

POLİTEKNİK DERGİSİ

JOURNAL of POLYTECHNIC

ISSN: 1302-0900 (PRINT), ISSN: 2147-9429 (ONLINE)
URL: http://dergipark.org.tr/politeknik



Using sulphur concrete on defense buildings

Kükürtlü betonun savunma yapılarında kullanımı

***Yazar(lar)(Author(s))**: İlker Bekir TOPÇU[1], M. Emre DANIŞ[2]*

ORCID[1]: 0000-0002-2075-6361

ORCID[2]: 0000-0002-3594-3231

Bu makaleye şu şekilde atıfta bulunabilirsiniz (To cite to this article): Topçu İ. B. ve Danış, M. E., "Using Sulphur Concrete on Defense Buildings", ***Politeknik Dergisi***, 25(1): 9-17, (2022).

Erişim linki (To link to this article): http://dergipark.org.tr/politeknik/archive

DOI: **10.2339/politeknik.722423**

Using Sulphur Concrete on Defense Buildings

Highlights

- *Sulphur concrete is a concrete type without water and cement in the concrete mix.*
- *Sulphur combines with aggregate to reach high strengths.*
- *Flexural and splitting tensile strength is higher than cement reinforced concrete.*
- *Sulphur concrete can provide resistance to radiation with low thickness.*
- *Using sulphur concrete in military or critical buildings will reduce the damage to the building.*

Graphical Abstract

Making shelters from SC at the operation site will be more resistant in a shorter time. This article will describe the use of SC in the field of defense. In addition, compressive test results is given at the performed with SC sample.

Properties		Sulphur Concrete[a]	Portland Cement Concrete[b]
Strengths, MPa	Compressive	48-69	25-35
	Splitting Tensile	7-10	3,5
	Flexural	9,5-14	4
Coefficient of Thermal Expansion (μin/in)/°C		14,0 – 14,7	12
Moisture Absorption, %		0,0 – 0,10	0,30 – 3,0
Air void Content, %		3,0 – 6,0	4,0
Elastic Modulus, 10^6 kN/m^2		27,5	27,5
Specific gravity		2,4 – 2,5	2,5
Linear Shrinkage		0,08 – 0,12	0,06 – 0,10
Impact Strength, J	Compressive	136 - 161	110
	Flexural	0,407 - 0,678	0,271
Mix Proportions, wt %	Sulphur	14 – 18	0
	Water	0	6 – 9
	Mineral Filler	6 - 9	0
	Portland Cement	0	12 - 18
	Sand	38 – 42	30
	Coarse Aggregate	33 - 37	45

Table. Comparison of mechanical properties of sulphur concrete and portland cemented concrete

Aim

It aims to construct military and critical buildings and structures with sulphur concrete, to reduce the damage to reinforced concrete and to protect the shelters in a shorter time.

Design & Methodology

The mixture formed by mixing with sulphur and aggregates of different sizes is poured according to the project of the relevant defense structure.

Originality

Although there is not yet enough information about the use of sulphur concrete, the fact that there is no literature information about the use of this type of concrete in defense structures shows that the subject is original.

Findings

Experimental results show that sulphur concrete is about two times more advantageous than portland cement concrete.

Conclusion

As a result, sulphur concrete has brought a new vision to the load-bearing systems, and it has also been found to provide significant advantages in critical buildings and structures such as defense structures.

Declaration of Ethical Standards

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Using Sulphur Concrete on Defense Buildings

Araştırma Makalesi / Research Article

İlker Bekir TOPÇU*, M. Emre DANIŞ

Eskişehir Osmangazi Üniversitesi, Mühendislik-Mimarlık Fakültesi, İnşaat Mühendisliği Bölümü, Eskişehir, Türkiye

(Geliş/Received : 17.04.2020 ; Kabul/Accepted : 29.06.2020 ; Erken Görünüm/Early View : 20.07.2020)

ABSTRACT

Sulphur concrete (SC) is a concrete type without water and cement in the concrete mix. It becomes binder by heating sulphur up to 114 ^{o}C. Sulphur combines with aggregate to reach high strengths. Flexural and splitting tensile strength is higher than cement reinforced concrete. It gets 80% of its strength in 24 hours and is ready to use in a short time. Also, it has very high resistance against aggressive environments. The porosity rate is partially low. SC can provide resistance to radiation with low thickness. Also, it is very easy to provide. Besides mineral deposits, it can be produced as waste in oil and natural gas production. It has resistance of fire. This concrete can be repaired locally against damage and deformations. According to studies, it provides its strength before damage. Using SC in military or critical buildings will reduce the damage to the building. Making shelters from SC at the operation site will be more resistant in a shorter time. This article will describe the use of SC in the field of defense. In addition, compressive test results is given at the performed with SC sample.

Keywords: Sulphur concrete, defense area, strength, aggressive environments, explosive.

