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TECHNICAL ARTICLE

Investigating the Important Factors of Use and Replacement of Thirsty Concrete Materials in Urban Development

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Sustainable has recently become the favorite subject of many disciplines due to sustainable development. Nowadays, due to the environmental problems of the construction industry, the development of materials, products, and methods of construction, sustainable architecture leads to higher efficiency, better economic cost, and environmental sustainability.

It can be supposed sustainable development means preserving nature also fulfil the human needs through modern technologies. One of the goals of sustainable development is to construct with less energy consumption and a long life that in this part, materials play an important role in content production. the most important role that materials and structures can play is to help people survive natural disasters and respect nature by using it properly. For example, in some areas, floods and rainfalls cause many Life and financial damages, and on the other hand, some countries by consecutive droughts try to manage drinking water. Meanwhile, it is claimed that with the help of smart materials, these wastes can be prevented and using optimization of environment and renewable energy. Creating this harmony between man and nature has given rise to a new challenge in many fields.

For this reason, this paper seeks to address the challenge of using thirsty concrete, a type of smart material and sustainable architectural innovation, to coordinate between old, present and future structures. Therefore, by using a qualitative method, these materials will be studied and some samples would be used, followed by a quantitative method of analysis of the usage of these materials in Barış Park in Kyrenia which is the intersection of historical place and contemporary one.

Keywords: Sustainability; smart material; Thirsty Concrete; north Cyprus; Kyrenia

1. Introduction

Porous, permeable, no-fines concrete is some of the names of the thirsty concrete. The permeable pavement is a kind of concrete with lots of holes and empty spaces inside and it should be used in the flat works that let the precipitations and other surface waters pass (Zhong & Wille 2016).

The 20 to 30 percent empty spaces in this kind of concrete has made it different from the kinds of concrete. In addition, this criterion has made it to have the ability to let 880 gallons per minute to pass up to 36000 millimeters of water per hour (Tarmac.com 2019).

By having this information using this material over the common and traditional kind of concrete and material, the accidents related to the running water can be prevented, also by using the pervious concrete the ground water and fresh storage can be enriched.

A great kind of storm can be handled every century if the traditional concrete has the potential to penetrate the water to the ground with the criteria of letting 300 mm of water per hour to the ground due to the information from Tarmac.com. Due to the existing information, hard materials have caused problems for nature, and using thirsty concrete has shown that water sources could be preserved much better compare to materials that are used normally. Also in the rainy areas, the thirsty concrete helps the water cycle and preventing the surface running waters to cause damage.

Also by applying a decent drainage system the drained surface water that has high speed and causes financial stress, can be a long lasting solution. So that in this study it is tried to find solutions for the old, recent and future buildings in the expansion of the urban designs by the help of the thirsty concrete.

2. General Problem

With the advent of urbanization and the need for massive construction, the use of building materials and urban development has expanded, which has reduced the natural soil in cities and covered the ground with impermeable

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materials. Therefore, over the years, water has become a major crisis around the world these days. Underground cavities have been drained due to low water permeability, and sometimes because of the im-permeability of used materials, rain sometimes causes flood. Additionally, in some areas, floods and rainfalls cause many Life and financial damages, and on the other hand, some countries by consecutive droughts have a problem with a Water supply crisis, which are the main reason disruption of the natural cycle and healthy communication between human and environment.

In the meantime, innovations have created materials that, in addition to meet human needs, help to respect the environment and the natural water cycle. Meanwhile, it is claimed that with the help of some smart materials that they called Thirsty Concrete or permeable concrete, these wastes can be prevented and using optimization of environment and renewable energy.

2.1. Research Problem

The Problems with the water cycle and the loss of life and finances are evident due to lack of management of structures and many people are trying to protect humans from natural disasters and respect for the environment but lack of knowledge of technology uses, and materials for proper infrastructure cause many communities still facing financial and health problems.

