Effect of locally available water and admixture on compressive strength of concrete.

Engr. Zeeshan Ullah*, Engr. Asad Latif, Engr. Shahjahan, Engr. Maryam Sadia

1. PhD student, Dept. of Construction Engineering & Management (CE&M), NIT-SCEE, National University of Sciences and Technology (NUST), Islamabad, Pakistan
   Email: zeshan880@gmail.com
2. Site Engineer
   Email: asadlatif55@gmail.com
3. Assistant Professor, The University of Lahore, Gujerat Campus
   Email: shahjahan1002@gmail.com
4. Design Engineer ADF, Lahore
   Email: maryamsadia124@gmail.com

Abstract

Construction industry is considered as one of the biggest industries in the world. It mainly covers construction of roads, dams, highways, bridges, residential and commercial and high-rise buildings. Some useful construction materials including steel, concrete and wood are used for the construction of all the structures. Concrete is widely used construction material all over the world for the construction of different structures. Concrete usually contains cement, sand, crush and water which collectively regulate its strength and other properties. Water is the most important ingredient of concrete which takes most of the part in the functional properties that is why it is necessary to evaluate the quality and availability of water. In this study, the effect of quality of locally available water on the properties of concrete has been identified. The locally available water from Tap, Spring, Nula and Marble waste sources were used for the sampling. In first run the effect of water quality on strength of concrete was determined. In second step of sampling, the sample having maximum compressive strength in stage one was considered as benchmark and other samples were made by adding admixture to get the benchmark strength. In the first stage 120 concrete samples including 60 cubes and 60 cylinders were casted to check the effect water quality on compressive strength of concrete at different stages like 7 days, 14 days and 28 days. In this stage concrete made up of spring water yielded the maximum strength and concrete made up of Nula water yielded minimum strength. In the second stage fly ash was added as an admixture in concrete and casted same number of samples to check the effect of fly ash on concrete strength. It was observed that with addition of admixtures, concrete with Nula water and marble waste water yielded maximum strength as compare to that of tap water and spring water. Therefore, it is recommended that at the site where water is not easily available these types water can be used to prepare concrete by using some suitable admixture.

Keywords: Concrete Ingredients, Water sources, Water Quality, Compressive Strength and Admixture..

1. Introduction

Construction industry consists of five major sectors including Environmental Structures, Infrastructures, Residential Buildings, Commercial Building and Industrial Buildings. Concrete is mostly used construction material all over the world. The properties of concrete highly depend upon the properties of its ingredients like water, cement, crush and sand. An attempt is made here to investigate the effect of water quality on the compressive strength of concrete prepared by using locally available water in the studied area (Gilchrist, 1972).

For proceeding the work for different qualities of water that is Tap water, Spring water, Nula water, and industrial waste water are the best options chosen for practice because in our country various sources of water are available in different regions of the country but above-mentioned qualities of water are most feasible and easy to be collected for mixing the concrete. The water which is fit for drinking will be good for concrete but this criterion is not applicable in all condition like if water contains small amount of sugar or salt even then it would be fit for drinking but it will not be fit for concrete (Ofori, 1993).

The construction industry is a tool through which society accomplishes its objective of urban and provincial development (Horner, Marenjak, & El ‐ Haram, 2002). It greatly affects the economy of all nations however it is at or close to the best in the yearly rate of business disappointment and coming about liabilities contrasted with different industries. This is a result of the complexities of the development procedure itself and the expansive number of parties involved in the development procedure i.e. customers, clients, originators, controllers, temporary workers, providers, subcontractors and experts. Construction industry is one of the greatest employers of the working population (Hooi & Leong, 2017).

Concrete is used in construction, which is made up of Coarse Aggregate, fine aggregate, binding material like Ordinary Portland Cement (OPC) and water. Concrete have good ability to bear Compressive stresses, which comes from the Structure self-weight and live loads but it Is weak in tension, Steel is use in concrete to resist the tensile stresses and it is also known as Reinforced Concrete cement. The coarse aggregate must be retained on sieve no (4.75mm) and fine Aggregate should be passing from sieve no (4.75mm) (Papadakis, Fardis, & Vayenas, 1992).

