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RESEARCH ARTICLE

CONCRETE COMPRESSIVE STRENGTH VARIATIONS USING SALTY, BRACKISH, AND FRESH WATERS OF BINAHAAN RIVER IN CONCRETE MIX

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ABSTRACT

This study investigated the potential use of Leyte, Philippines, Binahaan riverine waters in concrete mix. Stratified water sample stations (n=3) were characterized as follows: station 1 was salty or seawater, station 2 was brackish, and station 3, was presumably fresh water. Water cement ratio used 0% (control-potable water), 25%, 50%, 75%, and 100% of seawater, brackish, and fresh riverine waters respectively. Hardened concrete cylinder samples were tested for compressive strength after a curing period of 7, 14, and 28 days. Analysis of Variance (ANOVA) was used to compare the results between and among stations, source water percentage, and curing periods. Results of the statistical analysis indicated that, although the three (3) stations yielded results equal or better than control, still, probably water source significantly affects the compressive strength of the concrete cylinders with brackish water yielding the best compressive strength values. Among water parameters, salinity, chlorides, and alkalinity showed variations among the sampling stations, and perhaps affect the compressive strength of the concrete cylinders.

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INTRODUCTION

Water security has become a major pursuit for many nations. In fact, it has become a national security concern for most countries (United Nations, 2013). Water scarcity affects every continent and almost every country at varying degrees; and around 2.8 billion people around the world are affected (PAI, 1999). In recent years, the lack of supply of potable fresh water is worsened by climate change that includes drought and floods; by the increasing pollution in lakes, rivers, and ground water systems; and the increasing demand by the increasing world population (United Nations, 2013). One of the major uses that consumes water are concrete mixes, a such there is always a continuous search for alternatives of using fresh water in concrete construction activities. The quantity and quality of the water is vital in making concrete (Kucche *et al.*, 2015). Contaminants in water influence the setting of the cement and it affects the strength properties of the concrete. The water and cement ratio (w/c ratio) help determine the durability and strength of the concrete material after a reasonable curing period (Kim *et al.*, 2014). Commonly, potable water (suitable for human consumption) is used in concrete mix; and ASTM 1602M suggests that potable water can be used in concrete without testing for conformance with the requirements of its specification. However, non-potable water maybe used "in mixing concrete in accordance with Section 5.1 of the standard which involves testing water quality of both total mixing water and combined mixing water". Water quality in concrete mixes is important as non-potable water can have bacteria and other organisms that can cause leaching in concrete (NRMCA, 2016). Various studies that used non-potable water in concrete mix have been undertaken all over the world; and the results showed mostly positive results. These studies include the use of grey water that reported increase in compressive strength by 1.86 % compared to the control samples (Rajeesh *et al.*, 2015), the use of waste water that reported increase in compressive strength after a curing period of 28 days (Joo-Hwa Tay *et al.*, 1987), the use of polyvinyl acetate resin wastewater that also reported increase in compressive strength after a curing period of 28 days. Furthermore, various studies have been undertaken that used seawater and brackish water in concrete mix and curing; and their results and findings, although not exhaustive but enough to provide an overview and guidance to this study, are listed in Table 1. Certainly, from a water conservation point of view, there are clear advantages in using seawater and brackish water in concrete mixes; however, there may be undesirable effects on the concrete structures that needs to be looked into. Common problem posed by the use of seawater and brackish water in concrete construction is corrosion to the steel bar reinforcement.