The problem that this article seeks to find is What is the impact of thirsty concrete on reducing the damages in rainy areas and how it can be helpful in collecting rain water in the north of Cyprus, and also it is responsive the challenges of creating harmony in structures with different times (past, present, future) in the path of sustainable architecture Organisation of the paper.

2.2. Research Question

Nowadays, the issue of environmental protection and energy conservation for the next generations is all-pervasive, and most countries are trying to reduce energy consumption by revising construction policies. But there are very few countries that are thinking about restoring the environment to health through water management. So this article comes with some questions that are:

How can smart materials like thirsty concrete help the natural water cycle?

2.3. Research Aim and Objective

One of the most urgent issues that every society thinks about is the provision of drinking water. In addition to hot and dry areas in some fertile areas, it is very difficult to get fresh water supply, such that floods and heavy rains in these areas, lead to deaths and financial losses. In the event that organizes and used the potential of precipitation can improve the water system. Therefore, this article first attempts to address the challenges of using thirsty concrete to coordinate the structure of the past, present, and future, then it is trying by examining the using thirsty concrete in Barış park which is located in North Cyprus help to study on natural water cycle and the benefits of this materials for improving people lives.

2.4. Methodology

In this research, both qualitative and quantitative methodology are collaborating. At the beginning by Grounded theory will try to collect some information about thirsty concrete and describe the characteristics, then Correlational which is mostly observational in terms of data collection try to analyze the case study. Data are collected on each item and then relationships are examined. Since the selected park is historical and cannot be altered much and it has been suggested to use thirsty concrete materials to improve the quality this park, it will try to use the Correlational method and assesses the impact of thirsty concrete on improving the freshwater storage system in the park.

3. Literature Review

Nowadays architects and engineers are encouraged to use green and eco-friendly materials for construction, due to the energy crisis and the demand for green and clean energy sources. Accordingly, the conventional materials are examined from the life cycle, thermodynamic, carbon dioxide release, and energy usage point of view and also some other kinds of criteria (Vats & Vaish 2019). In civil engineering, architecture and the construction industry the material science innovations have always played an important role. All these innovations not only decrease the energy consumption and improve the life expansion of the building and construction, but also improve the Indore life quality, and sustainability of the building environment (Shi & Wang 2019).

The idea of the urban environment sustainability has brought up the scenario of the problems related to social and environmental with the help of processes of fast-growing global urbanization. It should be mentioned that urban sustainability is used in many multidisciplinary approaches (Kremer, Haase & Haase 2019). Assess various concepts of land usage in a place where is growing and expanding rapidly and illustrates the trade-off among the urbanization and production of agricultural productions in sustainable planning (Moein et al. 2018). Lee and Lim (2018) determine the tools that are affected by the local government policy choices to improve the ideas and concepts of the cities, which are compact.

Due to the rapid cities' urbanization, the majority of the surfaces are covered with an impenetrable material such as concrete, and this issue is affecting the surface water table. So that for this problem the pervious concrete pavements and pedestrians can have positive impacts on the groundwater tables (Maguesvari & Narasimha 2013). The pervious concrete (thirsty concrete) is used for covering the pavements has revealed its potential to control the free surface water (Brattebo and Booth 2003; EPA 2000). This kind of concrete is a mixture of cement, granular collection, some percentage of fine combined materials and water (Maguesvari & Narasimha 2013).

Unfortunately, the huge amount of rain in the cities cause damage and erosion to the surface water forms. This material is a decent solution for the trees and plants, which are planted in the paved lands, due to the lack of water penetration to the soil when the impenetrable

concrete is used for the pavements. By using the previous kind of concrete, the water and air can penetrate easily to the soil and the routes of the trees are able to function in a decent situation, while the pavement surface can be used in a proper manner (Lee et al. 2013).