Concrete is the oldest and common material which is use in construction. Concrete is mainly use due to it is in low cost and material which is use in concrete it is easily available. Steel is use in concrete to handle the tensile stresses. Volume of concrete is made up of around 75% of Aggregate and 15 % of cement. The Ph. Value of water that is going to be used in concrete must be in the range of 6-8. Water should not contain salt contents because it cannot make proper bonding between cement and Aggregate (Page & Vennesland, 1983).

Concrete have different properties at different state like slump value, Initial and final setting times, bleeding, segregation, consistency, pore pressure and freeze and thaw are the basic properties of fresh concrete in plastic stage while compressive strength, tensile strength flexural strength, shrinkage, creep elastic behavior and thermal behavior are the basic properties of hardened concrete. Admixture are used in concrete to controls the quality of concrete (Neville, 1995).

Addition of admixture in concrete improves the properties of concrete. The addition of fly ash in concrete in the replacement of cement enhance the mechanical properties, chemical properties and also durability of concrete (Flatt, 2004). Similarly, the addition of super plasticizers in the concrete will also improve the compressive strength, workability, flexural strength, permeability of concrete (Criado, Palomo, Fernández-Jiménez, & Banfill, 2009).

The water in concrete is very important role in making of concrete, it is used in concrete to complete the hydration process. The quality of water is important factor in concrete. The water ph. value must 7 to 7.5 (Raki, Beaudoin, Alizadeh, Makar, & Sato, 2010)
Water functions as the single most important and critical factor influencing the workability or ease of mixing and placing the concrete. Moreover, water also controls the fresh and harden properties in concrete. These properties include compressive strength of concrete, durability, cracking, permeability and workability (Flower & Sanjayan, 2007).
Concrete is well-defined as a combined tough material that is attained by the setting of a mixture of cement, aggregates, and water in standard detailed proportions. The discrete materials when mixed together forms a plastic mixture, which can be molded to any shape. Later, within a specified time period into hardens. Concrete is a numerous material with variable assets. The mixing ratio of concrete ingredients is changeable and depending upon the properties of constituent and mix design (Palacios, Puertas, Bowen, & Houst, 2009).
Water is the most important ingredient of concrete which takes most of the part in the bond formation that is why it is necessary to be studied regarding its availability and preference. Concrete is composed of coarse aggregate, fine aggregate and water. Cement is used as a binding material which forms a strong bond between all its ingredients. This binding power of cement is only being activated through the application of water in short the hydration of cement is only possible in its presence (Siddique & Chahal, 2011).
So many properties of concrete of concrete i.e. setting time, hardening time and strength can be affected by the quality of a mixing water. As the strength and durability of structures depend more upon the properties of concrete which is used in the construction of that structure (Wongpa, Kiattikomol, Jaturapitakkul, & Chindaprasirt, 2010).
Sea water usually comprehends 3.5salinity but faintly hurries the setting time of cement. This comprises approximately 78% sodium chloride and 15% chloride sand sulphates of magnesium and these chlorides which are present in concrete comprehending surrounded steel to steel corrosion. The chemical composition of different types of water are analyzed and it is concluded that the sea water and rain water had less strength due to their chlorides and some other constituents while the fresh water showed better results and achieved high strength concrete (Pangdaeng, Phoo-ngernkham, Sata, & Chindaprasirt, 2014)
As the world is suffering from the water scarcity that is why it is the need of the time to reuse the water from different sources like wash basin, kitchen floor wash and other sources. But the properties of concrete like setting time of concrete, compacting factors, slump, compressive and tensile strength properties are highly depending upon the quality of water. These properties are highly affected by the impurities in the mixing water. That is why pure and drinkable water must be used in concrete to achieve maximum (Le et al., 2012).

2. Research methodology

The research is based on the experimental study. In the initial stage different preliminary tests were performed like dry density, bulk density, surface saturated dry density, water absorption, crushing value, initial and final setting time of cement, sieve analysis of cement, fine and coarse aggregates and consistency of cement. After performing the preliminary tests on ingredients of concrete, several trials were carried out to find the best suitable concrete mixture design for the required compressive strength of concrete. From each trial mixture cubes, cylinder and beams were casted to perform compressive strength, tensile strength and flexural strength tests respectively. Below table indicates the results of preliminary tests for the concrete mixture design.