Kükürtlü Betonun Savunma Yapılarında Kullanımı

ÖZ

Kükürtlü beton karışımında su ve çimento bulunmayan bir beton türüdür. Kükürt 114 ℃'ye kadar ısıtılmasıyla bağlayıcılık özelliği kazanır. Agrega ile birleşerek yüksek dayanımlara ulaşır. Yüksek basınç dayanımlarına ulaşmasıyla birlikte eğilme ve yarmada çekme dayanımı normal betonlara göre daha yüksektir. Kükürtlü beton 24 saatte dayanımının %80'ine ulaşır ve kısa sürede kullanıma açılır. Ayrıca zararlı ortamlara karşı dayanıklılığı çok yüksektir. Boşluk oranı kısmen düşüktür. Düşük kalınlıklarla bile radyasyona karşı direnç sağlayabilir. Ayrıca kükürdün bulunması ve bu betonun üretimi çok kolaydır. Kükürt maden yataklarının yanısıra petrol ve doğalgaz üretiminde atık olarak üretilebilir. Yangına karşı dayanıklıdır. Bozulma ve hasar oluşumuna karşı lokal tamir edilebilir. Çalışmalara göre önceki dayanımını büyük oranda karşılar. Askeri ve kritik öneme sahip binaları kükürtlü beton kullanılarak yapmak, betonarmeye göre alacağı hasarları azaltmayı amaçlamaktadır. Operasyon sahalarında kükürtlü betondan korunaklar daha kısa sürede daha dayanımlı olarak sağlanır. Makalede kükürtlü betonun savunma alanında kullanımı anlatılacaktır. Ayrıca kükürtlü beton numunelerine ait ile basınç deneyleri sonuçları verilmiştir.

Anahtar Kelimeler: Kükürtlü beton, savunma sanayi, dayanım, zararlı ortamlar, patlama.

1. INTRODUCTION

Sulphur concrete is a concrete including modified sulfur cement and aggregate, which is produced without water. Its binder property is obtained with molten modified sulfur. The first studies with SC were obtained in 1970. Mostly, the scientists studied on the advantages of SC [1]. The construction of the watchtowers and defense lines from concrete enabled military personnel to survive the attacks with minimum loss. In the past years, many painful events have been experienced in how insecure the outposts consisting of sheet roofs and brick walls are compared to the outposts made of HSC. With these experiences, it was decided to build defense structures from customized concrete with high explosion resistance and these structures protected the life of military personnel in many areas. In addition, thanks to concretes that can be quickly set up, it is also important to build helicopter runways, assembly areas, logistics centers within the operational areas and the establishment of logistic support structures.



Figure 1. The shelters made with SC are rendered as in the figure.

**Sorumlu yazar(Corresponding Author)*
e-posta : ilkerbt@ogu.edu.tr

Providing security, creating a counterattack or defending the current attack develops thanks to instant decision mechanisms. The rocket targeting a tank must be destroyed within seconds before reaching the target. In this process, the creation of a counterattack depending on the movement of the rocket is created by computers that make millions of transactions in the second. In buildings, this situation is quite different. Rapid production of structures takes days due to the setting process of cement. However, it is almost impossible to do days for construction work in the field of operation. Therefore, military shelters have been established by tents in many operations come to the fore. But this shelter is insufficient for security causes. Rarely used prefabricated buildings are not preferred due to the difficulty of carrying. In some of the new generation operations use textile concrete has been tried to be used partially, but efficiency has not been achieved. These findings have led us to new searches.

Sulphur concrete is a special type of concrete that consists of modified sulphur and aggregate main components and does not contain water and cement in its mixture. Structurally, it gets its binding feature from sulphur. SC in the other word is waterless concrete, which is also binding-activated by heating, has also increased its load bearing capacity over reinforced concrete with the aggregates in its mixture. Sulphur modified with some chemicals such as DCPD and styrene contribute to its mechanical properties such as desired workability and strength. Sulphur is an element which it can be elementally revealed in nature. Besides, it can also be produced by oxidizing and precipitating H_2S and SO_2 gases in factories. As 0.06% of the world is made up of sulphur, too much sulphur stock in factories emerges as waste. Pure sulphur, whose density varies between 2.03 and 2.06 g/cm^3, is very low in thermal conductivity and it is a very good insulator since it has no electrical conductivity. On the contrary, electrical conductivity increases in moist environments. After this Portland cement concrete will called PCC and Sulphur Concrete will call SC. Sulphur concrete, which emerged in the last century and it is need of research and development, is a solution to the negative effects mentioned above. Also, it is economically satisfactory and raises security levels. In this article, sulphur concrete which is used in the defense area will be introduced and it will explain place on area. Compressive strength test will be done with sulphur concrete samples.

2. USING SULPHUR ON CONCRETE

The goals of human beings can be achieved more easily with the development of the rapidly developing construction industry and technology in the world. The discovery of PC in the 19th century and the use of steel as reinforced concrete has survived until today. Also, concrete additives and using different production techniques have reached an essential position and make it possible all the requested architectural projects. But this position of reinforcement in the world is not enough in the space and defense area what humanity desires. In Figure 2, shown that SC samples.