The thirsty concrete was first used in 1852as a material but it patented in 1980, and although it is not a new material, its usage renewed attention (Grubeša et al. 2018). This kind of concrete is also known as the porous or permeable concrete, which is classified by a large number of connected holes, that the amount of them are between 15–30% with sizes between 2 to 8millimeter, and with the water penetrability about 2–6 mm/s (Zhong & Wille 2016). The thirsty concrete, is consists of cement, water, and granular aggregate, which can be consists of some amount of fine aggregate or without it. due to the necessity of the pore connectivity for the functioning of this kind of concrete, the compassion for the pervious concrete is decreased due to the possibility of the paste of cement creation at the lowest level that can end up in the functionality or decreased proper strength of the concrete. The asphalt and pervious concrete installation are very much like each other, but the previous concrete should be cured until reaching the desired power and cannot be used immediately like asphalt (Grubeša et al. 2018).

It can be considered as one of the best environmentally friendly construction materials that have been certified by the environmental protection agency (EPA) for storm water as the best practice management (BMP) (Maguesvari, & Narasimha 2013).

The urban environment can be improved by using the thirsty concrete due to its beneficial characters in the pavements according to the U.S. EPA claims, that some of them can be mentioned as follows:

1. Removing the water pollutants and helping the water treatment.
2. Decreasing the need for the waysides as well as rain sewers.
3. Increase in the slip resistance and improve the road safeties.
4. Helping to refill the local aquifers.

The thirsty concrete pavements are a great tool to fulfill the environmental issues and reach the green environment desires, due to its potential to letting the storm water to pass and letting it to enter the ground and refill the water sources. It can help the storm water from running off and fulfill the U.S. EPA storm water regulation (Lee et al. 2013). Due to the fulfilment, the standards, and storm water regulations of the Federal Water Pollution Control Act and the Environmental Protection Agency (EPA) the interests of the thirsty concrete are renewed (Zhong & Wille 2016). The thirsty concrete has a decent drainage quality, and in the horizontal surfaces if it is constructed properly has the potential to improve the surrounding soil and groundwater quality also prevents the water from pulling away unlike other kinds of concrete pavements. It has high noise absorption property, due to its sponginess behavior. The other decent property of the thirsty concrete makes it prevents the creation of the heat islands that can be referred to as the urban temperature development within an urban area compared to the rural and suburban areas. This character has the benefit of reducing energy consumption for cooling the buildings (Grubeša et al. 2018).

Ming-Gin Lee had discovered the thirsty concrete ability for purifying and reducing the water pollution from sulphuric acid, motor oil, and artificial seawater. The diluted sulphuric acid with the PH 2.0 after flowing through the pervious concrete increased to an almost neutral PH of 7.0 (Bhuinyan et al. 2019). Unfortunately, thirsty concrete despite its environmental benefits and potentials has a weaker twisting and structural resistance capacity, due to its limited bonding between the cementitious integrity and aggregate materials. In the thirsty concrete, the cement paste is a thin layer that should bind the cores aggregates together, so that the compression resistance is not high. Generally, the ratio between water and cement in the concrete is an important factor for indicating the compression resistance (Maguesvari & Narasimha 2013).

The limitation of usage in the highway and other high traffic roads is the result of the low and poor mechanical properties due to the limited strength of the pervious concrete, which is between 2.8–28 MPa and flexural strengths ranging between1 MPa and 3.8 MPa (Grubeša et al. 2018). So that the thirsty concrete should be used only in the light traffic areas, such as the parking lots and the sidewalks. In addition, it should be considered the difference between the total from the effective sponginess of the pervious concrete to predict its compression strength. The effective porosity is used for predicting the hydraulic