Table 1: Properties of Material for Mix Design

Properties of Material for Mix Design	Values with Units	Properties of Material for Mix Design	Values with Units
Grade of concrete	M15	1 Gallon water	8.34 lbs
Nominal maximum aggregate size	19mm	Slump value	75 mm
Specific gravity of cement	3.15	Dry rodded weight of aggregate	109
Specific gravity of fine aggregate	2.69	Coarse aggregate moisture content	1.20 %
Specific gravity of coarse aggregate	2.63	Coarse aggregate water absorption	0.52 %
Density of cement	195 Pcf	Fine aggregate moisture content	5.20 %
density of water	62.4 Pcf	Fine aggregate water absorption	0.71 %
1 cubic foot water	7.48 Gal	Fine aggregate fineness modulus	3.71

After that procurement of materials, preliminary tests on material as per ASTM D-7332, mix design procedure as per ASTM C-94, sampling of concrete as per ASTM C-172 and curing of samples as per ASTM C-31was carried out. After the final concrete mixture design, ingredients of concrete were mixed as per the ASTM C-94 standards and then cubes and cylinders were casted and cured in the ponds for different time like 7-days, 14-days and 28-days. Total 120 samples comprised of 60 cylinders and 60 cubes were casted with and without addition of admixture for the compressive strength of concrete. Tests on fresh concrete included slump test and density & void content test were performed.
After prescribed time period, compressive strength tests were performed to find out the rate of gain of compressive strength at different age.

3.Results and Discussion

After the detail and preliminary tests, 120 samples without admixtures and 120 samples with admixtures were casted to find out the effect of locally available water quality and admixture of compressive strength of concrete. It was observed that in initial samples where admixture was not added in concrete, spring water yielded the maximum strength as compere to other sample whereas concrete prepared with marble waste water and Nula water yielded the minimum strength. The ultimate strength that achieved from the concrete sample prepared y using marble waste water and Nula water was lesser than the target strength. These results are shown in the below figure-I.

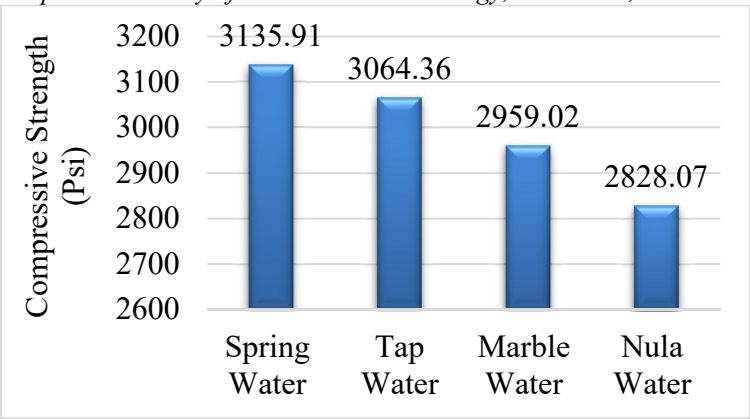

Figure 1: Analysis of Results of Cylinders of All Water Qualities at 28 Days

It is clear from the above figure that there is a clear difference in the compressive strength of concrete samples prepared with spring water and tap water as compare to marble waste water and Nula water. It is also clear from the above graph that compressive strength of concrete prepared with marble waste and Nula water is lesser than the target strength and hence it is not recommended to use these types of water to prepare concrete at any site without use of proper admixtures.

As concrete samples prepared with Nula water and marble waste water failed to provide required strength, therefore, an admixture was added while casting the samples of Nula water, Marble Waste Water and also tap water. Admixture which was used to improve the strength was Superplasticizers. Selection of this type of admixture was based on its availability and literature. This type of admixture is used to improve the compressive strength of concrete by reducing the water to cement ratio in concrete. Amount of admixture was calculated according to ASTM C-494 and also from the specifications provided by the supplier. Twelve cubes and twelve cylinders samples were prepared for each water quality and they were kept for curing for different time period. All of these samples were tested at time period of 7-days,14-days and 28-days to check the rate of gain of compressive strength at these intervals of time. Below figure-2 indicates the results of these samples.

