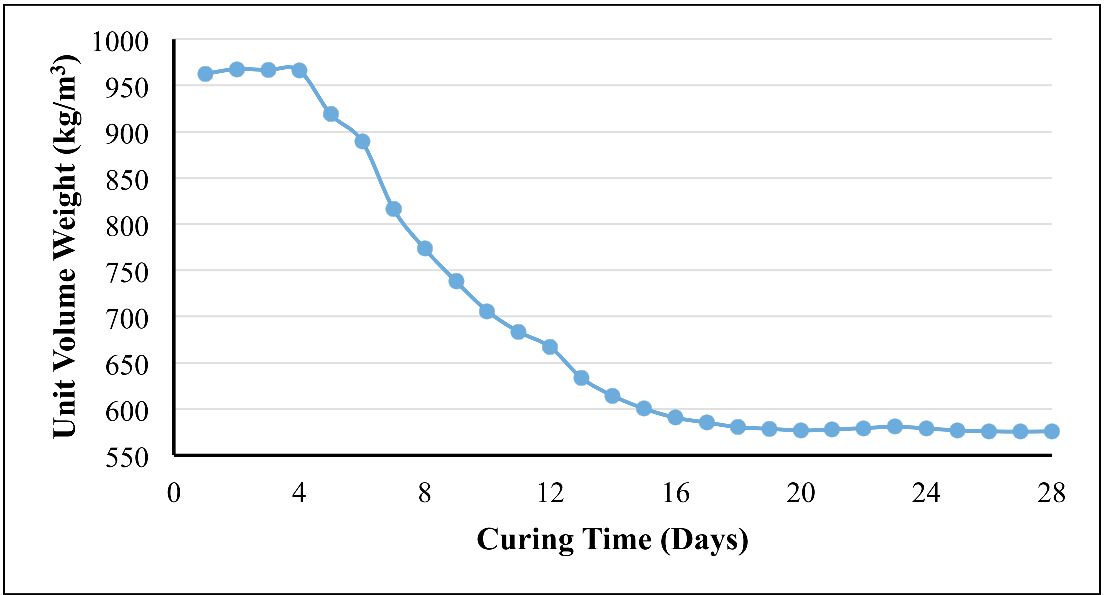

Figure 4.19 : UVW vs curing time for plaster containing 5.0% polyester fiber.

According to the Figure 4.19, the UVW of 5P sample, prepared with 1.04 W/S ratio, was not change after 20th day of curing. 5P sample lose the water in the body at 20th day.

It seems that drying is slowing down at the 15-16 days. It was analyzed that the composite plasters containing polyester waste fiber dried on average in 20-21 days.

That corresponds to the time which the any treatment can be carried out on the applied plaster surface after such periods.

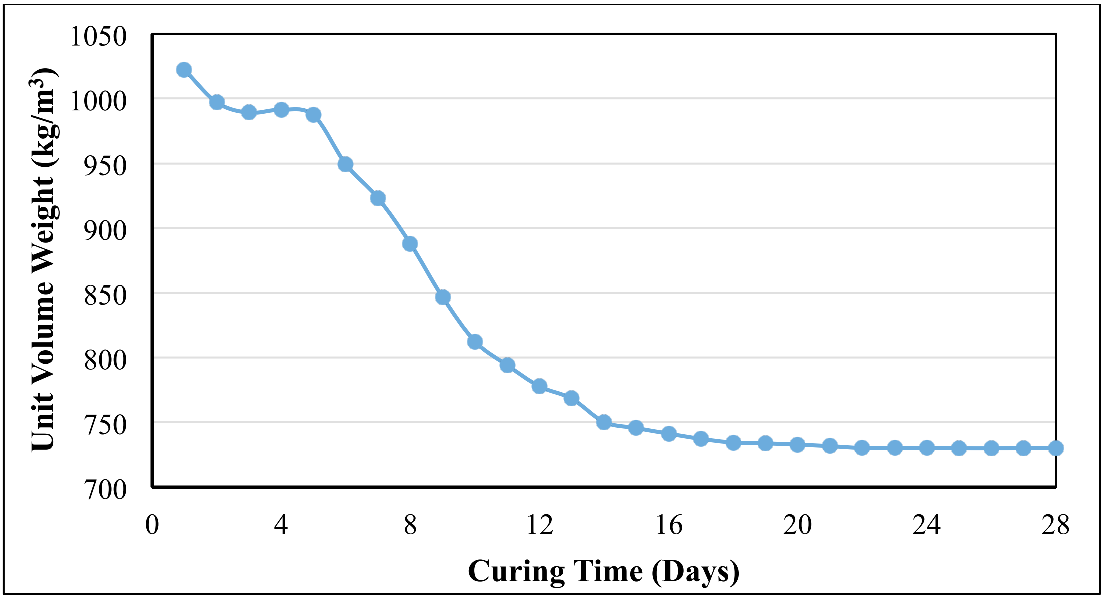

Figure 4.20 : UVW vs curing time for plaster containing 0.75% cotton+polyester fiber.

According to the Figure 4.20, the UVW of 075CP sample, prepared with 0.7 W/S ratio, was not change after 21th day of curing. 075CP sample lose the water in the body at 21th day.

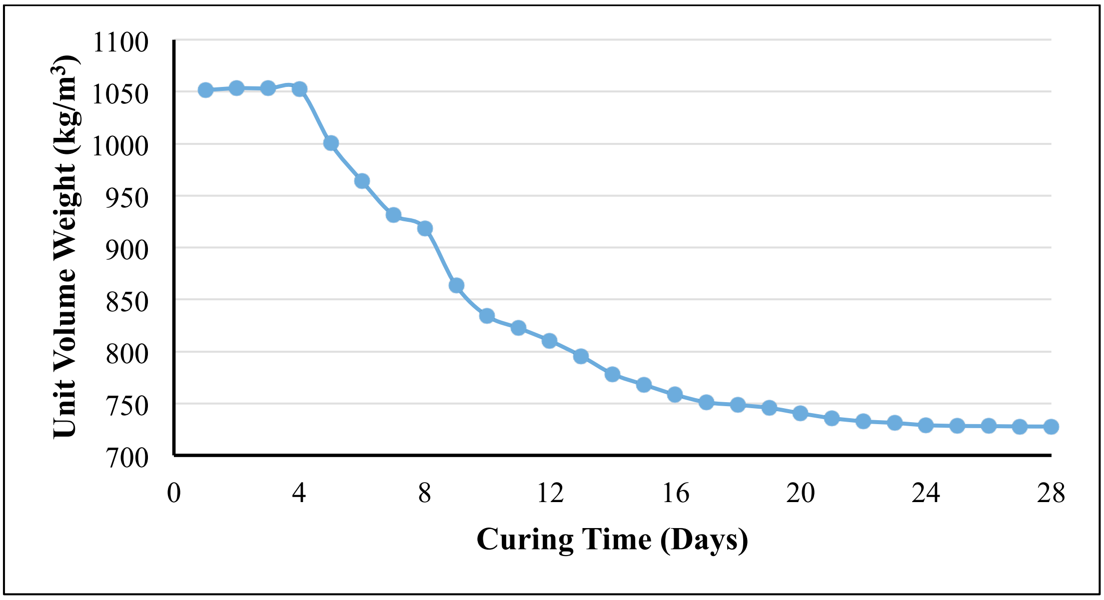

Figure 4.21 : UVW vs curing time for plaster containing 1.5% cotton+polyester fiber.

According to the Figure 4.21, the UVW of 15CP sample, prepared with 0.74 W/S ratio, was not change after 24th day of curing. 15CP sample lose the water in the body at 24th day.

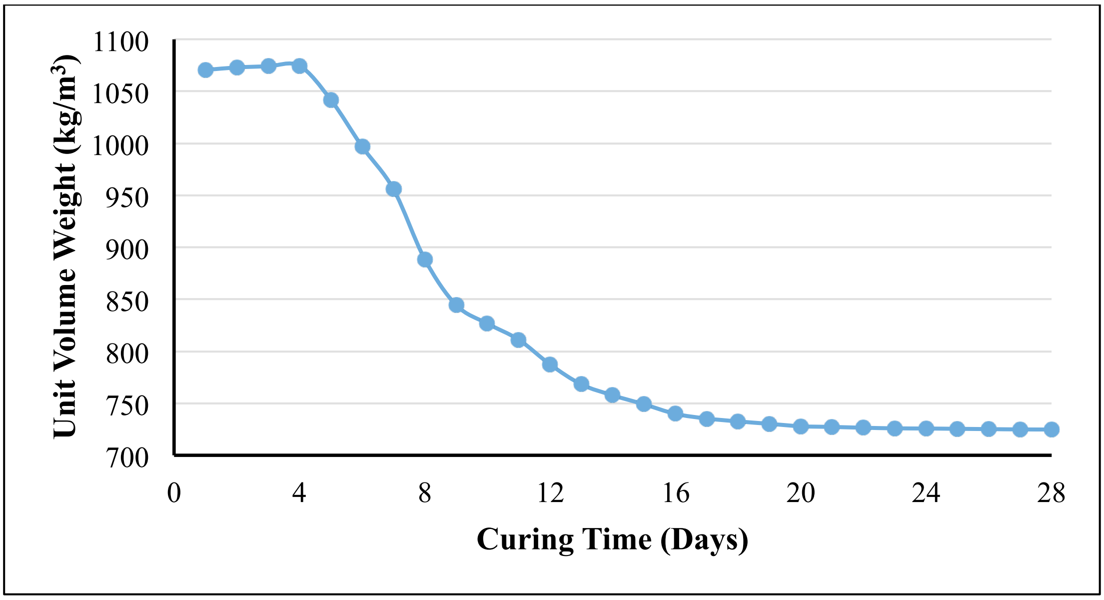

Figure 4.22 : UVW vs curing time for plaster containing 2.0% cotton+polyester fiber.

According to the Figure 4.22, the UVW of 2CP sample, prepared with 0.78 W/S ratio, was not change after 20th day of curing. 2CP sample lose the water in the body at 20th day.

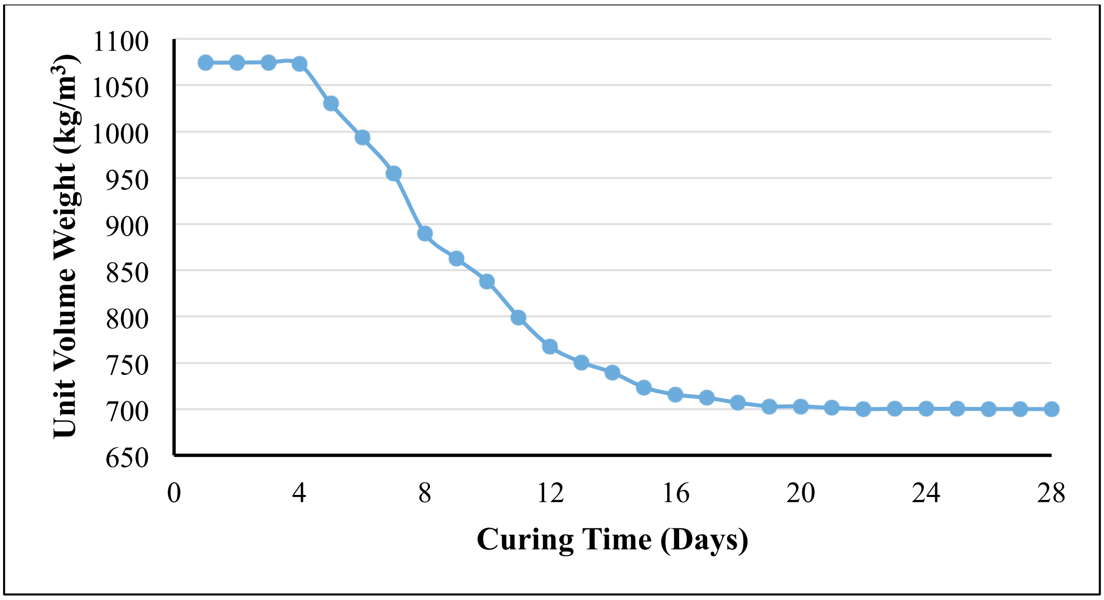

Figure 4.23 : UVW vs curing time for plaster containing 3.0% cotton+polyester fiber.

According to the Figure 4.23, the UVW of 3CP sample, prepared with 0.86 W/S ratio, was not change after 22th day of curing. 3CP sample lose the water in the body at 22th day.

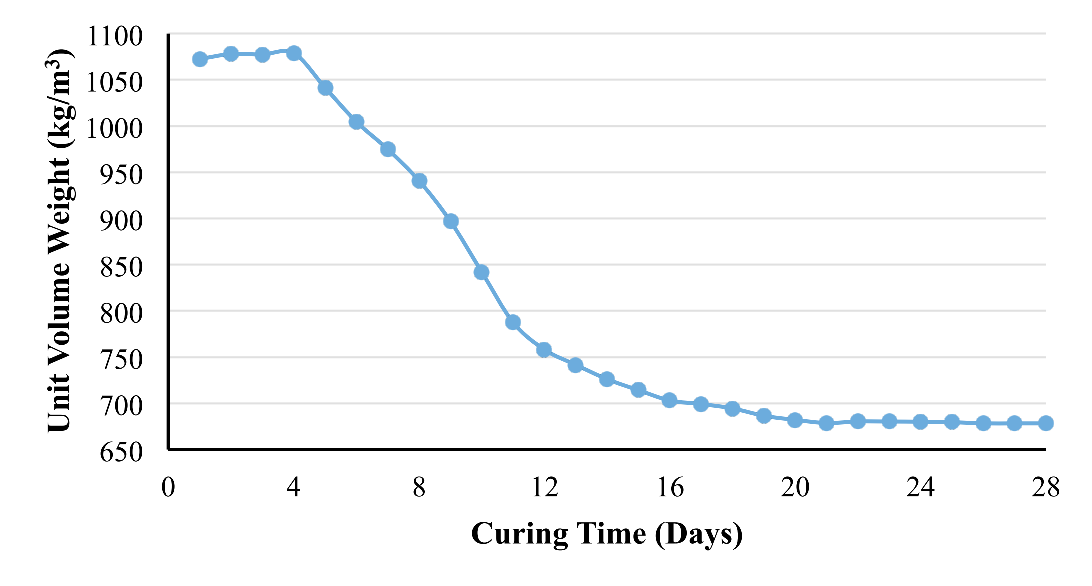

Figure 4.24 : UVW vs curing time for plaster containing 4.0% cotton+polyester fiber.

According to the Figure 4.24, the UVW of 4CP sample, prepared with 0.93 W/S ratio, was not change after 20th day of curing. 4CP sample lose the water in the body at 20th day.

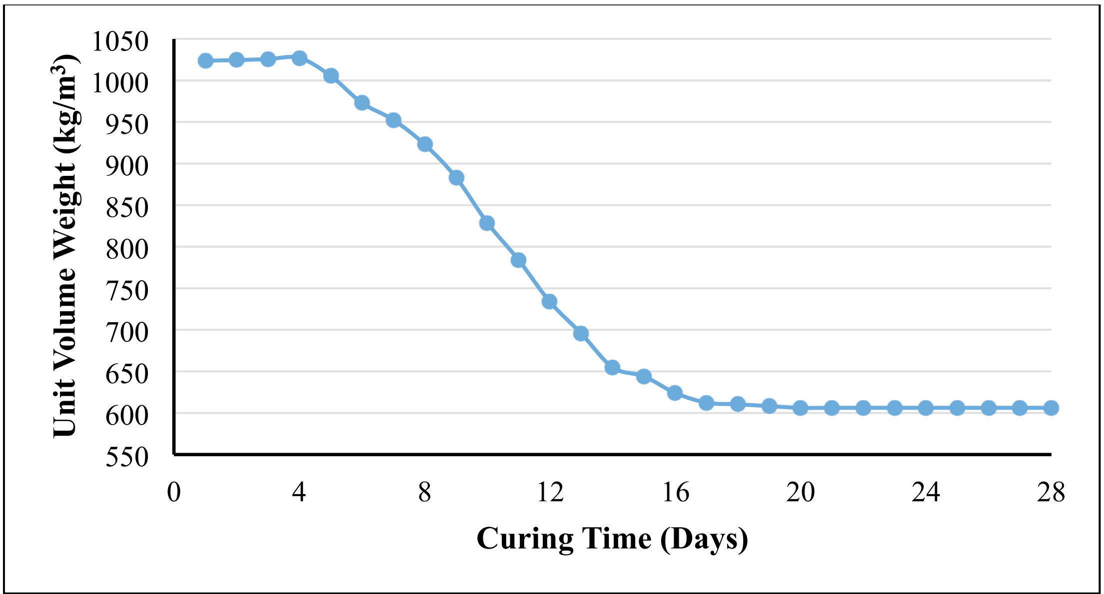

Figure 4.25 : UVW vs curing time for plaster containing 5.0% cotton+polyester fiber.

According to the Figure 4.25, the UVW of 5CP sample, prepared with 1.03 W/S ratio, was not change after 19th day of curing. 5CP sample lose the water in the body at 19th day.

It seems that at the 15-16 days drying is slowing down. It was analyzed that the composite plasters containing mixture of cotton+polyester waste fiber dried on average in 20-21 days.

This analysis was carried out to understand the completely drying duration after in case of application on site. After the material becomes dry, it can easily carry the load. This period tells when the material can carry a load safely. That corresponds to the time which the any treatment can be carried out on the applied plaster surface after such periods. It can be observed that in general, samples containing all types of fibers were dried in 19-20 days.

To analyze the effect of fiber using ratio on the unit volume weight of all samples, the research findings were plotted in Figure 4.26 to Figure 4.29 based on UVWs of 7 and 28 day of curing versus four types of textile waste fibers.

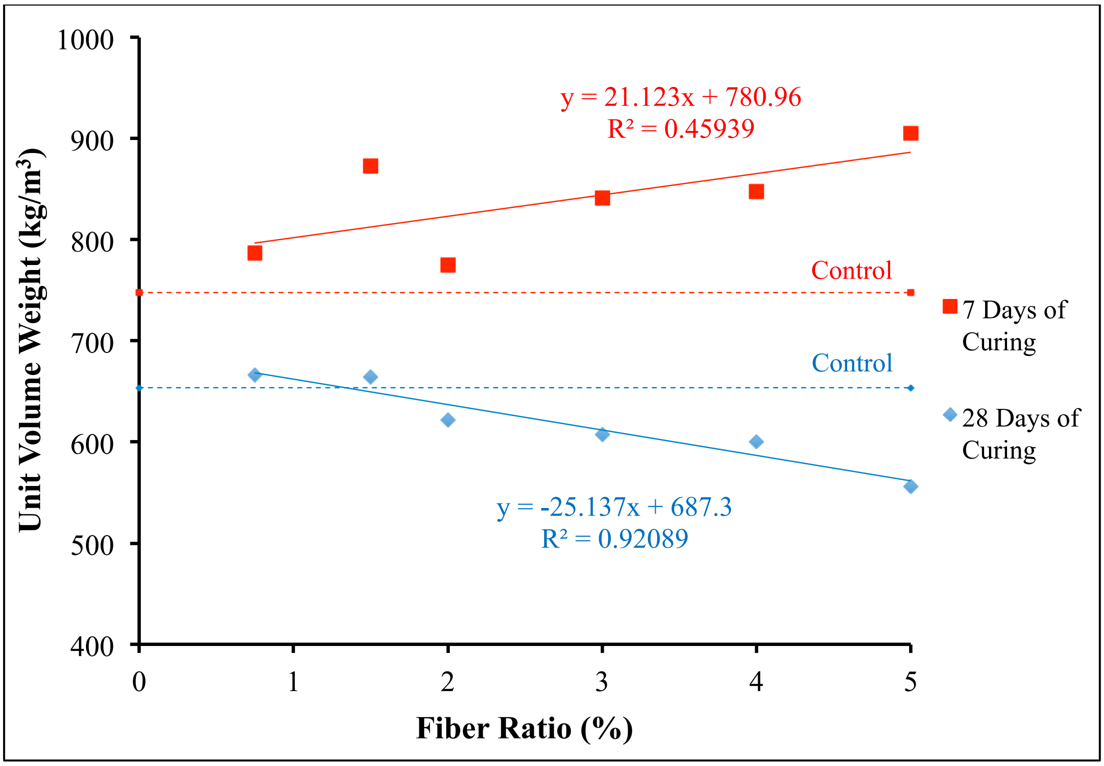

Figure 4.26 : UVW vs cotton fiber ratio.

As Figure 4.26 is examined, the regression between fiber ratio and UVW is not meaningful in 7 days curing condition due to the samples still in the drying phase.

On the other hand, the samples dried in 28 days of curing give a meaningful result. The relation between UVW and cotton fiber ratio could be found by the linear equation found by regression analysis.

UVWs of cotton fiber additive plasters are in a decreasing trend depending on increase in cotton fiber addition in the plasters. UVW of plaster with 0.75% cotton waste fiber utilization is 666 kg/m^3 and it drops about 17% to 556 kg/m^3, when cotton waste fiber utilization is 5%. According to the trend line in 28 days curing condition, up to about 1.25% fiber utilization unit volume weight is going higher than the control sample. Under these conditions, if it is desired to get benefit from unit volume weight, cotton fibers should be used more than 1.25% by weight.

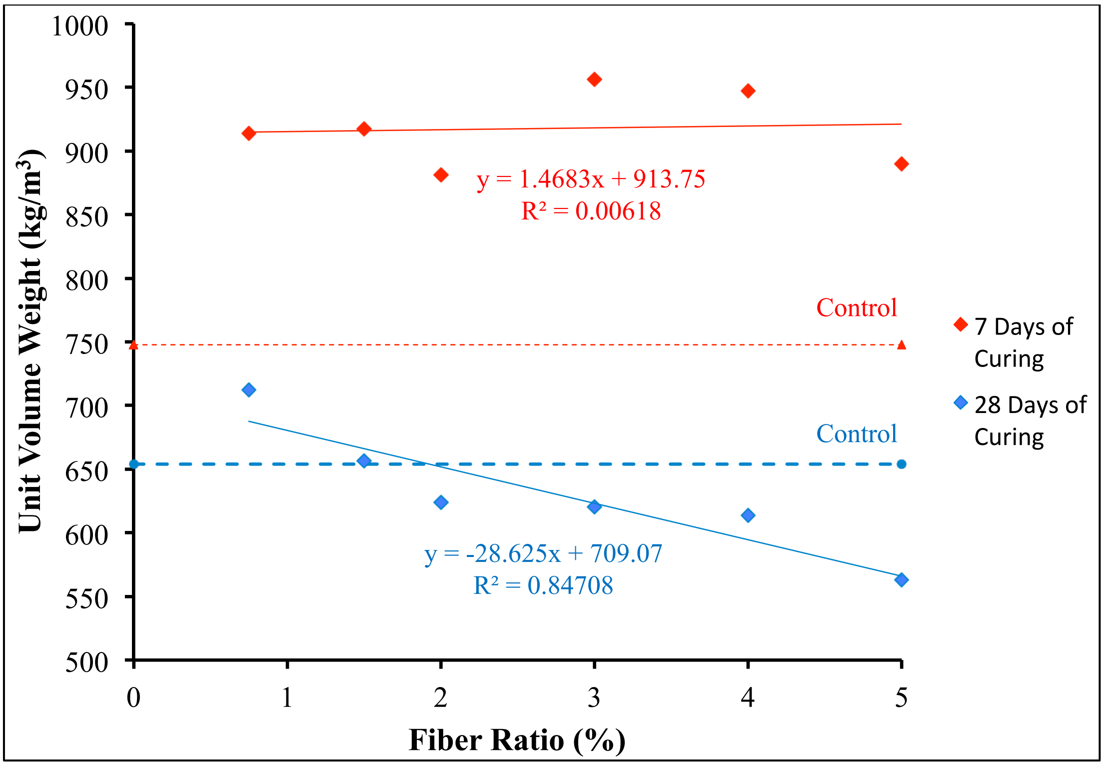

Figure 4.27 : UVW vs mixture of cotton+polyester+acrylic fiber ratio.

On the other hand, as analyzing the Figure 4.27, the regression between fiber ratio and UVW is not meaningful in 7 days of curing condition due to the samples still in the drying phase. On 7 days of curing, the weights are still much higher than the control sample, because there is still a lot of water in the structure of the samples. On the other hand, the samples dried in 28 days of curing give a meaningful result. The relation between UVW and mixture of cotton+polyester+acrylic fiber ratio could be found by the linear equation found by regression analysis.

UVWs of mixture of cotton+polyester+acrylic fiber additive plasters are in a decreasing trend depending on increase in mixture of cotton+polyester+acrylic fiber addition in the plasters. UVW of plaster with 0.75% waste fiber utilization is 712 kg/m^3 and it drops about 21% to 563 kg/m^3, when mixture of cotton+polyester+acrylic waste fiber utilization is 5%. According to the trend line in 28 days curing condition, up to about 1.8% fiber utilization, unit volume weight is going higher than the control sample. Under these conditions, if it is desired to get benefit from low unit volume weight, mixture of cotton+polyester+acrylic fibers should be used more than 1.8% by weight.

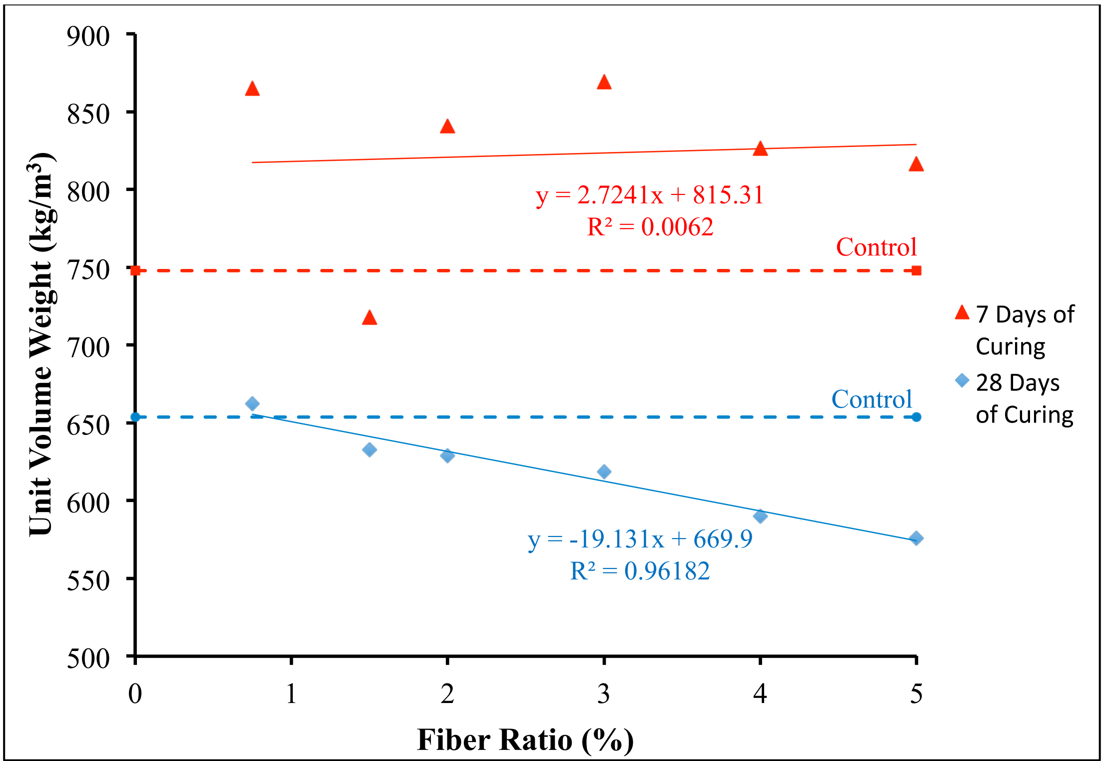

Figure 4.28 : UVW vs polyester fiber ratio.

As Figure 4.28 is examined, there is a similarity with the above figures related to 7 days of curing that the regression between fiber ratio and UVW is not meaningful due to the samples still in the drying phase, too. During the mixing, more water is supplied to ensure the workability of plastic mixture. Which means that there is more water in the material after final setting. On 7 days of curing, the weights are still much higher than the control sample, because there is still a lot of water in the structure of the samples. On the other hand, the samples dried in 28 days of curing give a meaningful result. The relation between UVW and polyester fiber ratio could be found by the linear equation found by regression analysis.

UVWs of polyester fiber additive plasters are in a decreasing trend depending on increase in mixture of polyester fiber addition in the plasters. UVW of plaster with 0.75% waste fiber utilization is 662 kg/m^3 and it drops about 13% to 576 kg/m^3, when polyester waste fiber utilization is 5%. This series is determined as a lower drying rate. Because polyester does not absorb water, the initial W/S ratio is relatively lower than the other series. According to the trend line in 28 days curing condition, up to about 0.75% fiber utilization, unit volume weight is going higher than the control sample. Under these conditions, if it is desired to get benefit from low unit volume weight, polyester fibers should be used more than 0.75% by weight.

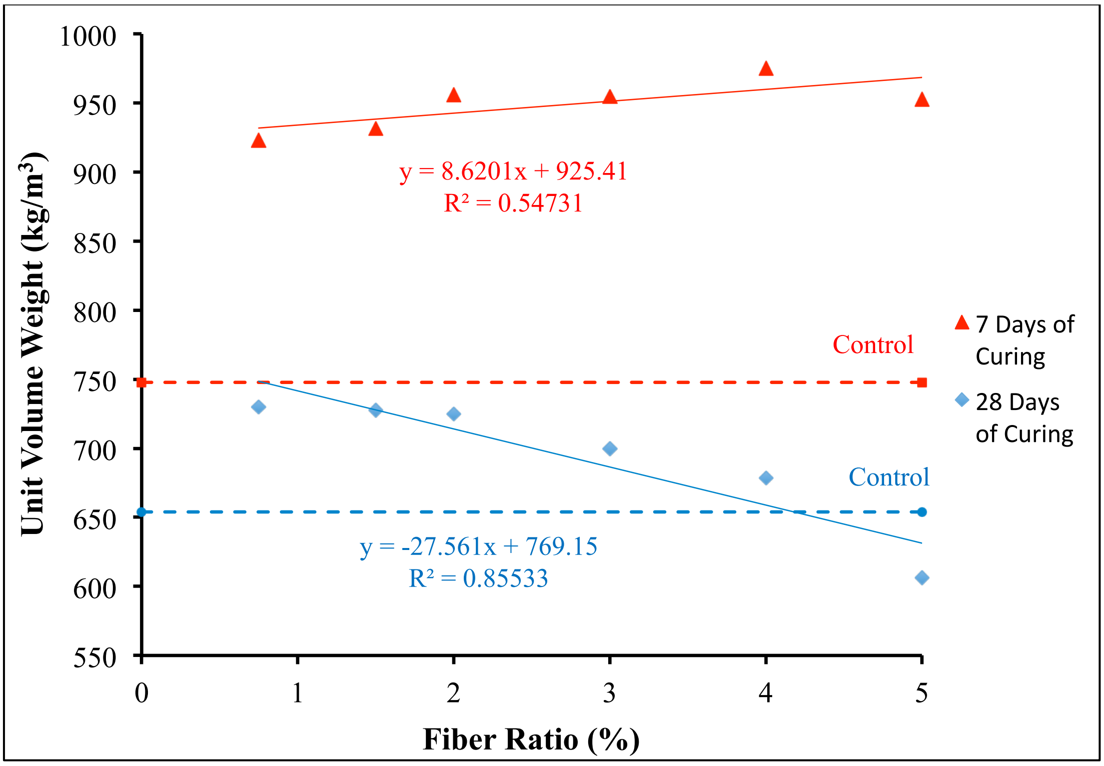

Figure 4.29 : UVW vs mixture of cotton+polyester fiber ratio.

Furthermore as evaluating the Figure 4.29, the research findings showed that the regression between fiber ratio and UVW is not meaningful at 7 days of curing condition in similar drying phase. During the mixing, more water is supplied to ensure the workability of plastic mixture. Which means that there is more water in the material after final setting. On 7 days of curing, the weights are still much higher than the control sample, because there is still a lot of water in the structure of the samples. On the other hand, the samples dried in 28 days of curing give a meaningful result. The relation between UVW and mixture of cotton+polyester fiber ratio could be found by the linear equation found by regression analysis.

UVWs of mixture of cotton+polyester fiber additive plasters are in a decreasing trend depending on increase in mixture of cotton+polyester fiber addition in the plasters. UVW of plaster with 0.75% waste fiber utilization is 720 kg/m^3 and it drops about 16% to 606 kg/m^3, when mixture of cotton+polyester waste fiber utilization is 5%. According to the trend line in 28 days curing condition, up to about 4.1% fiber utilization, unit volume weight is going higher than the control sample. Under these conditions, if it is desired to get benefit from low unit volume weight, mixture of cotton+polyester fibers should be used more than 4.1% by weight. Mixture of cotton+polyester fiber use has transformed the plasters into a more dense structure. This phenomenon will worsen the thermal performance while improving the mechanical performance of the mixture of cotton+polyester fiber additive plaster comparing with the control samples.

Findings obtained from unit volume weight analysis showed that as the fiber ratio increases in general, the unit volume weight values of the plaster samples in the composite structure show a decreasing tendency after a slight increase first. In other words, the fiber amount plays a role of unit weight reduction in the mixtures. When the numerical value obtained from the unit volume weight analysis is taken into consideration, it was seen that the unit volume weight values of hardened samples did not exceed 730 kg/m^3. When the mortar samples with a unit volume weight of 900 kg/m^3 in terms of heat insulation are considered as acceptable density values, it is understood that mixtures with max. 730 kg/m^3 can be evaluated in heat insulated plaster category.

Additionally, there is a condition about lightweight plasters that they should have maximum unit volume weight of 1300 kg/m^3. If a comparison is made between this requirement and the samples produced in this thesis study, it can be easily seen that unit volume weights of produced samples are between half of and one third of 1300 kg/m^3. This phenomenon is indicating that the produced plasters are sufficiently lightweight materials.

In Figure 4.30, a comparison for all types of fibers in terms of UVW is given.