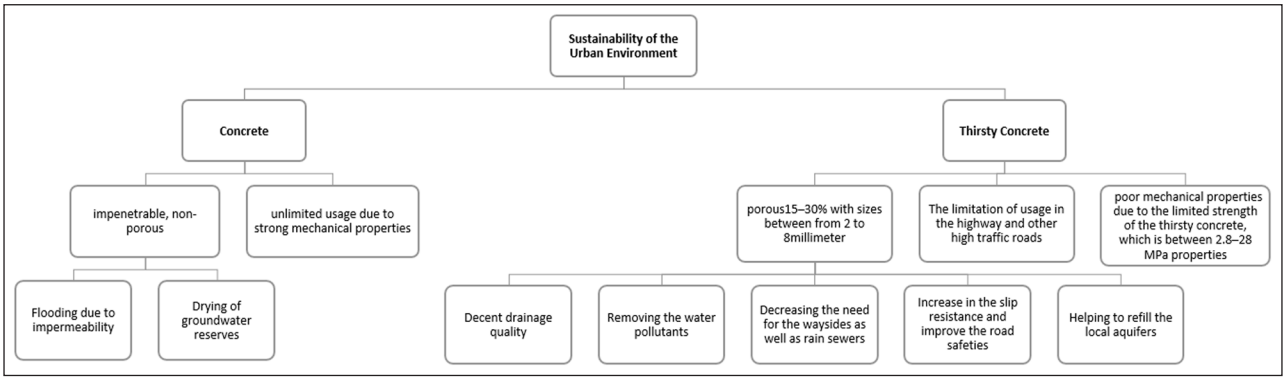

Figure 1: Summary of literature review.

conductivity, that is smaller than the total porosity (Zhong, & Wille 2016).

As Maguesvari has mentioned that decreasing in the CA size, concrete compressive strength increases. In addition, replacing the CA percentage with FA can lead to the increase in compressive strength, due to an increase in the contact area. Flexural and split tensile strength would be increased by means of the increase in the FA percentage. The increase in the FA percentage and a decrease in the size of the aggregates the permeability would be decreased. The common uses can be mentioned as: (Tarmac.com, 2019) the residential low volume roads, parking lots, Pavements, bike and pedestrian roads, patios, tennis courts, road shoulders, decks of swimming pools, alleyways and driveways, greenhouse floors, pavement edge drains and gutters, hard standing for sports facilities, underneath ground stabilization permeable blocks **Figure 1**.

3.1. Case Study, Example

In Taiwan a studied on the pervious concrete has been dine on a parking lot which was produced by of a 20 cm pervious concrete layer on the surface following a 10 cm gravel base layer, revealed that the compression strength of the surface has exceeds the common concrete expectations which is 17.15 MPa, also it should be mentioned that the field permeability is around 1000 mL which is equal 15 s. the permeability of the pervious concrete of the top layer is reported that it is in a good condition, also no crack on it has been reported (Lee et al. 2009). Also for the 2008 Beijing Olympic, a vast area of parking lots to sidewalks for the national stadium had been placed for 4 years, and no raveling or excessive cracking has been reported (ACI 2002).

4. Case study, Kyrenia, Bariş Park

Kyrenia, which is located in the North Cyprus **Figure 2**, is well known for its castle and port. Lusignins ruled the city after the ninth century, and due to its fortress, the city became so famous and important. Venisians rebuilt the fortress of Kyrenia in the fifteenth century but in the 1571, Ottomans took the control of the city. Today the city with the population of 33,207 has become a cultural and touristic source for the Kyrenia where is under the control of the Turkish Cypriots (Şahin, 2011).

Kyrenia has a beautiful city park that is used by families with children, old and young people. according to the municipality of Kyrenia: Baris park by 11700 m^2 stablish in 1994_1998 it was developed in 2006_2010. This

Figure 2: Keyrenia in the North of Cyprus (En.wikipedia.org 2019).

Figure 3: Bariş Park, Kyrenia (Kyrenia Municipality 2019).

park using for festivals, ceremonies and because of some facilities as a small zoo and playgrounds that a variety of people use **Figure 3**.

Bariş Park is near the Girne's bus station and the also the place of the Wednesday market. In this park the pleasant sound of the duck pound fountain can be heard, also by strolling around the animals of the park zoo can be attractive for the visitors. In addition, children can have fun in the playground trampoline and carousel, furthermore the youngsters can gather around and enjoy them accompany, while the senior citizens have the possibility of playing backgammon and drinking coffee (Anas, D. and Nisar, Z. 2017).