Figure 2. Sulphur Concrete Samples

SC has superior properties compared to PC in terms of physical and mechanical properties. SC mixing rate,

Table 1. Comparison of Mechanical Properties of Sulphur Concrete and Portland Cemented Concrete

Properties		Sulphur Concrete[a]	Portland Cement Concrete[b]
Strengths, MPa	Compressive	48-69	25-35
	Splitting Tensile	7-10	3,5
	Flexural	9,5-14	4
Coefficient of Thermal Expansion (µin/in)/"C		14,0 – 14,7	12
Moisture Absorption, %		0,0 – 0,10	0,30 – 3,0
Air void Content, %		3,0 – 6,0	4,0
Elastic Modulus, 10^6 kN/m^2		27,5	27,5
Specific gravity		2,4 – 2,5	2,5
Linear Shrinkage		0,08 – 0,12	0,06 – 0,10
Impact Strength, J	Compressive	136 - 161	110
	Flexural	0,407 - 0,678	0,271
Mix Proportions, wt %	Sulphur	14 – 18	0
	Water	0	6 – 9
	Mineral Filler	6 - 9	0
	Portland Cement	0	12 - 18
	Sand	38 – 42	30
	Coarse Aggregate	33 - 37	45

[a] : Properties obtained at age of **1** day, [b] : Properties obtained at age of 28 days. [4]

manufacturing process, molding and setting properties are not same as PCC. Compared to PCC, SC is resistant to aggressive environments, mold setting time, very low porosity, and high tensile and compressive strengths [2]. In the studies, it has been observed that it can reach high strengths in a short time. Mechanical properties gain 90% in 24 hours [3]. The mechanical properties of PCC and SC were compared in Table 1. In the Table 1, 28 days of PCC and 1 day of SC were compared. As can be seen, the mechanical properties of SC are very developed. Many features almost doubled in as short time as 24 hours. Besides these features, it is stated that SC has reached over 90% strength in 6 hours [10-11].

When it is desired to create a new living space in space by using reinforced in space, lack of raw materials, transportation problems, production stages and, most importantly, the mechanical properties of concrete are not enough for built. On the other hand, the ease of transportation and communication in the global world, the increasingly complicating policy, the desire to be strong, the desire to possessiveness and manage, increase the attacks. Therefore, countries allocate big budgets and time to the defense area and competes on new techniques attack and defense technologies. The demand for protection, which is one of the issues related to the construction sector, cannot be met sufficiently and causes loss of life and property. Very strong explosives can be produced, but reinforced concrete structures that can resist it cannot provide enough strength. Scientists have turned to different carrier and protective composite materials in this regard. One of them, sulphur concrete, is not yet widespread, but there is hope in the future.

As it is understood from the name of sulphur concrete, it is a type of concrete that uses sulphur instead of cement as a binder and is heat activated instead of water [5]. It is produced by mixing the elemental sulphur with the aggregate after it is melted by heating and mixing it with additives such as Dicyclopentadiene (DCPD), styrene and setting it at the appropriate temperature [5]. The production process of SC is different from PCC. The sulphur heating process is like the asphalt production method [6]. For the sulphur used to mix homogeneously with the aggregate, all materials like mold to be used must be heated at 100 ^{o}C. Sulphur start melting 95.4 ^{o}C. The complete melting occurs in 119 ^{o}C. If it remains below 95.4 ^{o}C, sulphur turns into a crystal form and its volume decreases by 6% [7]. For the sulphur to mix homogeneously and not turn into a crystalline structure during setting time, aggregate must have a temperature higher than 100 ^{o}C. In addition, the mold should be heated to at least 100 ^{o}C. This process is necessary for the controlled molding of the composite mixture [8-9].

3. PROPERTIES OF SULPHUR CONCRETE

In this section, some of the reasons for preferred SC will be explained as substances. Also, main criteria required in the area of defense will be mentioned.

3.1. Mechanical Properties: In Table 1, the experimental studies conducted by McBee et al. compared the PCC and SC mix rates and mechanical properties. The age of SC was tested for 1 day and the age of PCC was 28 days. Similar results were also found in other studies in which the same experiments were carried out. Compressive strength showed between 48-69 MPa in one day age in SC, while PCC showed between 25-35 MPa. In Figure 3, show that sulphur concrete sample during compressive test.



Figure 3. Sulphur concrete sample during compressive test.

3.2. Recyclability: According to Gracia et al, they proposed SC application areas. They indicated that if the building element is damaged, it would be appropriate to apply it in precast structures due to its fast and high strength property and recyclability. They indicated that due to the high resistance of sulphur in aggressive environments (chemical effect, corrosion and abrasion), it can be successful in chemical plants, air tracks, pavements cover and coating of the marine environment [12]. If shelters, security cabins, or even living space have any damage or deformation, they can be easily and quickly repaired and recycled. Anyszka et al. indicated that it is a promising building material for the construction due to the lack of water in the production of SCs, the absence of CO_2 emissions and its recycling capabilities and high mechanical properties. The amount of sulphur in SC usually contains 15-40% by weight. Due to the percentage of sulphur in it, mechanical properties should not change too much after recycling. According to the study published by Anyszka in 2016, if the SC is recycled, its strength will remain satisfactory after recycle process [13]. Damage, after explosion or attack, restore if damage is small and proper for build. Otherwise the building will be demolished. This process can take weeks. In SC with the current developments in a short time locally strengthen and repair can be achieved.