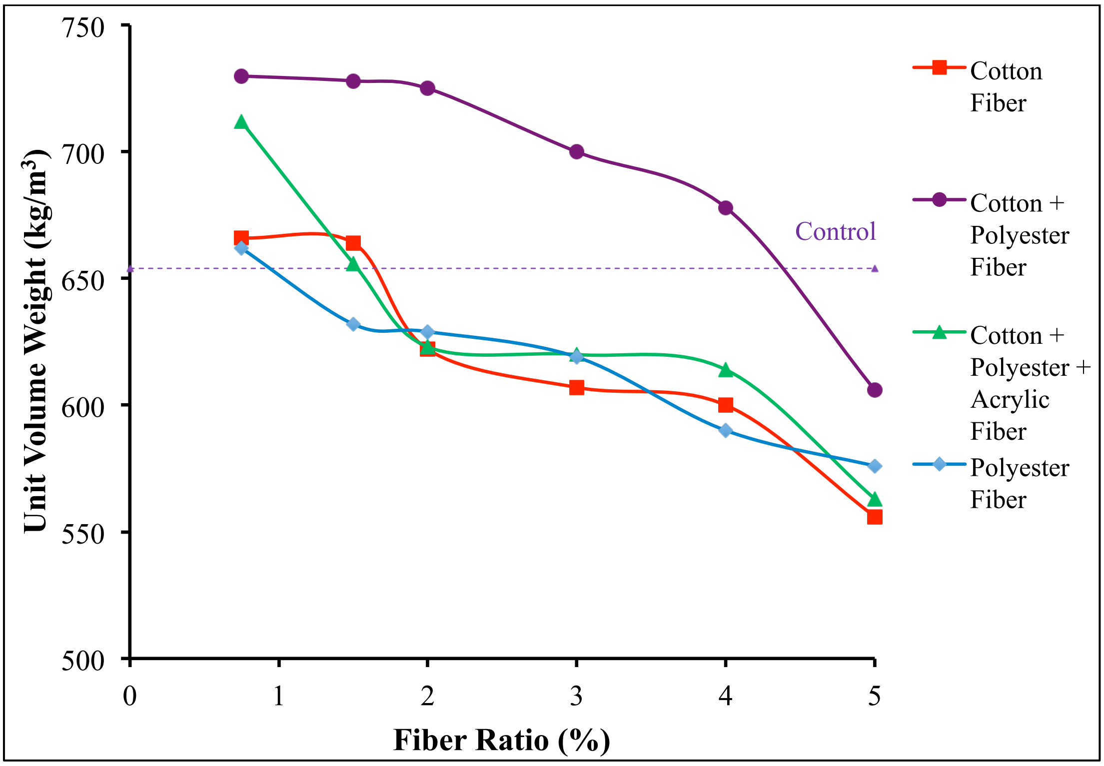

Figure 4.30 : Comparison for all types of fibers in terms of UVW.

According to the Figure 4.30, the unit volume weights of the composites having the cotton fiber were found to be relatively low although the variation in the unit volume weight was observed. Except cotton and polyester mix fibers all fiber types exhibits lower unit volume weight characteristics than the control sample.

4.2. Analysis of Compressive Strength of Hardened Composite Mortars

Compressive strength test was carried out in accordance with TS EN 1015-11 standard. Six cubic samples were produced for each mixture series to perform the compressive strength analysis. The samples, after removal from the molds and cured at 3 days and then dried at room temperature until the testing time, were taken directly on the compressive strength test without any further action. The tested compressive strength values of all mortar batches at 7 days to 28 days curing time are presented in Figure 4.31 to Figure 4.39 based on the percentage of waste fiber usage ratio by weight.

Compressive strength values of tested plasters were all analyzed in accordance of TS EN 998-1 standard. Compressive strength values of cement based mortar samples are divided by 4 different groups in TS EN 998-1 standard at 28 days curing time. These are; CS I class (0.4 – 2.5 N/mm^2), CS II class (1.5 – 5.0 N/mm^2), CS III class (3.5 – 7.5 N/mm^2) and CS IV class (≥6 N/mm^2).

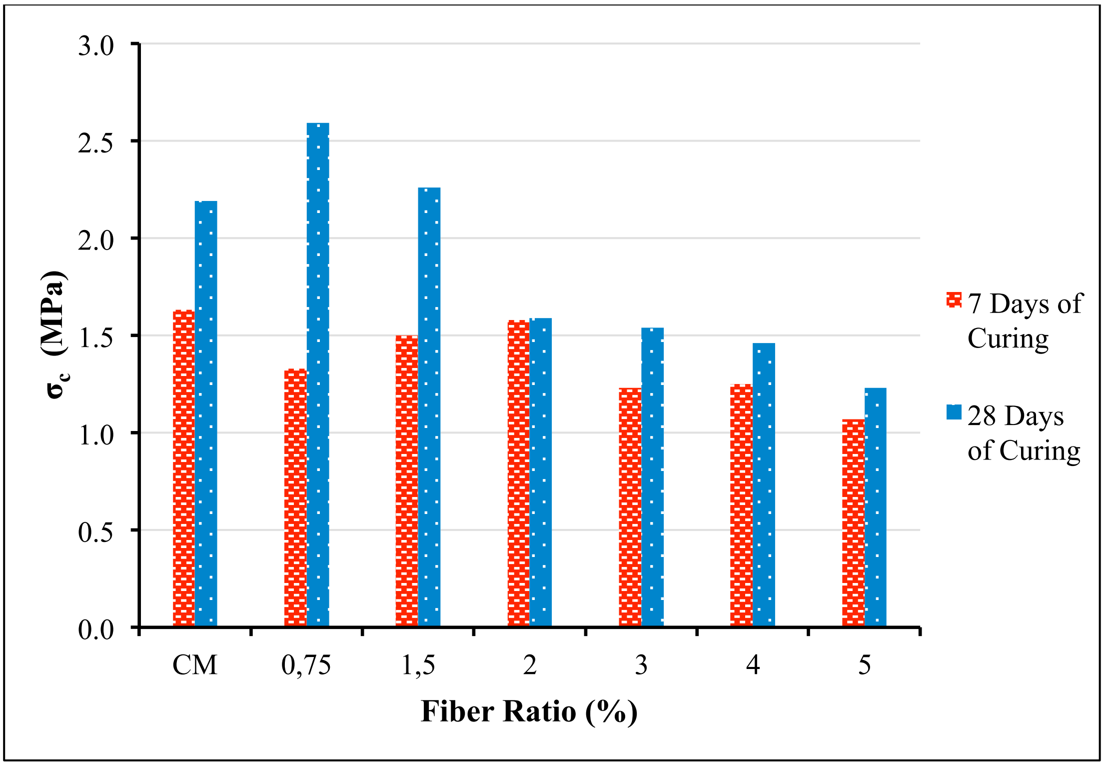

Figure 4.31 : Compressive strength vs cotton fiber ratio.

When Figure 4.31 is examined, compressive strength of mixture combinations were decreased with the increase of fiber content in both 7 days and 28 days curing time. Compressive strength values of samples with 28 days curing time were found higher than 7 days cured samples, as it should be. There is a fluctuation in the 7 day strengths because, the samples hold water in fibers, which creates inconsistencies in the results of the experiment conducted on wet samples. Whereas the compressive strength value of the control sample was 2.19 MPa, the compressive strength values of the cotton fiber additive samples varied between 2.59 MPa and 1.23 MPa. While the use of cotton fibers at rate of 0.75% and 1.5% improved the compressive strength values of the material, more uses than these values reduced the compressive strength in 28 days of curing. A decrease of 53% in compressive strength was observed when the cotton waste fiber utilization ratio increased from 0.75% to 5%. As mentioned before, a decrease in the unit volume weight values of the samples was observed as the fiber utilization ratio in the mixture increased. Since the strength characteristics of the samples are directly proportional to the unit volume weight values, the decrease in the compressive strength of the samples could be explained by the decrease in the unit volume weights.

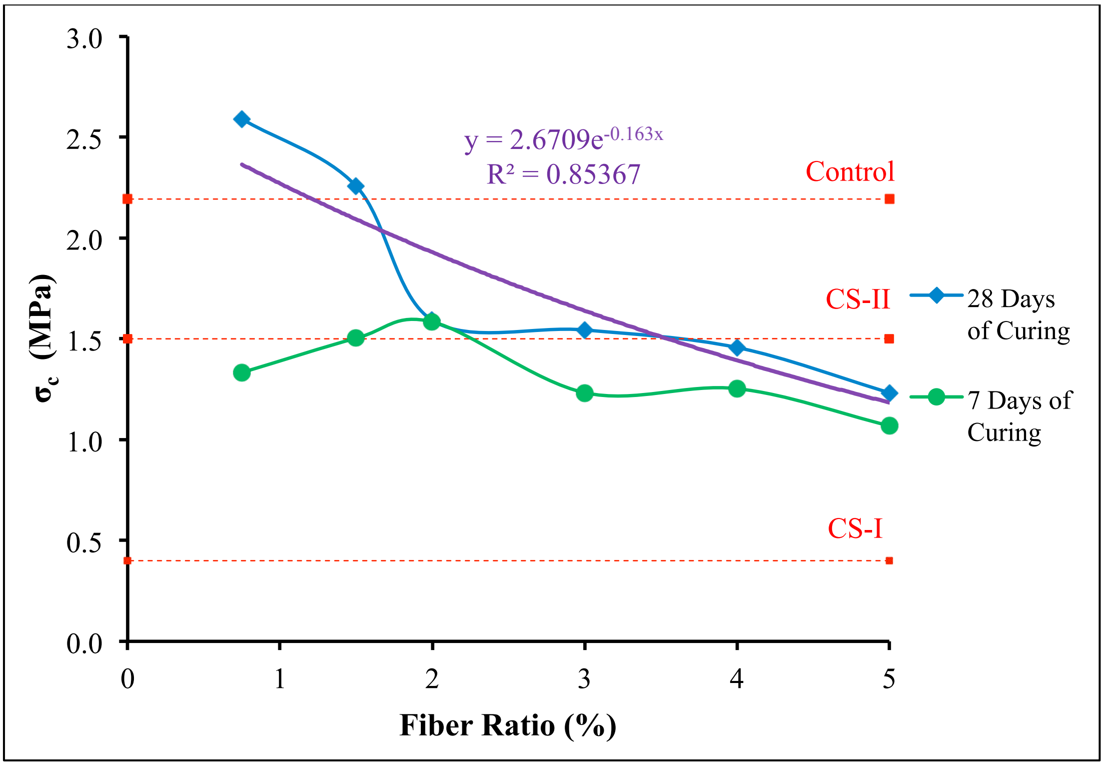

Figure 4.32 : The relation between compressive strength and cotton fiber ratio.

In Figure 4.32, an exponential approach is given to make a prediction between compressive strength and cotton fiber usage. This approach is given for the compressive strength and fiber utilization rates of the 28 day cured samples. Again in this figure, it can be easily seen that even on the 7th day of curing period, the samples provide the minimum value required, which is CS I class and 0.40 MPa, for the compressive strength in TS EN 998-1 standard. Besides, almost all mixtures are in CS II class in terms of compressive strength according to the requirements declared in TS EN 998-1 standard. Actually that means that all the mixture types containing cotton fibers are applicable on site in terms of compressive strength. However, only up to 1.5% cotton fiber utilization gave better compressive strength performance than the control sample. This basically represents that up to 1.5% usage, the cotton fiber additive provides added value to the compressive strength in a positive way. Nevertheless, as mentioned earlier, the compressive strength values of the produced specimens comply with the criteria of the relevant standard, so there is no obstacle in their use.

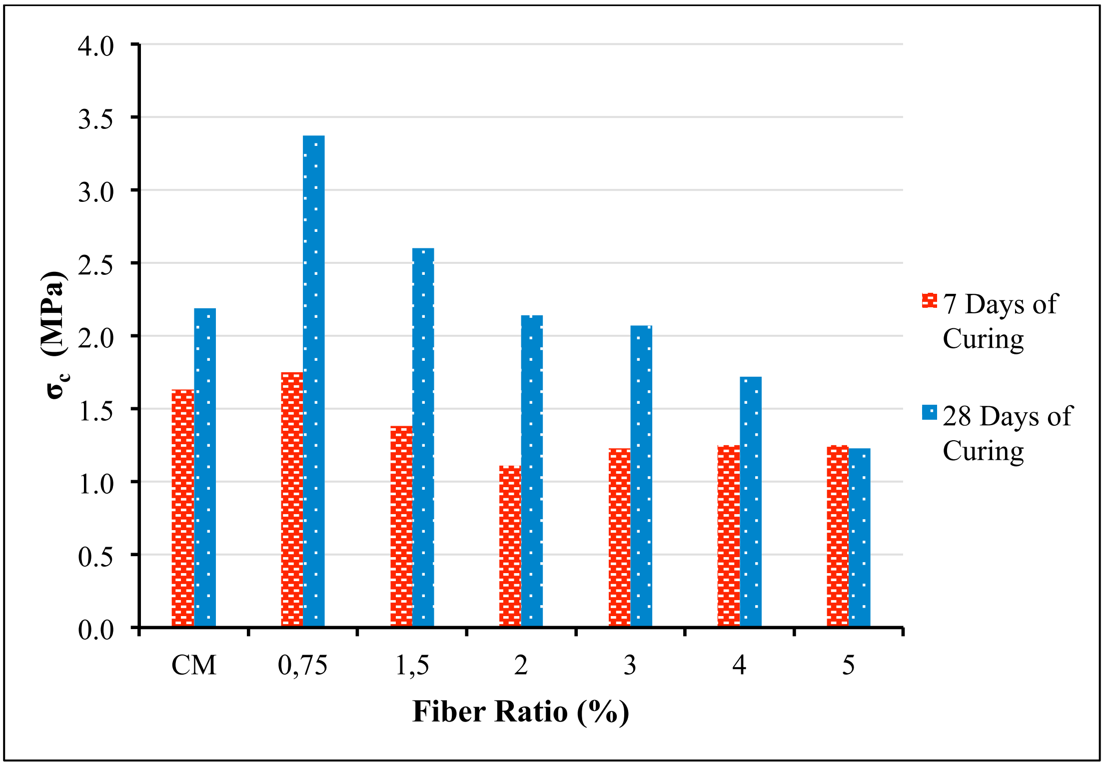

Figure 4.33 : Compressive strength vs mixture of cotton+polyester+acrylic fiber ratio.

As Figure 4.33 is evaluated, it was observed that compressive strength of mixture combinations were decreased with increase in mixture of cotton+polyester+acrylic fiber content in both 7 days and 28 days of curing period. Almost all compressive strength values of samples with 28 days curing time were found higher than 7 days cured samples, as it should be. However, the compressive strength value, which should be improved due to the curing time, of 5% fiber addition was not observed as improved, which indicates that above 5% mixture of cotton+polyester+acrylic fiber usage is useless. There is again a fluctuation in the 7 days strengths because, the samples hold water in fibers, which creates inconsistencies in the results of the experiment conducted on wet samples. Whereas the compressive strength value of the control sample was 2.19 MPa, the compressive strength values of the mixture of cotton+polyester+acrylic fiber additive samples varied between 3.37 MPa and 1.23 MPa. While the use of mixture of cotton+polyester+acrylic fibers at rate of 0.75% and 1.5% improved the compressive strength values of the material, more using ratio of this type of fiber than 1.5% reduced the compressive strength in 28 days of curing. A decrease of 64% in compressive strength was observed when the mixture of cotton+polyester+acrylic waste fiber utilization ratio increased from 0.75% to 5%.

As mentioned above, a decrease in the unit volume weight values of the samples was observed as the fiber utilization ratio in the mixture increased. Since the strength characteristics of the samples are directly proportional to the unit volume weight values, the decrease in the compressive strength of the samples could be explained by the decrease in the unit volume weights.

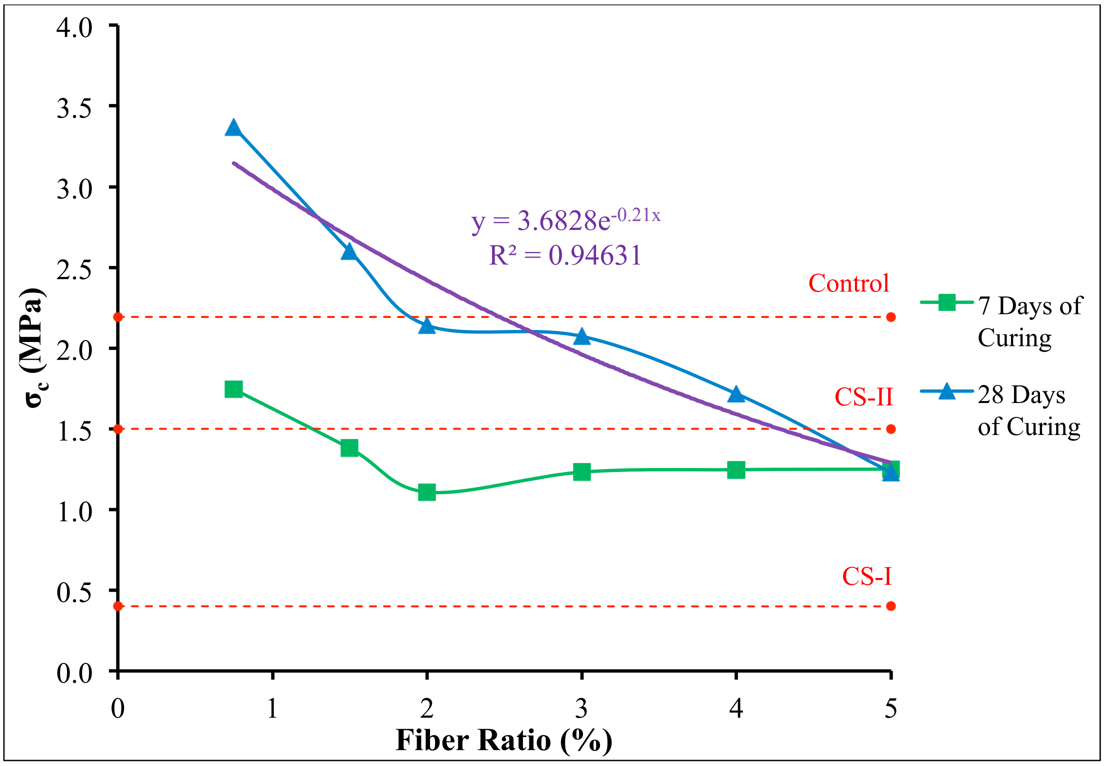

Figure 4.34 : The relation between compressive strength and mixture of cotton+polyester+acrylic fiber ratio.

In Figure 4.34, an exponential approach is given to make a prediction between compressive strength and mixture of cotton+polyester+acrylic fiber usage. This approach could be given given for the compressive strength and fiber utilization rates of the 28 day cured samples. Again in this figure, it can be easily seen that even on the 7th day of curing period, the samples provide the minimum value required, which is CS I class and 0.40 MPa, for the compressive strength in TS EN 998-1 standard. Besides, almost all mixtures are in CS II class in terms of compressive strength according to the TS EN 998-1 standard. This technically refers that all mixture types containing mixture of cotton+polyester+acrylic fibers are applicable on site in terms of compressive strength. However, only up to 2.0% mixture of cotton+polyester+acrylic fiber utilization gave better compressive strength performance than the control sample. As up to 2.0% mixture of cotton+polyester+acrylic fiber usage, the mixture of cotton+polyester+acrylic fiber additive provides added value to the compressive strength in a positive way. Nevertheless, as mentioned earlier, the compressive strength values of the produced specimens comply with the criteria of the relevant standard, so there is no obstacle in their use.

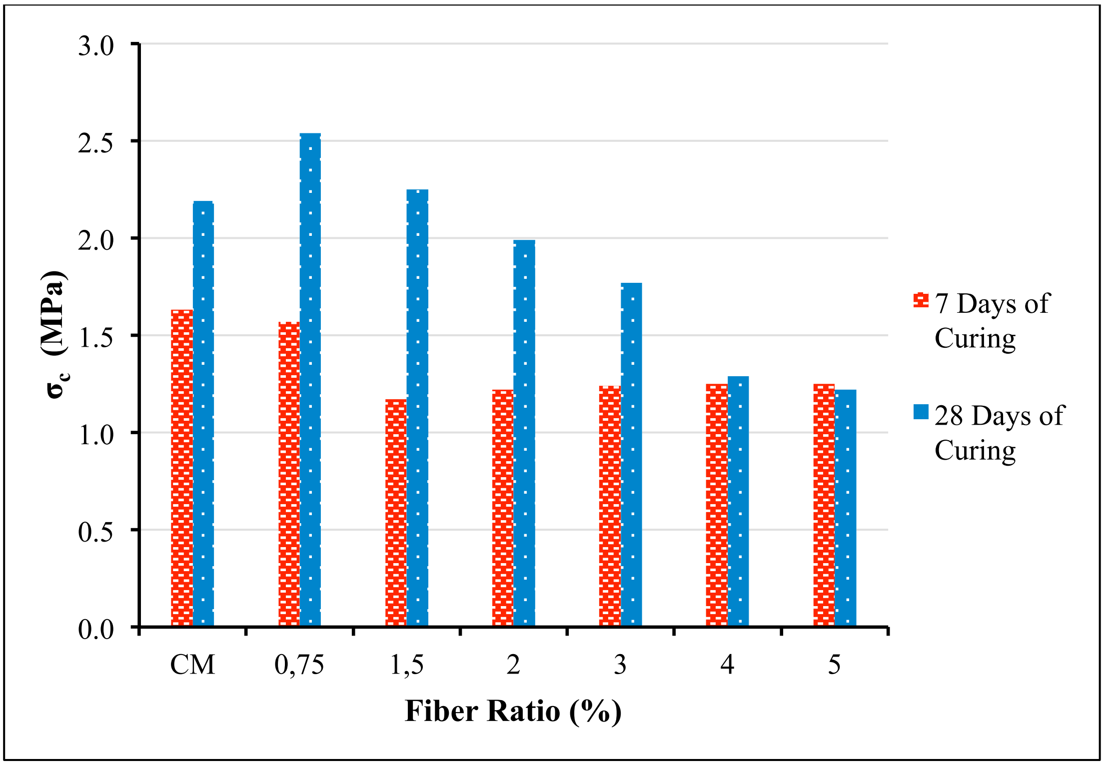

Figure 4.35 : Compressive strength vs polyester fiber ratio.

When Figure 4.35 is examined, compressive strength of mixture combinations were decreased with increase in polyester fiber content in both 7 days and 28 days of curing period. Almost all compressive strength values of samples with 28 days curing time were found higher than 7 days cured samples, as it should be. However, the compressive strength value, which should be improved due to the curing time, of 5% fiber addition was not observed as improved, which indicates that above 5% polyester fiber usage is useless. There is again a fluctuation in the 7 day strengths because, the samples hold water in fibers, which creates inconsistencies in the results of the experiment conducted on wet samples. Whereas the compressive strength value of the control sample was 2.19 MPa, the compressive strength values of the polyester fiber additive samples varied between 2.54 MPa and 1.22 MPa. While the use of polyester fibers at rate of 0.75% and 1.5% improved the compressive strength values of the material, more using ratio of this type of fiber than 1.5% reduced the compressive strength in 28 days of curing. A decrease of 52% in compressive strength was observed when the polyester waste fiber utilization ratio increased from 0.75% to 5%. As mentioned before, a decrease in the unit volume weight values of the samples was observed as the fiber utilization ratio in the mixture increased. Since the strength characteristics of the samples are directly proportional to the unit volume weight values, the decrease in the compressive strength of the samples could be explained by the decrease in the unit volume weights.

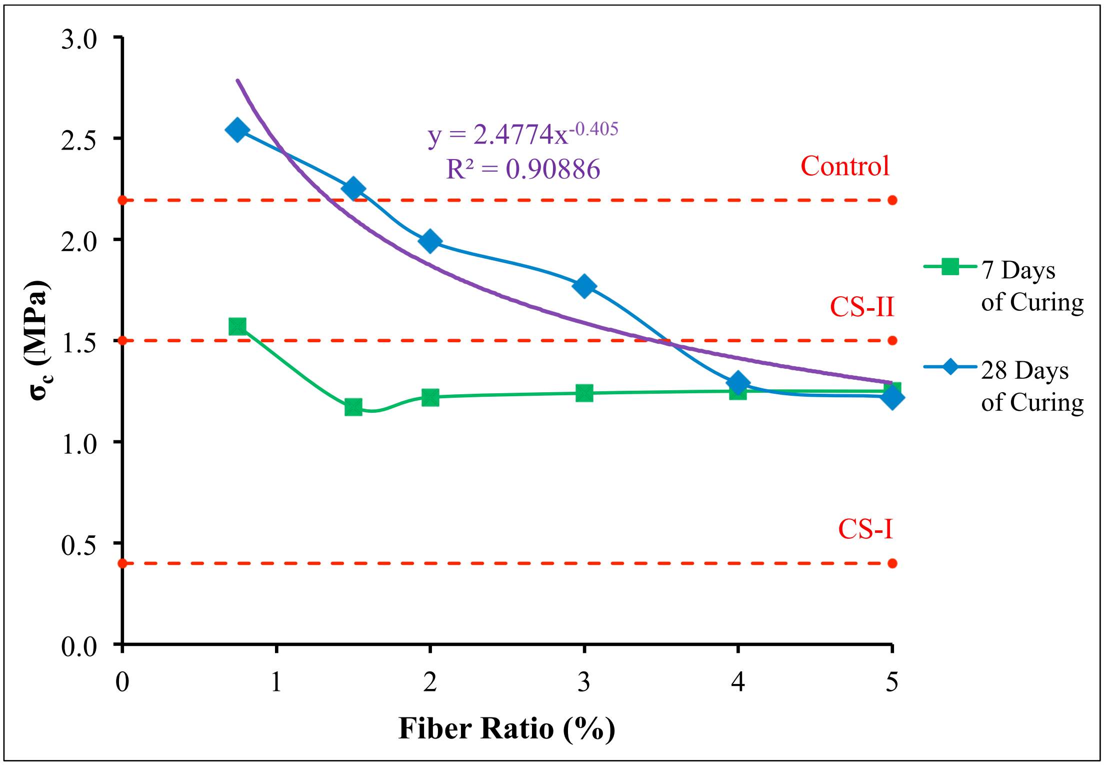

Figure 4.36 : The relation between compressive strength and polyester fiber ratio.

In Figure 4.36, an exponential approach could be derived to make a prediction between compressive strength and polyester fiber usage. This prediction is given for the compressive strength and fiber utilization rates of the 28 day cured samples. Again in this figure, it can be easily seen that even on the 7th day of curing period, the samples provide the minimum value required, which is CS I class and 0.40 MPa, for the compressive strength in TS EN 998-1 standard. Besides, almost all mixtures are in CS II class in terms of compressive strength according to the TS EN 998-1 standard. The research showed that all mixture types containing polyester fibers are applicable on site in terms of compressive strength. However, only up to 1.5% polyester fiber utilization gave better compressive strength performance than the control sample. The polyester fiber additive provides added value to the compressive strength in a positive way up to 1.5% polyester fiber usage. Nevertheless, as mentioned earlier, the compressive strength values of the produced specimens comply with the criteria of the relevant standard, so there is no obstacle in their use.

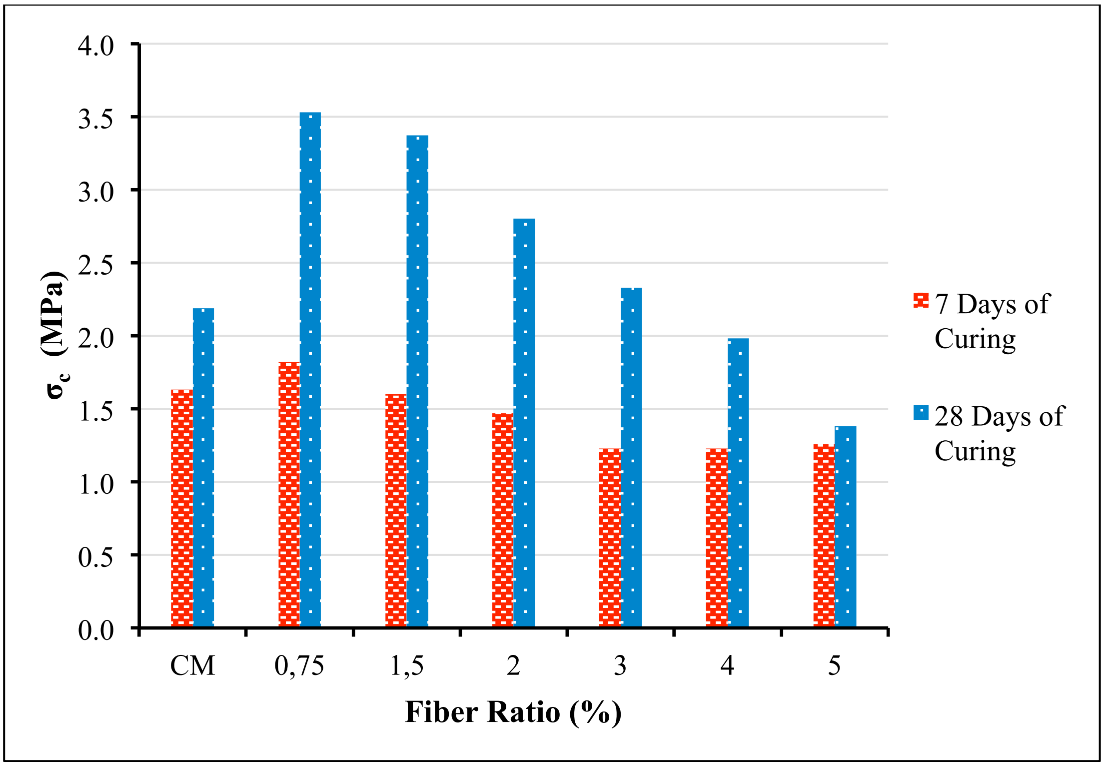

Figure 4.37 : Compressive strength vs mixture of cotton+polyester fiber ratio.

When Figure 4.37 is examined, compressive strength of mixture combinations were decreased with increase in mixture of cotton+polyester fiber content in both 7 days and 28 days of curing period. All compressive strength values of samples with 28 days curing time were found higher than 7 days cured samples, as it should be. There is again a fluctuation in the 7 day strengths because, the samples hold water in fibers, which creates inconsistencies in the results of the experiment conducted on wet samples. Whereas the compressive strength value of the control sample was 2.19 MPa, the compressive strength values of the mixture of cotton+polyester fiber additive samples varied between 3.53 MPa and 1.38 MPa. While the use of mixture of cotton+polyester fibers at rate of up to 4.0% improved the compressive strength values of the material, more using ratio of this type of fiber than 4.0% reduced the compressive strength in 28 days of curing. A decrease of 61% in compressive strength was observed when the mixture of cotton+polyester waste fiber utilization ratio increased from 0.75% to 5%. As evaluated above, a decrease in the unit volume weight values of the samples was observed as the fiber utilization ratio in the mixture increased. Since the strength characteristics of the samples are directly proportional to the unit volume weight values, the decrease in the compressive strength of the samples could be explained by the decrease in the unit volume weights.

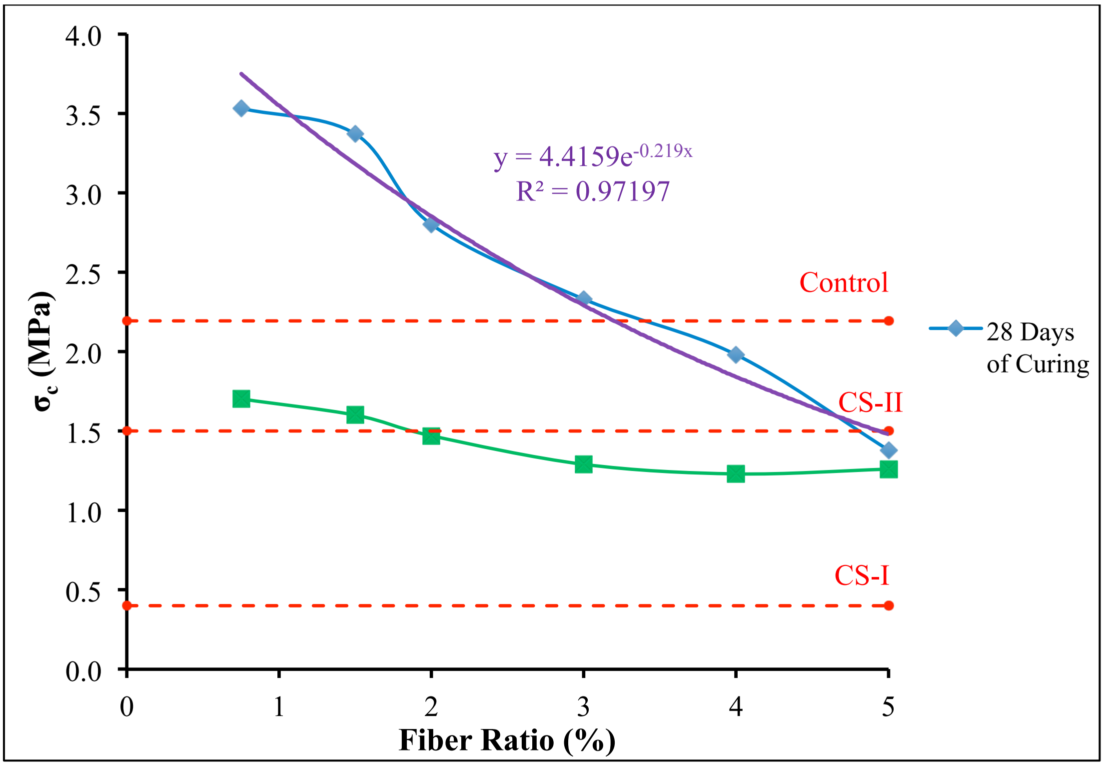

Figure 4.38 : The relation between compressive strength and mixture of cotton+polyester fiber ratio.

As shown in Figure 4.38, an exponential approach could also be derived to make a prediction between compressive strength and mixture of only cotton+polyester fiber usage, too. This approach is furthermore given for the compressive strength and fiber utilization rates of the 28 day cured samples. Again in this figure, it can be easily seen that even on the 7th day of curing period, the samples provide the minimum value required, which is CS I class and 0.40 MPa, for the compressive strength in TS EN 998-1 standard. Besides, almost all mixtures are in CS II class in terms of compressive strength according to the TS EN 998-1 standard. In other words, all mixture types containing mixture of cotton+polyester fibers are applicable on site in terms of compressive strength. However, only up to 3.2% polyester fiber utilization gave better compressive strength performance than the control sample. The mixture of cotton+polyester fiber additive provides added value to the compressive strength in a positive way specially up to 3.2% mixture of cotton+polyester fiber usage. Nevertheless, as mentioned earlier, the compressive strength values of the produced specimens comply with the criteria of the relevant standard, so there is no obstacle in their use.

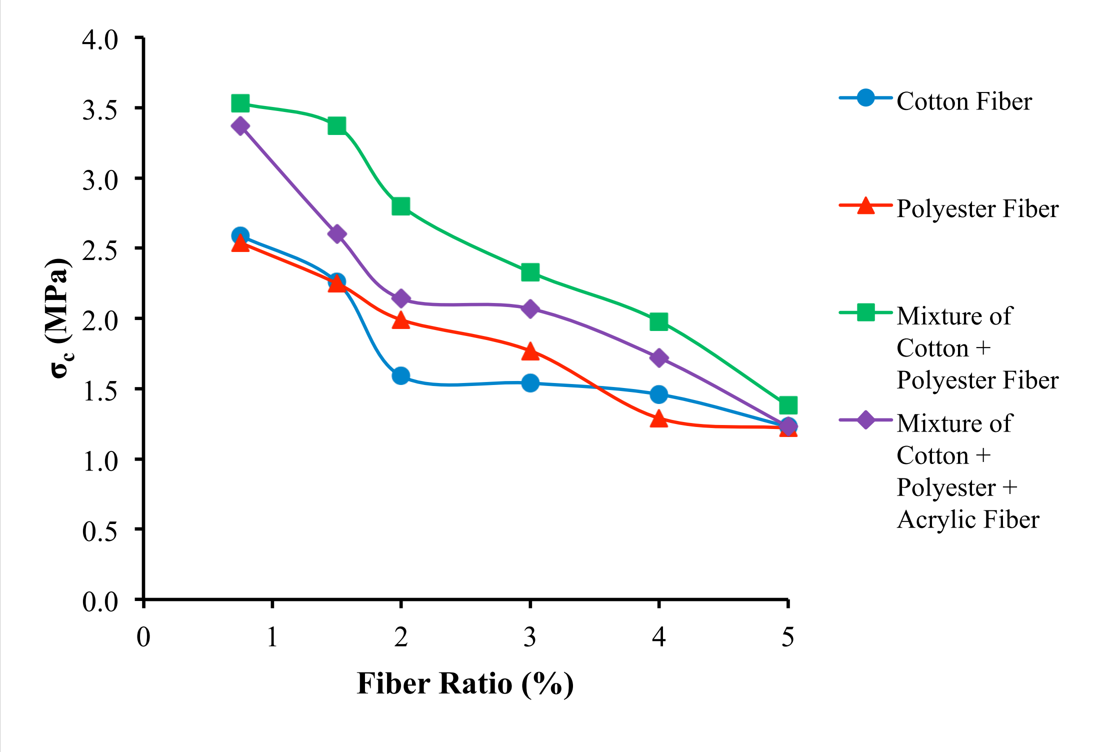

Figure 4.39 : Comparison for all types of fibers in terms of compressive strength.