5. Evaluation of Using Thirsty Concrete in Case Study

The urbanization of rural and slightly developed areas creates an increase for impermeable surfaces due to the construction of buildings and their supporting infrastructure. Increases in impermeable surfaces, with conventional drainage systems and curbs directly connected to surface drainage networks, will lead to high water flows, resulting in higher flash flood risks, overwhelming the existing infrastructure. the thirsty concrete as a Permeable surface management system can provide a way to regulate surface water by absorbing and reducing the flow of natural water.

The approach is typically comprising of three layers; permeable concrete as a surface layer, accompanied by a continuous soil with a permeable sub-base aggregate. This kind of concrete can charge surface water through the worn layer to the underlying soil (or drainage system) in order to act as a reservoir during heavy precipitation times. It has a high vacuum content between 20–35 percent, unlike traditional concrete. Permeable concrete The maximum flow rate is 30 percent porosity with a compressive and flexural strength of 10–20 N/mm^2 and 1.5–3.0 N/mm^2, respectively. The scale and layout of the surface depend on criteria, the site circumstances existing and performance standards (Tarmac.com, 2019).

Given that the selected park has a large audience for activities such as festivals, ceremonies, visiting the zoo and play area and the use of restaurants and cafes, the other side is made of thirsty concrete, has more porosity that causes to break it under the much pressure, using this material in whole park surface is impossible. According to observations made during the day, the park's low-traffic areas have been identified and preferred to use thirsty concrete with appropriate subsurface where approximately 40% of the park's environment can be covered by these smart materials.

According to the rainfall statistics obtained from the Meteorological Organization of Kyrenia, the rainfall was 546.2 mm last year (Kktcmeteor.org 2019), shown by the blue colour in **Figure 4**.

Figure 4: Analyses of Bariş Park (By author 2019).

Kyrenia is a rainy city that only three months are zero rainfall and the rainiest month of last year was February by 171.8 mm/m^2, total rainfall in this city was 509.3 mm/m^2. Considering the 40% of space used for thirsty concrete in the Barise Park 4.680 m^2 suggested for being covered. Since the company claims that porosity in these materials is between 20% and 35%, it was attempted to study in the park with two types of porosity, one with high porosity (35%) and one with porosity 20% as shown in the **Figure 5**.

As the diagram illustrates **Figure 6** for the two types porosity of thirsty concrete, it can get the result that the thirsty concrete percent porosity state passes all the available water from the precipitation, so there is no difference between 20% and 35% probable concrete for using in the park environment, but the important point is thirsty concrete does not have significant strength due to porosity, and one of the disadvantages of this material is that it starts to break if used in high-pressure paths, On the other hand, high porosity causes the surface of the concrete to get dirty and to clean it is another disadvantage of these materials. Therefore, based on the information obtained from the analysis, it can be suggested to use thirsty concrete with a 25% porosity in the park to maintain greater strength and durability in the environment.

Since it can be stored annually 24771.24 m^3 in 40% of the park, the required infrastructure needs to be optimized for greater efficiency. Multiple tanks at several points in the park should be considered to provide more strength for flooring with thirsty concrete and reduce the need for installations to access stored water. Therefore, reservoirs with a depth of 2.5 meters are considered to be installed below surface of the park. For this purpose, suggesting a reservoir within the zoo is intended for the service and maintenance of animals and another reservoir near the restaurants and cafes, and a larger reservoir is proposed at the lower end of the park, with less commuting. generally, suggested a place in the park, is provided as a pool with insulation in some areas to store fresh water to reach the park users and some of them without insulation are implemented to strengthen groundwater aquifers and to improve the water cycle and compensate for the damage to nature with modern inefficient construction **Figure 7**.