3.3. Short Setting Time: A very important feature of SC is rapid hardening. It is between 15 mins and several hrs, depending on the size and shape of the sample. Allows demolding and curing in about 24 hrs at room temperature [14]. According to Omar, it is an important advantage that SC gets faster setting than PCC. Thus, he indicated that building will provide faster completion of the construction to be produced especially on the Moon

[15]. Rizwan et al. In their work, they stated that the desired strength was taken within 5 mins for fast construction demands. They also pointed out that SC is a building material that creates a green environment by reducing CO_2 emissions [16]. According to the researches described above, SC can be set in about 10 mins and it can gain more than 80% of its strength in a short time like 24 hrs. This feature is very fast compared to PCC. It is thought that the feature of SC will gain a lot of advantages and time in the defense area, in the fields of operation, in terms of rapid mobility.

3.4. Recruitment: Fiona Boyd, director of Houston-based Acuity Commodities, discussed the sulphur appearance at the Fertilizer Overview and Technology Conference in Savannah, Georgia in mid-November 2019. Produced 55 million metric tons (mmt) worldwide in 2013, sulphur reached 60 mmt in 2017. However, as a result of statistical studies, it is thought that it will exceed

Table 2. Sulphur quantities produced in the world [18]

World 2018-2019 Sulphur Production (x1000 mmt)		
Country	**Years**	
	2018	**2019**
China	17.400	17.400
United States	9.680	8.800
Russia	7.080	7.100
Saudi Arabia	6.500	6.600
Canada	5.320	5.300
Kazakhstan	3.510	3.600
India	3.430	3.400
Japan	3.400	3.400
United Arab Emirates	3.300	3.400
Republic of Korea	3.080	3.100
Other countries	16.688	16.810
World total (rounded)	**79.400**	**79.000**

69 mmt in 2023 [17]. In the world; In addition to the volcano deposits and elemental sulphur extracted from the evaporate, it is known to have approximately 5 billion tons of sulphur as natural gas, oil and petroleum deposits, metal sulphate. In addition to this, the sulphur in gypsum and anhydride is almost unlimited, as well as 600 million tons of sulphur content in shale rich in coal, oil shale and organic matter. To make production of these resources are needed to develop low cost methods of extraction. Sulphur sources are equivalent to one fifth of the world [18]. In Table 2 shows the amount of sulfur produced in 2018 and 2019 on world.

Sulphur can be obtained as a by-product of oil and natural gas besides mineral deposits. According to the data, the quantity and supply demand increases every year. As it is known that natural gas and oil refineries will continue to make provisions for many years to come, sulphur production will continue to do so. Elemental sulphur, which is mostly used in the agricultural fertilizer sector and industrial raw materials, is now thought to be preferred in the construction sector.

3.5. Radiation: Toutanji et al. showed impact test and radiation experiment in their study. They used different substance such as sulfur concrete, aluminum, polyethylene and lunar regolith (JSC-1 simulant) in their radiation test. In Figure 4, it is seen that the thickness required to provide 80 cSv/yr radiation shield in the ICRP 60 curve is 15 g per cm^2 [19].

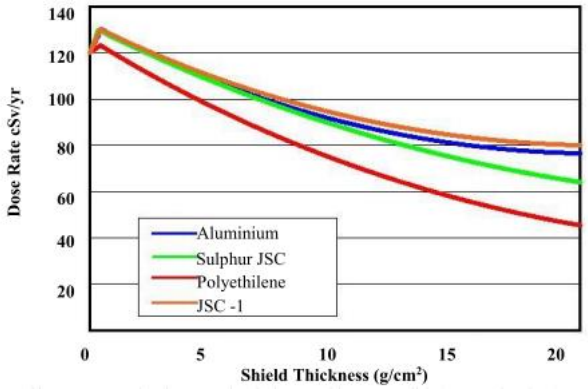


Figure 4. Sulfur concrete, aluminum, polyethylene and lunar regolith (JSC-1 simulant) on radiation test graphic

According to the study in the applied radiation experiment above that the especially simultaneous lunar soil radiation value was higher than aluminum. In addition, it can be said that the SC has similar density with PCC therefore its radiation property is similar. This behavior can be an advantageous position in nuclear attacks in defense area and shelter structures.