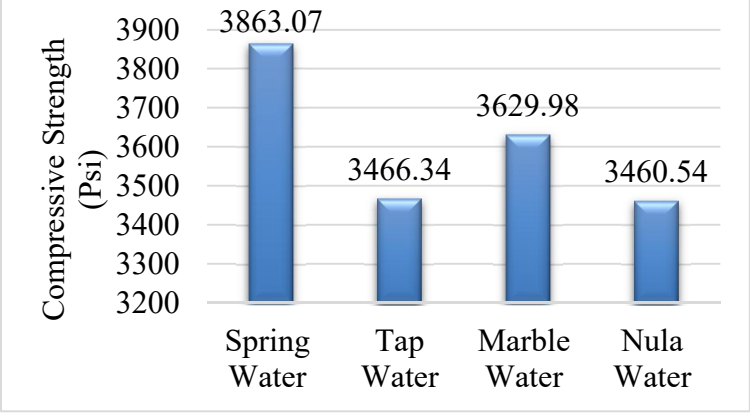

Figure 2: Analysis of Results of Cubes of All Water Qualities at 28 Days

It is clear from above figure that the strength of all the samples with addition od admixture has been improved but samples prepared with marble waste water has gained more strength as compare to tap and Nula water. There is an improvement of 18.54% in compressive strength of concrete

prepared with marble waste water by adding admixture in it. Therefore, marble waste water can be used in concrete mixture by adding suitable admixture to achieve the target strength.

Below figure-3 indicates the rate of gain of compressive strength of concrete samples at different ages like 7-days, 14-days and 28 days with the addition of admixture in the concrete samples.

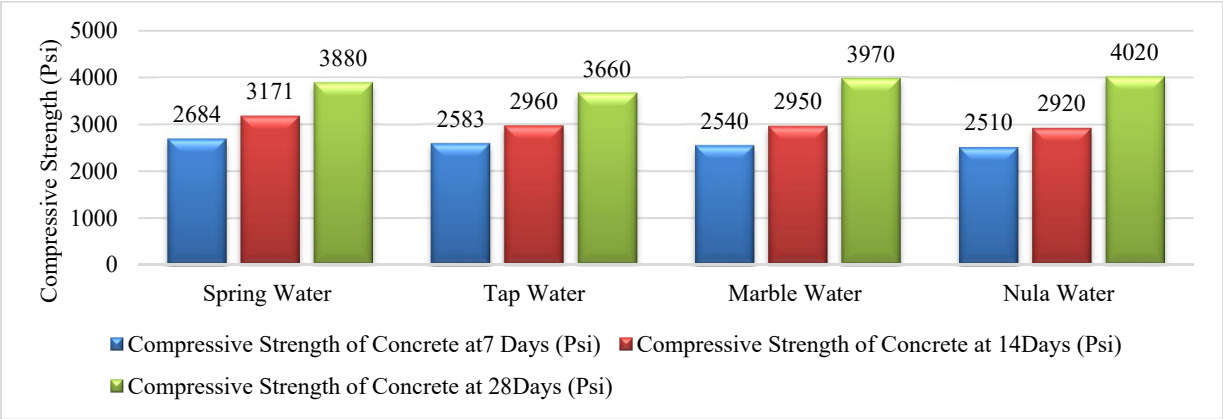

Figure 3: Compressive Strength of Cubes of All Water qualities with Admixture

It is clear from above figure that the maximum improvement in compressive strength of concrete is in concrete prepared with Nula water where concrete achieved maximum strength as compare to all other samples. But these cubes sample tests result also indicates the reasonable improvement of compressive strength of concrete with admixture.

Similarly, cylinders were casted, cured and then tested at different ages to check the improvement in the rate of gain of compressive strength of concrete prepared with these qualities of waters. The results are given below in figute-4.