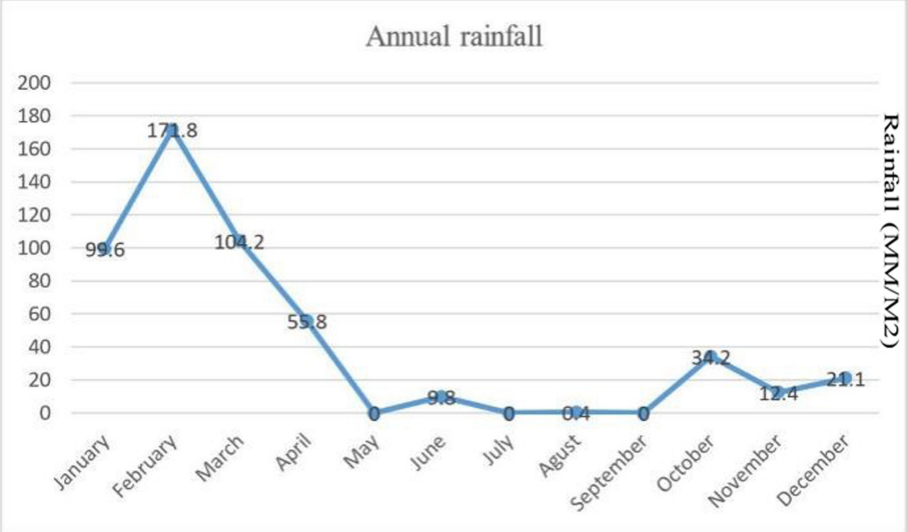

Figure 5: Annual Rainfall of Kyrenia (Kyrenia meteorology 2019).

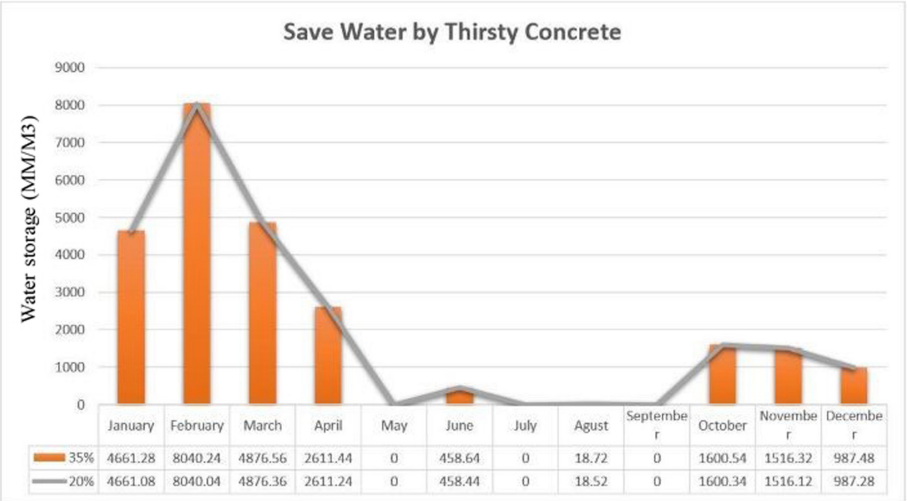

Figure 6: The Saving of Water Stored by Thirsty Concrete, mm/m^3 (By author 2019).