3.6. No Need Water: Sulphur Concrete call also waterless concrete in the literature. Binding property of concrete is provided with melting sulphur on 114 ^oC. Elemental sulphur doesn't interact with water. The amount of water is expected to decrease due to climate changes in the world. Assume that PCC used in the construction industry approximately used 200 liters water in 1 m^3 concrete mixing. Considering that 10 billion m^3 of ready-mixed concrete is produced annually, the amount of water used is 2 quadrillion liters. Water so much consumption increases the concern for the future.

3.7. Fire Resistance and Aggressive Environments Resistance: Dehestani et al. have tested the SC in various aggressive environments. They have tested against fire resistance and has been examined to resistance of acidic environments. The results were observed to be favorable [20]. Yue et al. indicated in their own study that the SC has high strength, high abrasion resistance and high chemical corrosion resistance. They said that it is not flammable and that the surface only burns when exposed to fire and goes out when contact with fire is interrupted. They showed that in study sulphur that binds aggregates has thermoplastic feature. SC can be recycled without loss of mass and strength as a result of crushing, impact or burning. Although the production cost is high at the

beginning, the low recycling costs can tolerate itself [21]. In the studies described above, it is observed that SC has fire resistance compared to PCC. It is also known to have high resistance to aggressive environments. Its recyclability saves speed and time in defense lines and shelters. Fire can be easily extinguished, and local repair can be done.

4. EXPERIMENTAL STUDIES

SC were tested at the Materials of Construction and Concrete Laboratory in Eskişehir Osmangazi University. Compressive strengths were tested using 7x7x7 cm steel molds with different aggregate ratios and sulphur.

Table 3. Mixing Ratios of Sulphur Concrete Samples

Ingredients	**SC 1**	**SC 2**	**SC 3**
Sulphur (gr)	1000	1000	1000
Standard Sand (0-2 mm) (gr)	800	1000	400
Fine Aggregate (2-4 mm) (gr)	600	600	1000
Coarse Aggregate (4-8 mm) (gr)	600	400	600
Sulphur/Aggregate Ratio	0,5	0,5	0,5



Figure 5. Mixing the aggregate mixtur into homogeneous



Figure 6. Heating of sulphur and providing binder feature



Figure 7. Pouring sulphur aggregate composition into molds

The steel mold was heated to 100 ºC. Then, the aggregate, whose mixing ratios are given below, is mixed and heated up to 120 ºC. Then, the sulphur was heated up to 114 ºC in the cooker and mixed and heated until it reached the rhombic phase. The mixed aggregate heated during this phase is poured into the cooker. It was mixed for a while and then it was mixed homogeneously and then poured into heated molds (Figures 5-7). The reason for the aggregate and molds to be heated is to extend the setting time of the sulphur. Because the sample is setting fast, it reduces its workability. In Table 3 show that, SC mixing ratios that using in tests.

5. RESULTS OF EXPERIMENTS

Three concrete cubes were produced from each sample and subjected to compressive strength tests. The average of the compressive strength values of each sample is written in the table. The test is made as to kN was written statements MPa. The results of the compressive strength tests are given in the Table 4 below.

Table 4. Compressive Strength Results of SC Samples

Samples	**SC 1**	**SC 2**	**SC 3**
Compressive Strength, MPa	45,130	35,780	39,600

