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Evaluation of concrete pavers affected by Manavgat wildfires

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ABSTRACT

In recent years, wildfires have devastated many regions in many countries, especially in Turkey. In addition to the loss of human lives, villages and business facilities have been destroyed, livestock and domestic animals have perished, and forests and natural assets have burned. The wildfires have affected tourism and agriculture, which account for a large part of economic activity and employment in many of the affected areas. There was also significant destruction of local infrastructure, including roads, power, telecommunications, and community facilities. Some of the paving stones on the roads affected by the Manavgat wildfires were also burnt. The replacement of concrete paving stones used in pavements has both economic and environmental negative impacts. The reuse of these stones is important for the regional economy.

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1. INTRODUCTION

Global warming is the most serious problem in history which humankind faceoff. Climate change is affecting meteorological balance of weather and threatening food production, water and energy security and causing variability in temperature, precipitation and evaporation patterns. Climate change increases forest fire risk depending on high air temperature and low humidity weather especially in subtropical ecoregions such as Mediterranean climate zones (i.e, Turkey, Greece, Italy, Spain). The expected negative impacts of climate change in these countries are heat waves, increased forest fires and floods, etc. Every year, hundreds of thousands of hectares burn in wild forest fires in European Mediterranean countries. According to Intergovernmental Panel on Climate Change (IPCC) assessment reports and other national and international scientific studies, the impact of climate change in the Mediterranean region, which includes Turkey, will reach a level that would threaten the countries' sustainable development and national security. In light of this knowledge, Turkey is inevitably affected by global warming. The Table 1 shows the city areas in the Mediterranean that are burning [1–3].

Climate change has a number of negative effects that raise the risk of fire in both direct and indirect ways. For example, climate change leads to warmer than average temperatures, which increases evaporation and leads to a moisture deficit at the surface. Low soil moisture increases the amount of dry bushfire fuel available (defined as dead or living vegetation that affects fire intensity and rate). Extreme heat and drought are one of the main triggers of widespread bushfires. Anthropogenic climate change has increased the likelihood of bushfires by at least 30% compared to pre-industrial times, mainly due to extreme heat. Climate change also indirectly affects the bushfire season by influencing large-scale and regional factors [4].

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Table 1. Burned city areas by county, 2002–2003 [3]

	Area (km²)		Area (km²)
Turkey	264.7	Portugal	10.8
Syria	232.5	Serbia	10.5
Algeria	106.5	Lebanon	9.1
Morocco	70.5	Croatia	5.1
Bulgaria	63.1	Macedonia	4.6
Cyprus	57.7	Kosovo	1.0
Italy	54.6	Montenegro	0.7
Libya	30.5	Albania	0.5
Greece	30.4	Bosnia-Herzegovina	0.3
Israel	24.7	Malta	0.2
Tunisia	23.5	Other micro-statesa	0.2
Egypt	18.2	Jordan	0.0
France	15.0	Palestine	0.0
Spain	13.2	Slovenia	0.0

a: Andorra, Gibraltar, Monaco, San Marino, Vatican.

Climate change is extending the fire season in large areas worldwide by prolonging the hot weather of summer. Between 1979 and 2013, an 18.7% increase in the seasonal extent of fires was observed. The global burnable area has doubled, and the frequency of long fire season has increased by 53% of the global vegetated land area [4].

Wildfires are uncontrolled and nonprescribed burns or fires of plants in a natural environment such as forest, grassland, shrubland, or tundra that consume natural fuels and spread due to environmental conditions (e.g., wind, topography). The zone where these fires occur at the edge of the forest and where urban development has occurred is usually referred to as the interface zone. Wildfires in a forested area are referred to as forest fires and can cause great damage if the interface zone spreads to properties or land of economic value and to areas populated by people. In a report published in 2015, Forest fires were the natural disasters that most affected the Canadian economy. The damage of the forest fires to the Canadian economy approached 6.5 billion dollars. Furthermore, in 2007 the worst wildfires in recent Greek history - affecting 270,000 hectares of land - caused estimated total damage of close to 3 billion euros (1.3 percent of nominal Gross Domestic Product) [5–7].