When Figure 4.39 is examined, it can be easily seen that the plaster samples with mixture of cotton+polyester fiber have the highest compressive strength values, between 3.53 MPa and 1.38 MPa, than the other types. Compressive strength values of mixture of cotton+polyester+acrylic fiber additive plasters follow the mixture of cotton+polyester fiber with 3.37 MPa to 1.23 MPa. It was seen that when cotton and polyester fibers used in plaster combinations alone, their effects on compressive strength values were found as less than those used as a mixture fiber.

As evaluating together with Table 4.2 and Figure 4.39, CP and CPA coded samples have higher compressive strengths and unit volume weights than the other samples. This phenomenon also shows the relationship between strength and unit volume weight. Figure 4.40 shows the relationship between compressive strength and unit volume weight.

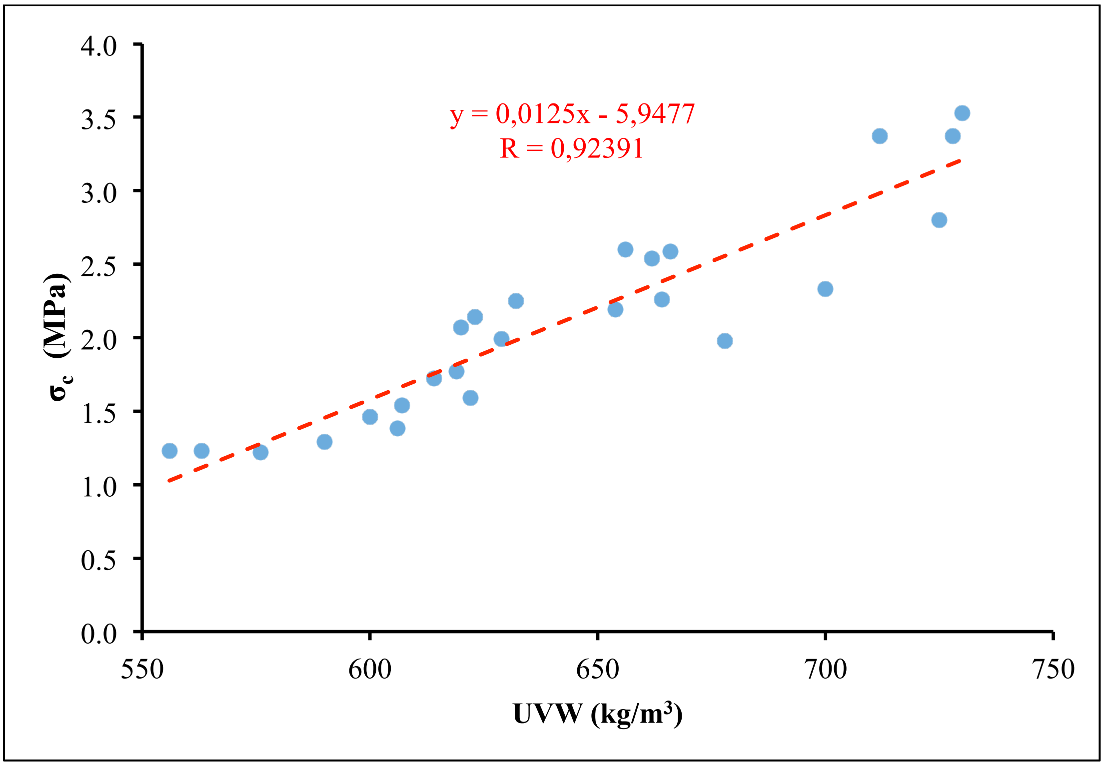

Figure 4.40 : Unit volume weight vs compressive strength

In Figure 4.40, the unit volume weight and compressive strength data obtained from the 25 different plaster mixture series were matched. As can be seen in the graph, the compressive strength tends to increase as the unit volume weight increases.

If it is desired to make selection by taking into consideration the compressive strength criterion alone, plaster mixtures containing cotton + polyester fibers (075CP, 15CP, 2CP, 3CP, 4CP and 5CP) should be preferred. Because the highest compressive strength values are determined in these mixture combinations among all tested mixtures. However, these mixtures have also higher unit volume weight characteristic. This situation could be considered as a disadvantage in terms of lightweight criterion. High unit volume weights affect the economy and thermal conductivity of the materials in the negative direction.

The compressive strength values of all the samples produced and cured for 28 days are included in the compressive strength classes according to TS EN 998-1 standard. In fact, even with 7 day cured compressive strengths are in these classes for all samples.

4.3. Analysis of Flexural Strength of Hardened Composite Plasters

The flexural strength analysis of hardened plasters was carried out in accordance with the test method prescribed in TS EN 1015-11 standard. Three point flexural strength test was applied to the samples. In TS EN 998-1 standard, there are no restrictions on the bending strength of hardened mortars. The waste fiber utilization ratio played an important role in the flexural strength values of the produced composite mortar samples.

Six cubic samples were produced for each mixture series to perform the flexural strength analysis. The samples, after removal from the molds and cured at 3 days and then dried at room temperature until the testing time, were taken directly on the flexural strength test without any further action. The tested flexural strength values of all mortar batches at 7 days to 28 days curing time are presented in Figure 4.41 to Figure 4.50 based on percentage of waste fiber usage ratio by weight.

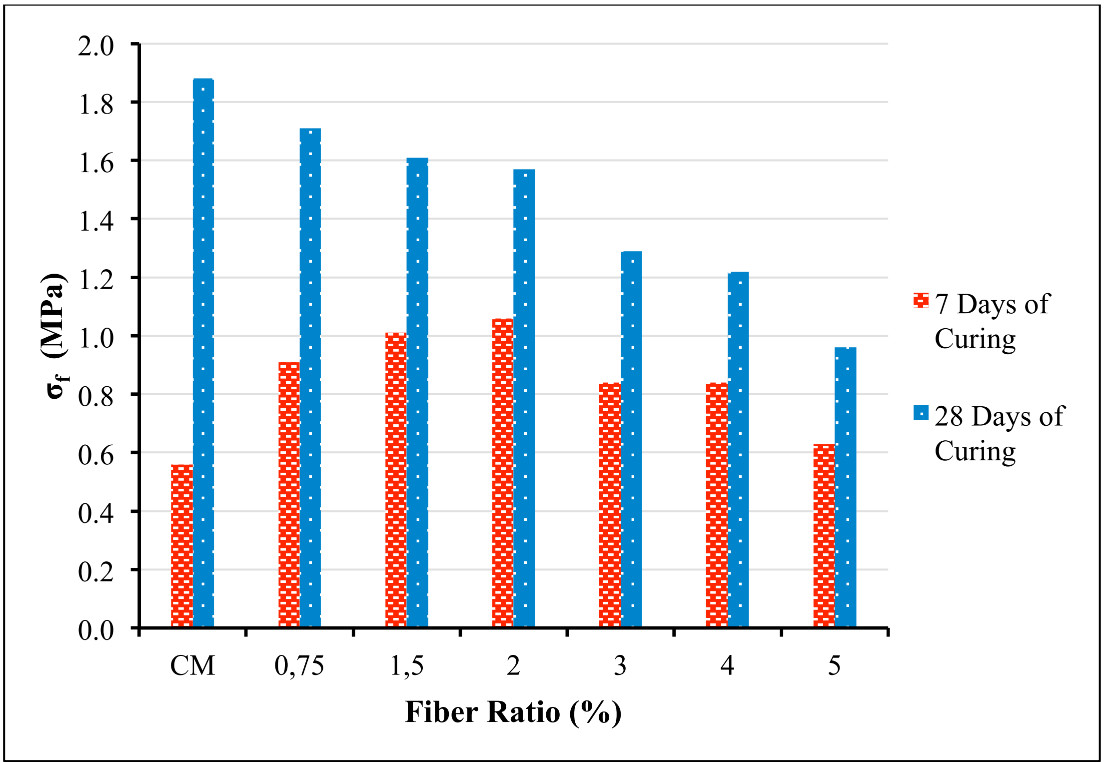

Figure 4.41 : Flexural strength vs cotton fiber ratio.

As Figure 4.41 is examined, flexural strength of mixture combinations were seen in a decreasing trend with the increase of cotton fiber content in both 7 days and 28 days of curing period. All flexural strength values of samples with 28 days curing time were found higher than 7 days cured samples, as it should be. There is a fluctuation in the 7 days strengths because, the samples hold water in fibers, which creates inconsistencies in the results of the experiment conducted on wet samples. Whereas the flexural strength value of the control sample was 1.88 MPa, the flexural strength values of the cotton fiber additive samples varied between 1.71 MPa and 0.96 MPa. In all fiber usage rates used in mortar combinations, a decrease in the flexural strength of the mortars was observed. A decrease of 60% in flexural strength was observed when the cotton waste fiber utilization ratio increased from 0.75% to 5%.

As mentioned before, a decrease in the unit volume weight values of the samples was observed as the fiber utilization ratio in the mixture increased. Since the strength characteristics of the samples are directly proportional to the unit volume weight values, the decrease in the flexural strength of the samples could be explained by the decrease in the unit volume weights. Because the flexural strengths of the mortar samples containing cotton fiber were lower than the flexural strength of the control sample, it was understood that the cotton fiber affects the flexural strength in negative direction.

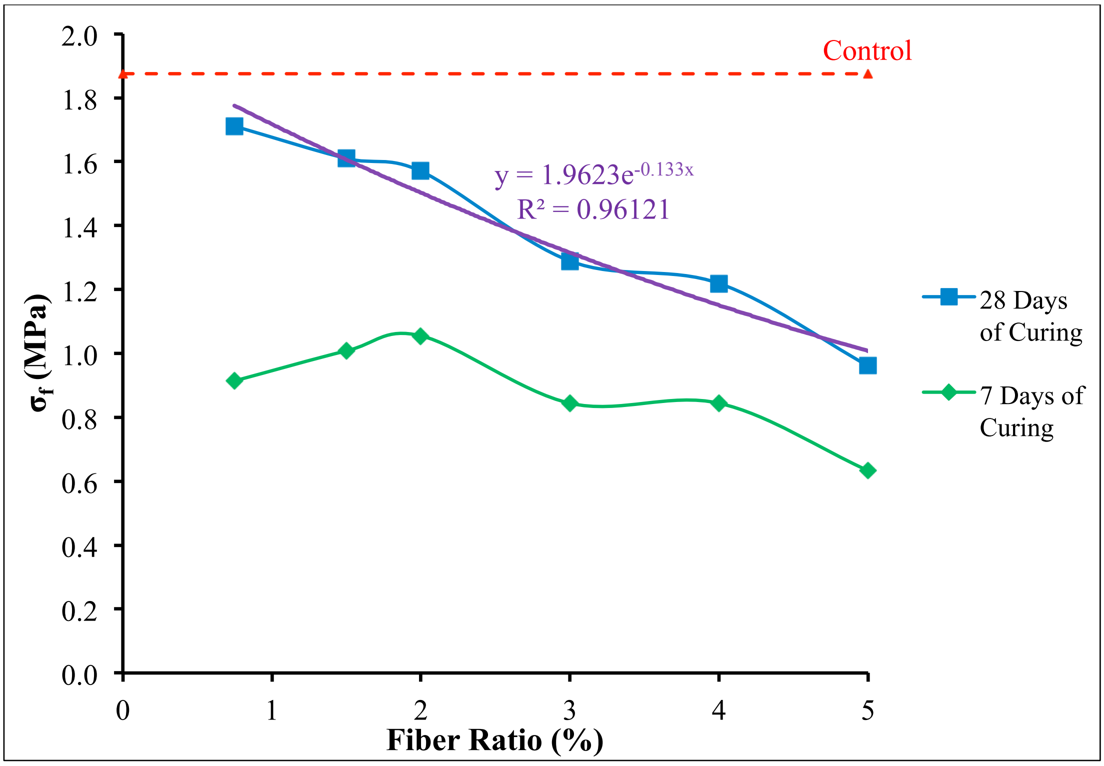

Figure 4.42 : The relation between flexural strength and cotton fiber ratio.

In Figure 4.42, an exponential approach is given to make a prediction between flexural strength and cotton fiber usage. This approach is given for the flexural strength and fiber utilization rates of the 28 days cured samples.

It has been found that the cotton fiber does not provide resistance to bending. Because, the flexural strengths of the mortars containing cotton fiber are lower than the flexural strength of the control mixture. Since there is no limit value for flexural strength for mortars in TS EN 998-1 standard, flexural strength analysis of the plasters was only compared to graphically with each other. The shredded cotton fibers did not provide the necessary resistance to the flexural load. So that the bending strength is even lower than the control sample.

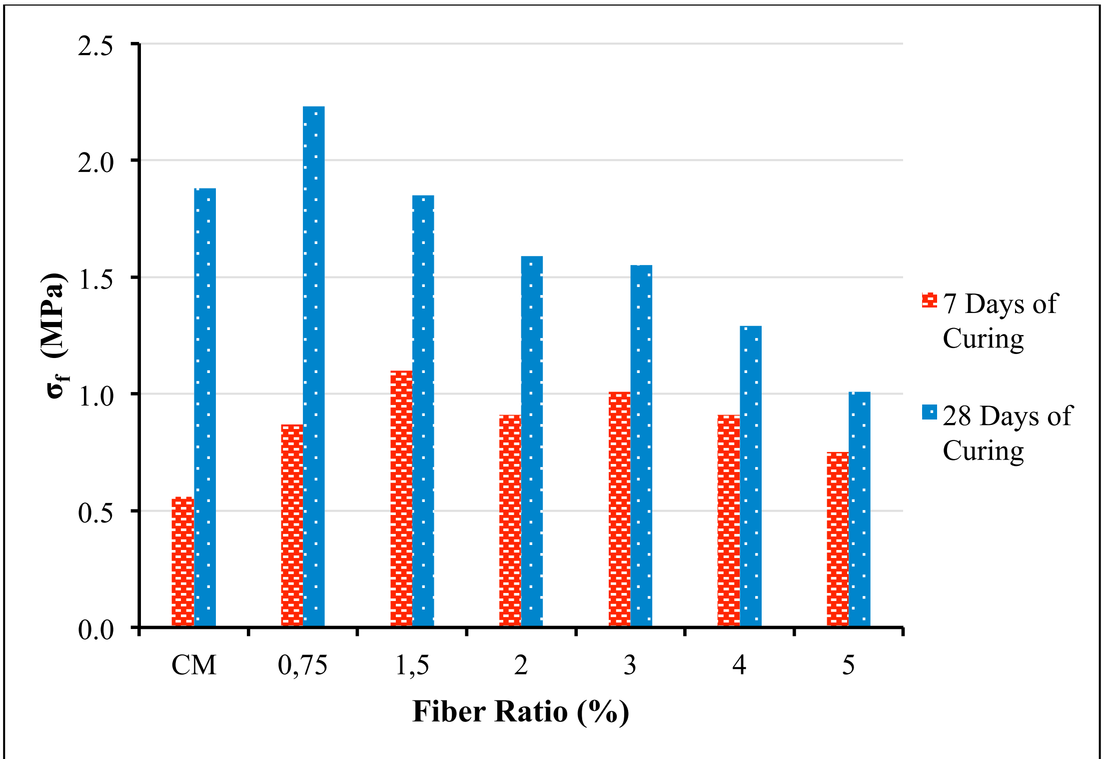

Figure 4.43 : Flexural strength vs mixture of cotton+polyester+acrylic fiber ratio.

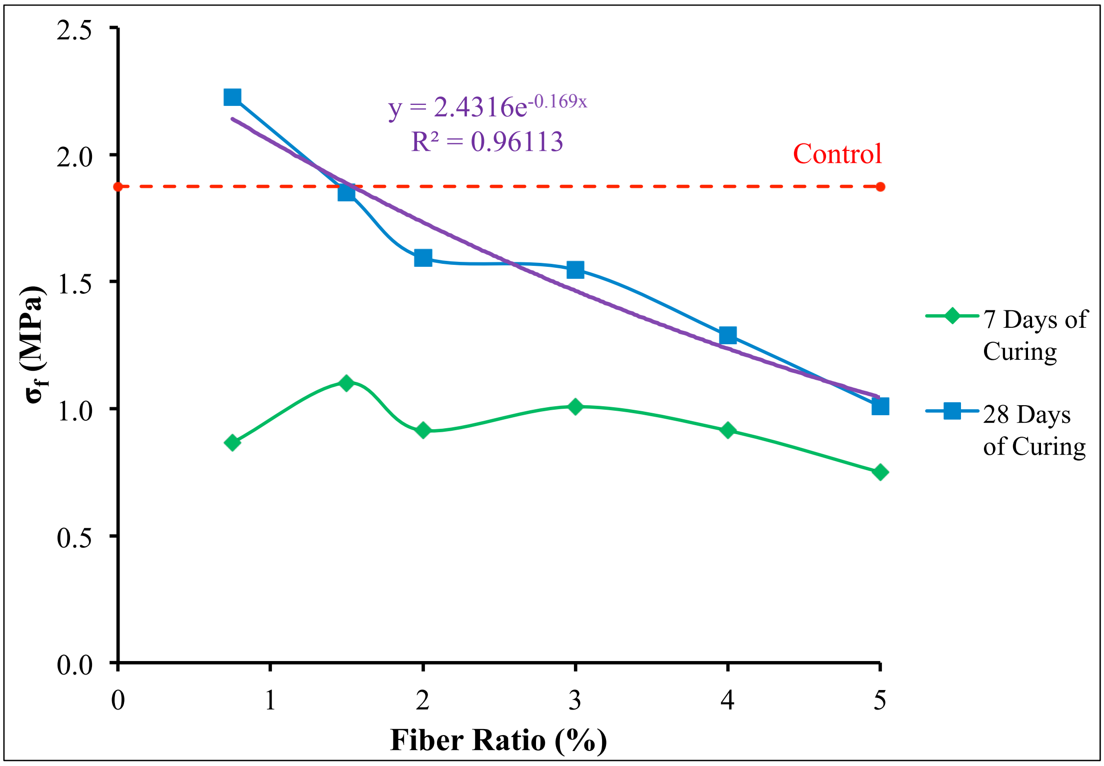

Figure 4.44 : The relation between flexural strength and mixture of cotton+polyester+acrylic fiber ratio.

When Figure 4.43 and Figure 4.44 are examined, it was observed that flexural strength of mixture combinations were decreased with increase in mixture of cotton+polyester+acrylic fiber content in both 7 days and 28 days of curing period. All flexural strength values of samples with 28 days curing time were found higher than 7 days cured samples, as it should be. There is again a fluctuation in the 7 days strengths because, the samples hold water in fibers, which creates inconsistencies in the results of the experiment conducted on wet samples.

Whereas the flexural strength value of the control sample was 1.88 MPa, the flexural strength values of the mixture of cotton+polyester+acrylic fiber additive samples varied between 2.23 MPa and 1.01 MPa. While the use of mixture of cotton+polyester+acrylic fibers at rate of up to 1.4% improved the flexural strength values of the material, more using ratio of this type of fiber than 1.4% reduced the flexural strength in 28 days of curing. A decrease of 55% in flexural strength was observed when the mixture of cotton+polyester+acrylic waste fiber utilization ratio increased from 0.75% to 5%.

As mentioned above, a decrease in the unit volume weight values of the samples was observed as the fiber utilization ratio in the mixture increased. Since the strength characteristics of the samples are directly proportional to the unit volume weight values, the decrease in the flexural strength of the samples could be explained by decreasing the unit volume weights. Since synthetic fibers are resistant to tensile loads, they have increased the flexural strength of the samples to a certain usage rate.

In Figure 4.44, an exponential approach is given to make a prediction between flexural strength and mixture of cotton+polyester+acrylic fiber usage. This approach is basically given for the flexural strength and fiber utilization rates of the 28 days cured samples.

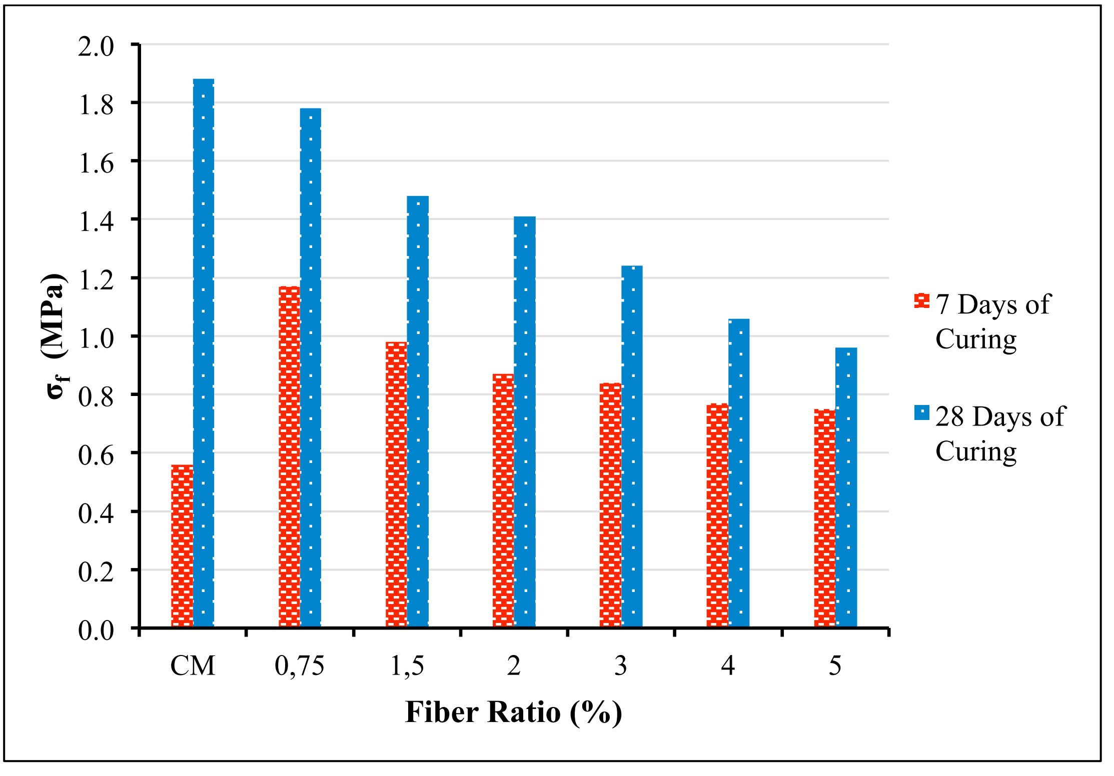

Figure 4.45 : Flexural strength vs polyester fiber ratio.

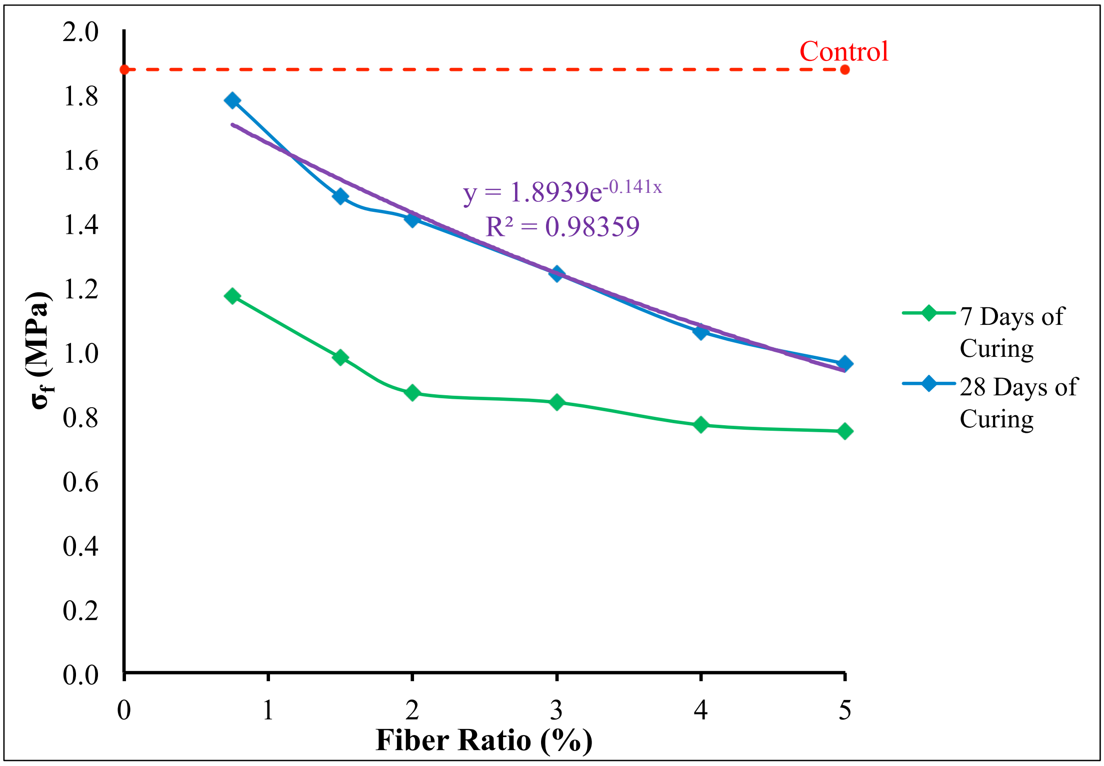

Figure 4.46 : The relation between flexural strength and polyester fiber ratio.

As shown in Figure 4.45 and Figure 4.46, the flexural strength of mixture combinations were seen in a decreasing trend with increase in polyester fiber content in both 7 days and 28 days of curing period. All flexural strength values of samples with 28 days curing time were found higher than 7 days cured samples, as it should be.

While the flexural strength value of the control sample was 1.88 MPa, the flexural strength values for the polyester fiber additive samples varied between 1.78 MPa and 0.96 MPa. In all fiber usage rates used in mortar combinations, a decrease in the flexural strength of the mortars was observed. A decrease of 46% in flexural strength was observed when the cotton waste fiber utilization ratio increased from 0.75% to 5%.

In similar to above mentioned fact, a decrease in the unit volume weight values of the samples was observed as the fiber utilization ratio in the mixture increased. Since the strength characteristics of the samples are directly proportional to the unit volume weight values, the decrease in the flexural strength of the samples could be explained by decreasing the unit volume weights. Because the flexural strengths of the mortar samples containing polyester fiber were lower than the flexural strength of the control sample, it was understood that the polyester fiber affects the flexural strength in negative direction. The smoothness on the surface of randomly distributed polyester fibers may have prevented the fibers from sticking to the cement matrix. Thus, the use of polyester fiber alone has not improved the flexural strength.

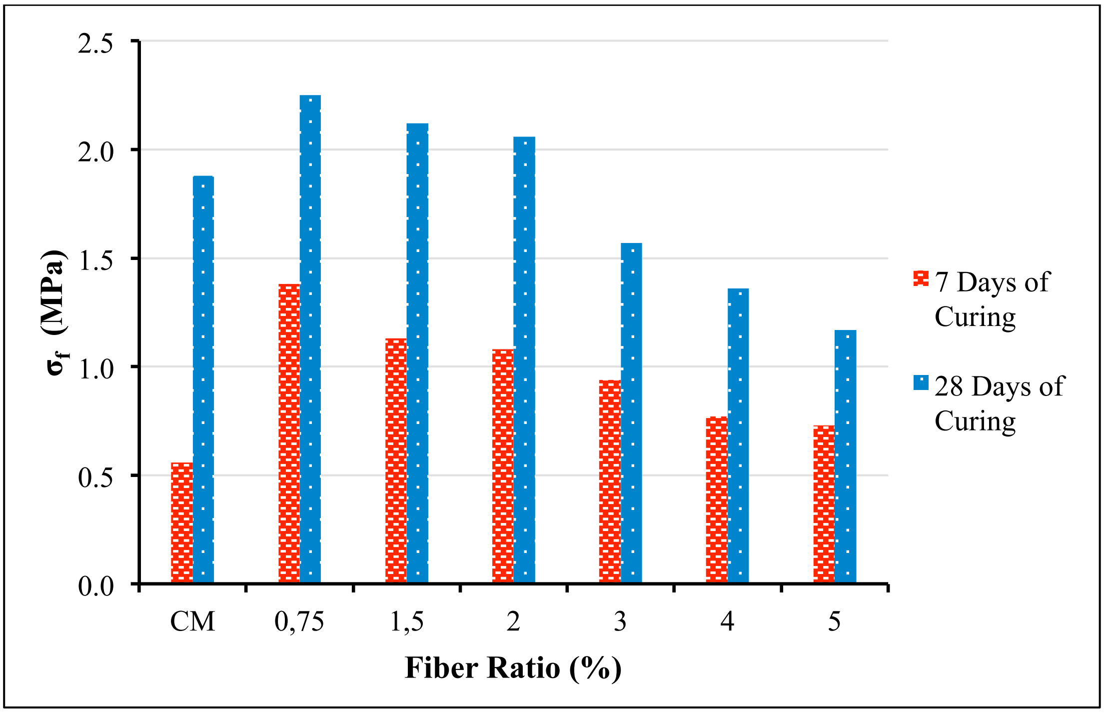

Figure 4.47 : Flexural strength vs mixture of cotton+polyester fiber ratio.

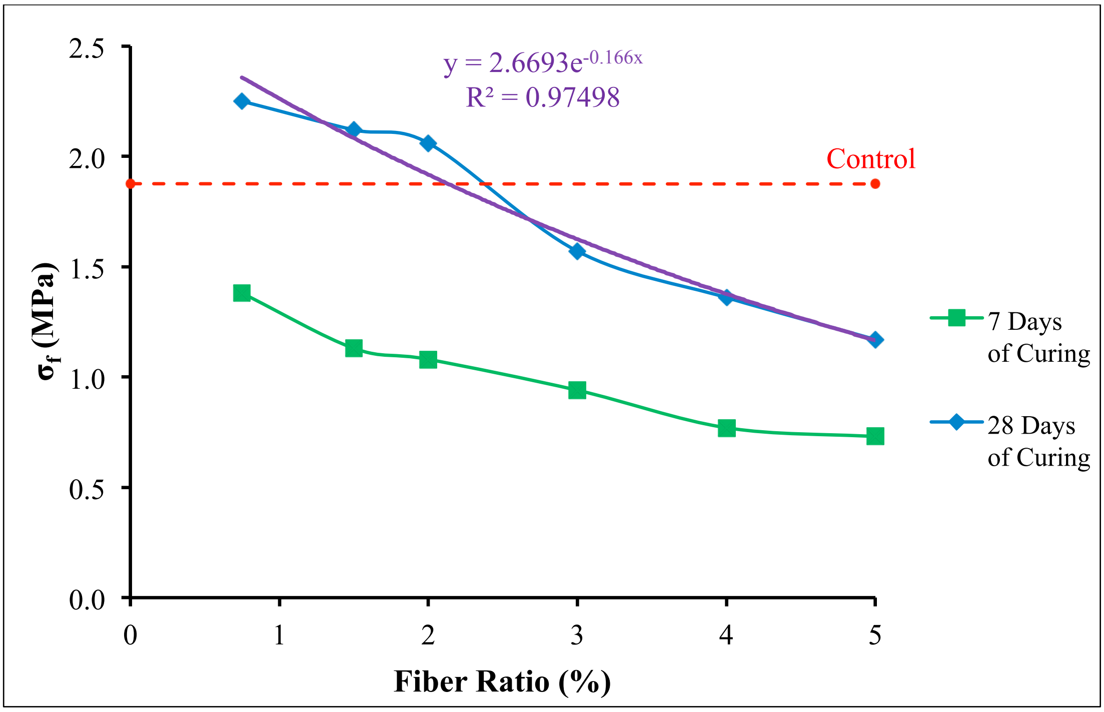

Figure 4.48 : The relation between flexural strength and mixture of cotton+polyester fiber ratio.

According to Figure 4.47 and Figure 4.48, it can be observed that the flexural strength of mixture combinations were decreased with increase in mixture of cotton+polyester fiber content in both 7 days and 28 days of curing period. All flexural strength values of samples with 28 days curing time were found higher than 7 days cured samples, as it should be.

Whereas the flexural strength value of the control sample was 1.88 MPa, the flexural strength values of the mixture of cotton+polyester fiber additive samples varied between 2.25 MPa and 1.17 MPa. While the use of mixture of cotton+polyester fibers at rate of up to 2.5% improved the flexural strength values of the material, more using ratio of this type of fiber than 2.5% reduced the flexural strength in 28 days of curing. A decrease of 48% in flexural strength was observed when the mixture of cotton+polyester waste fiber utilization ratio increased from 0.75% to 5%.

In similar fact, a decrease in the unit volume weight values of the samples was observed as the fiber utilization ratio in the mixture increased. Since the strength characteristics of the samples are directly proportional to the unit volume weight values, the decrease in the flexural strength of the samples could be explained by the decrease in the unit volume weights. Since synthetic fibers are resistant to tensile loads, they have increased flexural strength of the samples to a certain usage rate. The unit volume weights were higher in mixtures in which this fiber type was used. Since the unit volume is proportional to the strength characteristic, the flexural strength of this series is higher than the others.

In Figure 4.48, an exponential approach is given to make a prediction between flexural strength and mixture of cotton+polyester fiber usage. This approach is given for the flexural strength and fiber utilization rates of the 28 days cured samples.