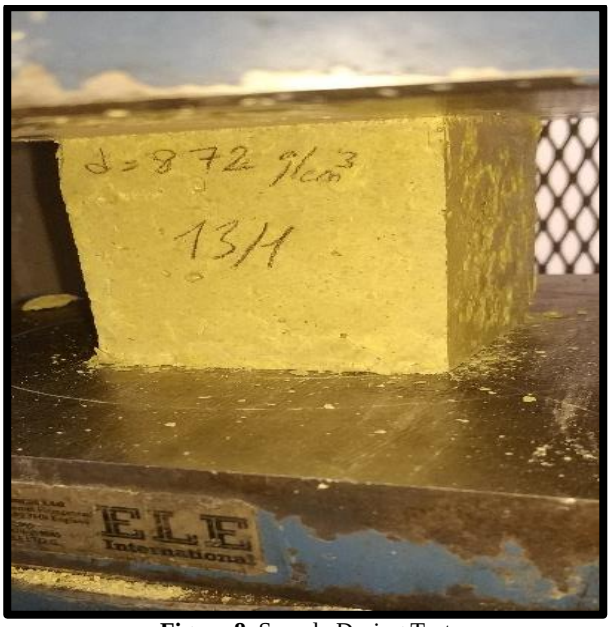


Figure 8. Sample During Test



Figure 9. Compressive Strength (KN) of SC 1

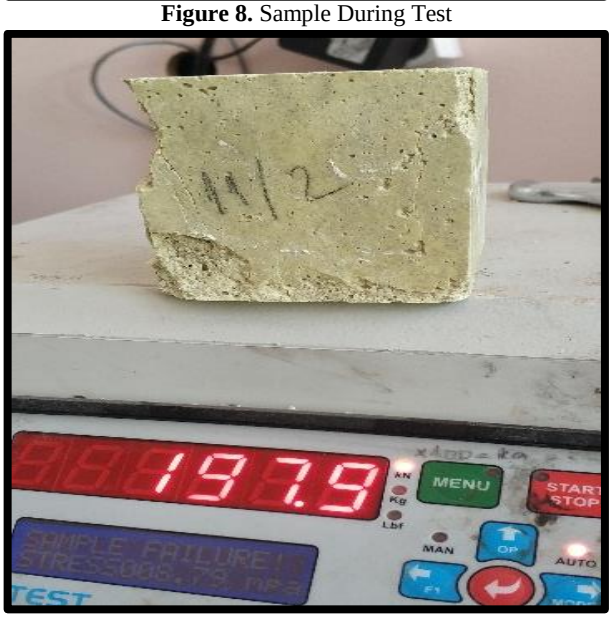


Figure 10. Compressive Strength in SC 2

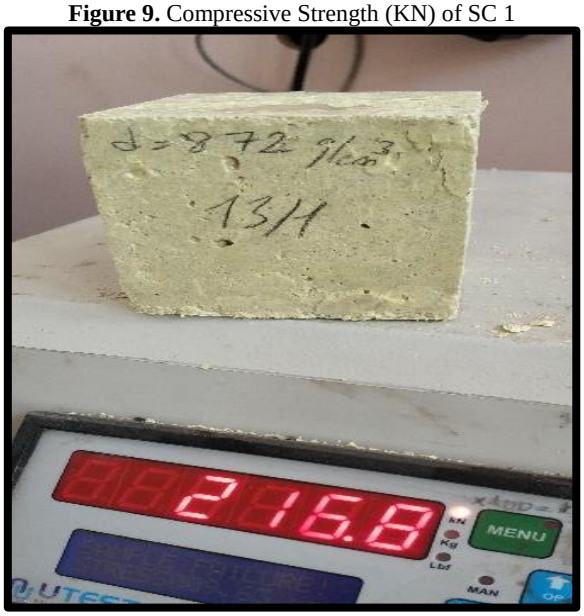


Figure 11. Compressive Strength in SC 3

This experiment has been done with the lowest compressive strength values of the sulphur/sand ratio in the literature, with a rate of 0.5, which is the lowest. Higher results were obtained if the sulphur content was reduced by 0,3. Also, sulphur-modifying additives such as DCPD, styrene are not used in this experiment. However, as can be seen from the results, the compressive strengths exceeded 35 MPa. Today, defensive buildings have used traditional PCC, which gives compressive strength of 30 MPa. From this point of view, it is obvious that SC will be more advantageous than PCC.

6. SULPHUR CONCRETE IN DEFENSE AREA

Explosion; It come into existence as a result of chemical reactions of solid or liquid explosives. It is suddenly spread compressed gas in large scale, on high speed, high density and high temperature [22]. Explosions can be examined in 3 different groups that is physical, chemical and nuclear. Physical explosion is form when a gas with compressed energy is suddenly released. Chemical explosions are generally caused by the sudden oxidation of C and H elements. Nuclear explosion is form when the protons and neutrons of different atomic nuclei are activated, and the energy occurred as a result of formation in the nucleus released [23].

When the explosions explode, high energy is released, and shock waves form out of the center. Shock waves reach high pressure and speed in milliseconds. As the waves that continue to move away from the center, the surface area expands and the pressure decreases. This movement continues until it is balanced with the air surrounding and shock wave. This phase is called

positive phase. In places where the positive phase passes, the ambient pressure drops below normal pressure and vacuum effect occurs. This phase is called negative phase. Positive pressure is quite high and short-term than negative pressure. The negative phase is longer but less effective. In the studies show that, the negative phase is neglected because of the most damage is in the positive phase [23]. As seen in Figure 12, shock waves decrease with positive and negative phase until they are balanced.

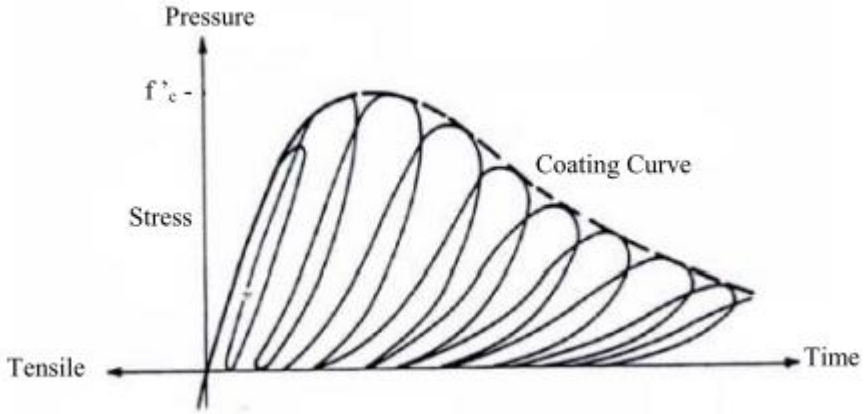


Figure 12. Positive and negative phase decrease till balanced [22]