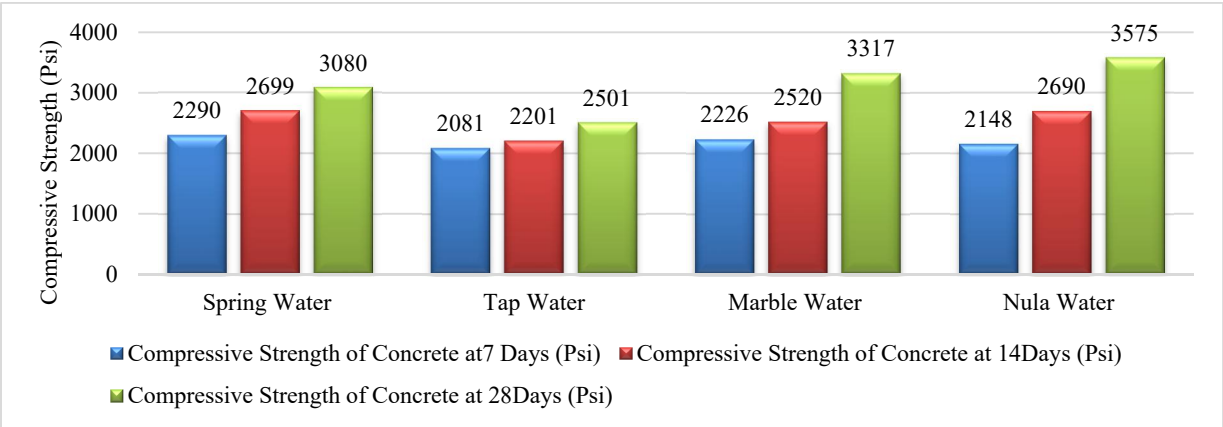

Figure 4: Compressive Strength of cylinders of All Water qualities with Admixture

It is also clear from the above graph that again the improvement in compressive strength of concrete samples prepared with Nula water yielded maximum strength as compare to all other samples. But it is also cleared that the rate of gain of compressive strength and also improvement in compressive strength of all samples is quite good. That is why it can be concluded here that at the construction sites where tap water or drinkable water is not available for concrete work any type of water can be used to prepared the concrete but with the addition of some suitable admixture.

4.Conclusions

Conclusions are made after the sampling and testing of concrete prepared with locally available water including spring water, tap water, Nula water and marble waste water. Sample were tested at 7-days, 24-days and 28-days to check the rate of gain of compressive strength also to check the effect of quality of water on concrete strength. It is concluded that spring water yielded maximum strength as spring water is the purest form of water that is why it provided suitable results. Compressive strength of concrete prepared with tap water, Marble waste water and Nula water yielded relatively lesser strength as compare to spring water respectively. It is also concluded that concrete having Nula and marble waste water yielded lesser than the target strength. Therefore, it is highly recommended that at any construction site concrete should not be prepared with these types of water.

After the addition of admixture in concrete mix, Nula water yielded maximum strength as compare to all other samples. There was a significant increase in the compressive strength of concrete prepare with Nula and marble waste water with the addition of admixture. The rate of gain of compressive strength of concrete having Nula water and marble waste water was also improved as compare to spring and tap water. The results of both cylinder and cubes tests indicated that with the addition of admixture in concrete having Nula and marble waste water yielded maximum strength as compare to traditional tap water concrete sample. Therefore, at construction sites where tap water is not easily accessible, these types of studies helpful to provide the suitable replacement of water for concreting.

After analyzing the results of concrete samples of all water qualities with admixture and without admixture it was concluded that Compressive Strength of concrete which is one of the most important property of concrete and it is affected significantly by the water quality which is to be used in the casting of samples. Therefore, it is necessary to study water quality for its chemical properties regarding its suitability for making the concrete because it does not only have an effect on the strength of concrete but it also affects concrete quality after construction.

Recommendations

From the results and conclusions, the recommendations are made that spring water should be used in concrete if it is easily available to achieve better compressive strength as compared to tap water and other types of water. Marble waste water and Nula water can also be used in the concrete mixing by using suitable admixture. Marble Waste Water can also be used in preparation of concrete if Compressive Strength is to be achieved regardless its other effects on concrete after preparation as this is waste water and if it will be used in concreting then its effect on environment will overcome. Future research can be made on evaluation of chemical properties of water and their effect on the compressive strength of concrete. In future, the research can be done by exploring other qualities of water and check their effect on properties of concrete such as Tensile Strength, Flexural Strength etc.