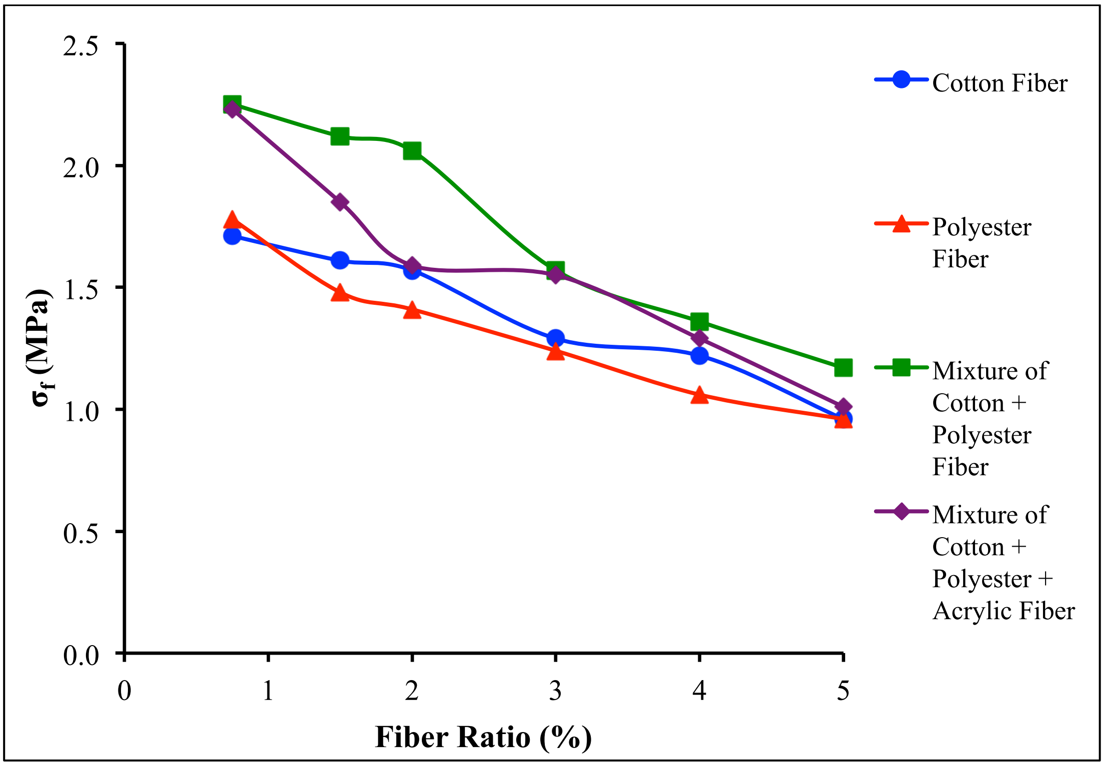

Figure 4.49 : Comparison for all types of fibers in terms of fexural strength.

When Figure 4.49 is examined, it can be easily understood that the plaster samples with mixture of cotton+polyester fiber have the highest flexural strength values, between 2.25 MPa and 1.17 MPa, than the other types. Flexural strength values of the mixture of cotton+polyester+acrylic fiber additive plasters follow the mixture of cotton+polyester fiber additive plasters with 2.23 MPa to 1.01 MPa. It was observed that when cotton and polyester fibers used in plaster combinations are alone, their effects on flexural strength values were found as less than those used as a mixture fiber.

When table 4.2 and figure 4.49 are examined together, CP and CPA coded samples have higher flexural strengths and unit volume weights than the other samples. This also considers the relationship between strength and unit volume weight.

Figure 4.50 shows the relationship between flexural strength and unit volume weight.

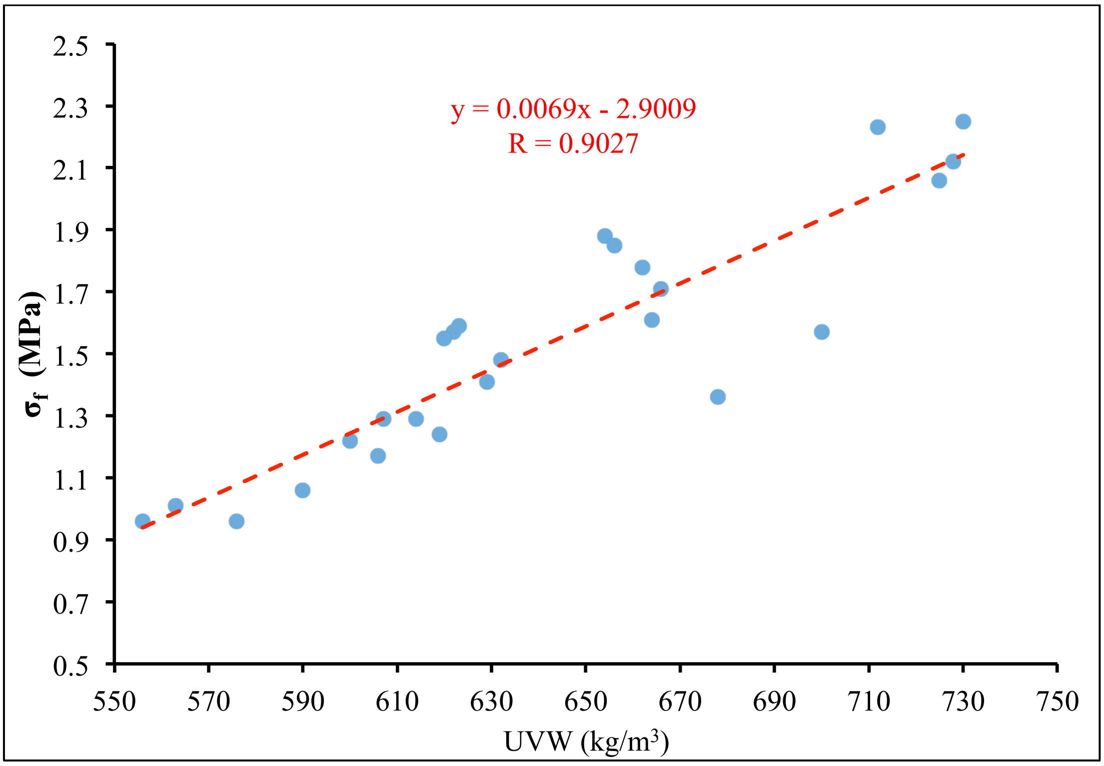

Figure 4.50 : Unit volume weight vs flexural strength.

In Figure 4.50, the unit volume weight and flexural strength data obtained from the 25 different plaster mixture series were matched. As can be seen in the graph, the flexural strength tends to increase as the unit volume weight increases.

A general evaluation for flexural strength; if it is desired to make selection by taking into consideration the flexural strength criterion alone, plaster mixtures containing cotton + polyester fibers (075CP, 15CP, 2CP, 3CP, 4CP and 5CP) should be preferred. It is possible that the highest flexural strength values are determined in these mixture combinations among all tested mixtures. However, these mixtures have also higher unit volume weight characteristic. This situation could be considered as a disadvantage in terms of lightweight criterion. High unit volume weights affect the economic aspects and thermal conductivity of the materials in the negative direction.

4.4. Splitting Tensile Strength of Hardened Composite Plasters

This test method covers the determination of the splitting tensile strength of Ø50x100 mm cylindrical mortar specimens. This test method consists of applying a diametral compressive force along the length of a cylindrical mortar specimen at a rate that is within a prescribed range until failure occurs. This loading induces tensile stresses on the plane containing the applied load and relatively high compressive stresses in the area immediately around the applied load. Tensile failure occurs rather than compressive failure because the areas of load application are in a state of triaxial compression, thereby allowing them to withstand much higher compressive stresses than would be indicated by a uniaxial compressive strength test result. Splitting tensile strength is generally greater than direct tensile strength and lower than flexural strength (ASTM, 2004).

Six cubic samples were prepared for each mixture series to perform the splitting tensile strength analysis. The samples, after removal from the molds and cured at 3 days and then dried at room temperature until the testing time, were taken directly on the splitting tensile strength test without any further action. The tested splitting tensile strength values of all mortar batches at 14 days to 28 days curing time are presented in Figure 4.51 to Figure 4.60 based on percentage of waste fiber usage ratio by weight.

The splitting tensile strength values of fiber reinforced samples were not consistent at 7 days curing time. For this, splitting tensile strengths on the 14th and 28th days were measured.

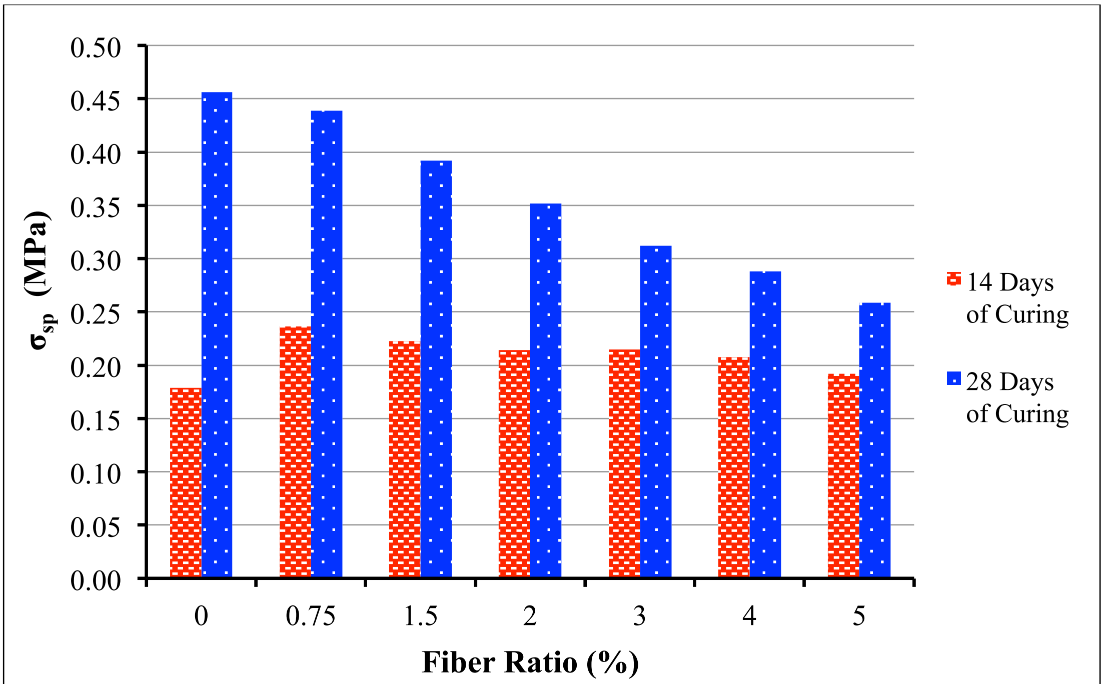

Figure 4.51 : The relation between splitting tensile strength and cotton fiber ratio.

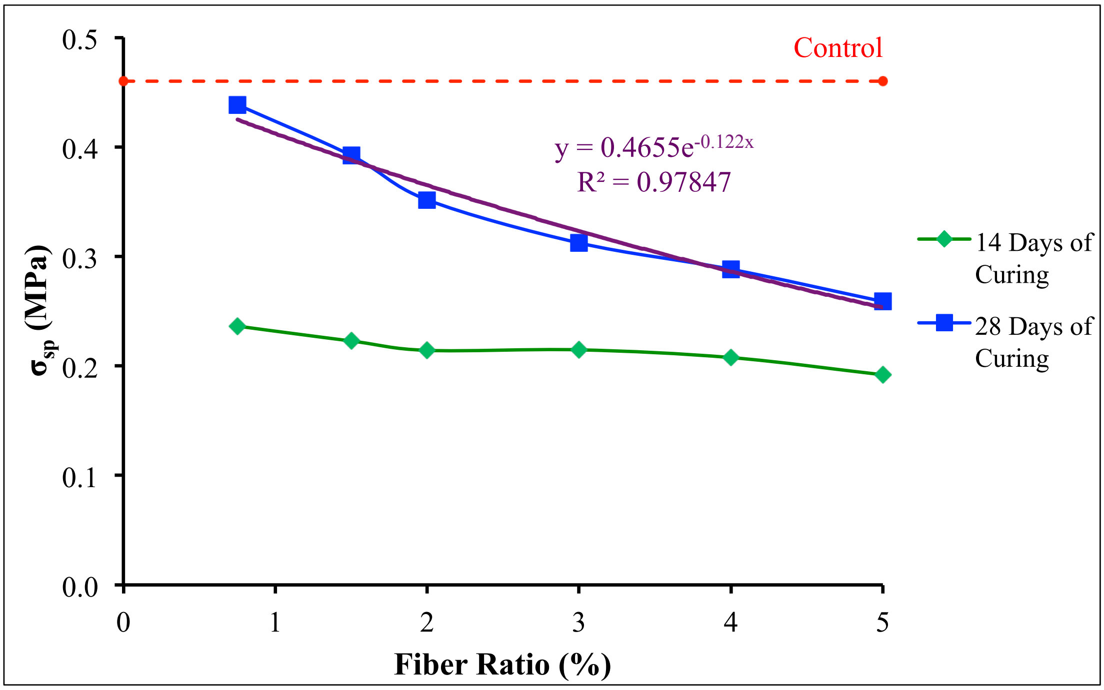

Figure 4.52 : The relation between splitting tensile strength and cotton fiber ratio.

When Figure 4.51 and Figure 4.52 are examined, splitting tensile strength of mixture combinations exhibited a decreasing trend with the increase of cotton fiber content in both 14 days and 28 days of curing period. All splitting tensile strength values of samples with 28 days curing time were found higher than 14 days cured samples, as it was expected to be. While the splitting tensile strength value of the control sample was 0.46 MPa, the splitting tensile strength values of the cotton fiber additive samples varied between 0.44 MPa and 0.26 MPa. In all fiber usage rates used in mortar combinations, a decrease in the splitting tensile strength of the mortars was observed. A decrease of 41% in splitting tensile strength was also observed when the cotton waste fiber utilization ratio increased from 0.75% to 5%.

As briefly discussed above, a decrease in the unit volume weight values of the samples was observed, when the fiber utilization ratio increased in the mixture. Since the strength characteristics of the samples are directly proportional to the unit volume weight values, the decrease in the splitting tensile strength of the samples could be explained by the decrease in the unit volume weights. Because the splitting tensile strength of the mortar samples containing cotton fiber were lower than the splitting tensile strength of the control sample, it was understood that the cotton fiber affects the splitting tensile strength in negative direction.

In Figure 4.52, an exponential approach is given to make a prediction between splitting tensile strength and cotton fiber usage. This approach is given for the splitting tensile strength and fiber utilization rates of the 28 days cured samples.

It has been found that the cotton fiber does not provide resistance to tensile strength. Because, the splitting tensile strengths of the mortars containing cotton fiber are lower than the splitting tensile strength of the control mixture. Since there is no limit value for splitting tensile strength of mortars in TS EN 998-1 standard, splitting tensile strength analysis of the mortar samples was only compared graphically with each other. The shredded cotton fibers did not provide the necessary resistance to the tensile stress. So that the splitting tensile strength is even lower than the control sample.

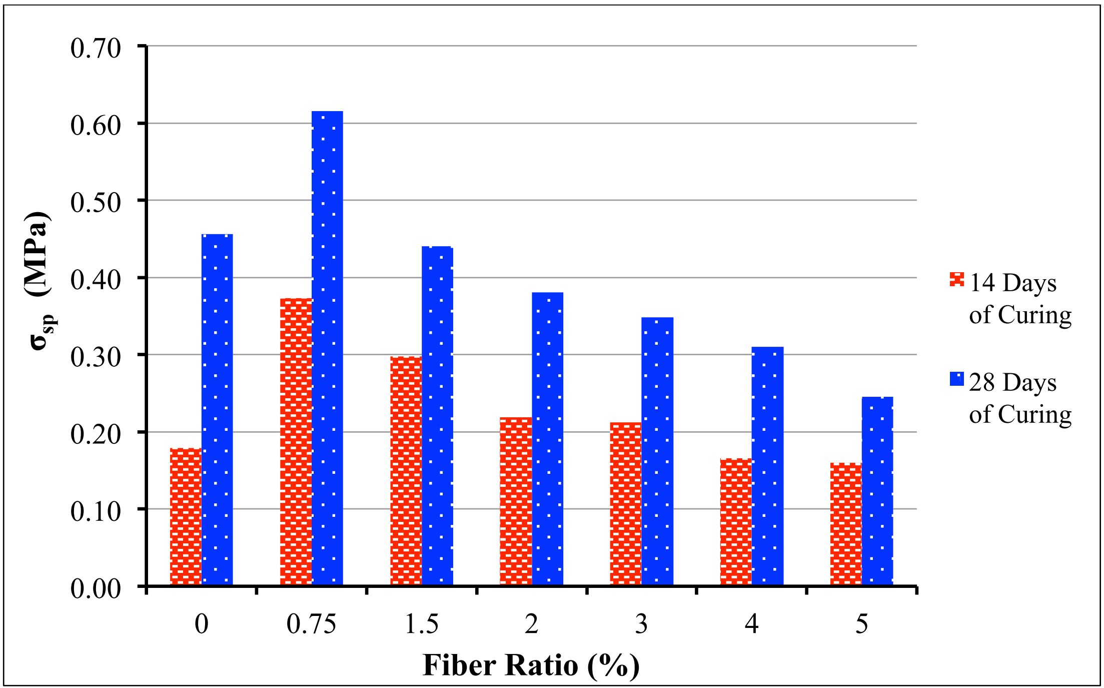

Figure 4.53 : The relation between splitting tensile strength and mixture of cotton+polyester+acrylic fiber ratio.

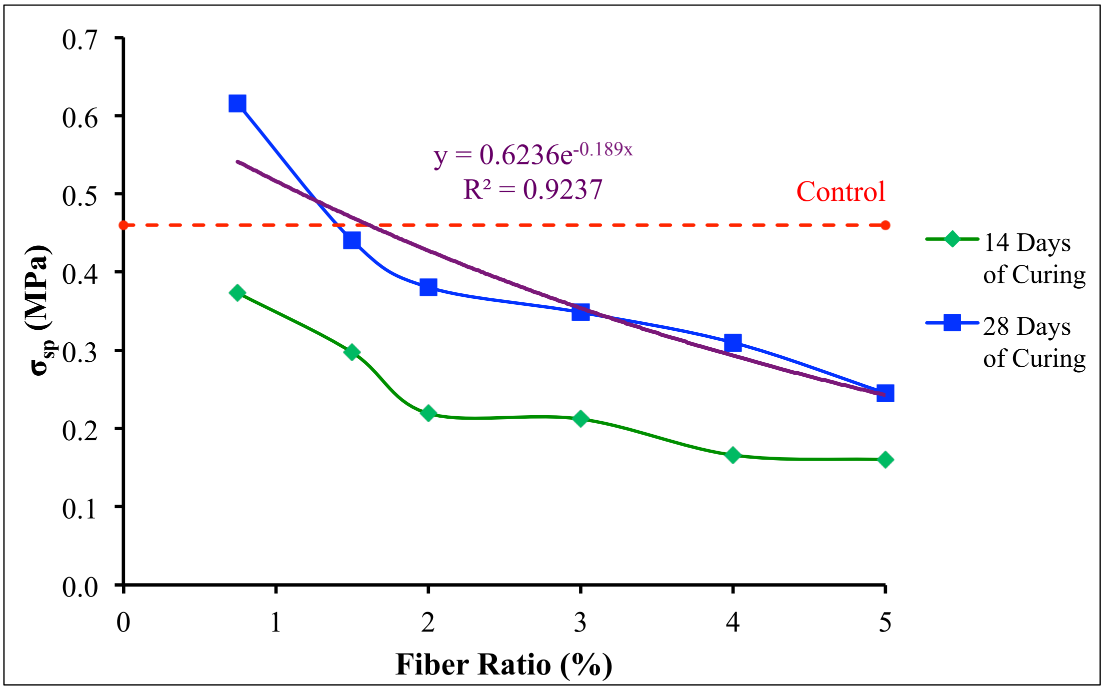

Figure 4.54 : The relation between splitting tensile strength and mixture of cotton+polyester+acrylic fiber ratio.

When Figure 4.53 and Figure 4.54 are examined, it can be seen that splitting tensile strength of mixture combinations were decreased with increase in mixture of cotton+polyester+acrylic fiber content in both 14 days and 28 days of curing period. All splitting tensile strength values of samples with 28 days curing time were found higher than 14 days cured samples, as expected, too.

Whereas the splitting tensile strength value of the control sample was 0.46 MPa, the splitting tensile strength values of the mixture of cotton+polyester+acrylic fiber additive samples varied between 0.62 MPa and 0.25 MPa. While the use of mixture of cotton+polyester+acrylic fibers at rate of up to 1.4% improved the splitting tensile strength values of the material, more using ratio of this type of fiber than 1.4% reduced the splitting tensile strength in 28 days of curing. A decrease of 60% in splitting tensile strength was observed when the mixture of cotton+polyester+acrylic waste fiber utilization ratio increased from 0.75% to 5%.

On the other hand, a decrease in the unit volume weight values of the samples was further observed as the fiber utilization ratio in the mixture increased. Since the strength characteristics of the samples are directly proportional to the unit volume weight values, the decrease in the splitting tensile strength of the samples could be explained by the decrease in the unit volume weights. Since synthetic fibers are resistant to tensile loads, they have increased splitting tensile strength of the samples to a certain usage rate. Besides, in Figure 4.54, an exponential approach is given to make a prediction between splitting tensile strength and mixture of cotton+polyester+acrylic fiber usage. This approach is given for the splitting tensile strength and fiber utilization rates of the 28 days cured samples.

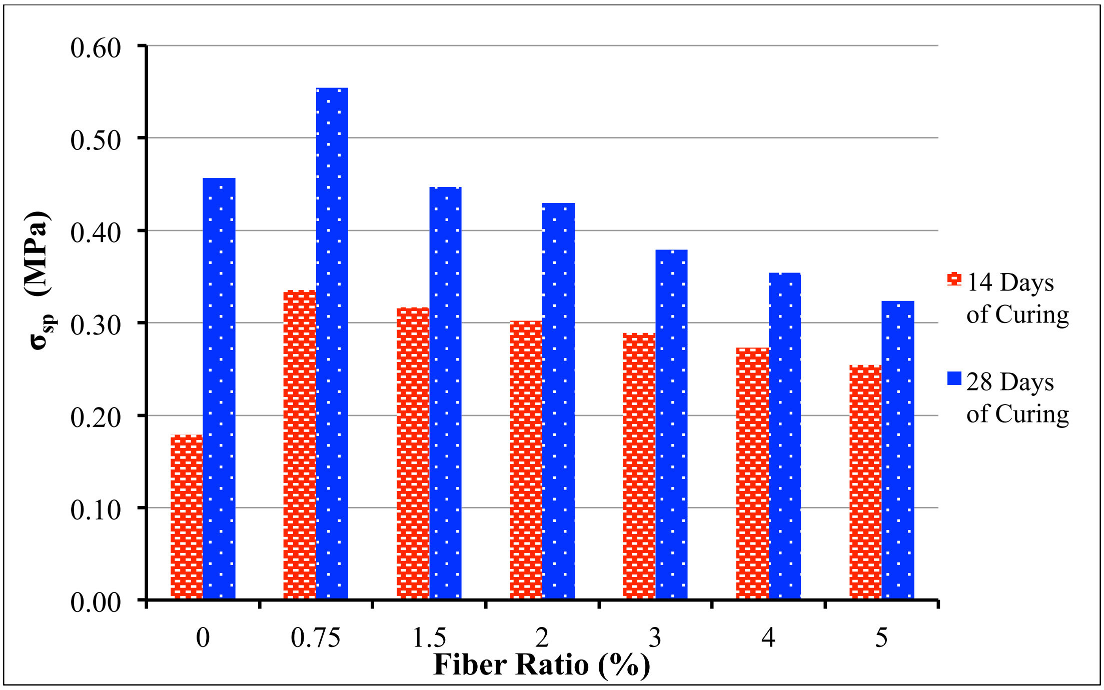

Figure 4.55 : The relation between splitting tensile strength and polyester fiber ratio.

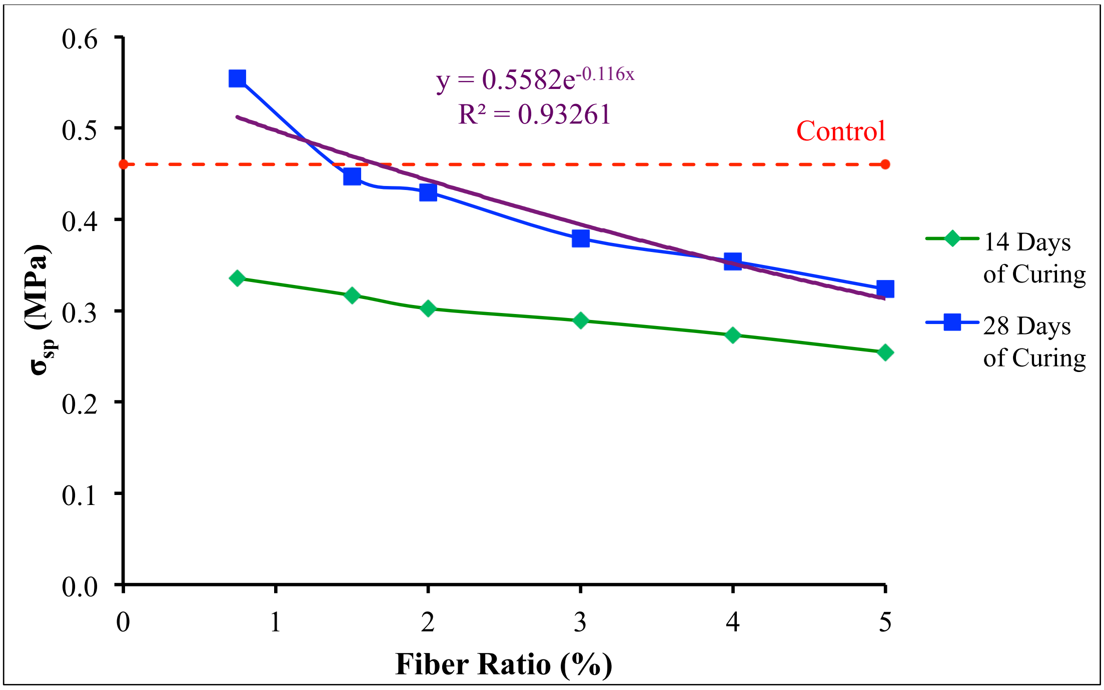

Figure 4.56 : The relation between splitting tensile strength and polyester fiber ratio.

As Figure 4.55 and Figure 4.56 are examined, it can be seen that splitting tensile strength of mixture combinations were decreased with increase in polyester fiber content in both 14 days and 28 days of curing period. All splitting tensile strength values of samples with 28 days curing time were found higher than 14 days cured samples.

While the splitting tensile strength value of the control sample was 0.46 MPa, the splitting tensile strength values of the polyester fiber additive samples varied between 0.55 MPa and 0.32 MPa. While the use of polyester fibers at rate of up to 1.4% improved the splitting tensile strength values of the material, more using ratio of this type of fiber than 1.4% reduced the splitting tensile strength in 28 days of curing. A decrease of 42% in splitting tensile strength was observed when the polyester waste fiber utilization ratio increased from 0.75% to 5%.

Furthermore, a decrease in the unit volume weight values of the samples was observed as the fiber utilization ratio in the mixture increased. Since the strength characteristics of the samples are directly proportional to the unit volume weight values, the decrease in the splitting tensile strength of the samples could be explained by the decrease in the unit volume weights. Since synthetic fibers are resistant to tensile loads, they have increased splitting tensile strength of the samples to a certain usage rate.

In Figure 4.56, an exponential approach is given to make a prediction between splitting tensile strength and polyester fiber usage. This approach is given for the splitting tensile strength and fiber utilization rates of the 28 days cured samples.

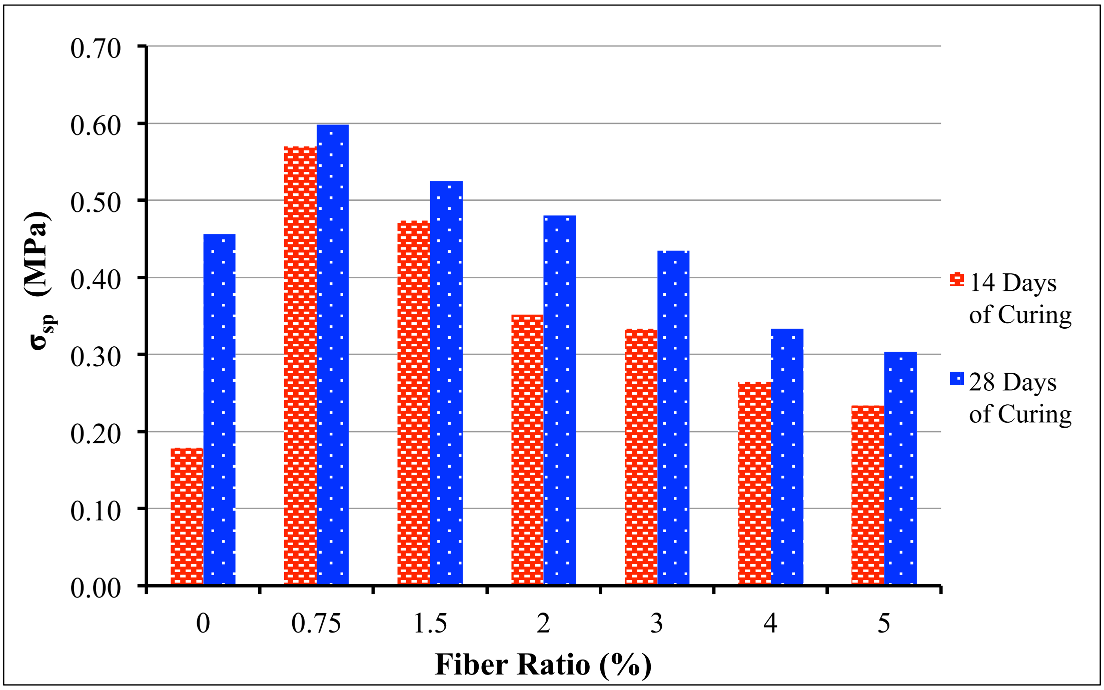

Figure 4.57 : The relation between splitting tensile strength and mixture of cotton+polyester fiber ratio.

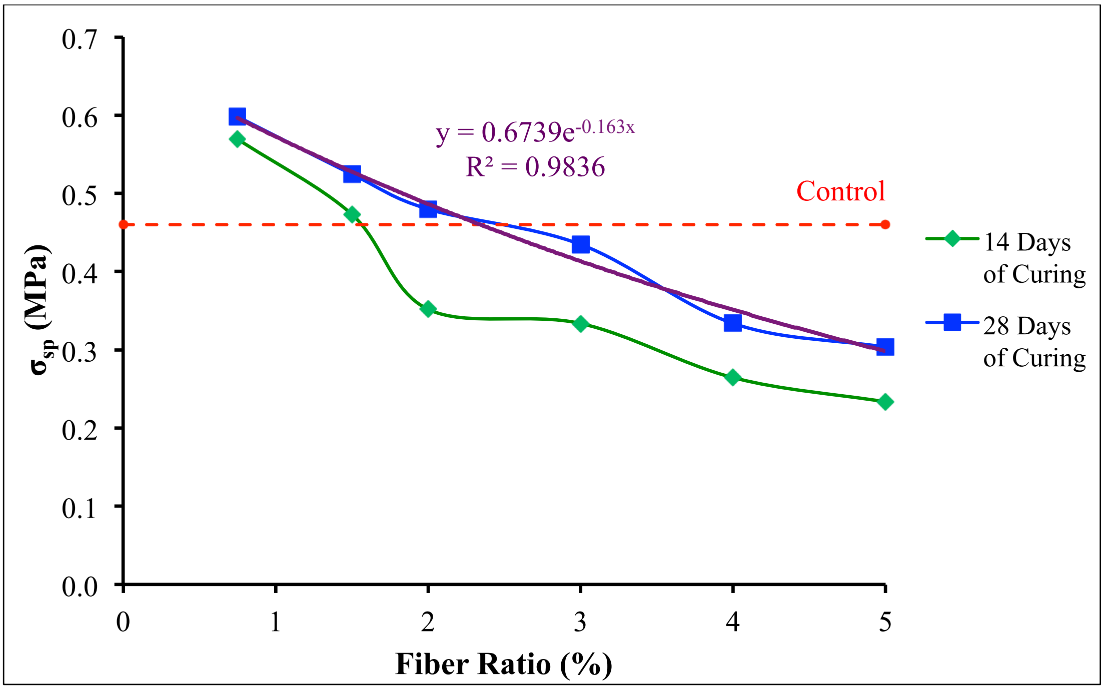

Figure 4.58 : The relation between splitting tensile strength and mixture of cotton+polyester fiber ratio.

Figure 4.57 and Figure 4.58 states that splitting tensile strength of mixture combinations decrease with increase in mixture of cotton+polyester fiber content in both 14 days and 28 days of curing period. All flexural strength values of samples with 28 days curing time were found higher than 14 days cured samples.

Whereas the splitting tensile strength value of the control sample was 0.46 MPa, the splitting tensile strength values of the mixture of cotton+polyester fiber additive samples varied between 0.60 MPa and 0.30 MPa. While the use of mixture of cotton+polyester fibers at rate of up to 2.5% improved the splitting tensile strength values of the material, more using ratio of this type of fiber than 2.5% reduced the flexural strength in 28 days of curing. A decrease of 50% in splitting tensile strength was observed when the waste fiber ratio increased from 0.75% to 5%. Similar another research finding observe in the research is a decrease in the unit volume weight values of the samples as the fiber utilization ratio in the mixture increased. Since the strength characteristics of the samples are directly proportional to the unit volume weight values, the decrease in the splitting tensile strength of the samples could be explained by the decrease in the unit volume weights. Since synthetic fibers are resistant to tensile loads, they have increased splitting tensile strength of the samples to a certain usage rate. The unit volume weights were higher in mixtures in which this fiber type was used. Since the unit volume is proportional to the strength characteristic, the splitting tensile strength of this series is higher than the others. In addition, in Figure 4.58, an exponential approach is given to make a prediction between splitting tensile strength and mixture of cotton+polyester fiber usage. This approach is given for the 28 days cured samples.

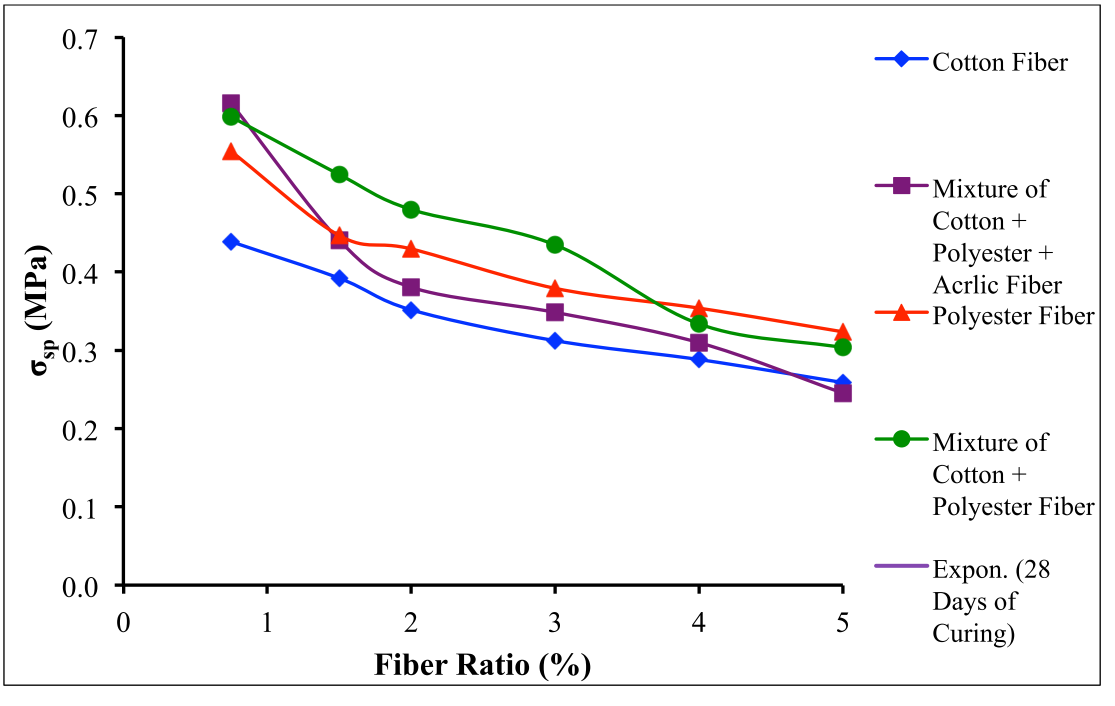

Figure 4.59 : Comparison for all types of fibers in terms of splitting tensile strength.