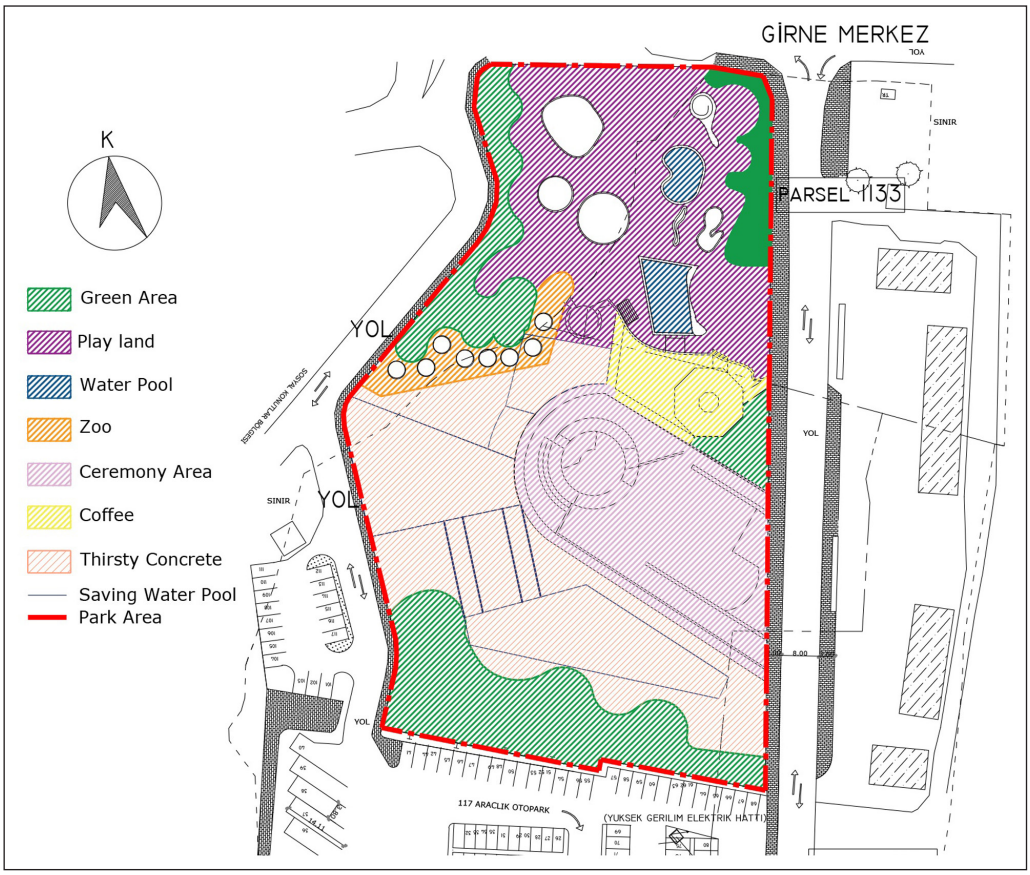

Figure 7: proposal coating with thirsty concrete (By author 2019).

6. Conclusion

Urban development has reduced soil in cities, and construction with modern materials has covered a large area of land with impermeable materials. Therefore, over the years, underground cavities have been drained due to low water permeability. Also sometimes due to the material's permeability, rain causes floods. So water has become a major crisis around the world these days. But in recent decades, the discovery of thirsty concrete has partially answered these problems. The Thirsty concrete, known as porous concrete, is capable of actively controlling and managing rainwater drainage and significantly reduces the risk of surface floods and with the ability to pass over water help recharge the aquifers. In this way, the amount of water absorption of the pervious concrete, its level of porosity does not have a significant effect on water absorption. so that thirsty concrete with 25% porosity can be used to eliminate the risk of fracture of these materials due to high empty spaces and it can be used in most of the spaces, including public or private spaces.

One of the concerns of architects and urban planners in using new materials is to create harmony between past, present, and future architecture and always tries to avoid contradictions between constructions, which is one of the advantages of using concrete for its modern appearance that it can be easily used along with other materials that had been used in the past, and this does not damage the past structures. So coordinating the structure of the past, present and future would not be a complicated task. And even with the future development, these materials can also be presented in block or desired forms to enhance this apparent harmony.

The important and financial challenging points are that the thirsty concrete substrate is more sensitive to modern materials before it is used, and if it is used to help water storage, also one of the strong points of the Thirsty concrete is that it plays the role of a basic water filter due to its potential to neutralize some of the substances such as the diluted sulphuric acid, as well by the water passing through the three sub-layers of the thirsty concrete foundations, significantly the need for water purification can be reduced.

So, if this type of concrete is used in most countries, in addition to preventing floods and damages, it can reduce many side costs and by having all the given information the use of thirsty concrete in many countries, due to its beneficial potentials seems not just helpful, but also might be necessary.

Competing Interests

The authors have no competing interests to declare.

References

American Concrete Institute (ACI). 2002. Guide for selecting proportions for no slump concrete. *ACI 211.3R-02, Farmington Hills, MI*, 1–26.