Increasing urbanization and the accompanying urban sprawl have been cited as a major cause of landscape change in many countries around the world. Recent decades show a steady shift of urban populations to the suburbs and the expansion of cities towards forested areas. This change has led to an increase in urban fringe areas that are either in contact with or mixed with forest and rural areas. Especially in the coastal and tourist areas of the European Mediterranean countries, many small towns and resorts have been built in or around natural and forest areas, mainly for their recreational attractions and scenic beauty [8].

Table 2. Compressive strengths of concrete paving stones

Paving stone type	Strength (MPa)	Strength (MPa)	Strength (MPa)
Unburned	36.24	36.01	35.87
Half-burned	48.72	49.67	50.14
Completely burned	50.61	50.97	50.91

The presence of residential developments in contact with forested areas increases the vulnerability of these areas to fire damage. Uncontrolled wildfires can have disastrous consequences for properties and land use, and even threaten human life. The contact zone between human infrastructure and wildland vegetation is referred to as the wildland-urban interface (WUI). WUI areas are increasing worldwide as the mixing of urban settlements and forested areas increases due to (i) urban areas colonizing forested areas and (ii) forested areas colonizing rural areas due to rural migration. The WUI is central to the development of wildfire management strategies in the United States, Canada, Australia, and Europe, and extensive research has been conducted on this topic in recent decades [9].

The contact zone between human infrastructure and wild vegetation, the so-called wildland-urban interface (WUI), has increased worldwide in recent decades and is directly related to wildfire risk. Human activities increase the likelihood of wildfires, which can have catastrophic consequences for property and land use and pose a serious threat to human life. A study shows that Galicia has the highest rate of forest fires in Spain. The results show that more than half of the built-up area is in the WUI area and that fires are about twice as likely to break out in WUI areas than in non-WUI areas. Most wildfires occur in non-forested areas of the WUI, while the lowest fire density is associated with isolated buildings. Areas with very dense clusters of buildings surrounded by forested areas, referred to here as near-urban areas, have the highest fire density. This trend highlights the vulnerability of the interface to fire in this region [9].

Natural disasters are a persistent danger to all critical infrastructures. Severe storms, hurricanes, earthquakes, tornadoes, volcanoes, drought, floods, landslides, tsunamis, and wildfires can all cause substantial property and economic damage, as well as obstruct access to key resources like power, water, transportation, and food. Critical infrastructure and services will be damaged or destroyed if they come into contact with a severe wildfire. Transportation networks are disrupted by road closures, with roads directly affected by the flames and heat remaining closed until associated infrastructure can be replaced and trees assessed. Restoring the road network is an important step for many affected communities to begin the economic recovery process, particularly with regard to the tourism industry [10, 11].

Figure 1. Manavgat-Oymapınar Neighborhood.

The aim of this study is to help reduce the economic impacts of forest fires on infrastructure through the reuse of concrete pavers. In a previous study on concrete, it was observed that the compressive strengths decreased at certain rates as the temperature increased, but it was observed that the compressive strengths at 250 °C were higher than 100 °C, and even close to the compressive strengths at room temperature [12]. When the studies in the literature about concrete pavers are examined, it is seen that the roads affected by the fire are handled with an only general point of view. Renewal of paving stones creates high costs for municipalities. In this study, concrete paving stone samples affected by forest fires were taken in Manavgat province. Concrete paving stones whose compressive strengths were determined were compared and suggestions were made.

2. MATERIALS AND METHODS

Paving stones are natural or artificial floor covering materials, the use of which is increasing day by day for transportation and landscaping purposes, especially on roads where there is no heavy vehicle traffic with the development of urbanization. It is especially seen on roads and pavements, in parking lots, in commercial centers, around factories and similar places that are exposed to intense work. These stones are widely used as they can be produced in various shapes, sizes and colours [13].

Figure 2. Pavement in the fire zone.

In order to obtain the materials in this research, the Manavgat fire area was investigated. The area shown in Figure 1 is the Oymapınar neighborhood. It is clearly seen that this region, where forest and habitats are very close to each other, is WUI.

The field marked red in Figure 1 is the area with the most affected pavement from the fire. It was decided to take the samples from this area. When the paving stones were examined, it was seen that there were completely burned, half-burned and unburned concrete paving stones in the same area. It is planned to take three samples from all three combustion conditions to compare them with each other in terms of the mean value of compressive strength. The pavement affected by the fire is shown in Figure 2.

Figure 3. Concrete paving stones in different conditions.