As examining Figure 4.59, it is found that the plaster samples with mixture of cotton+polyester fiber have better splitting tensile strength values, between 0.60 MPa and 0.30 MPa, than the other types. Splitting tensile strength values of polyester fiber additive plasters follow the mixture of cotton+polyester fiber additive plasters with 0.55 MPa to 0.32 MPa. The research findings showed that when cotton fibers used in plaster combinations alone, their effects on splitting tensile strength values were found as less than those used as a mixture fiber. Splitting tensile strength of 0.75% mixture of cotton+polyester+acrylic fiber additive mortar was found as the highest value (0.62 Mpa), although splitting tensile strength of 5.0% usage of same fiber additive in the plaster combinations was found as the lowest value with 0.25 MPa. This actually represents that lower utilization ratio of mixture of cotton+polyester+acrylic fiber additive provides the added value to the mortars splitting tensile characteristics.

When Table 4.2 and Figure 4.59 are examined together, CP and CPA coded samples have higher splitting tensile strengths and unit volume weights than the other samples. Therefore, a relationship between strength and unit volume weight could be considered.

Figure 4.60 shows the relationship between splitting tensile strength and unit volume weight.

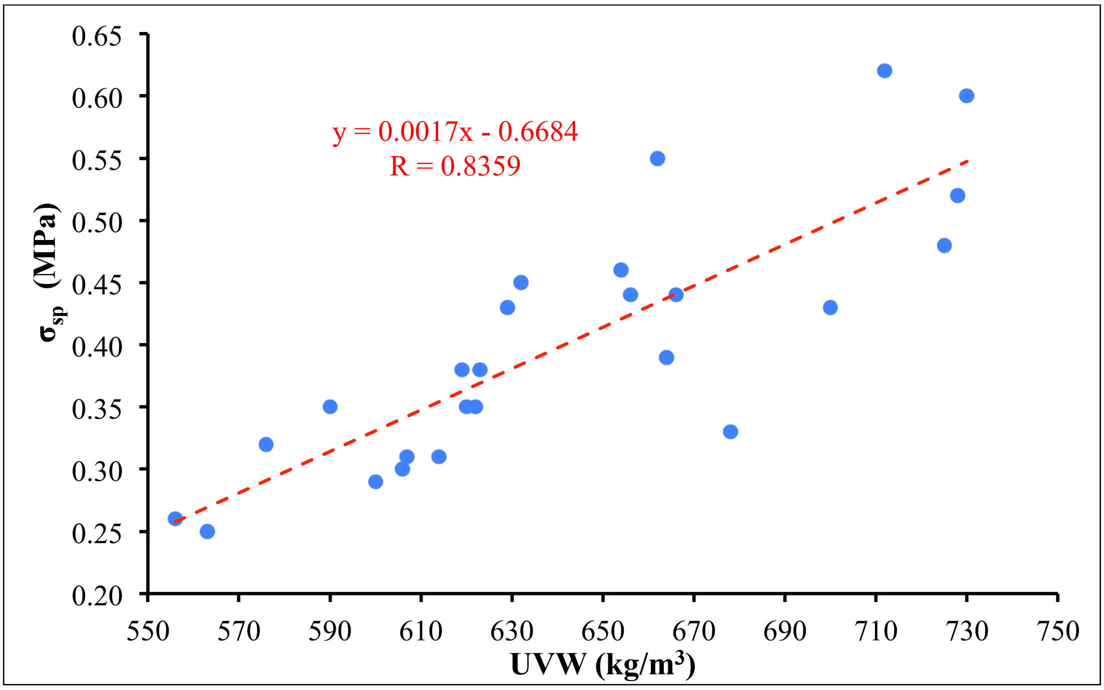

Figure 4.60 : Unit volume weight vs splitting tensile strength.

In Figure 4.60, the unit volume weight and splitting tensile strength data obtained from the 25 different plaster mixture series were matched. As can be seen in the graph, the splitting tensile strength tends to increase as the unit volume weight increases.

A general evaluation for splitting tensile strength; if it is desired to make selection by taking into consideration the splitting tensile strength criterion alone, the test samples containing cotton + polyester fibers (075CP, 15CP, 2CP, 3CP, 4CP and 5CP) should be preferred. This investigation showed that the highest splitting tensile strength values could be determined in these mixture combinations among all tested samples. These samples have higher unit volume weight characteristic. This situation could be considered as a disadvantage in terms of lightweight criterion. High unit volume weights affect the economic aspects and thermal conductivity of the materials in the negative direction.

4.5. Analysis of Structural Strength Parameters of Hardened Composite Plasters

Structural mechanical properties, such as internal friction angle, failure angle, normal strength, shear strength and cohesion parameters, of the samples were carried out in this thesis study. Structural strength analysis of materials provides more comprehensive information about internal actions of the material.

Mohr Coulomb Failure Criterion was used to determine the structural strength properties of samples. This criterion could be used to estimate some mechanical properties of cement matrix composites based on the tension and compression stresses.

Structural strength parameters are chiefly used in rock mechanics and soil mechanics. Internal friction angle, failure angle and cohesion parameters are the main parameters in rock and in soil classification and load bearing calculations. Mohr coulomb criterion is used to obtain these parameters. With a similar approach, in order to find these parameters and to understand the inner structure of cementitious mortars, Mohr Coulomb criterion was tried to be used in this research. Structural strength properties of composite mortars are given in Table 4.4.

Table 4.4 : Structural strength properties of the composite plasters.

Mix	α (°)	ϕ (°)	σ_n (MPa)	C (Mpa)	σ_s (MPa)
CM	64.5	41.0	0.40	0.51	0.85
075C	66.9	44.6	0.39	0.54	0.92
15C			0.34	0.48	0.82
2C			0.29	0.38	0.62
3C			0.26	0.35	0.58
4C			0.25	0.34	0.56
5C			0.22	0.29	0.48
075CP	68.4	46.7	0.52	0.73	1.25
15CP			0.46	0.67	1.14
2CP			0.42	0.59	1.01
3CP			0.37	0.51	0.85
4CP			0.28	0.41	0.69
5CP			0.24	0.33	0.54
075P	65.7	41.6	0.46	0.61	0.98
15P			0.38	0.51	0.85
2P			0.35	0.47	0.76
3P			0.32	0.41	0.68
4P			0.28	0.34	0.54
5P			0.25	0.31	0.50
075CPA	67.5	45.5	0.52	0.73	1.20
15CPA			0.39	0.54	0.93
2CPA			0.32	0.47	0.77
3CPA			0.30	0.43	0.74
4CPA			0.26	0.38	0.62
5CPA			0.21	0.29	0.46

α : Failure Angle
ϕ : Internal Friction Angle
σ_n : Normal Strength
C : Cohesion
σ_s : Shear Strength

4.5.1. Mohr circle

Mohr Coulomb Failure Criterion was used to determine the structural strength properties of samples. It can be estimated some mechanical properties of concrete based on the tension and compression stresses.

Mohr envelopes were drawn by the use of the compressive and splitting tensile stress data. Some examples of drawn Mohr envelopes are given in Figure 4.61 and Figure 4.75. These drawings have been done separately for each mixture combination and structural mechanical properties of the materials have been found through the drawings.

Firstly, a coordinate system, which x plane represents normal strength and y plane represents shear strength, is drawn. Mohr circles were generated by plotting a half circle to the left of the x-axis of the coordinate system representing splitting tensile strength and another half circle to the right of the x-axis of the coordinate system representing compressive strength. Then, a tangent line is drawn to the two half circles. The slope of this line gives the internal friction angle of the material. The point where the tangent line cut the y plane gives cohesion. Center of the compressive strength and tangent line are joint by a straight line. Value of this point at x-axis gives normal strength and at y-axis shear strength. In this study, these values are discussed as structural strength values.

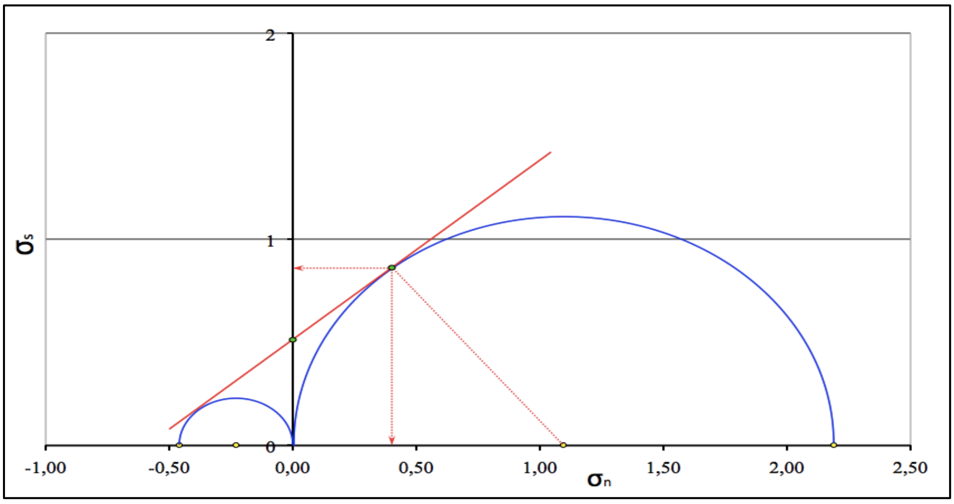

Figure 4.61 : Mohr Circles of CM.

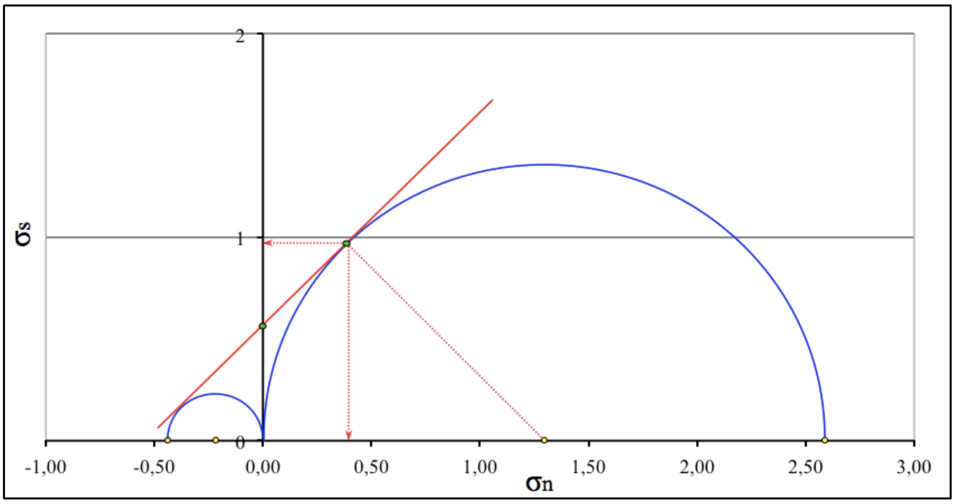

Figure 4.62 : Mohr Circles of 075C.

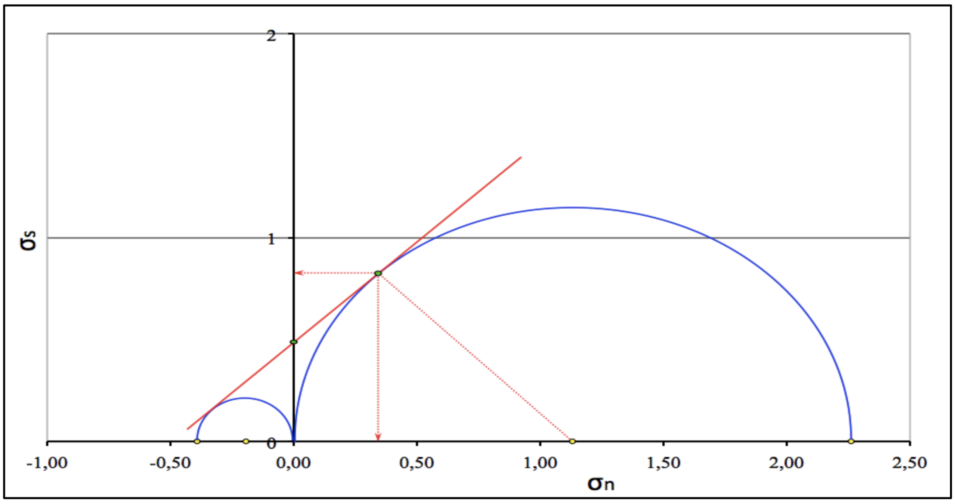

Figure 4.63 : Mohr Circles of 15C.

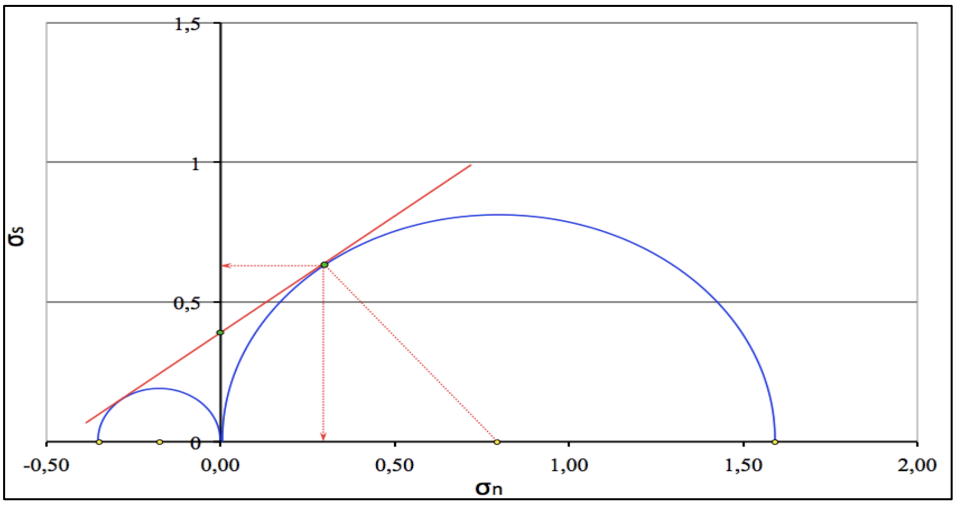

Figure 4.64 : Mohr Circles of 2C.

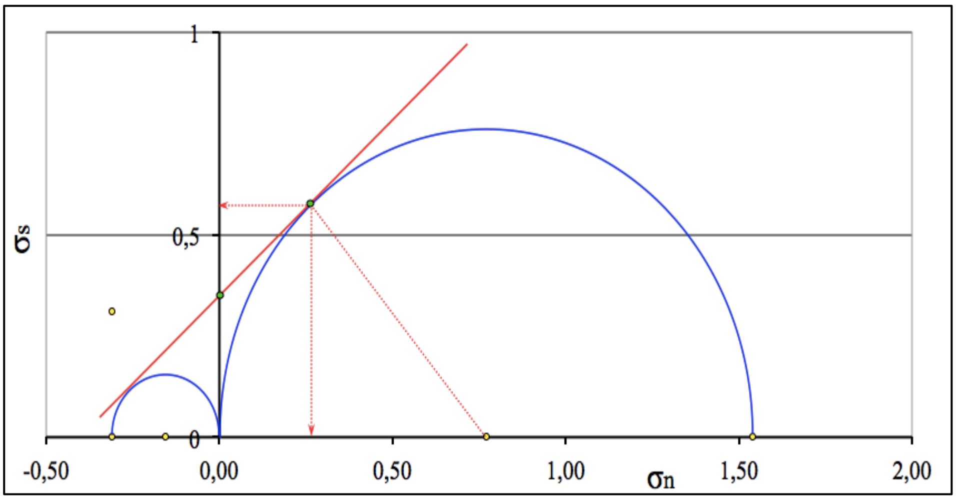

Figure 4.65 : Mohr Circles of 3C.

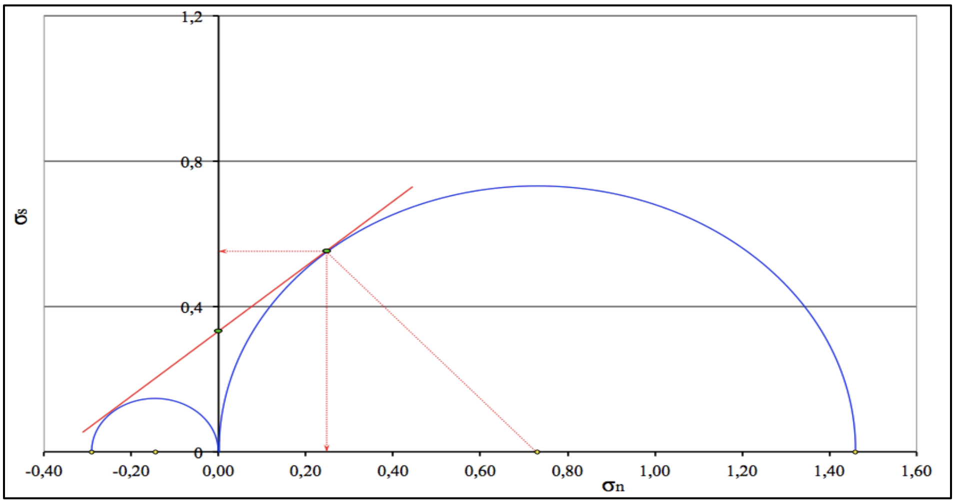

Figure 4.66 : Mohr Circles of 4C.

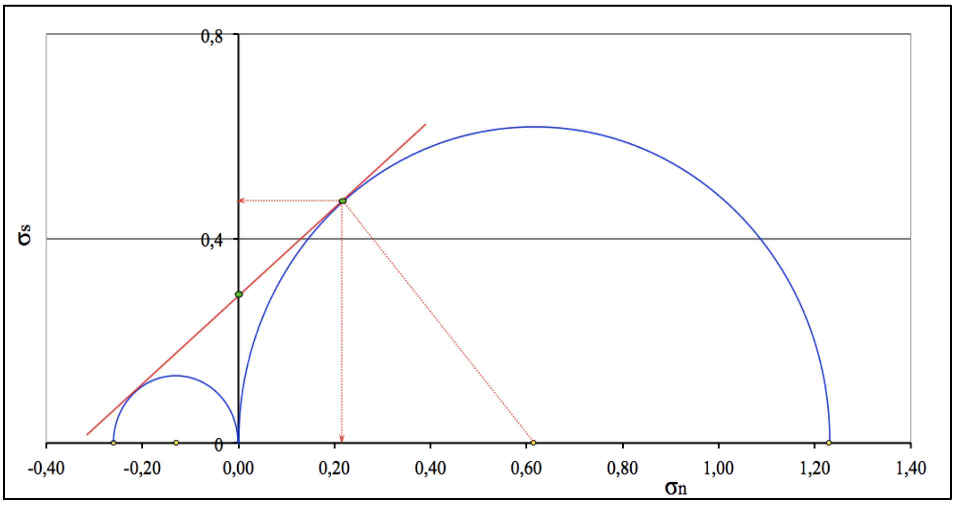

Figure 4.67 : Mohr Circles of 5C.

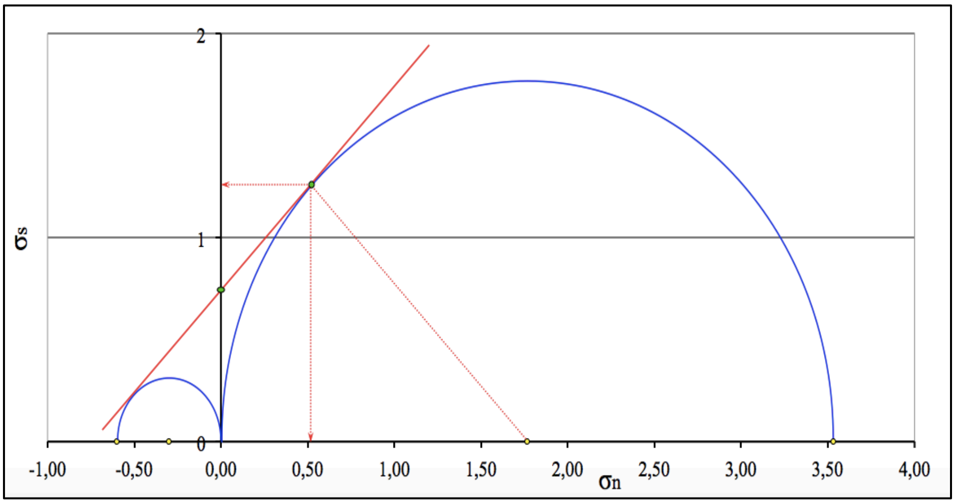

Figure 4.68 : Mohr Circles of 075CP.

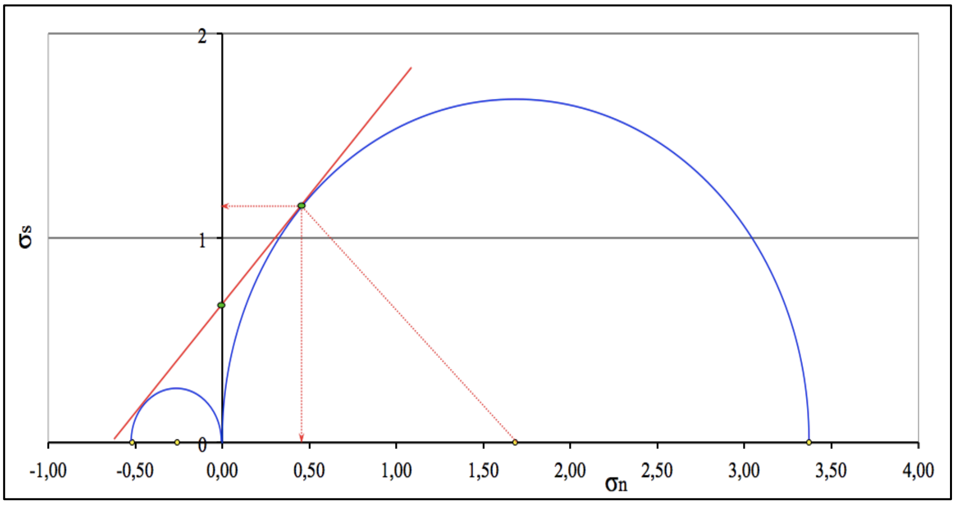

Figure 4.69 : Mohr Circles of 15CP.

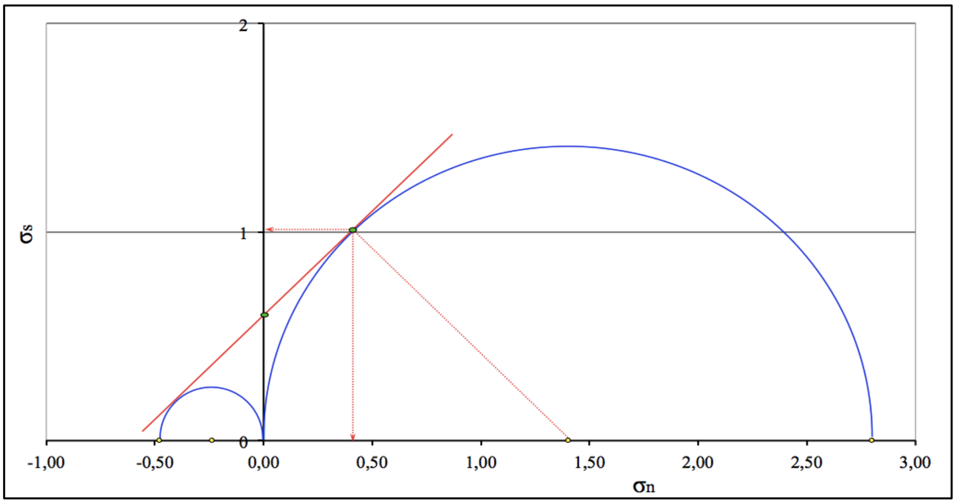

Figure 4.70 : Mohr Circles of 2CP.

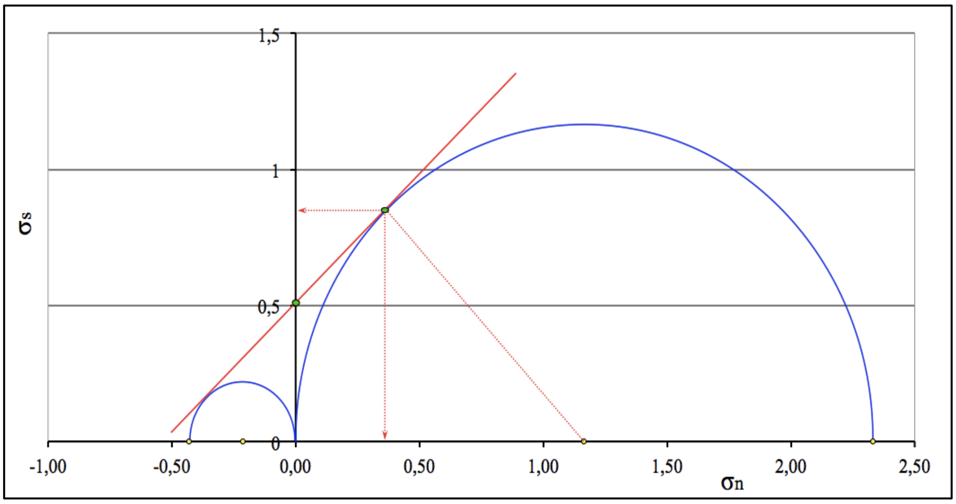

Figure 4.71 : Mohr Circles of 3CP.

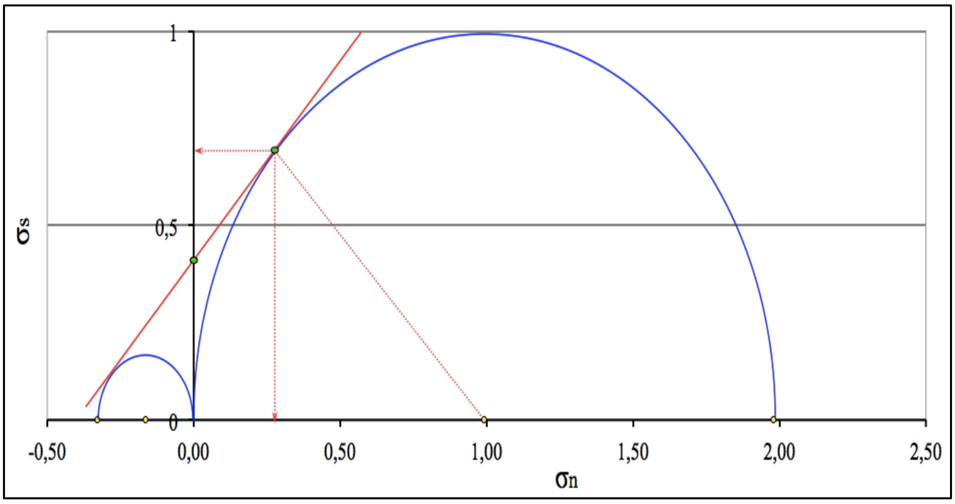

Figure 4.72 : Mohr Circles of 4CP.

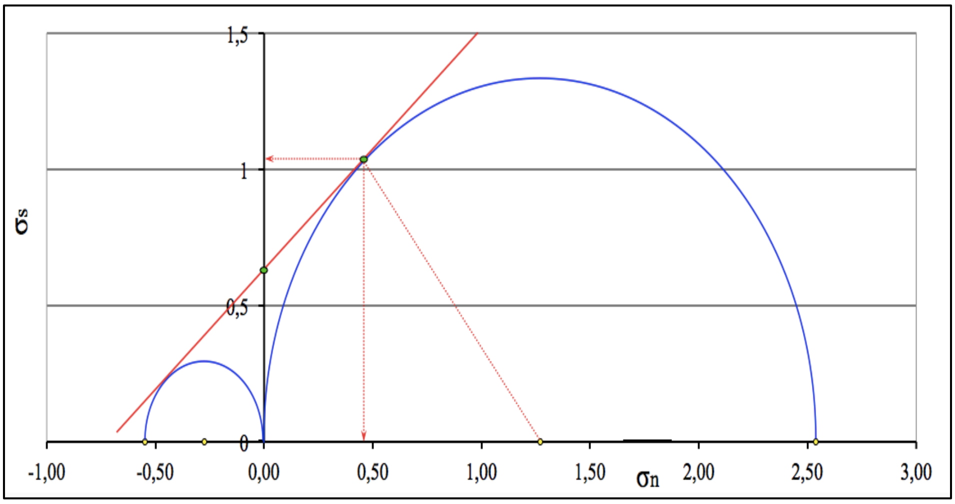

Figure 4.73 : Mohr Circles of 075P.

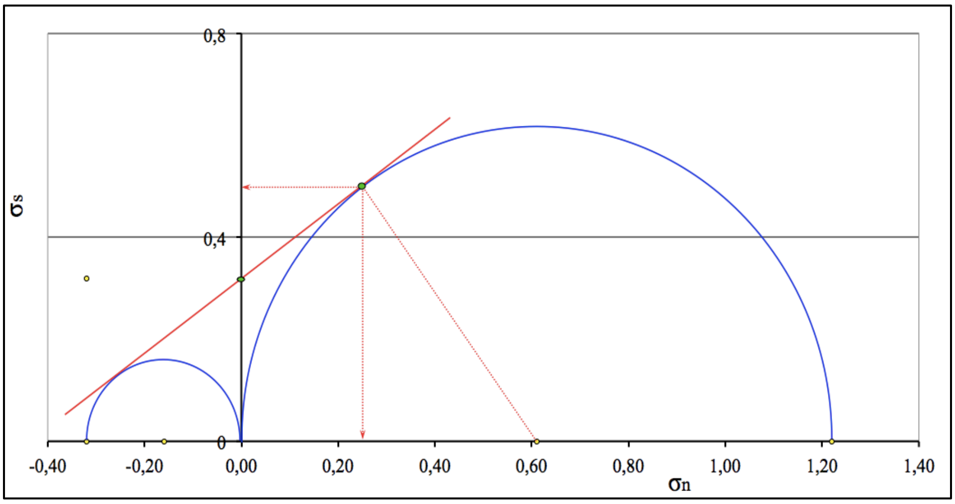

Figure 4.74 : Mohr Circles of 5P.

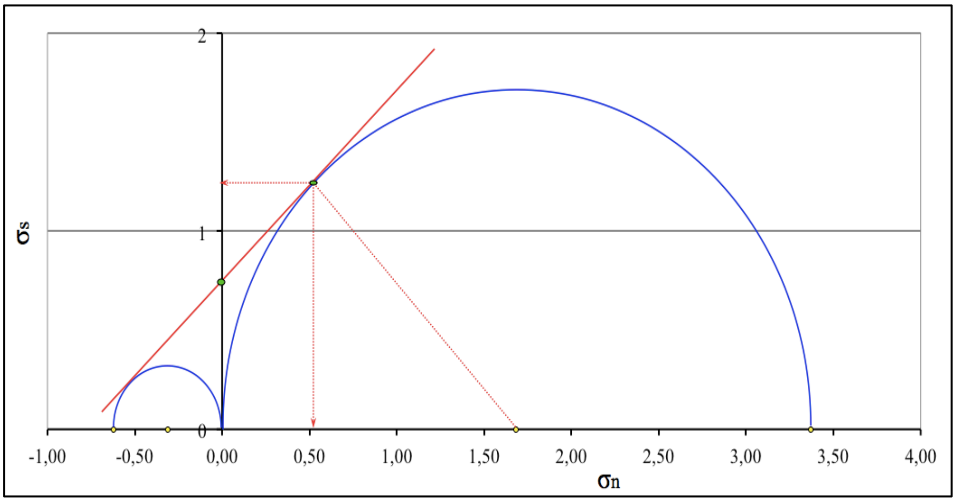

Figure 4.75 : Mohr Circles of 075CPA.

4.5.2. Failure angle

In rock mechanics, the value of failure angle mostly depends on formation type of the rock. Whereas failure angle is steeper in hard and brittle rock, it is less inclined in other words; value of failure angle is smaller, in the soft and ductile rock types. In particular, the value of the failure angle is very small in the formations that can be easily slide, such as sand. The same approach may be valid for cementitious composite mortars. The failure angles of the produced specimens were standardized separately for each group. Standardized failure angles of the composite mortars are given in Figure 4.76.

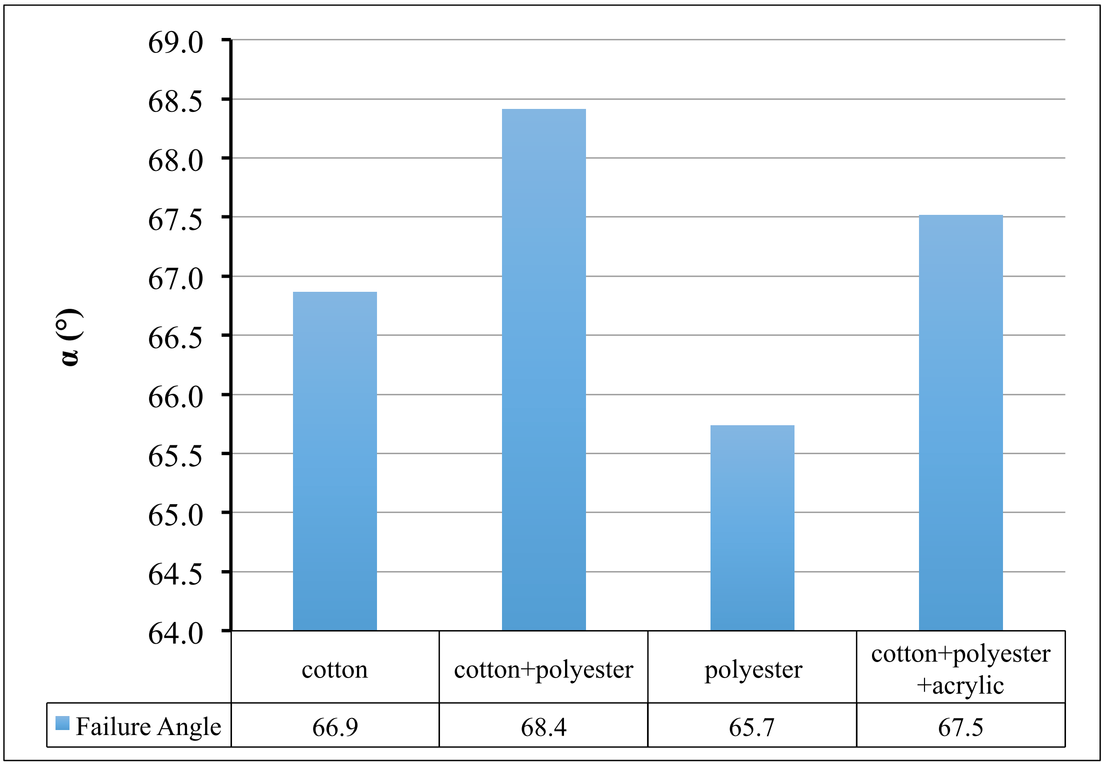

Figure 4.76 : Failure angle of the fiber reinforced composite plasters.