Anas, D and **Nisar, Z.** 2017. Flexible Architecture: Optimization of Technology and Creativity. *International Journal of Engineering and Technology*, 9(3S): 510–520. DOI: https://doi.org/10.21817/ijet/2017/v9i3/170903S078

Bhuinyan, SS, Luniya, S, Mane, M, Modi, S and **Tapkir, R.** 2019. A Review Paper on an Experimental Study on Strength and Properties of Thirsty Concrete.

En.wikipedia.org. 2019. Kyrenia. [online] Available at: https://en.wikipedia.org/wiki/Kyrenia#Gallery [Accessed 18 Nov. 2019].

Grubeša, IN, Barišić, I, Ducman, V and **Korat, L.** 2018. Draining capability of single-sized pervious concrete. *Construction and building materials*, 169: 252–260. DOI: https://doi.org/10.1016/j.conbuildmat.2018.03.037

Kktcmeteor.org. 2019. Kıbrıs İklimi – K.K.T.C. Meteoroloji Dairesi. [online] Available at: http://kktcmeteor.org/meteorolojikbilgi/kibris-iklimi [Accessed 18 Nov. 2019].

Kremer, P, Haase, A and **Haase, D.** 2019. The future of urban sustainability: Smart, efficient, green or just? Introduction to the special issue. *Sustainable Cities and Society*, 51: 101761. DOI: https://doi.org/10.1016/j.scs.2019.101761

Kyrenia, North Cyprus. Meteorology. 2019.

Lee, JH and **Lim, S.** 2018. The selection of compact city policy instruments and their effects on energy consumption and greenhouse gas emissions in the transportation sector: The case of South Korea. *Sustainable Cities and Society*, 37(March 2017): 116–124. DOI: https://doi.org/10.1016/j.scs.2017.11.006

Lee, MG, Chiu, CT, Kan, Y and **Yen, T.** 2009. Experimental study of pervious concrete on parking lot. *ASCE Geotech. Special Publ.*, 193: 125–131. DOI: https://doi.org/10.1061/41045(352)20

Lee, MG, Tia, M, Chuang, SH, Huang, Y and **Chiang, CL.** 2013. Pollution and purification study of the pervious concrete pavement material. *Journal of Materials in Civil Engineering*, 26(8): 04014035. DOI: https://doi.org/10.1061/(ASCE)MT.1943-5533.0000916

Maguesvari, MU and **Narasimha, VL.** 2013. Studies on characterization of pervious concrete for pavement applications. *Procedia-Social and Behavioral Sciences*, 104: 198–207. DOI: https://doi.org/10.1016/j.sbspro.2013.11.112

Moein, M, Asgarian, A, Sakieh, Y and **Soffianian, A.** 2018. Scenario-based analysis of land-use competition in central Iran: Finding the trade-off between urban growth patterns and agricultural productivity. *Sustainable Cities and Society*, 39(March): 557–567. DOI: https://doi.org/10.1016/j.scs.2018.03.014

Şahin, S. 2011. Open borders, closed minds: The discursive construction of national identity in North Cyprus. *Media, culture & society*, 33(4): 583–597. DOI: https://doi.org/10.1016/j.scs.2018.03.014

Shi, D, Wang, J and **Deng, W.** 2019. Smart building and construction materials. *Advances in Materials Science and Engineering*, 2019. DOI: https://doi.org/10.1177/0163443711398694

Tarmac.com. 2019. [online] Available at: https://www.tarmac.com/media/960572/topmix-permeable-summary-of benefits.pdf [Accessed 29 Oct. 2019]. DOI: https://doi.org/10.1155/2019/2432915

Vats, G and **Vaish, R.** 2019. Smart Materials Selection for Thermal Energy Efficient Architecture. *Proceedings of the National Academy of Sciences, India Section A: Physical Sciences*, 89(1): 11–21. DOI: https://doi.org/10.1007/s40010-017-0364-7

Zhong, R and **Wille, K.** 2016. Compression response of normal and high strength pervious concrete. *Construction and Building Materials*, 109: 177–187. DOI: https://doi.org/10.1016/j.conbuildmat.2016.01.051

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