As a result of the strength tests to be made, it will be tried to determine whether the burned concrete paving stones can be reused or not. Efforts will be made to obtain the most suitable solution both economically and environmentally.

A sample of the completely burned, half-burned and unburned concrete paving stones taken from the Manavgat wildfire area are shown in the Figure 3.

The paving stones were tested in the pressure machine in the Civil Engineering Laboratory of Alanya Alaaddin Keykubat University. The experimental setup is shown in the Figure 4.

3. RESULTS AND DISCUSSION

All experiments were successfully completed, and compressive strengths were obtained in accordance with the standard of BS6717 [14, 15]. The compressive strengths measured as a result of the tests are shown in the Table 2. According to the results obtained, the mean value of compressive strengths of unburned, half-burned, and completely burned stones were 36.04 MPa, 49.51 MPa, and 50.83 MPa, respectively.

It is seen that the compressive strength increases as the amount of combustion increases. Normally, the strength of concrete is expected to decrease when exposed to very high temperatures. The reason for the increase in the strength of concrete paving stones may be that the fire went out before it reached a very high temperature on the pavements in the region. A well-known basic fact in thermodynamics, gases have higher temperatures rise up depending on their low density. Increasing in the strengths of the concrete pavers in the burned regions like heat-treated concrete can be explained using this fundamental thermodynamic law. It is also an indication that the fire does not burn the entire pavement and does not spread to the driveway. These results are also consistent with the study [12] in the literature that concretes treated at 250 °C have higher strength than concretes at room temperature.

Figure 4. Compression testing machine.

The results obtained prevent the replacement of paving stones in the region due to strength. However, this result also needs to be evaluated from an architectural point of view. It is clear that the half-burned and completely burned concrete pavers are dirty and have colour mismatch. Therefore, replacement or staining of the stones may be considered.

The cost of only 1 m^2 of concrete paving stone is known as 30 TL. When expenses such as transportation, labour and sand are added, the total cost reaches 60 TL/m^2. The cost of concrete paint per square meter is 20 TL. The cost of paintwork is 10 TL/m^2. Since it is easy to apply to the concrete surface, it can also be done with the municipality's own workers. In this way, it is possible to get no labour cost. In order to better understand the cost difference between renovation and painting, the renovation cost of 1 km long and 1.5 meters wide burnt pavement, including all labour and other expenses, will be approximately 100000 TL. The maximum cost that will occur as a result of painting the same pavement will be 50000 TL. As clearly seen, the cost of renovation is much higher than the cost of painting. Moreover, considering that the existing paving stones must be removed and moved for the renovation process, the cost will be much higher. In addition, the painting process will take much less time than the renovation process. Besides, it is clear that painting of paving stones is a more environmentally friendly solution.

4. CONCLUSIONS AND RECOMMENDATIONS

Wildfires have ravaged several parts of the world in recent years, particularly Turkey. Villages and business buildings have been destroyed, cattle and domestic animals have died, and forests and natural assets have been destroyed in addition to human lives lost. Tourism and agriculture, which make for a significant portion of economic activity and jobs in many of the affected areas, have been negatively impacted by the wildfires. Roads, power, telecommunications, and community amenities were all severely damaged. The Manavgat wildfires also burned several paving stones on the highways. Pavement replacement with concrete paving stones has both financial and environmental costs. The economic impact of reusing these stones is significant.

In previous studies, problems such as opening the roads affected by the fire and protecting the existing buildings were mentioned, but no study was conducted on the renewal of paving stones. The goal of this research is to reuse concrete pavers to assist lessen the economic impact of forest fires on infrastructure. Municipalities face substantial costs when pavement stones need to be replaced. Concrete paving stone samples impacted by forest fires were collected in Manavgat province for this research. The compressive strengths of concrete paving stones were compared, and recommendations were made.

Before changing the paving stones at the the fire zones, strength tests should be done on the sample and no change should be made unless a negative situation is encountered. In our study, the strength of the concrete increased with burning. Using burnt paving stones with increased strength will be much more convenient than the cost of replacement.

In addition, the cost of painting the fire-affected concrete paving stones is half of the replacement cost when labour and other costs are taken into account. Considering the use of cement in the concrete stones to be used in the renovation process, it is clear that paint will be the most economical and environmentally friendly solution.

DATA AVAILABILITY STATEMENT

The author confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declare that they have no conflict of interest.

FINANCIAL DISCLOSURE

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