Parameters affecting of the explosion are the distance between the structure where the explosion is targeted and the explosion center, Location of explosion, Type and weight of the explosive, Architecture of the building and Structure bearing system listed in [23]. Koccaz et al. (2008), in their study show that, the type of the explosion spread, its behavior to structure, structural and architectural approaches to the structural elements, environment and people. Especially they made several suggestions regarding to strengthening of existing buildings. They advocated the construction of high-strength official and commercial center buildings against terrorist attacks at all costs [24]. Yusof et al. (2014)



Figure 13. Helipad Samples [27]

examined the behavior of the reinforced concrete retaining wall exposed to blasting load at different weights and 2 m distance in their study. They adjusted the wall thickness as 25 cm and the height as 450 cm. They performed analyzes in Autodyn program with TNT explosive type weighing 5, 50, 400 and 1500 kg respectively. It was observed that the explosives at 50 kg and below did not cause destruction of the wall, but 400 kg and above caused damage or even complete destruction in the building. It has been concluded that building retaining walls around the building does not completely protect the structure, but severe damage and injuries and deaths can be prevented of the burst load



Figure 14. Protection walls [28]

has reached the conclusion that it causes increased cracks in the concrete as a function of corrosion. As a result of the study carried out, it was found that, together with the increased explosion distance, it is not important in the change of cracks in the corroded concrete and the contribution of corrosion to the percentage of hysterical energy does not play a very important role [26]

With the new technologies in developing aircraft are taking major tasks in the field. For these vehicles to land safely and quickly, a runway is required. Because of SC can be getting set in a very short time, it is advantageous compared to reinforced concrete.

Strengthening of structural elements such as bearing elements and walls, which have an impact on minimizing the impact of blasting and attack activities, is very effective in reducing loss of life and material damage as much as possible. In this sense, the mechanical and physical values show the importance of the SC, which is higher than the traditional PCC. So, preferred to SC will

reduce loss of life and property. Shelters used in military operations can be installed quickly with SC. Due to the high strength of SC, it can play an active role in saving military personnel's lives against attacks. In addition, it can repair the damage it has received and obtain a value close to its strength of before attack.

Sulphur concrete can be preferred for use in the load bearing system of the intelligence center, the building of public institutions and organizations, military buildings and base centers to be used in operations, such as column, beam, and floor. Because of the high compressive strength, shear and bending strengths are high, the durability and lifetime of the building will increase. SC can also be preferred in the protection walls around the police stations and military stations. SC will absorb the effect of the explosion shockwave from outside. It can be used in infrastructure and sewage works as its resistance to high acidic environments is very high. Since it has a very high resistance to acidic environments, it can be used in infrastructure and sewage works.

7. CONCLUSION

In this article, SC is introduced and given some information about process of production. Sulphur concrete compared with PCC. In defense structures, it was mentioned why SC should be used in target structures against attacks. In experiments, it was observed in the studies and pressure test that SC was superior to PCC.

- Sulphur concrete has superior strength values, physical and mechanical values compared to PCC. Despite the scientists' work on SC development, it is not as widespread as PCC. Known features have remarked the attention of scientists. It is hoped that it will be researched more widely in the globalizing world and applied in the field.
- Sulphur concrete, whose compressive, bending and tensile values are at least twice as compared to PCC, has high resistance against aggressive environments, corrosion resistance and fire resistance. Sulphur, which has gained its binding properties by reaching high temperatures, has combined with aggregate to reach high compressive strength values and is intended to be used as a bearing element with high strength. In addition, it doesn't need to water.

It is thought that there is no need to use the amount of potable water consumed worldwide. Sulphur concrete, which can use in police stations, important buildings, military operations in a short time like 24 hours; makes us advantageous to use in areas that need to be defended with its features such as mobilization, long lifetime, and higher resistance against attacks and easy to recycle.

DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

İlker Bekir TOPÇU: Performed the experiments and analyse the results.

Muhammed Emre DANIŞ: Performed the experiments and analyse the results.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

REFERENCES

[1] Topçu, İ.B., Işıkdağ, B., "An Overview on the Properties of Sulphurous Concrete". ***3. Intern. Conf. on Civil and Environmental Engineering*** (**ICOCEE**), Çeşme İzmir, 449-452, (2018).

[2] Tunç, G, Demirtürk, D, "Waterless concrete and Reality of Turkey", ***Ready Mixed Concrete Journal***, 69-82, (2016).

[3] Mohammed, S, Poornima, V., Strength and Durability study of Sulphur Concrete with Replaced fine aggregate, ***Materials Today*****(IConAMMA)**, 23888–23897, (2018).

[4] McBee, C.W., Weber, H.H., "Sulphur Polymer Cement Concrete", ***Proceedings of the Twelfth Annual Department of Energy Low-Level Waste Management Conference(CONF-9008),*** Idaho National Engineering Laboratory, Idaho Falls, Idaho, 120-141, (1990).

[5] Mohamed, A.M., Gamal, M.M., "Sulphur Concrete for the Construction Industry", Sulphur Concrete for the Construction Industry, ***J. Ross Publishing***, (2010).