When examining Figure 4.76, failure angle of composite mortars containing polyester waste fibers was obtained lower than the others. In this case, it could be concluded that composite mortars containing polyester fibers are more ductile and soft materials than the other mortar samples. Therefore, it could be understood that the use of polyester waste fiber in the mixtures makes the mortar more ductile and it becomes more flexible. Mixture of cotton+polyester reinforced mortars having a failure angle of almost 3 degrees greater than the polyester waste fiber reinforced mortar could be evaluated as the most brittle mixture type in all combinations. The greatest value among the failure angles in terms of 68.4 degree failure angle belongs to mixture of cotton+polyester reinforced mortar mixture group.

4.5.3. Internal friction angle

Internal friction angle for a given material is the angle on the Mohr's Circle graph of the shear stress and normal stresses at which shear failure occurs. In literature, researchers have generally used the internal friction angle in rock and soil classification. In soil classification, soils with less than 30° internal friction angle are considered as very loose and as the internal friction angle increases the classification continues as loose, compact, dense and very dense soil. Similar phenomenon can be seen in rock classification; rocks with internal friction angle less than 15° are called as very poor and as the internal friction angle increases the classification continues as poor, fair, good and very good rock. As with this perspective, cementitious composite mortars with higher value of internal friction angle could be evaluated as better-compacted materials. The internal friction angles of the test samples were standardized separately for each group. Standardized internal friction angles of the composite mortars are given in Figure 4.77.

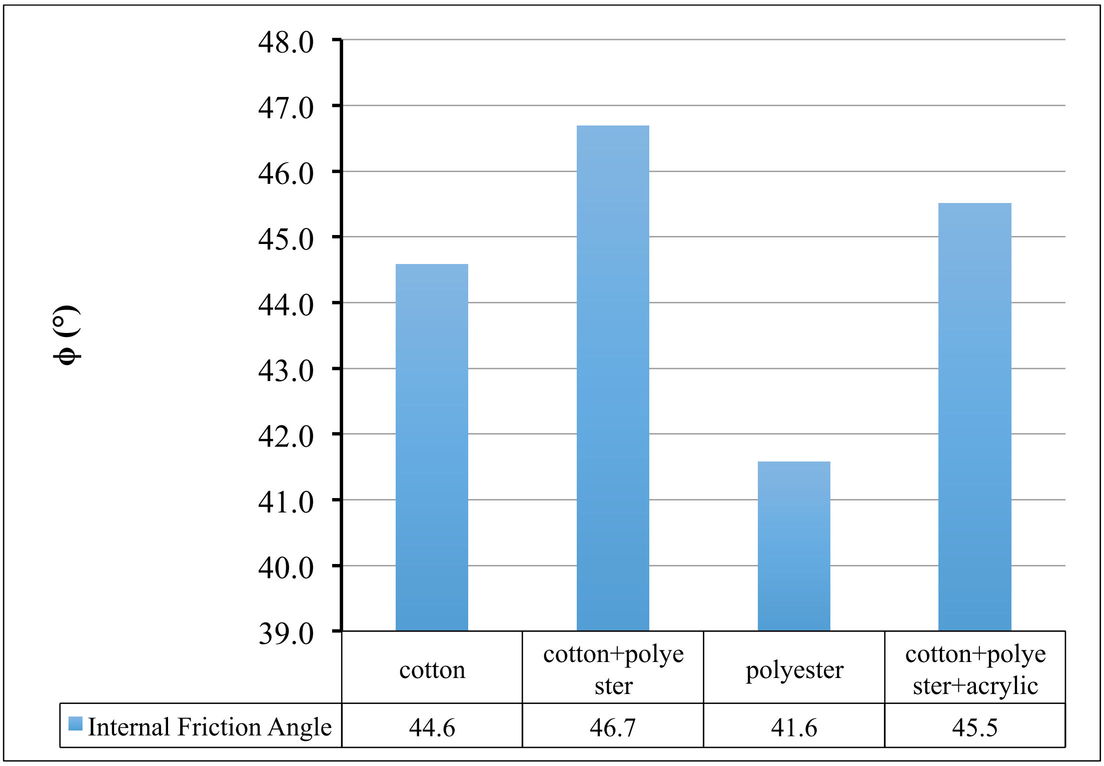

Figure 4.77 : Internal friction angle of the fiber reinforced composite plasters.

According to Figure 4.77, the internal friction angle of mixture of cotton+polyester fiber reinforced specimens was found to be 46.7°. This value is higher than the internal friction angle values of the other mixture types. This actually shows that the mixture of cotton+polyester fiber reinforced composite mortars are denser and more compacted than the other types. The internal friction angle of polyester fiber composite with 41.6° was found to be the lowest among all four types of composite mixtures. In this respect, it could be concluded that polyester reinforced plasters have poor and loose structure.

4.5.4. Normal strength

The normal strength is found by using the angle of slope of the plane of failure on Mohr Circle. Normal strength is the normal load to be carried by the material. Normal strength is the load that material could carry without permanent deforming. Higher loading than normal strength of material causes the permanent deformation in the material. Up to normal strength that found by Mohr's Circle, any permanent deformation does not occur in the material. However, the material is permanently damaged in a value of between normal strength and compressive strength values. In this case, it could be said that normal strength is the moment that material take the first permanent damage. The space between normal strength and compressive strength could be related to the load bearing capacity of the material. Load bearing capacity per unit area was found by the ratio of normal strength and compressive strength (σ_n/σ_c) (Table 4.5).

Table 4.5 : Load bearing capacity of the composite mortar samples.

Mix	σ_n (MPa)	σ_c (MPa)	σ_c/σ_n
CM	0.40	2.19	5.48
075C	0.39	2.59	6.64
15C	0.34	2.26	6.65
2C	0.29	1.59	5.48
3C	0.26	1.54	5.92
4C	0.25	1.46	5.84
5C	0.22	1.23	5.59
075CP	0.52	3.53	6.79
15CP	0.46	3.37	7.33
2CP	0.42	2.80	6.67
3CP	0.37	2.33	6.30
4CP	0.28	1.98	7.07
5CP	0.24	1.38	5.75
075P	0.46	2.54	5.52
15P	0.38	2.25	5.92
2P	0.35	1.99	5.69
3P	0.32	1.77	5.53
4P	0.28	1.29	4.61
5P	0.25	1.22	4.88
075CPA	0.52	3.37	6.48
15CPA	0.39	2.60	6.67
2CPA	0.32	2.14	6.69
3CPA	0.30	2.07	6.90
4CPA	0.26	1.72	6.62
5CPA	0.21	1.23	5.86

Graphical views of load bearing capacity versus fiber ratios are given in between Figure 4.78 and Figure 4.81.

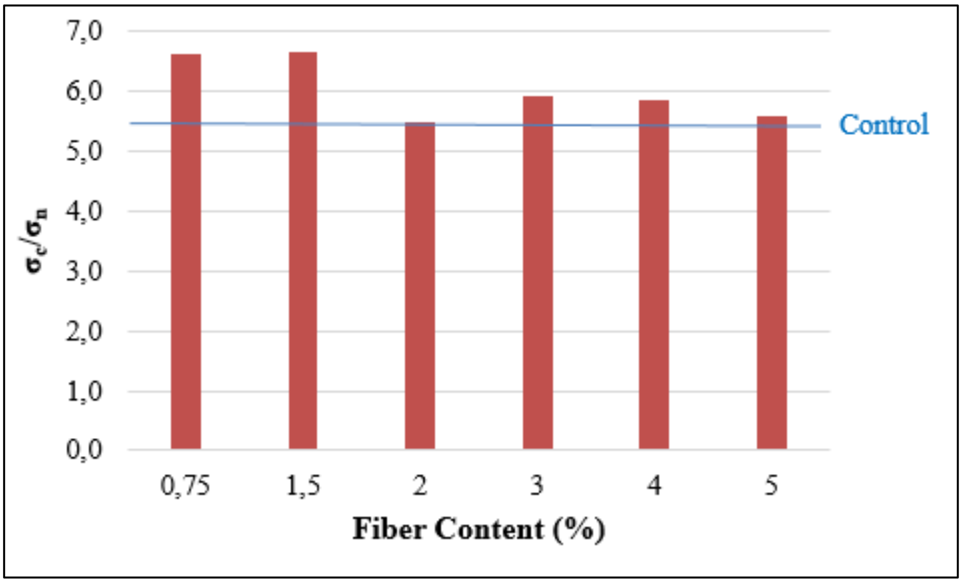

Figure 4.78 : Load bearing capacity of cotton fiber reinforced composite mortar samples.

As evaluating Figure 4.78, it can be seen that cotton fiber reinforced mortatrs have better load bearing capacity than the control test mortar samples. Up to 1.5%wt fiber utilization, load bearing capacity of the samples way better than the control sample. At the rate of fiber usage after 1.5% usage rate, load bearing capacity ratio falls to similar values as the control sample.

It can be concluded from the figure that after reaching the first deformation (σ_n), the control sample has a resistance of 5.48 times that of its normal strength. However, in 0.75% and 1.5% cotton waste fiber reinforced plasters, after the first deformation, the sample must be exposed to a force of 6.64 and 6.65 times its normal strength to break the sample.

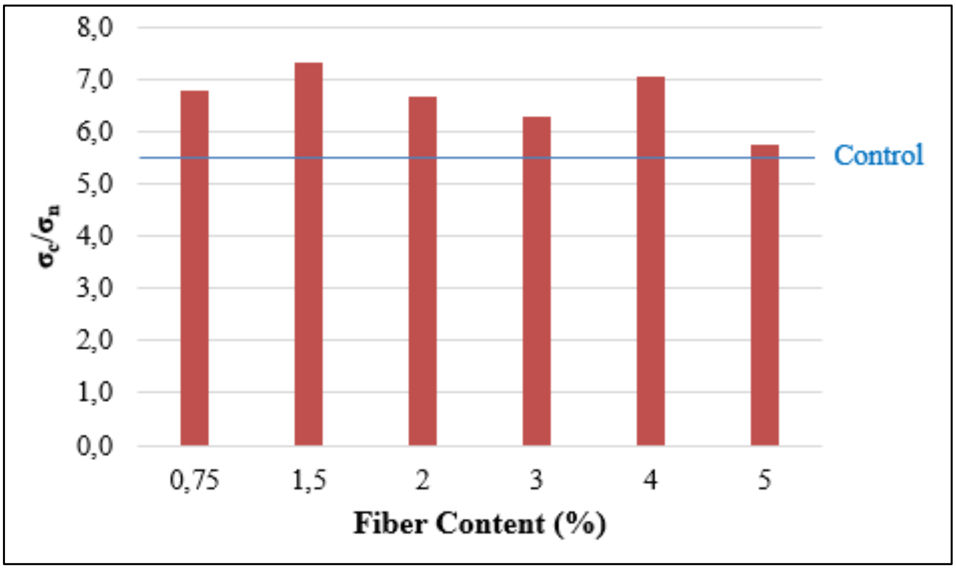

Figure 4.79 : Load bearing capacity of mixture of cotton+polyester fiber reinforced composite mortar samples.

When Figure 4.79 is examined, it is observed that cotton+polyester fiber reinforced plaster samples have better load bearing capacity than the control test mortar samples. In almost all fiber utilization ratios, load bearing capacity of the samples way better than the control sample. At the rate of 5%wt fiber usage load bearing capacity ratio falls to similar value as the control sample.

According to the figure after reaching the first deformation (σ_n), the control sample has a resistance of 5.48 times that of its normal strength. However, in 1.5%wt cotton+polyester waste fiber reinforced plasters, after the first deformation, the sample must be exposed to a force of 7.33 times its normal strength to break the sample.

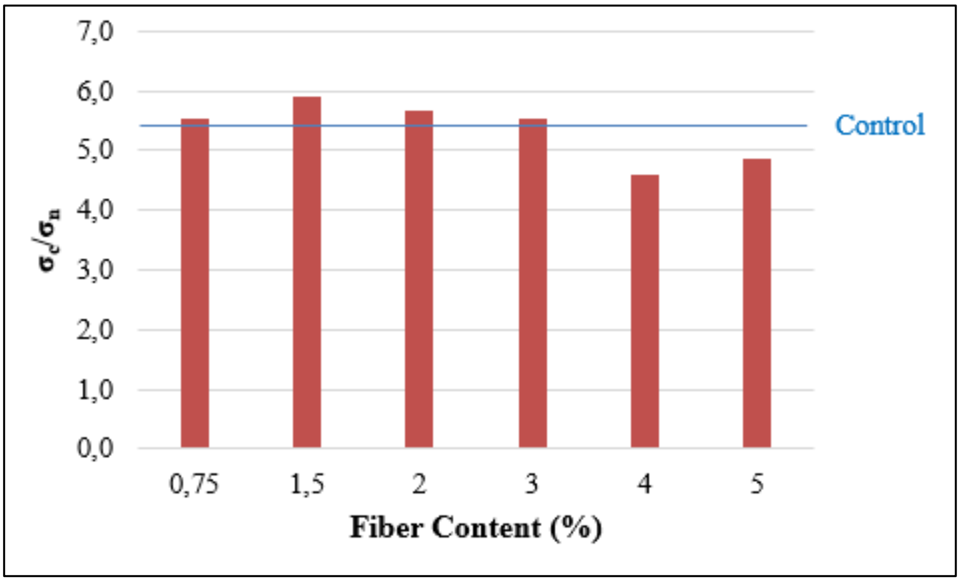

Figure 4.80 : Load carrying capacity of polyester fiber reinforced composite plasters.

It could be evaluated from Figure 4.80 that polyester fiber reinforced plasters have relatively low load bearing capacity than the other produced plasters. Up to 3.0%wt fiber utilization, load bearing capacity of the samples are similar values as the control sample. After 3.0% usage, load bearing capacity ratio even lower than the control sample. This is indicating that it achieves faster failure strength at lower loads.

According to the figure, after reaching the first deformation (σ_n), the control sample has a resistance of 5.48 times that of its normal strength. At 1.5% polyester fiber usage, composite plaster improved its load bearing capacity ratio as 0.44 to 5.92.

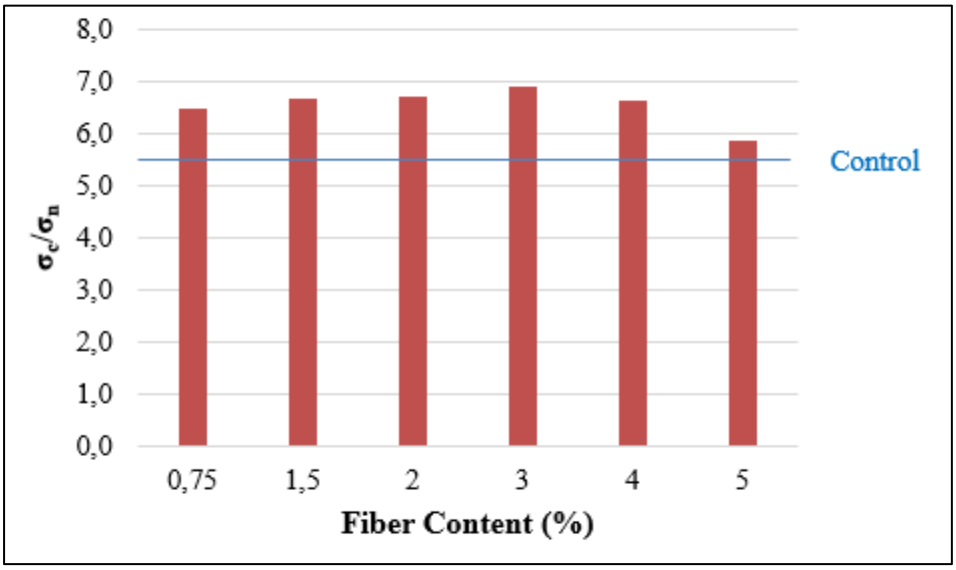

Figure 4.81 : Load bearing capacity of mixture of cotton+polyester+acrylic fiber reinforced composite plasters.

When Figure 4.81 is evaluated, it is observed that cotton+polyester+acrylic fiber reinforced plasters have better load bearing capacity than the control sample. In almost all fiber utilization ratios, load carrying capacity of the samples way better than the control sample. At the rate of 5%wt fiber usage load bearing capacity ratio falls to similar value as the control sample.

According to the figure after reaching the first deformation (σ_n), the control sample has a resistance of 5.48 times that of its normal strength. However, in 3.0%wt cotton+polyester+acrylic waste fiber reinforced plasters, after the first deformation, the sample must be exposed to a force of 6.90 times its normal strength to break the sample.

After receiving the first deformation, the rate of load, which can be carried by the composite plasters reinforced with different fiber derivatives, was found greater than the control sample. Especially at the rate of 1.5% fiber usage, load bearing capacity ratio of the samples had better values. The lowest values were found when the fiber usage was %5.0.

In order to compare the strength values of the samples between the control and each other with their first deformation, Figure 4.82-86 are given.

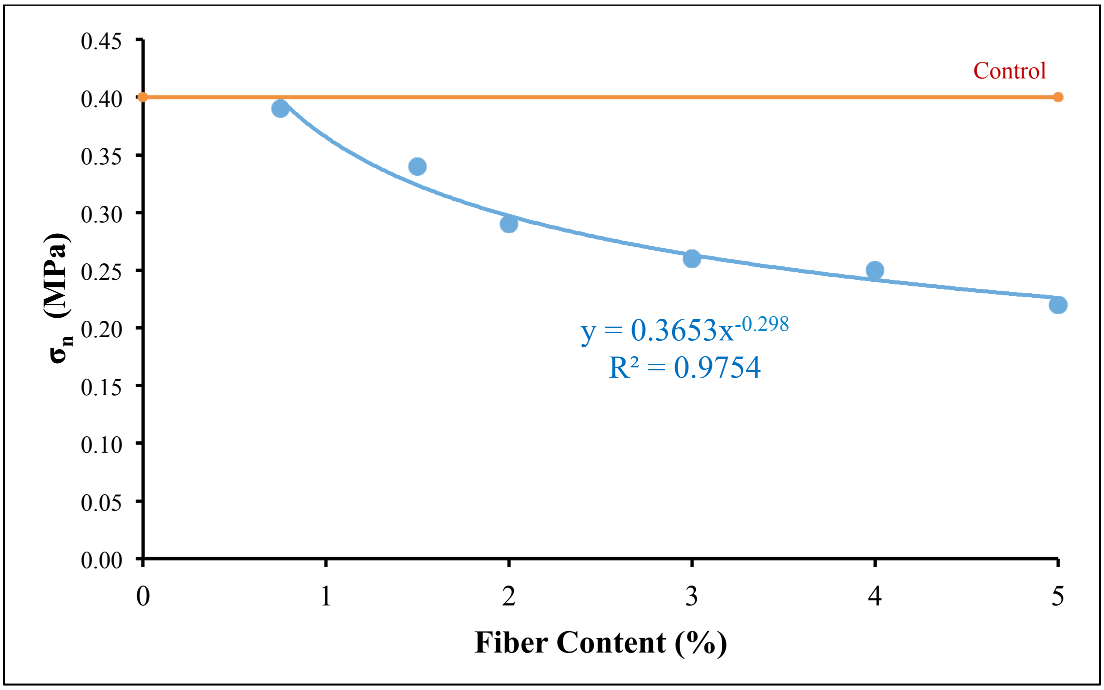

Figure 4.82 : Normal strength vs fiber content for cotton fiber reinforced composite plasters.

When figure 4.82 is examined, although regression analysis yields to meaningful result, the normal strength values of the cotton fiber reinforced plots are below the normal strength value of the control sample. This indicates that the addition of cotton fiber worsens the value of the first deformation of the material in all usage ratios.

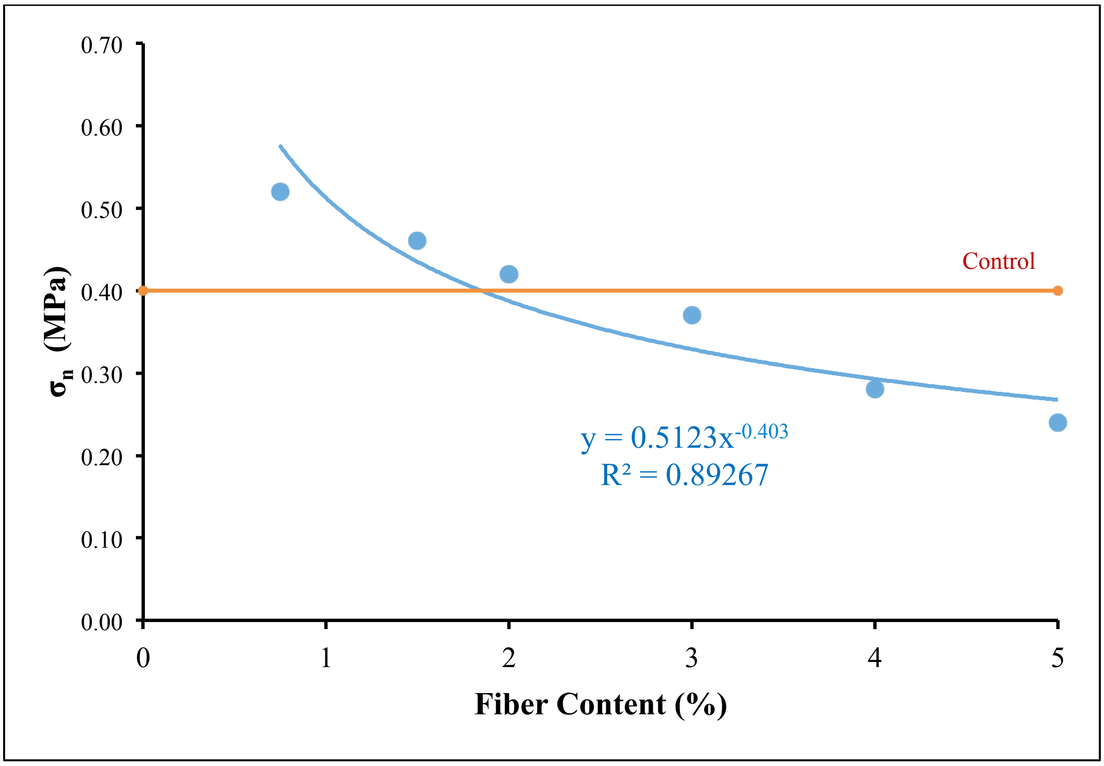

Figure 4.83 : Normal strength vs fiber content for cotton+polyester fiber reinforced composite plasters.

Figure 4.83 shows that the addition of cotton+polyester fiber increases the strength that the material can carry without any deformation until the usage rate is 2.0%. It was observed that the normal strength value of the material decreased at higher usage rates than 2.0%wt.

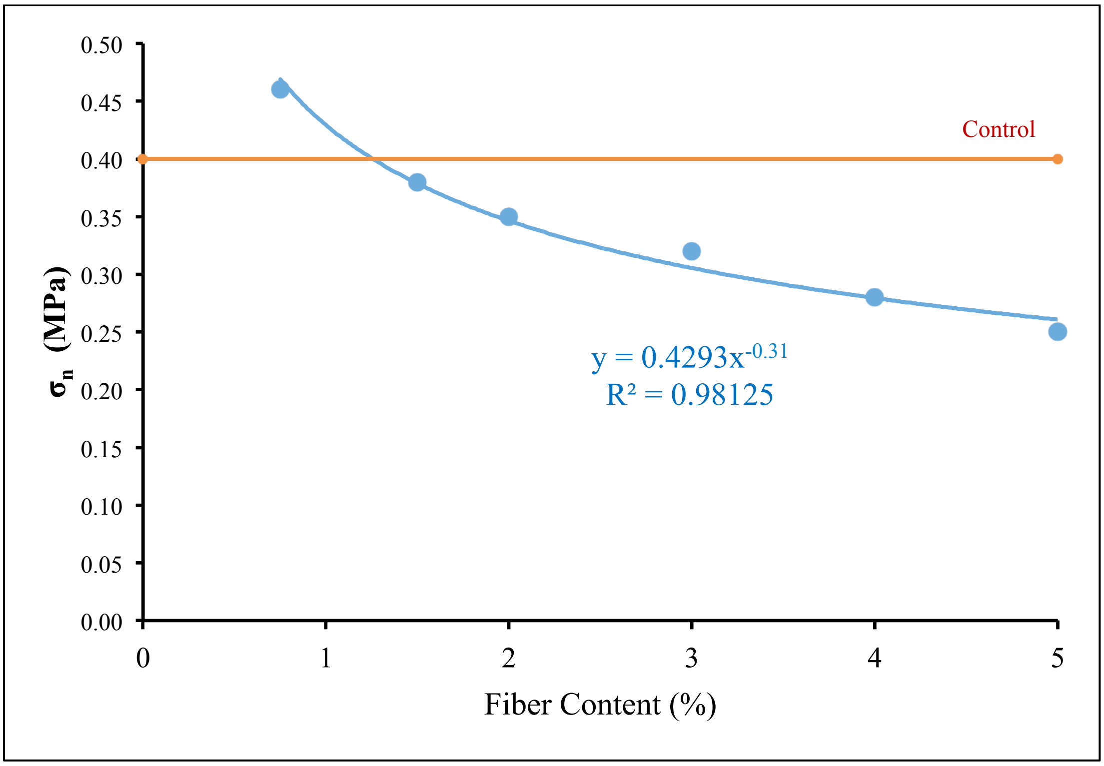

Figure 4.84 : Normal strength vs fiber content for polyester fiber reinforced composite plasters.

Figure 4.84 also shows that when the linear line is intersected by the curvilinear function, the addition of polyester fiber increases the strength that the material can carry without any deformation until the usage rate is 1.25%. It was observed that the normal strength value of the material decreased at higher usage rates than 1.25%wt. In other words, polyester fibers improved the normal strength up to 1.25%wt usage rate and made worse the normal strength above 1.25%wt usage rate.

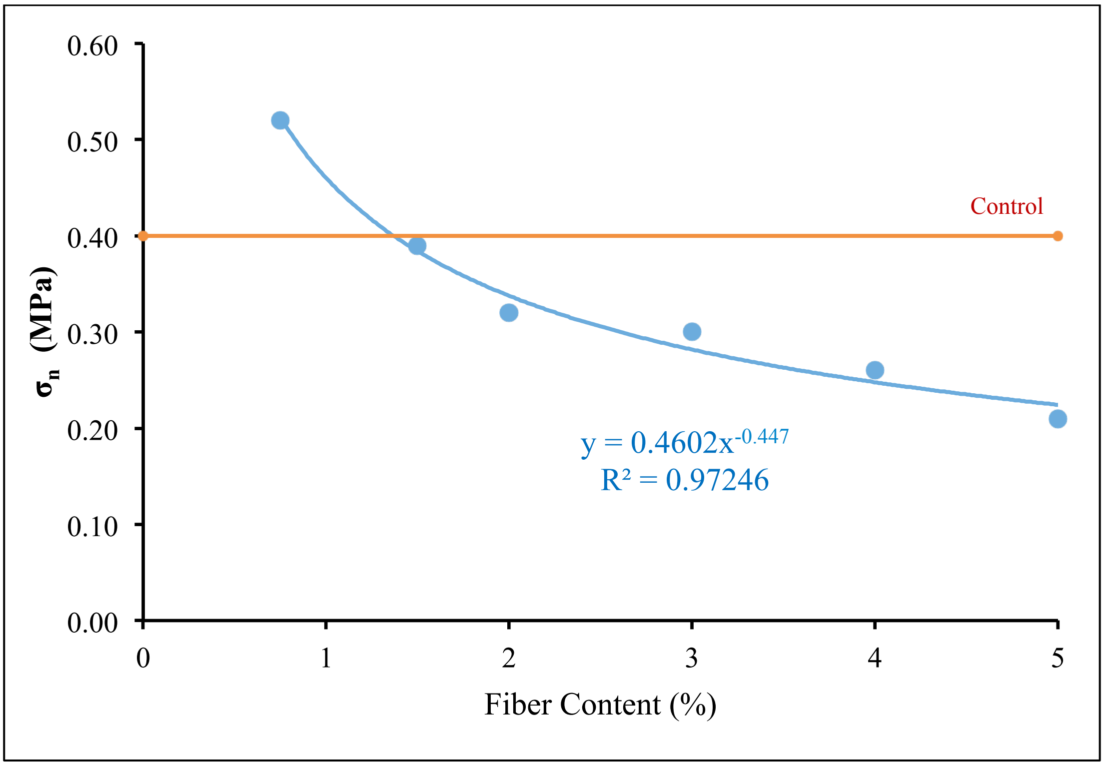

Figure 4.85 : Normal strength vs fiber content for mixture of cotton+polyester+acrylic fiber reinforced composite plasters.

As evaluating the Figure 4.85 it could be easily seen that the addition of mixture of cotton+polyester+acrylic fiber increases the strength that the material can carry without any deformation until the usage rate of 1.5%. It was observed that the normal strength value of the material decreased at higher usage rates than 1.5%wt.

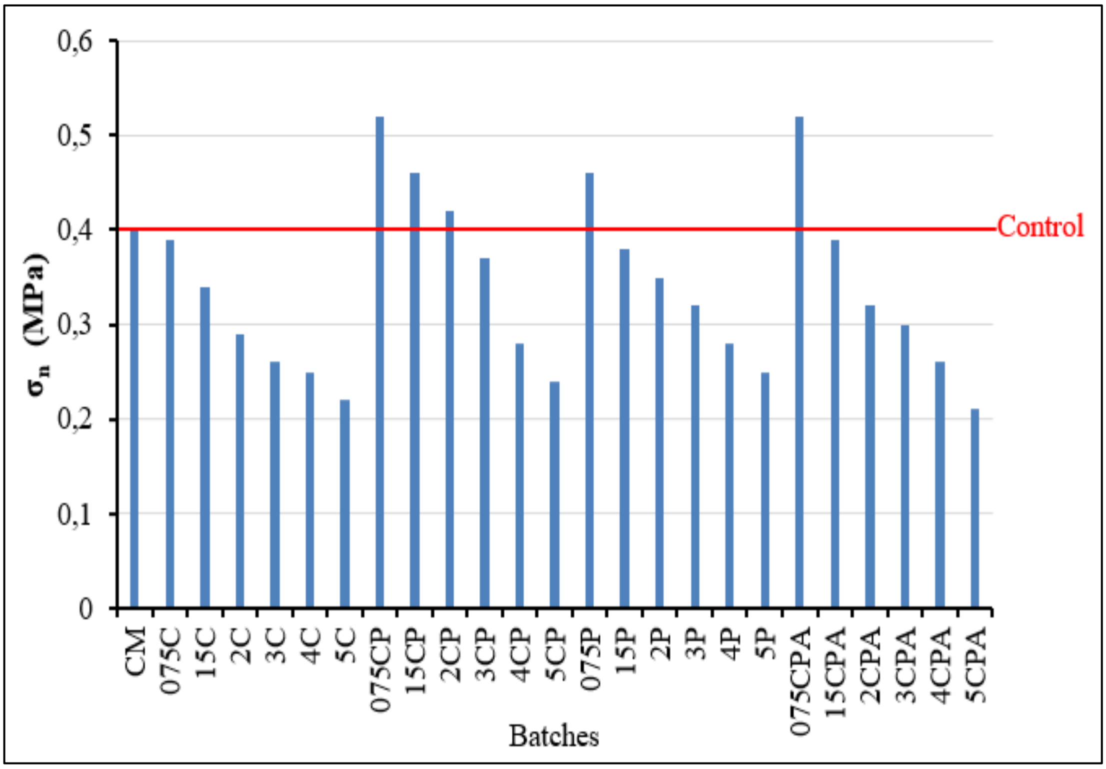

Figure 4.86 : Normal strength values of all batches.

As discussed above sections, according to TS EN 998-1 standard, minimum compressive strength of cementitious mortars must be at least 0.4 MPa (lower limit of CSI class for compressive strength). It can be easily seen in Figure 4.86 that normal strength values of 075CP, 15CP, 2CP, 075P and 075CPA are greater than the value (0.4 MPa) specified in TS EN 998-1 standard. In other words, these mixtures prepared in this study can provide the compressive strength condition prescribed in the standard even without any deformation inside the material.

As a general conclusion for normal strength analysis, it could be declared that normal strengths of composite plasters have a decreasing trend depending on the reduction in splitting tensile and compressive strength and an increase in fiber content in each type of mixtures. As it can be seen from the Figure 4.86, normal strength parameter of cotton+polyester reinforced plasters with highest value of 0.52 MPa (075CP) and lowest value of 0.24 MPa (5CP) are greater than the others. This refers that cotton+polyester reinforced mixtures could resist more load before the first deformation inside.

4.5.5. Cohesion

Cohesion is the force that holds the particles of concrete or mortar together. Cohesion indicates that what extent materials that forming the concrete or mortar are connected to each other. Additionally, the strength of the mortar or cement paste is dependent on the cohesion of the cement paste and adhesion of cement paste with aggregate particles (Neville, A.M., 1999). Cohesion values of all the tested samples were calculated by using Mohr Circle approaches and the specific values are given in Figure 4.87 to 4.90.

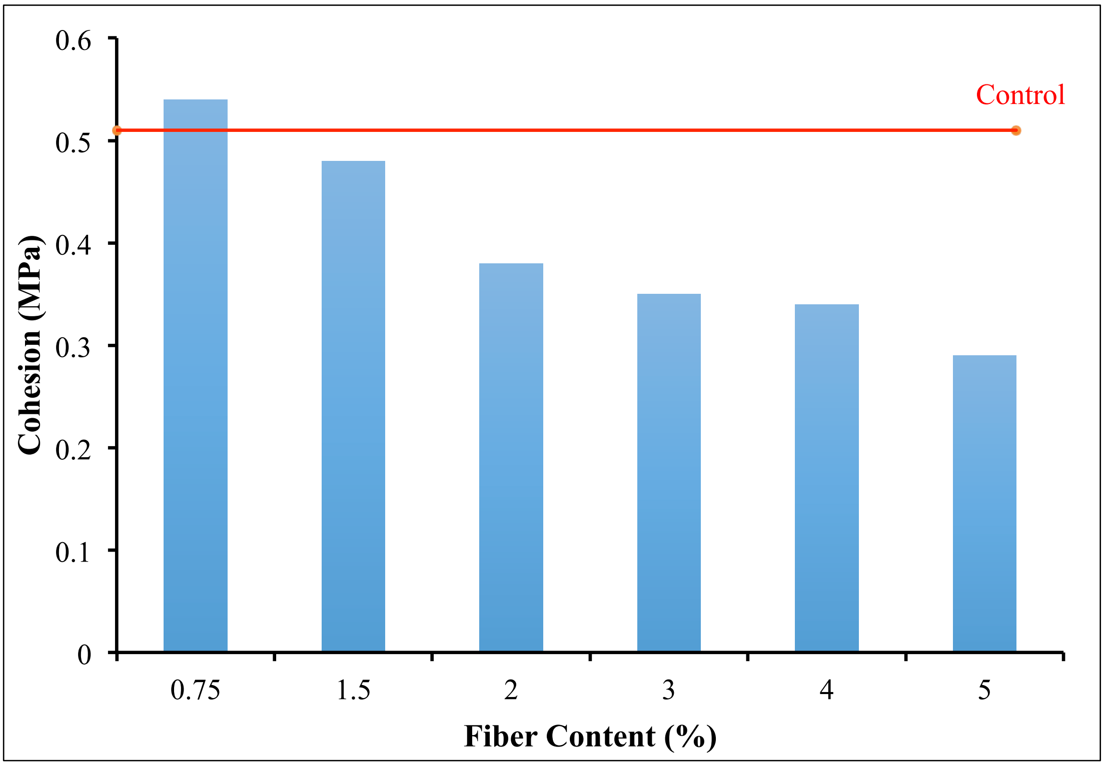

Figure 4.87 : Cohesion vs fiber content for cotton fiber reinforced composite plasters.