5. References

Criado, M., Palomo, A., Fernández-Jiménez, A., & Banfill, P. F. G. (2009). Alkali activated fly ash: effect of admixtures on paste rheology. *Rheologica Acta, 48*(4), 447-455. doi: 10.1007/s00397-008-0345-5

Flatt, R. J. (2004). Towards a prediction of superplasticized concrete rheology. *Materials and Structures, 37*(5), 289-300. doi: 10.1007/BF02481674

Flower, D. J. M., & Sanjayan, J. G. (2007). Green house gas emissions due to concrete manufacture. *The International Journal of Life Cycle Assessment, 12*(5), 282. doi: 10.1065/lca2007.05.327

Gilchrist, A. (1972). CLASSIFICATION IN THE CONSTRUCTION INDUSTRY. *Journal of Documentation, 28*(4), 296-321. doi: 10.1108/eb026545

Hooi, L. W., & Leong, T. Y. (2017). Total productive maintenance and manufacturing performance improvement. *Journal of Quality in Maintenance Engineering, 23*(1), 2-21. doi: 10.1108/JQME-07-2015-0033

Horner, M. W., Marenjak, S., & El-Haram, M. A. (2002). Development of a generic framework for collecting whole life cost data for the building industry. *Journal of Quality in Maintenance Engineering, 8*(2), 144-151. doi: 10.1108/13552510210430017

Le, T. T., Austin, S. A., Lim, S., Buswell, R. A., Gibb, A. G. F., & Thorpe, T. (2012). Mix design and fresh properties for high-performance printing concrete. *Materials and Structures, 45*(8), 1221-1232. doi: 10.1617/s11527-012-9828-z

Neville, A. (1995). Chloride attack of reinforced concrete: an overview. *Materials and Structures, 28*(2), 63. doi: 10.1007/BF02473172

Ofori, G. (1993). Research on construction industry development at the crossroads. *Construction Management and Economics, 11*(3), 175-185. doi: 10.1080/01446199300000017

Page, C. L., & Vennesland, Ø. (1983). Pore solution composition and chloride binding capacity of silica-fume cement pastes. *Matériaux et Construction, 16*(1), 19-25. doi: 10.1007/BF02474863

Palacios, M., Puertas, F., Bowen, P., & Houst, Y. F. (2009). Effect of PCs superplasticizers on the rheological properties and hydration process of slag-blended cement pastes. *Journal of Materials Science, 44*(10), 2714-2723. doi: 10.1007/s10853-009-3356-4

Pangdaeng, S., Phoo-ngernkham, T., Sata, V., & Chindaprasirt, P. (2014). Influence of curing conditions on properties of high calcium fly ash geopolymer containing Portland cement as additive. *Materials & Design, 53*, 269-274. doi: https://doi.org/10.1016/j.matdes.2013.07.018

Papadakis, V. G., Fardis, M. N., & Vayenas, C. G. (1992). Effect of composition, environmental factors and cement-lime mortar coating on concrete carbonation. *Materials and Structures, 25*(5), 293-304. doi: 10.1007/BF02472670

Raki, L., Beaudoin, J., Alizadeh, R., Makar, J., & Sato, T. (2010). Cement and Concrete Nanoscience and Nanotechnology. *Materials, 3*(2). doi: 10.3390/ma3020918

Siddique, R., & Chahal, N. K. (2011). Effect of ureolytic bacteria on concrete properties. *Construction and Building Materials, 25*(10), 3791-3801. doi: https://doi.org/10.1016/j.conbuildmat.2011.04.010

Wongpa, J., Kiattikomol, K., Jaturapitakkul, C., & Chindaprasirt, P. (2010). Compressive strength, modulus of elasticity, and water permeability of inorganic polymer concrete. *Materials & Design, 31*(10), 4748-4754. doi: https://doi.org/10.1016/j.matdes.2010.05.012