[6] Yue, L, Caiyun, J., Yunping, X., "The Properties of Sulphur Concrete", ***Journal of Wuhan University of Technology,*** 21:129-133**,** (2006).

[7] Toutanji, H., Tucker. D., Ethridge. E., New Fiber Reinforced Waterless Concrete for Extraterrestrial Structural Applications, ***12. International Conference on Composites/Nano Engineering***, Tenerife, Canary Islands; Spain (2005).

[8] Mattus, C.H., Mattus, A.J., "Evaluation of Sulphur polymer cement as a waste form for the immobilization of low-level radioactive or mixed waste", ***Chemical Technology Division,*** (1994).

[9] Darnell, G.R., Aldrich, W.C., Logan, J.A**.,** **"**Full-scale Tests of Sulphur Polymer Cement and Non-Radioactive Waste in Heated and Unheated Prototypical Containers", ***Idaho National Engineering Laboratory EG&G***, Idaho Falls, Idaho, (1992).

[10] Bretz, T. E., "Properties of Sulphur Concrete", ***Air Force Institute of Technology(ATC),*** 79, (1979).

[11] Loov, R.E., Vroom, A.H., Ward, M.A. "Sulphur Concrete - A New Construction Material", ***Journal of the Prestressed Concrete Institute,*** 86-95, (1974).

[12] Gracia, V., Vàzquez, E., Carmona S., "Utilization of by-produced Sulphur for the manufacture of unmodified Sulphur concrete". ***Int. RILEM Conference on the Use of Recycled Materials in Building and Structures***, 054-1063, (2004).

[13] Anyszka, R., Bieliński, D.M., Siciński M., Imiela M., Szajerski P., Pawlica J., Walendziak R., "Sulphurous Concrete–Promising Material for Space-Structures Building", ***Nasa NTRS,*** (2016).

[14] Vlahović, M.M., Martinovic, S., Tatjana, T.D, Husovic, V., "Durability of Sulphurous concrete in various aggressive environments", ***Construction and Building Materials,*** 25(10):3926-3934, (2011) .

[15] Omar, H.A., "Production of Lunar Concrete Using Molten Sulphurous", ***Final Research Report for JoVe NASA Grant***, 278, (1993).

[16] Rizwan, N., Jesuraj, D.M., Vipin, V.P., Anbuvel, V.V., Prabhakaran, S., "Feasibility and application of sulphur in concrete structures*",* ***International J. of Engineering Research and Technology***, 3: 2278-2281, (2014).

[17] Russ, Q., "Global Fertilizer Outlook – 4*",* ***Global Sulfur Market Well Balanced,*** (2019).

[18] "Sulfur Statistics and Information", ***Geological Survey, Mineral Commodity Summaries,*** National Minerals Information Center, (2020).

[19] Toutanji, H.A., Evans, S., Grugel, R.N., "Performance of Waterless Concrete", ***13th International Congress on Polymers in Concrete***, Structural Faults and Repair, Edinburgh, Scotland; United Kingdom (2010).

[20] Dehestani, M., Teimortashlu, E., Molaei, M., Ghomian, M., Firoozi, S., Aghili, S., "Experimental data on compressive strength and durability of sulphurous concrete modified by styrene and bitumen", ***Data in Brief***, 13:137-144. (2017).

[21] Yue, L., Caiyun, J., Yunping, X., "The Properties of Sulphur Rubber Concrete**",** ***Journal of Wuhan University of Technology - Mater. Sci. Ed***., 21:129-133 (2006).

[22] Mendis, P., Gupta, A., Ramsay, J., "Blast loading and blast effects on structures**",** ***E-journal of Science and Engineering***, 76-91, (2007).

[23] Önalan, F., "Investigation of Dynamic Behaviors of Reinforced Concrete Buildings Exposed by Explosion Load by Numerical Methods", ***Master's Thesis***, Karadeniz Technical University, Institute of Science, (2019).

[24] Koccaz, Z., Sütçü, F., Torunbalcı, N., "Architectural and Structural Design for Blast Resistant Buildings", ***The 14th World Conference on Earthquake Engineering***, China. (2008).

[25] Yusof, M.A., Rosdi, R.N., Nor, N.M., Ismail, A., Yahya, M.A., Peng, N.C., "Simulation of Reinforced Concrete Blast Wall Subjected to Air Blast Loading", ***Journal of Asian Scientific Research,*** 4:522-533, (2014).

[26] Yalçıner, H., "Structural Response to Blast Loading: The Effects of Corrosion on Reinforced Concrete Structures", ***Hindawi Publishing Corporation Shock and Vibration,*** (2014).

[27] Building Better Healthcare-First flight lands at life-saving new helipad, ***https://www.buildingbetterhealthcare.com/news/article_page/First_flight_lands_at_lifesaving_new_helipad/143942*** (2018). McGrath, C., ***Getty Images,*** iptc.org/ (2017).