It is observed from Figure 4.87 that as the cotton waste fiber ratio used in the mortar is increased, the cohesion value of the mortars decreases. However, an increase in cohesion value was observed even at a low fiber utilization rate of 0.75%. Cohesion value decreased up to 46.3%, when the use of fiber ratio increased from 0.75% to 5% by weight.

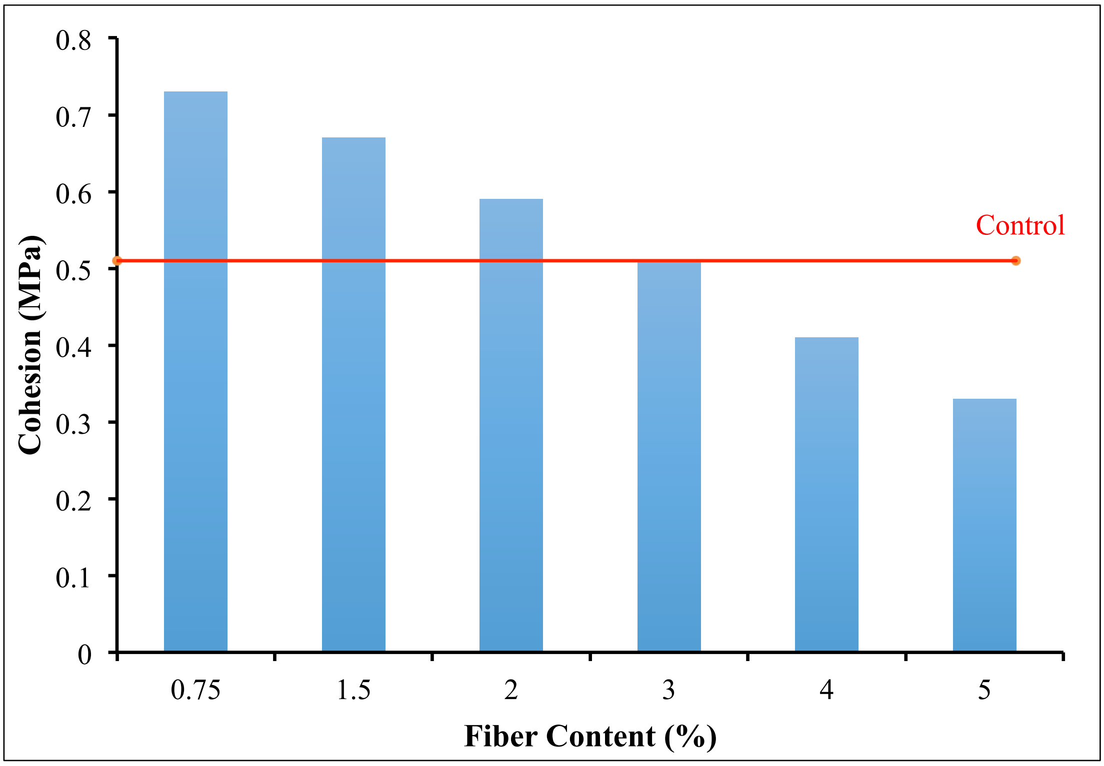

Figure 4.88 : Cohesion vs fiber content for mixture of cotton+polyester fiber reinforced composite plasters.

When Figure 4.88 is analyzed, it can be easily seen that as the mixture of cotton+polyester waste fiber ratio used in the mortar is increased, the cohesion value of the mortars decreases, too. Cohesion value decreased up to 54.8%, when the use of fiber ratio increased from 0.75% to 5% by weight. However, the cohesion values of the composite plaster samples were found to be higher than the cohesion value of the control sample up to 3% by weight of the mixture for cotton+polyester fiber usage. Mixture of cotton+polyester fiber has greatly increased the value of bonding in the samples.

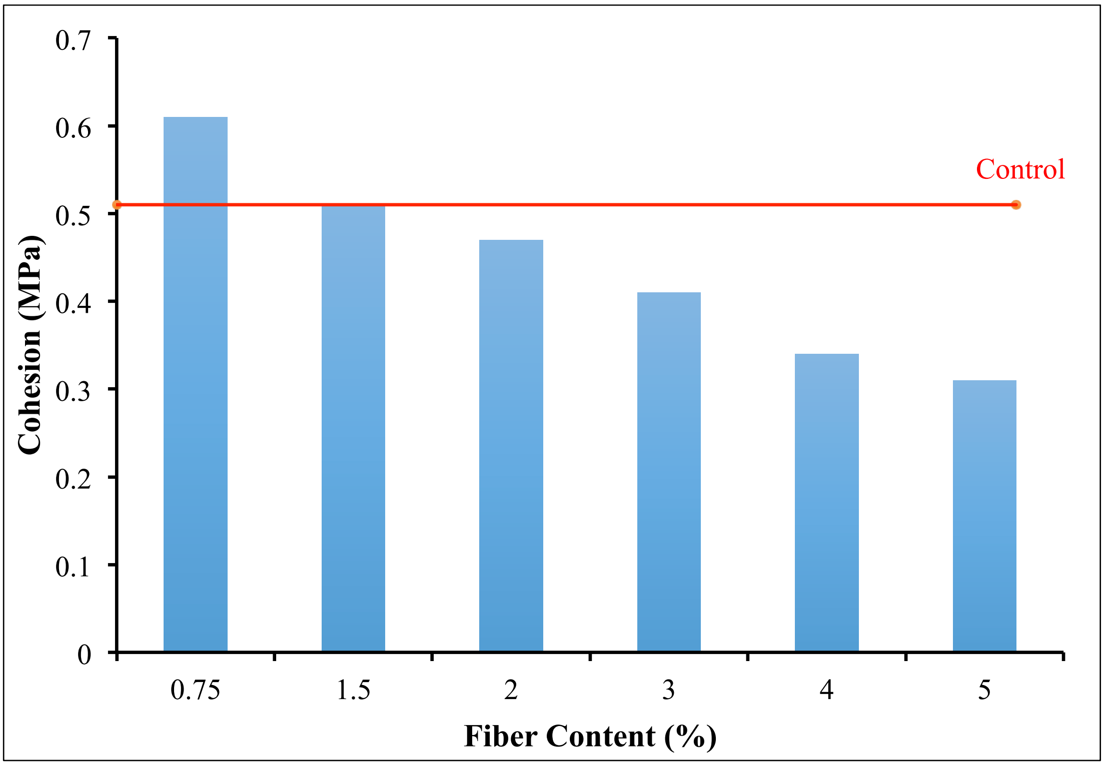

Figure 4.89 : Cohesion vs fiber content for polyester fiber reinforced composite plasters.

When Figure 4.89 is examined, it can be observed that as the polyester waste fiber ratio used in the mortar is increased, the cohesion value of the mortars decreases. However, as in cohesion of composite plaster samples reinforced with polyester fiber, an increase in cohesion value was observed at a low polyester fiber utilization rate of 0.75%. Cohesion values of the samples were below the cohesive value of the control sample after 0.75% fiber usage. Therefore, more than 0.75% of fiber usage negatively affects the degree of bonding in the internal structure of the composite plaster samples. Also, cohesion value of polyester fiber reinforced composite plasters decreased by 49.2%, when the use of fiber ratio increased from 0.75% to 5% by weight.

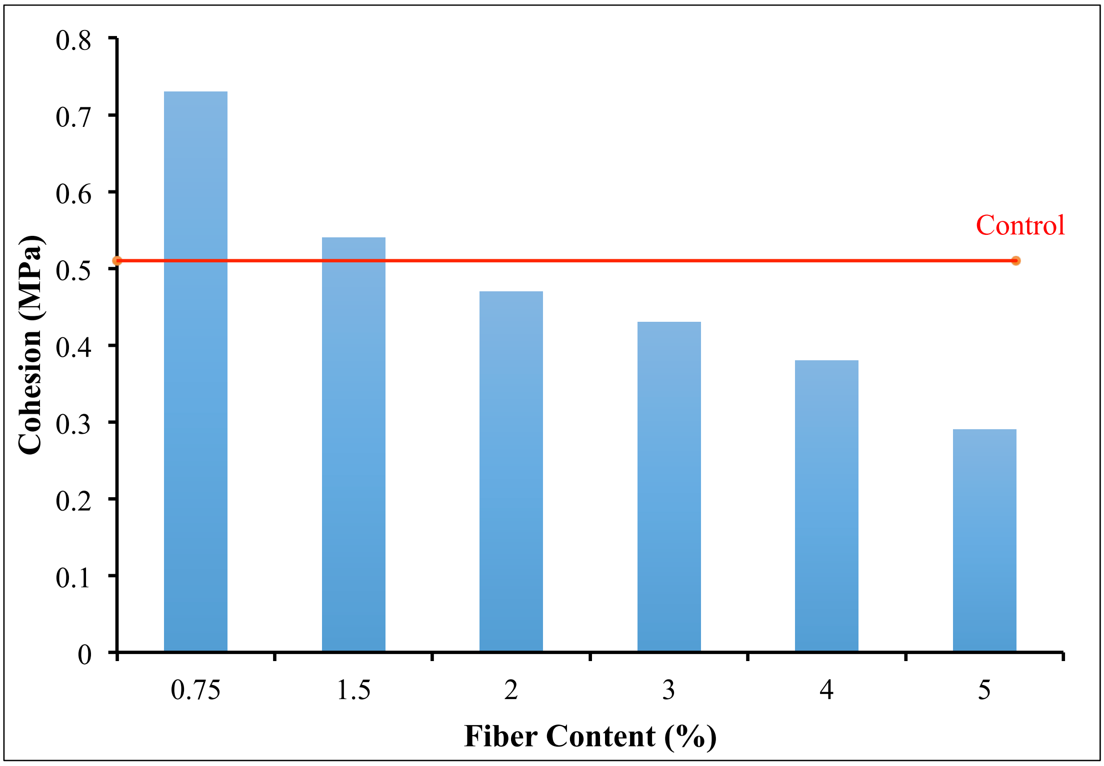

Figure 4.90 : Cohesion vs fiber content for mixture of cotton+polyester+acrylic fiber reinforced composite plasters.

Figure 4.90 indicates that as the mixture of cotton+polyester+acrylic waste fiber ratio used in the mortar is increased, the cohesion value of the mortars decreases. However, cohesion value showed a sudden increase at the rate of 0.75% fiber usage. When the fiber utilization rate reaches 1.5%, a sudden decrease in the value of cohesion is observed at this time. When 5.0% by weight fiber utilization rate is reached, this mixture type exhibits the lowest cohesion value again. Thus, a small amount of mixture of cotton+polyester+acrylic fiber utilization rate has an improving effect on cohesion. Also, cohesion value of polyester fiber reinforced composite plasters decreased by 59.5%, when the use of fiber ratio increased from 0.75% to 5% by weight.

4.5.6. Shear strength

According to Mohr-Coloumb Criterion, factors affecting the shear strength are normal strength, cohesion and internal friction angle, respectively. Besides, shear strength can be obtained by the Mohr's Circle. Decrease in normal strength and cohesion leads a reduction on shear strength parameter according to Mohr-Coloumb Criterion. This situation can be easily seen in Table 4.4. Analyses of the shear strengths corresponding to fiber utilization rates are further investigated in between Figure 4.91 and Figure 4.94.

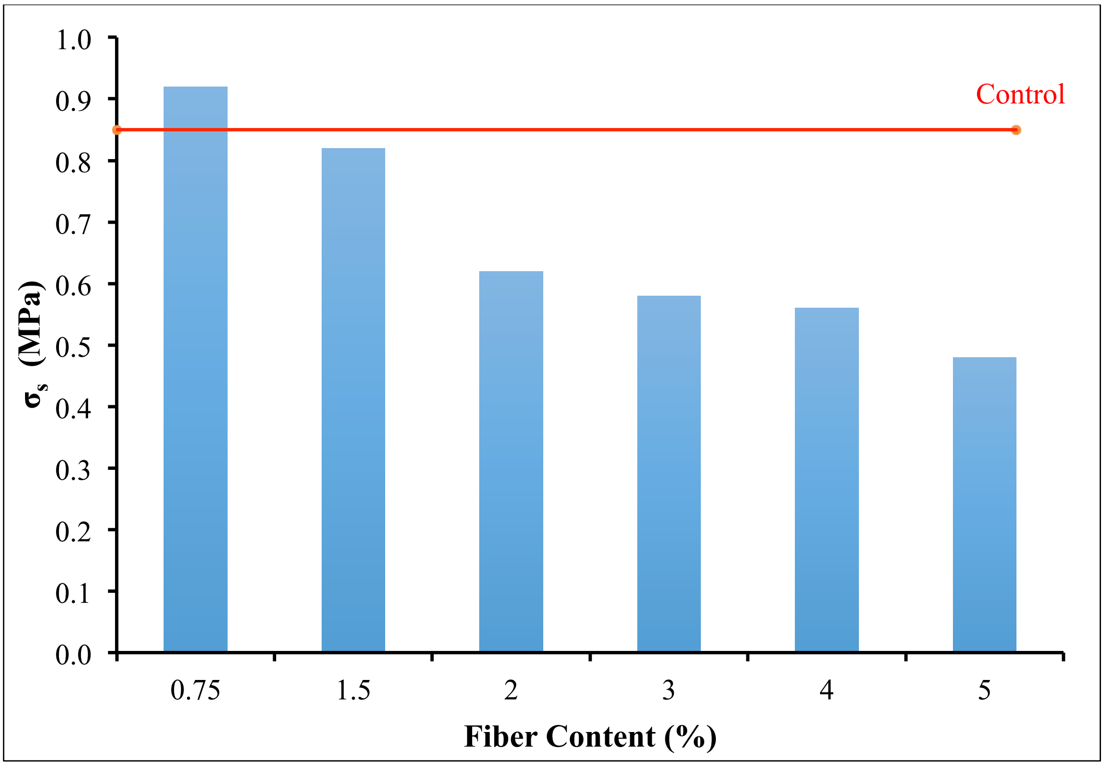

Figure 4.91 : Shear strength vs fiber content for cotton fiber reinforced composite plasters.

It is observed from Figure 4.91 that as the cotton waste fiber ratio used in the mortar is increased, the shear strength value of the mortars decreases. Since the shear strength value is directly related to the cohesion value, the shear strength graph corresponding to the fiber use has a similar trend to the cohesion versus cotton fiber content graph. Again, an increase in shear strength value was observed at a low fiber utilization rate of 0.75%. In case of using more cotton waste fiber than 0.75% by weight, the shear strength of the fiber containing samples was found to be lower than the control sample. It is indicating that the use of excess fiber affects the shear strength of the material in the negative direction. Shear strength value decreased by 47.8%, when the use of fiber ratio increased from 0.75% to 5% by weight.

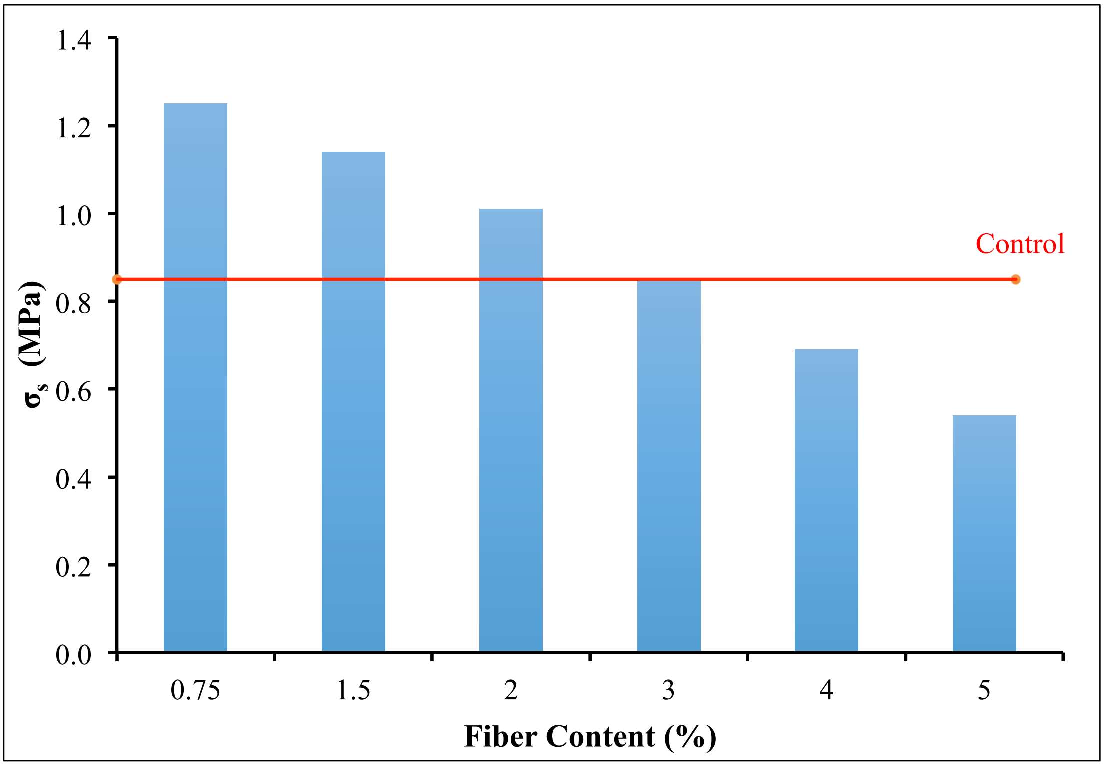

Figure 4.92 : Shear strength vs fiber content for mixture of cotton+polyester fiber reinforced composite plasters.

It can be concluded from Figure 4.92 that as the cotton+polyester waste fiber ratio used in the mortar is increased, the shear strength value of the mortars decreases. Shear strength value decreased by 56.8%, when the use of fiber ratio increased from 0.75% to 5% by weight. However, the shear strength values of the composite plaster samples were found to be higher than the shear strength value of the control sample up to 3%wt mixture of cotton+polyester fiber usage. Since the shear strength value is directly related to the cohesion value, the shear strength graph corresponding to the fiber use has a similar trend to the cohesion versus cotton+polyester fiber content graph. Although the shear strength is reduced at rates higher than 3%wt cotton+polyester fiber utilization, mixture of cotton+polyester fiber reinforced composite plasters have highest shear strength at 5% fiber utilization compared to all fiber types.

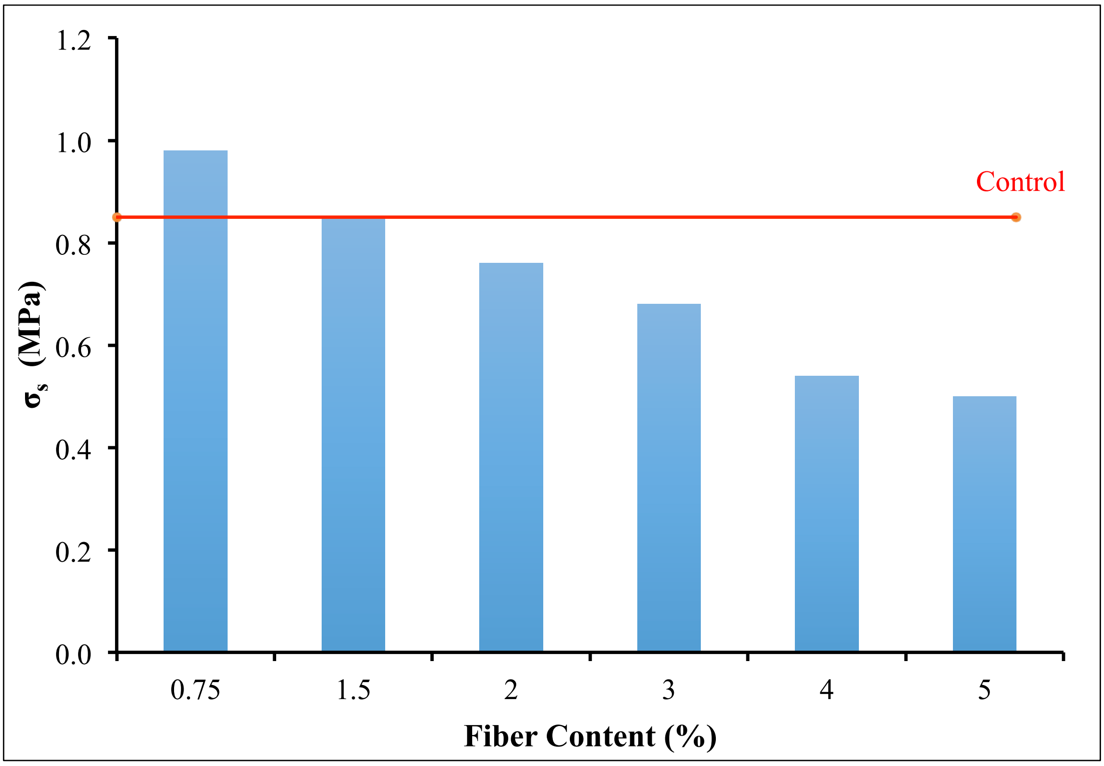

Figure 4.93 : Shear strength vs fiber content for polyester fiber reinforced composite plasters.

When Figure 4.93 is examined, it can be observed that as the polyester waste fiber ratio used in the mortar is increased, the shear strength value of the mortars decreases. However, as in shear strength of composite plaster samples reinforced with cotton fiber, an increase in shear strength value was observed at a low polyester fiber utilization rate of 0.75%. Shear strength values of the samples were found lower than the shear strength value of the control sample on the usage of higher than 0.75% fiber by weight. It could be concluded that more than 0.75% of fiber usage negatively affects strength to lateral loads of the composite plaster samples. Also, shear strength value of polyester fiber reinforced composite plasters decreased by 49.0%, when the use of fiber ratio increased from 0.75% to 5% by weight.

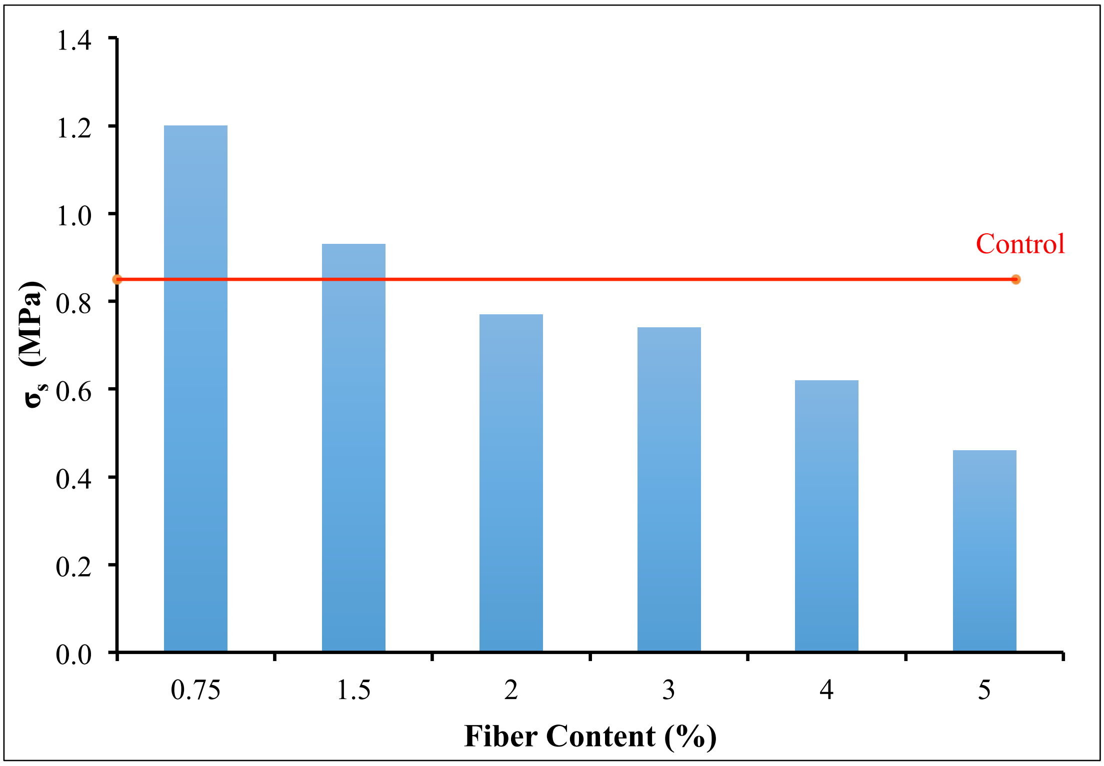

Figure 4.94 : Shear strength vs fiber content for mixture of cotton+polyester+acrylic fiber reinforced composite plasters.

Figure 4.94 indicates that as the mixture of cotton+polyester+acrylic waste fiber ratio used in the mortar is increased, the shear strength value of the mortars decreases. Since the shear strength value is directly related to the cohesion value, the shear strength graph corresponding to the fiber use has a similar trend to the cohesion versus cotton fiber content graph. Shear strength value showed a sudden increase at the rate of 0.75% fiber usage. While shear strength of control sample was found as 0.85 MPa, shear strength value of 0.75% cotton+polyester+acrylic fiber content sample was found as 1.20 MPa. When the fiber utilization rate reaches 1.5%, a sudden decrease in the value of shear strength is observed at this time. When 5.0% by weight fiber utilization rate is reached, this mixture type exhibits the lowest shear strength value again. Thus, a small amount of mixture of cotton+polyester+acrylic fiber utilization rate has a improving effect on shear strength. Also, shear strength value of cotton+polyester+acrylic fiber reinforced composite mortar samples decreased by 59.5%, when the use of fiber ratio increased from 0.75% to 5% by weight.

4.6. Analysis of Thermal Conductivity of the Composite Plasters

Reducing the heat transfer between the two different environments, i.e. heat insulation is taking necessary precautions on warming in the winter, reducing the energy spend in summer and reducing the heat transfer in the exterior walls, glass and fixtures, roofs, floors and insulation of buildings in order to live in more comfortable environments. Materials providing this phenomenon are called thermal insulation materials.

The most basic property that distinguishes heat insulation materials from each other is their thermal conductivity values (λ). According to TS EN 998-1, materials those have thermal conductivity values less than 0,200 W/mK are considered as a thermal insulation material.

Thermal insulation generally includes the following basic materials and mixtures; non-organic materials such as, glass, rock and slag wool, fibrous and cellular & porous materials i.e. calcium silicate, perlite, vermiculite and ceramic products etc. Besides these traditional materials, many new generation of material derivations are developing. Fibrous organic or synthetic fibers such as cotton, polyester, animal feathers and sheath, wood, paper, reed, cellular organic materials such as fungi, sponges, polymers and metallic or metallized organic reflective surfaces are mostly used some examples.

The most important and up-to-date application of composite building materials are the integrated products in which the heat transfer coefficient is low and the economic additive materials are present. In such integrated products, it is generally preferred to use waste materials (scrap tire, waste paper product, pet bottle, waste fibers etc.) as an additive (Kalkan, 2008).

Thermal conductivity values of cement based mortar samples are divided by 2 different groups in TS EN 998-1 standard. Table 4.6 shows the thermal conductivity value ranges according to the relevant standard.

Table 4.6 : Classification of thermal conductivity values for plasters according to the TS EN 998-1 standard.

	Classes	Values
Thermal conductivity	T 1	≤ 0.10 W/mK
	T 2	≤ 0.20 W/mK

Detailed examination of the thermal conductivity values of the tested samples in this research work according to the comparison with control sample and the related standard are given in between Figure 4.95 and Figure 4.98.

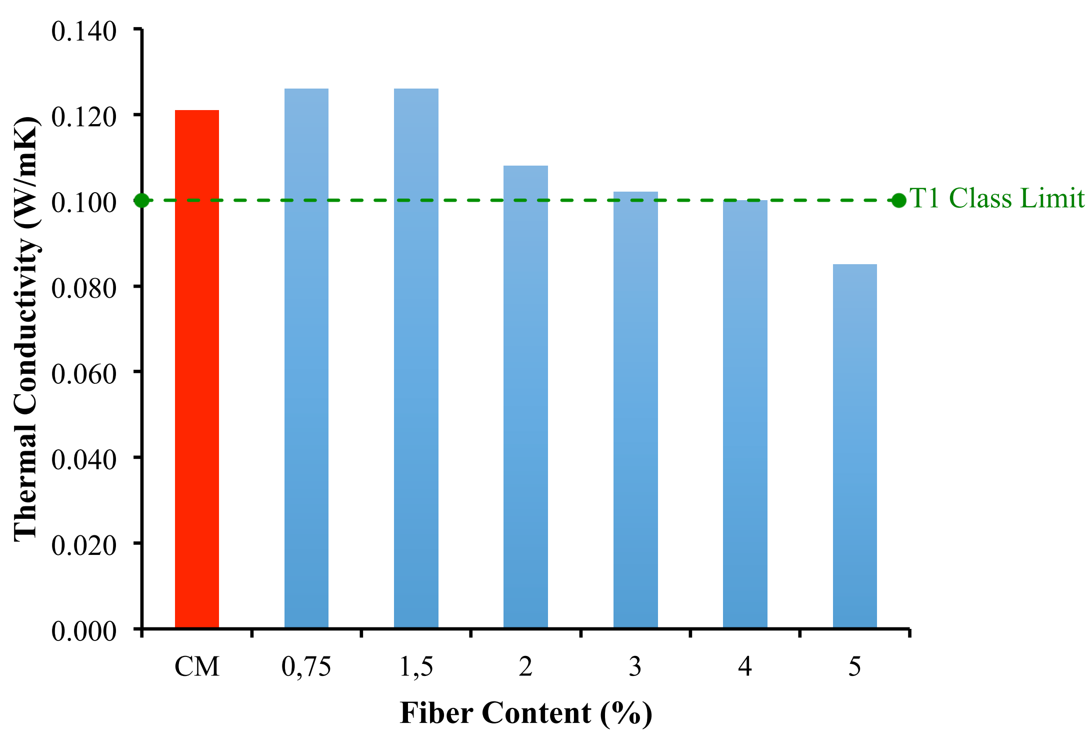

Figure 4.95 : Thermal conductivity vs fiber content for cotton fiber reinforced composite plasters.

Figure 4.95 explains that all the samples produced with cotton fiber reinforcement material meet the thermal conductivity requirement of TS EN 998-1 standard. Because the thermal conductivity values of all samples were found to be less than 0.200 W/mK. So that all samples containing cotton waste fiber can be included in the thermal insulation mortar category. When compared to control sample, the thermal conductivity values of the cotton fiber reinforced samples increased up to 1.5% fiber usage. While the thermal conductivity value of the control sample was 0.112 W/mK, it increased to 0.126 W/mK as 1.5% cotton fiber usage rate. Then the thermal conductivity value showed a decreasing trend from 1.5% to 4% fiber use. As a limit value of 4% fiber utilization ratio, it is in T1 class thermal insulation plaster category. At the 5% fiber utilization rate, the samples had a very low conductivity value of 0.085 W/mK as the thermal conductivity value, and they easily included in the T1 class according to the TS EN 998-1 standard. Also, a decrease of 32.5% in thermal conductivity value was recorded when the fiber utilization rate was increased from 0.75% to 5% fiber usage.

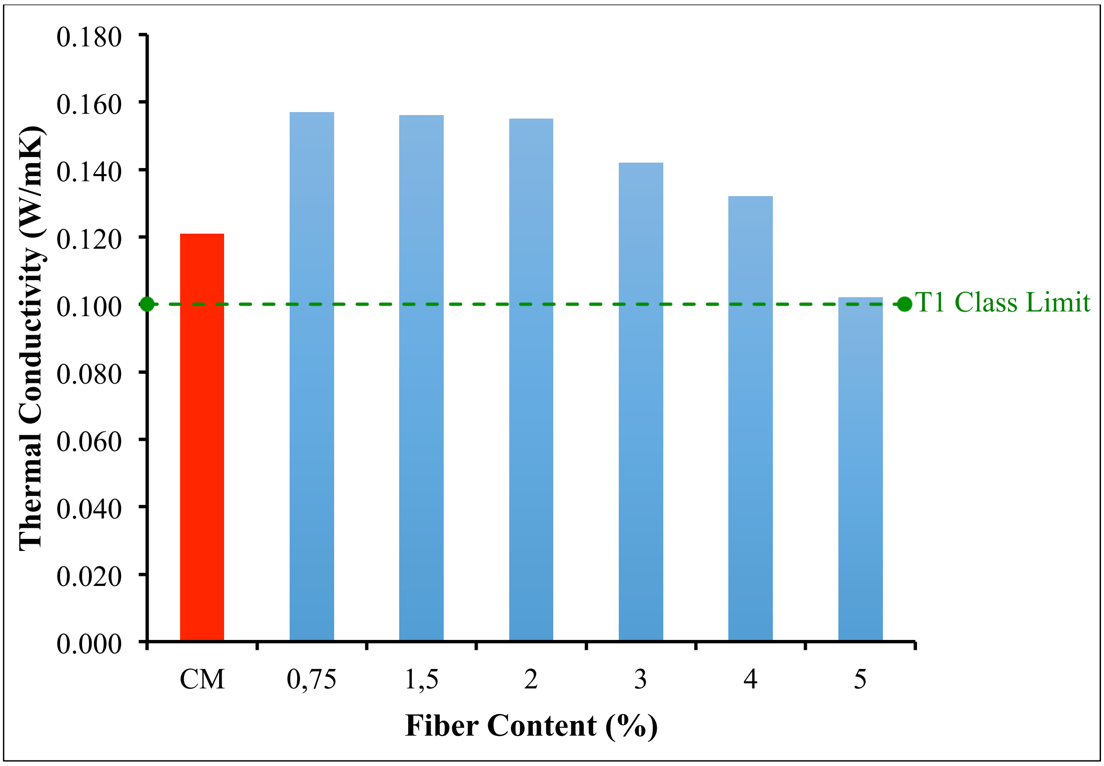

Figure 4.96 : Thermal conductivity vs fiber content for mixture of cotton+polyester fiber reinforced composite plasters.

It is clearly understood in Figure 4.96 that when mixture of cotton+polyester waste fibers are used, the thermal performance of the plaster samples worsens compared to the control mixture. In 0.75% mixture of cotton+polyester fiber use, thermal conductivity value increased by 0.036 W/mK and reached to 0.157 W/mK, when compared to the heat insulation value of the control sample. The thermal conductivity value continued at the same level up to the fiber utilization rate of 2%. While fiber use at a lower rate than 2% of the fiber utilization reduced the thermal conductivity value, none of the samples have a thermal conductivity value of T1 class according to the TS EN 998-1 standard. But even in this condition the produced mortars fall into the T2 thermal insulation mortar class according to the relevant standard. So, all the samples produced with mixture of cotton+polyester fiber reinforcement material meet the thermal conductivity requirement of TS EN 998-1 standard. It was shown that the thermal conductivity values of all samples were found to be less than 0.200 W/mK.

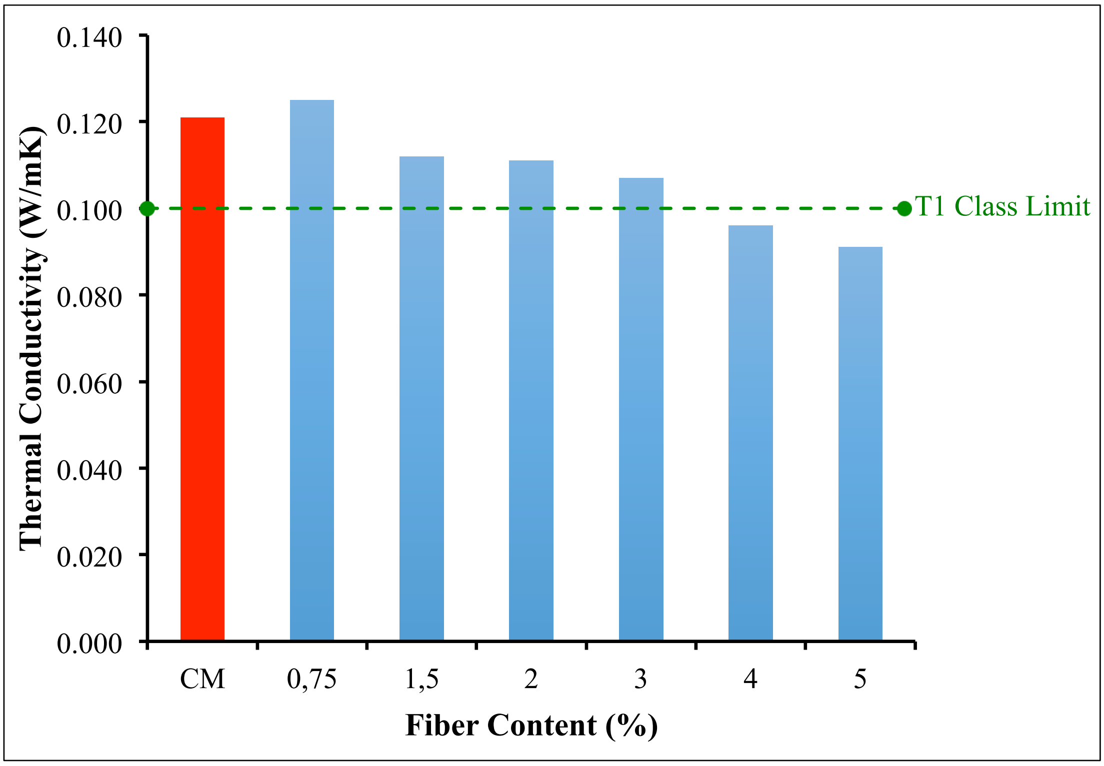

Figure 4.97 : Thermal conductivity vs fiber content for polyester fiber reinforced composite plasters.

When Figure 4.97 is examined, it can be concluded from the figure that all the samples produced with polyester fiber reinforcement material meet the thermal conductivity requirement of TS EN 998-1 standard. The thermal conductivity values of all samples were found to be less than 0.200 W/mK. So that all samples containing polyester waste fiber can be included in the thermal insulation mortar category. When compared to control sample, the thermal conductivity values of the polyester fiber reinforced samples increased only in 0.75% fiber usage. While the thermal conductivity value of the control sample was 0.112 W/mK, it increased to 0.125 W/mK in the 0.75% polyester fiber usage rate. Then the thermal conductivity value showed a decreasing trend from 0.75% to 3% fiber use. In other words, since the thermal conductivity values of the produced composite plaster samples, up to 3% polyester fiber usage ratio, was found between 0.200 W/mK and 0.100 W/mK, these samples fell into the category of T2 class thermal insulation plaster mortar. The thermal conductivity values of 4% and 5% fiber used samples were determined as 0.096 W/mK and 0.091 W/mK, respectively. Thus, these 2 groups were included in the T1 class of thermal insulation plaster. Also, a decrease of 27.2% in thermal conductivity value was recorded when the fiber utilization rate was increased from 0.75% to 5% fiber usage.

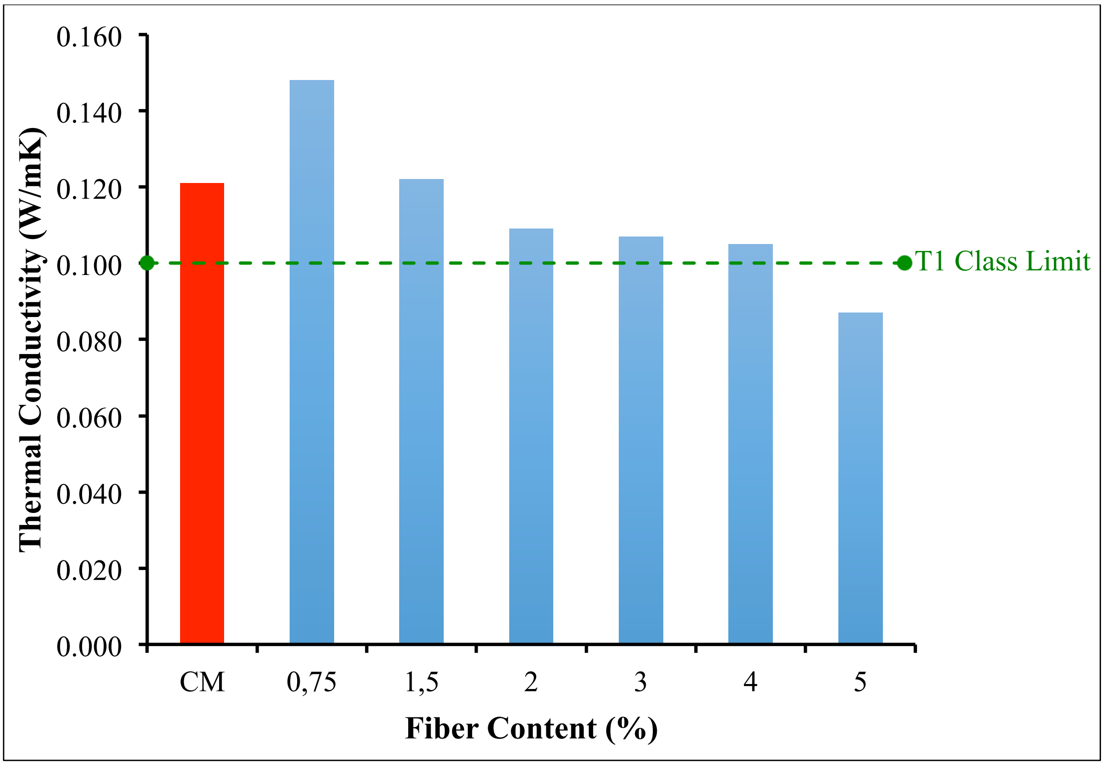

Figure 4.98 : Thermal conductivity vs fiber content for mixture of cotton+polyester+acrylic fiber reinforced composite plasters.

Figure 4.98 explains that all the samples produced with mixture of cotton+polyester+acrylic fiber reinforcement material meet the thermal conductivity requirement of TS EN 998-1 standard. The thermal conductivity values of all the samples were found to be less than 0.200 W/mK. So that all samples containing mixture of cotton+polyester+acrylic waste fiber can be included in the thermal insulation mortar category. When compared to control sample, the thermal conductivity values of the mixture of cotton+polyester+acrylic fiber reinforced samples increased only in 0.75% fiber usage. While the thermal conductivity value of the control sample was 0.112 W/mK, it increased to 0.148 W/mK in 0.75% mixture of cotton+polyester+acrylic fiber usage rate. The thermal conductivity value of 1.5% fiber usage rate was found to be slightly less than 0.75% fiber usage rate. Then the thermal conductivity value showed a stable trend from 1.5% to 4% fiber use. At the 5% fiber utilization rate, the samples had a low conductivity value of 0.087 W/mK as the thermal conductivity value, and 5% mixture of cotton+polyester+acrylic fiber reinforced plasters easily included in the T1 class according to the TS EN 998-1 standard. On the other hand, the rest of the mixtures was located at T2 class thermal insulation plaster. Also, a decrease of 41.2% in thermal conductivity value was recorded when the fiber utilization rate was increased from 0.75% to 5% fiber usage.

To make a general evaluation of the thermal conductivity performances of the produced composite plaster, it can be noted that all produced composite mortar combinations including control sample can be evaluated within the scope of thermal insulation plaster according to the TS EN 998-1 standard. The samples 4C, 5C, 4P, 5P and 5CPA remaining below the thermal insulation value of 0.100 W/mK and they have the T1 thermal insulation class. All the remaining plaster combinations are included in the T2 class as stipulated by the standard.

5. CONCLUSION

This study was carried out in order to evaluate the textile waste fibers obtained from Uşak region, Turkey in cement matrix composite plasters. The physical and mechanical properties of the produced composite mortars have been examined in detail. The outputs and comments obtained from this thesis study are listed below.

1. According to 2014 data, Turkey is the third country on textile export among the European countries. Besides, Turkey is the world's sixth largest garment exporter. With such a huge production power, in Turkey's textile sector, waste and/or residual textile materials are composed depends on the large scale production. According to EASME (2015), textile industry produces around 12 million tons of waste in a year only in the Europa. When these wastes are evaluated, it provides saving energy from one side, protecting the ecological balance and contributing to the prevention of environmental pollution from the other side.

2. The samples were found to be completely dry in 19-20 days. This analysis was carried out to understand the completely drying duration after in case of application on site. After the material is dry, it can easily carry loads. This period tells when the material can carry a load safely. That corresponds to the time which the any treatment can be carried out on the applied plaster surface after such periods. Findings obtained from unit volume weight analysis showed that as the fiber ratio increases in general, the unit volume weight values of the plaster samples in the composite structure show a decreasing tendency after a slight increase first. In other words, the fiber amount plays a role of unit weight reduction in the mixtures. When the numerical value obtained from the unit volume weight analysis is taken into consideration, it was seen that the unit volume weight values of hardened samples did not exceed 730 kg/m^3 (075CP). The lowest unit volume weight value, which is 556 kg/m^3, was obtained from the mixture containing 5% cotton waste fiber (5C). Additionally, there is a condition about lightweight plasters that they should have maximum unit volume weight of 1300 kg/m^3 in the TS EN 998-1 standard. If a comparison is made between this requirement and the samples produced in this thesis

study, it can be easily seen that unit volume weights of produced samples are between half of and one third of 1300 kg/m^3. This phenomenon is indicating that the produced plasters are sufficiently lightweight materials.

3. While, the use of low amounts of waste fiber in the composite plasters increased the compressive strength of the material compared to the control sample, the use of waste fiber at high rates reduced the compressive strength. Whereas the compressive strength value of the control sample was 2.19 MPa, the compressive strength values of the cotton fiber additive samples varied between 2.59 MPa and 1.23 MPa, the compressive strength values of the mixture of cotton+polyester+acrylic fiber additive samples varied between 3.37 MPa and 1.23 MPa, the compressive strength values of the polyester fiber additive samples varied between 2.54 MPa and 1.22 MPa, the compressive strength values of the mixture of cotton+polyester fiber additive samples varied between 3.53 MPa and 1.38 MPa. If it is desired to make selection by taking into consideration the compressive strength criterion alone, plaster mixtures containing cotton + polyester fibers (075CP, 15CP, 2CP, 3CP, 4CP and 5CP) should be preferred. Because the highest compressive strength values are determined in these mixture combinations among all tested mixtures. The mixture with the highest compressive strength was determined as 075CP with 3.53 MPa and the mixture with the lowest compressive strength as 5P with 1.22 MPa. The compressive strength values of all the samples produced and cured for 28 days are included in the compressive strength classes according to TS EN 998-1 standard. In fact, even with 7 day cured compressive strengths are in these classes for all samples.

4. The plaster samples with mixture of cotton+polyester fiber have the highest flexural strength values, between 2.25 MPa and 1.17 MPa, than the other types. Flexural strength values of mixture of cotton+polyester+acrylic fiber additive plasters follow the mixture of cotton+polyester fiber additive plasters with 2.23 MPa to 1.01 MPa. The mixture with the highest flexural strength was determined as 075CP with 2.25 MPa and the mixture with the lowest flexural strength as 5C and 5P with 0.96 MPa. It was seen that when cotton and polyester fibers used in plaster combinations alone, their effects on flexural strength values were found as less than those used as a mixture fiber. If it is desired to make selection by taking into consideration the flexural strength criterion alone, plaster mixtures containing

cotton+polyester fibers (075CP, 15CP, 2CP, 3CP, 4CP and 5CP) should be preferred. Because the highest flexural strength values are determined in these mixture combinations among all tested mixtures. However, these mixtures have also higher unit volume weight characteristic. This situation could be considered as a disadvantage in terms of lightweight criterion. High unit volume weights affect the economic aspects and thermal conductivity of the materials in the negative direction.

5. The plaster samples with mixture of cotton+polyester fiber have better splitting tensile strength values, between 0.60 MPa and 0.30 MPa, than the other types. Splitting tensile strength values of polyester fiber additive plasters follow the mixture of cotton+polyester fiber additive plasters with 0.55 MPa to 0.32 MPa. Splitting tensile strength of 0.75% mixture of cotton+polyester+acrylic fiber additive mortar was found as the highest value (0.62 Mpa), although splitting tensile strength of 5.0% usage of same fiber additive in the plaster combinations was found as the lowest value with 0.25 MPa. Which means that lower utilization ratio of mixture of cotton+polyester+acrylic fiber additive provides added value to the mortars splitting tensile characteristics. A general evaluation for splitting tensile strength; if it is desired to make selection by taking into consideration the splitting tensile strength criterion alone, plaster mixtures containing cotton + polyester fibers (075CP, 15CP, 2CP, 3CP, 4CP and 5CP) should be preferred. Because the highest splitting tensile strength values were determined in these mixture combinations among all tested mixtures.

6. Structural mechanical properties, which are internal friction angle, failure angle, normal strength, shear strength and cohesion parameters, of the samples were carried out in this thesis study. Structural strength analysis of materials provides more comprehensive information about internal actions of the material.

Mohr Coulomb Failure Criterion was used to determine the structural strength properties of samples. Mohr Coulomb Failure Criterion can be estimated some mechanical properties of concrete based on the tension and compression stresses. Mohr envelopes were drawn by the use of the compressive and splitting tensile stress data.

The greatest value among the failure angles in terms of 68.4 degree failure angle belongs to mixture of cotton+polyester reinforced mortar mixture group. It could be evaluated as the most brittle and the hardest mixture type in all combinations. Use of polyester waste fiber in mixtures makes the mortar more ductile and it becomes more flexible, because of smaller failure angle (65.7°).

The internal friction angle of mixture of cotton+polyester fiber reinforced specimens was found to be 46.7°.This value is higher than the internal friction angle values of the other mixture types. Which means that mixture of cotton+polyester fiber reinforced composite plasters are denser and more compacted than the other types. The internal friction angle of polyester fiber composite with 41.6° was found to be the lowest among all four types of composite mixtures. This means that polyester reinforced plasters have poor and loose structure.

Normal strength analysis was carried out to understand the situation that first crack occurs in the sample's structure. Normal strengths of composite plasters had a decreasing trend depending on the reduction in splitting tensile and compressive strength and increase in fiber content in each type of mixtures. Normal strength parameter of cotton+polyester reinforced plasters with highest value of 0.52 MPa (075CP) and lowest value of 0.24 MPa (5CP) are greater than the others. Which means that cotton+polyester reinforced mixtures could resist more load before first deformation inside.

Cohesion analysis was carried out to determine the strength that holds the particles of the mortar together. According to this analysis, as it can be seen between Figure 4.87 and Figure 4.90, composite plasters reinforced with the mixture of cotton+polyester fiber have exhibited a more cohesive structure. Cohesion values of this group were found as higher than the others with a cohesion value range from 0.73 MPa to 0.33 MPa.

Since the shear strength value is directly related to the cohesion value, the shear strength corresponding to the fiber use has a similar trend to the cohesion versus cotton fiber content. Shear strength values of mixture of cotton+polyester fiber reinforced plaster group was found as higher than the others with a shear strength value range from 1.25 MPa to 0.54 MPa.

7. To make a general evaluation of the thermal conductivity performances of the produced composite plaster, it can be noted that all produced composite mortar combinations including control sample can be evaluated within the scope of thermal insulation plaster according to the TS EN 998-1 standard. The

samples 4C, 5C, 4P, 5P and 5CPA remaining below the thermal insulation value of 0.100 W/mK and they have the T1 thermal insulation class. All the remaining plaster combinations are included in the T2 class as stipulated by the standard.

REFERENCES

Aghaee, K. and Foroughi, M. (2012). Construction of lightweight concrete partitions using textile waste, *International Conference on Sustainable Design, Engineering and Construction, ICSDEC 2012*, pp 793-800, doi: 10.1061/9780784412688.095.

Ahmed, A. and Sturges, J. (2015). *Materials science in construction: an introduction.* Oxon: Routledge.

Algin, H. M. and Turgut, P. (2008). Cotton and limestone powder wastes as brick material, *Construction and Building Materials,* 22, 1074–1080.

Anurag, K., Xiao, F. and Amirkhanian, S.N. (2009). Laboratory investigation of indirect tensile strength using roofing polyester waste fibers in hot mix asphalt, *Construction and Building Materials,* 23, 2035–2040.

Aral, N. (2009). Tekstil atiklarindan oluşturulan kompozitlerin performans özelliklerinin incelenmesi. *M.Sc. Thesis*, İstanbul Teknik University: İstanbul. (in Turkish).

Arıoğlu, N., Girgin, Z.C. and Arioglu E. (2006). Evaluation of Ratio between Splitting Tensile Strength and Compressive Strength for Concretes up to 120 MPa and its Application in Strength. *ACI Materials Journal*, 103(1).

Aspiras, F.F. and Manalo, J.R.I. (1995). Utilization of textile waste cuttings as building material, *Journal of Materials Processing Technology*, 48, 379-384.

ASTM C496 / C496M-11, (2004). Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, ASTM International, West Conshohocken, PA, www.astm.org

Babadağ, Y. (2009). Kimyasal katkıların sıva harçları üzerindeki etkileri. *M.Sc. Thesis*, İstanbul Teknik University: İstanbul. (in Turkish).

Baumann, R. et al. (2009). GDCh-Monographie 41; 35-42; Publisher: Gesellschaft Deutscher Chemiker.

Bezerra, E., Joaquim, A., Savastano, H., John, V. and Agopyan, V. (2006). The effect of different mineral additions and synthetic fiber contents on properties of cement based composites. *Cement and Concrete Composites*, 28(6), pp.555-563.

Binici, H., Eken, M., Dolaz, M., Aksogan, O. and Kara, M. (2014). An environmentally friendly thermal insulation material from sunflower stalk, textile waste and stubble fibres, *Construction and Building Materials,* 51, 24-33.

Binici, H., Gemci, R., Kucukonder, A. and Solak, H. H. (2012). Investigating sound insulation, thermal conductivity and radioactivity of chipboards produced with cotton waste, fly ash and barite, *Construction and Building Materials,* 30, 826–832.

Briga-Sá, A., Nascimento, D., Teixeira, N., Pinto, J., Caldeira, F., Varum, H. and Paiva, A., (2013). Textile waste as an alternative thermal insulation building material solution, *Construction and Building Materials,* 38, 155–160.

Callister, W. D. (2007). *Materials science and engineering: and introduction.* New York: John Wiley & Sons.

Chung, D. D. L. (2001). Interface engineering for cement-matrix composites. *Composite Interfaces,* 8(1), pp.67-81.

EASME (2015). Giving Textile Waste a Second Lease of Life In The Construction Industry, (ONLINE) Available at: https://ec.europa.eu/easme/en/news/giving-textile-waste-second-lease-life-construction-industry. [Accessed 4 August 2016].

EcoChic (2013). The EcoChic Design Award, Sourcing Textile Waste, (ONLINE) Available at: http://www.ecochicdesignaward.com/wp-content/blogs.dir/3/files/2013/07/LEARN_Sourcing_ENG.pdf 26/10/2016. [Accessed 4 August 2016].

Emekyapar, T. and Örüng, İ. (1993). İnşaat malzeme bilgisi. Atatürk Üniversitesi Ziraat fakültesi ders notları. No:145, Erzurum.

Gadkari, R., and Burji, M. C. (2015). Textiles Waste Recycling. India: Textile Value Chain Design. (ONLINE). Available at: http://www.textilevaluechain.com/index.php/article/technical/item/273-textiles-wasterecycling. [Accessed 4 August 2016].

Gordon, S. and Hsieh, Y. L. (2007). *Cotton: Science and Technology.* Cambridge: Woodhead.

Grabois, T., Cordeiro, G. and Toledo Filho, R. (2016). Fresh and hardened-state properties of self-compacting lightweight concrete reinforced with steel fibers. *Construction and Building Materials,* 104, pp.284-292.

Güleryüz, Ö. (2011**).** Küresel gelişmeler ışığında türkiye'de tekstil sektörü ve geleceği. *M.Sc. Thesis*, Süleyman Demirel University: Isparta. (in Turkish).

Gündüz, L. (2005). İnşaat Sektöründe Bimsblok. Süleyman Demirel Üniversitesi, Pomza Araştırma ve Uygulama Merkezi, Isparta, Turkey. (In Turkish).

Gündüz, L., Bekar, M. and Şapçı, N. (2007). Influence of a new type of additive on the performance of polmer-lightweight mortar composites. *Cement And Concrete Composites*, 29, 594-602.

Gündüz, L., Şapcı, N., Bekar, M., İsker, M. (2006). A technical analysis on improving the technical properties of pumice concretes with expanded perlite aggregates. IV.Ulusal Kırmataş Sempozyumu, 2-4 Aralık 2006, İstanbul. Available at: http://pomzamer.sdu.edu.tr/assets/uploads/sites/98/files/4ulusalkirmatassemp-28092012.pdf.

Habib, A., Begum, R. and Alam, M.M. (2013). Mechanical Properties of Synthetic Fibers Reinforced Mortars. *International Journal of Scientific & Engineering Research,* Vol. 4, Iss. 4, pp. 923-927. ISSN 2229-5518.

Hadded, A., Benltoufa, S., Fayala, F. and Jemni A. (2016). Thermo physical characterisation of recycled textile materials used or building insulating, *Journal of Building Engineering,* 5, 34-40.

Hannant, D., Buckley, K. and Croft, J. (1973). The effect of aggregate size on the use of the cylinder splitting test as a measure of tensile strength. *Matériaux et Constructions,* 6(1), pp.15-21.

Hejazi, S. M., Sheikhzadeh, M., Abtahi, S. M. and Zadhoush, A., (2012). A simple review of soil reinforcement by using natural and synthetic fibers, *Construction and Building Materials,* 30, 100-116.

Illston, J. and Domone, P. (2001). *Construction materials*. London: Spon Press.

Kadleček, V., Modrý, S. and Kadleček, V. (2002). Size effect of test specimens on tensile splitting strength of concrete: general relation. *Materials and Structures,* 35(1), pp.28-34.

Kalkan, R. (2008). Kompozit yapı malzemelerinde ısıl özellik ölçümü. *M.Sc. Thesis*, Harran University: Şanlıurfa. (in Turkish).

Karcı, M. (2011). Barit şlam atıklarının yüksek performanslı kompozit harç üretiminde değerlendirilmesi. *M.Sc. Thesis*, Süleyman Demirel University: Isparta. (in Turkish).

Kozak, M. (2010). Tekstil atıkların yapı malzemesi olarak kullanım alanlarının araştırılması. *Yapı Teknolojileri Elektronik Dergisi,* Vol. 6, No. 1, pp. 62-70. (in Turkish).

Kozak, M. (2010). Tekstil Atıkların Yapı Malzemesi Olarak Kullanım Alanlarının Araştırılması, *Yapı Teknolojileri Elektronik Dergisi*, Vol. 6, No. 1, 62-70.

Mahboubi, A. and Ajorloo, A. (2005). Experimental study of the mechanical behavior of plastic concrete in triaxial compression. *Cement and Concrete Research,* 35(2), pp.412-419.

Marikunte, S., Aldea, C. and Shah, S. (1997). Durability of glass fiber reinforced cement composites: Effect of Silica Fume and metakaolin. *Advanced Cement Based Materials,* 5, pp.100-108.

MEB (2011). Giyim Üretim Teknolojisi Tekstil Lifleri 542TGD019, Ankara, Turkey, Republic of Turkey Ministry of Education, (in Turkish), (ONLINE). Available at: http://www.megep.meb.gov.tr/mte_program_modul/moduller_pdf/Tekstil%20Lifleri.pdf. [Accessed 4 August 2016].

MEGEP (2007). Giyim üretim teknolojisi tekstil lifleri, meslekî eğitim ve öğretim sisteminin güçlendirilmesi projesi, T.C. Millî Eğitim Bakanlığı, Ankara. (in Turkish), (ONLINE) Available at: http://hbogm.meb.gov.tr/modulerprogramlar/kursprogramlari/giyim/moduller/tekstil_lifleri.pdf. [Accessed 4 August 2016].

Murathan, A., Murathan, A. and Karadavut, S. (2014). Yüksek yoğunluklu polipropilen tekstil atıklarının kompozit malzeme üretiminde kullanılabilirliği, Journal of the Faculty of Engineering and Architecture of Gazi University, Vol. 29, No. 1, pp. 9-14. (in Turkish).

Needles, H. (1986). *Textile fibers, dyes, finishes, and processes*. Park Ridge, N.J., U.S.A.: Noyes Publications.

Neville, A.M. (1999). Properties of Concrete. Pearson Education Ltd., London.

Oliveira, L. A. P. and Castro-Gomes, J. P. (2011). Physical and mechanical behaviour of recycled PET fibre reinforced mortar, *Construction and Building Materials,* 25, 1712–1717.

Onésippe, C., Passe-Coutrin, N., Toro, F., Delvasto, S., Bilba, K. and Arsène, M. (2010). Sugar cane bagasse fibres reinforced cement composites: Thermal considerations. *Composites Part A: Applied Science and Manufacturing,* 41(4), pp.549-556.

Öztekin, E., Pul, S. and Hüsem, M. (2016). Experimental determination of Drucker-Prager yield criterion parameters for normal and high strength concretes under triaxial compression. *Construction and Building Materials,* 112, pp.725-732.

Pakravan, H., Jamshidi, M., Latifi, M. and Pacheco-Torgal, F. (2012). Cementitious Composites Reinforced with Polypropylene, Nylon and Polyacrylonitile Fibres. Materials Science Forum, 730-732, pp.271-276. Available at: https://repositorium.sdum.uminho.pt/bitstream/1822/14651/1/Id%20191.pdf.

Pinto, J., Peixoto, A., Vieira, J., Fernandes, L., Morais, J., Cunha, V. and Varum, H. (2013). Render reinforced with textile threads. *Construction and Building Materials,* 40, pp.26-32.

Pogorelov, S. and Semenyak, G. (2016). Frost Resistance of the Steel Fiber Reinforced Concrete Containing Active Mineral Additives. *Procedia Engineering,* 150, pp.1491-1495.

Rajput, D., Bhagade, S. S., Raut, S. P., Ralegaonkar, R. V.and Mandavgane, S. A. (2012). Reuse of cotton and recycle paper mill waste as building materia", *Construction and Building Materials,* 34, 470–475.

Raut S. P., Ralegaonkar, R. V. and Mandavgane, S. A. (2011). Development of sustainable construction material using industrial and agricultural solid waste: A review of waste-create bricks, *Construction and Building Materials,* 25, 4037–4042.

Saçak, M. (1994). Lif Kimyası. *Döner Sermaye işletmesi Yayınları,* No. 18. Ankara: A.O.F.F. [in Turkish].

Savastano, H. and Agopyan, V. (1999). Transition zone studies of vegetable fibre-cement paste composites. *Cement and Concrete Composites*, 21(1), pp.49-57.

Savastano, H., Agopyan, V., Nolasco, A. and Pimentel, L. (1999). Plant fibre reinforced cement components for roofing. *Construction and Building Materials,* 13(8), pp.433-438.

Shah, S.P., Ludirdja, D., Daniel, J.I. and Mobasher, B. (1988). Toughness-durability of glass fiber reinforced concrete systems. *ACI Materials Journal,* Title no 85-M39, 85(5):352-360.

Silva, F., Filho, R., Filho, J. and Fairbairn, E. (2010). Physical and mechanical properties of durable sisal fiber–cement composites. *Construction and Building Materials,* 24(5), pp.777-785.

Uçar, M. and Wang, Y. (2011). Utilization of recycled post consumer carpet waste fibers as reinforcement in lightweight cementitious composites, *International Journal of Clothing Science and Technology,* Vol. 23, Iss. 4, pp. 242-248.

Ulcay, Y., Akyol, M. and Gemci, R. (2002). Polimer esaslı lif takviyeli kompozit malzemelerin arabirim mukavemeti üzerine farklı kür metotlarının etkisinin incelenmesi. *Uludağ Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi*, Vol. 7, No. 1, pp. 93-116. (in Turkish).

Url-1 <http://materialsworld.utep.edu/Modules/Composite/Morehouse%20Composites/Mor"eHouse%20Composites.htm>, date retrieved 04.08.2016.

Url-2 <http://navyaviation.tpub.com/14018/css/Categories-Of-Composite-Material-Damage-596.htm>, date retrieved 04.08.2016.

Url-3 <http://materialsworld.utep.edu/Modules/Composite/Morehouse%20Composites/MoreHouse%20Composites.htm>, date retrieved 04.08.2016.

Url-4 <http://materialsworld.utep.edu/Modules/Composite/Morehouse%20Composites/MoreHouse%20Composites.htm>, date retrieved 04.08.2016.

Url-5 <http://www.utest.com.tr/tr/20566/Otomatik-Cimento-Basma-ve-Egilme-Deney-Presleri>, date retrieved 04.08.2016.

Url-6 <http://www.utest.com.tr/tr/20566/Otomatik-Cimento-Basma-ve-Egilme-Deney-Presleri>, date retrieved 04.08.2016.

Url-7 <http://www.utest.com.tr/tr/20563/Egilme-Basinc-Deney-Govdeleri>, date retrieved 04.08.2016.

Üçgül, İ. and Turak, B. (2015). Tekstil katı atıklarının geri dönüşümü ve yalıtım malzemesi olarak değerlendirilmesi. *Akademik Platform Mühendislik ve Fen Bilimleri Dergisi,* Vol. 4, No. 3, pp. 39-48. (in Turkish).

Wang, Y. (2006*). Recycling in textiles.* Boca Raton: CRC Press.

Wang, Y., Zureick, A., Cho, B. and Scott, D. (1994). Properties of fibre reinforced concrete using recycled fibres from carpet industrial waste. *Journal of Materials Science,* 29(16), pp.4191-4199.

Yin, S., Tuladhar, R., Riella, J., Chung, D., Collister, T., Combe, M. and Sivakugan, N. (2016). Comparative evaluation of virgin and recycled polypropylene fibre reinforced concrete. *Construction and Building*

Materials, 114, pp.134-141.

Zhang, H., Liu, Y., Sun, H. and Wu, S. (2016). Transient dynamic behavior of polypropylene fiber reinforced mortar under compressive impact loading. *Construction and Building Materials,* 111, pp.30-42.

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List of Publications:

PUBLICATIONS, PRESENTATIONS AND PATENTS ON THE THESIS:

- **Kalkan Ş. O.** and Gündüz L. (2016). A Study on the Usage of Denim Waste as Reinforcement Element in Composite Mortars on Exterior Building Applications. *12th International Congress on Advances in Civil Engineering*, September 21-23, İstanbul, Turkey.

- **Kalkan Ş. O.** and Gündüz L. (2015). Dış Cephe Mimari Uygulamalarda Yeni Nesil Kompozit Bileşenli Harçların Teknik Değerlendirmesi Üzerine Bir Çalışma. *I. Uluslararası Mühendislik Mimarlık ve Tasarım Kongresi*, November 11-13, Kocaeli, Turkey.

OTHER PUBLICATIONS, PRESENTATIONS, AND PATENTS:

- Gündüz, L., **Kalkan, Ş.O.,** Ertan, F. (2017). Mikronize Edilmiş İzmir-Alaçatı Alapietra Taşinin Yalıtımlı Kompozit Dolgu Harci Üretiminde Kullanımı Üzerine Bir İnceleme. *Celal Bayar Üniversitesi Fen Bilimleri Dergisi*, 13 (2), 503-514. DOI: 10.18466/cbayarfbe.319931

- **Kalkan, Ş.O.,** Gündüz, L. (2017). Evaluation of Physical and Mechanical Performance of A New Generation Composite Mortar Containing Eggshell Powder. *International Conference on Applied Sciences '17,* May 26-27, İstanbul, Turkey.

- Gündüz, L., **Kalkan, Ş.O.,** İsker, A.M., Güreli-Urhan, B., Hacıoğlu, S. (2017). An Analysis on The Use of Fibrous Natural Rocks in Inorganic-Bonded Fiber Composites. *International Conference on Applied Sciences '17,* May 26-27, İstanbul, Turkey.

- Gündüz, L., **Kalkan, Ş.O.** (2017). Influence of Different Lightweight Aggregate Types on Technical Properties of Non-Load Bearing Foam Concrete Masonry Units. *International Conference on Applied Sciences '17,* May 26-27, İstanbul, Turkey.

- Gündüz, L., **Kalkan, Ş.O.** (2017). Influence of Elevated Temperatures on the Strength Properties of Lightweight Concrete Masonry Units Prepared With Pumice Aggregates. *International Conference on Advances and Innovations in Engineering,* May 10-12, Elazığ, Turkey.

- Gündüz, L., **Kalkan, Ş.O.,** Özgven, A. (2017). Genleşmiş Kil Agregaların Teknik Özelliklerinin Karşılaştırılması Üzerine Bir Çalışma: Ankara Kalecik Bölgesi Örneği. *2017 Hazır Beton Kongresi*, April 13-14, İstanbul, Turkey.

- Gündüz, L., **Kalkan, Ş.O.** (2017). Pirinç Kabuğu Külünün Çimentolu Hafif Kompozit Harçlarda Dayanım Arttırıcı Katkı Olarak Kullanılması Üzerine Teknik Bir İnceleme. *2017 Hazır Beton Kongresi*, April 13-14, İstanbul, Turkey.

- Gündüz L., **Kalkan Ş. O.** and Aydoğdu N. K. (2016). A Technical Analysis on Usability of İzmir-Alaçatı Rock as Dry Mixture Lightweight Concrete Aggregate. *8th International Aggregates Symposium*, October 13-14, Kütahya, Turkey.

- Gündüz L. and **Kalkan Ş. O.** (2016). Effect of Diatomite Aggregates on Improving the Cement Based Lightweight Mortar Properties. *8th International Aggregates Symposium*, October 13-14, Kütahya, Turkey.

- Gündüz L. and **Kalkan Ş. O.** (2016). Evaluation of Exfoliated Vermiculate Aggregates to Produce New Generation Composite Mortars in Environmentally Sustainable Buildings. *III. International Architectural Design Conference*, June 17-18, İstanbul, Turkey.