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In a 20-year study (Otsuki *et al*, 2011) reported that corrosion of steel reinforcement can be controlled or minimized through use of BFS (Blast Furnace Slag) cement mixed with pozzolanic materials to fix the free chloride ion, or through the use of corrosion inhibitor; and by using stainless steel or corrosion resistant reinforcement. This study was undertaken using the Binahaan waters because the river system is the logical and ideal source for water in the planned construction activities in the highly-urbanized city of Tacloban and the neighboring towns of Palo, Tanuan, and Tolosa. Furthermore, the river could provide the volume of water resources needed for massive construction activities. Indeed, the latest of these projects is the Japan International Cooperation Agency's (JICA) assisted DPWH's project called "Road Heightening and Tide Embankment for Tacloban-Palo-Tanauan". The Tide Embankment has a height of about 4.5 meters, and a total length of 27.3 kilometers (nro8.neda.gov. ph). This project is aimed at protecting Super Typhoon Haiyan-devastated areas (Perante, W.C., 2016) from future calamities.

Study site

This study was conducted in Palo, Leyte Island in Eastern Visayas, Philippines (Figure 1). The Binahaan River Basin stretches from a mountain ridge in the west to the Leyte Gulf in the east with an area of 272 km^2 (Olaf *et al*, 2008). The Binahaan River is the major tributary of the Binahaan Watershed. The Binahaan Watershed covers 37,126-hectare, and encompasses 79 barangays, from the City of Ormoc, the municipalities of Tanauan, Dagami, Jaro, Tabon-Tabon, Pastrana and Palo (Olaf *et al*, 2008). The Binahaan River inundates an area of 50 km^2 an average of more than once per year (Olaf *et al*, 2008) and it irrigates 6,317 hectares of farmland and is the water source of the Leyte Metropolitan Water District and is the main source of potable water of the municipalities of Pastrana, Santa Fe, Palo, Tanauan, Tolosa, Tabon-Tabon, Dagami, and Tacloban City (Philippine Information Agency 8, 2008).

METHODOLOGY

Variation of water quality along the river

Water samples were collected in three stations of the river system (Figure 2). Station 1 is seawater located a few meters away from the river mouth; station 2 is brackish, where sea and river water mixes; it is the incursion site where the sea water intrudes inside the river during high tide (site was determined using a floating device placed at the mouth of the river during low tide and allowed to travel inside the river during high tide); and station 3's location was presumably the fresh water part of the river. Two liters of water samples were collected in each of the stations (n=3); water samples were placed in 2.5 liters clean plastic bottles and were brought to the Department of Science and Technology (DOST) laboratory for analysis. The following (limited to number of parameters that the agency can analyze) were investigated: Chlorides, SO3, Alkali, Carbonates, TSS (Turbidity), ph, and Salinity. The analytical procedures employed were as follows: Total Alkalinity was measured using a Titrimetric method; the Chloride was via Argentometric; the Salinity was measured using a Refractometer; the TSS employed the Gravimetric; and Turbidity was measured using the Photometric; and pH was determined by using a Glass Electrode.

Concrete Mix Design

The ratios of the concrete mix followed the standards specified by the American Concrete Institute as presented in Table 2. The cement used in the concrete mix was Philippine National Standard, PNS 07:2005, Portland Cement – Specification, Type I- *for use when the special properties specified for any other type are not required.* The sand used in the concrete mix followed the fine aggregates recommendations of ASTM C 33 (AASHTO M 6). The gravel used conforms to the coarse aggregate grading requirements of ASTM C 33 (AASHTO M 80) permitting a wide range and a variety of grading sizes. Both sand and gravel used in this study were the commonly, commercially, and locally available and has the likelihood to be used in the construction activities anticipated for the City of Tacloban and its neighboring towns.

Experimental System

The proportions of the concrete mix ingredients used in every station are presented in Table 2. The mixing process employed was rotation and stirring so as to coat the surfaces of the aggregates with cement paste and to blend the concrete mix uniformly. After the mixing process, the mix were filled into cylinder tubes simultaneously and after reaching one third of the cylinder height, the mix were compacted 25 times, and compacted again in the same frequency upon reaching two-thirds of the height, and again until the cylinder was filled completely. Slump test was conducted and the value obtained was 30 mm to 100 mm. After at least 24 hours of hardening, the concrete samples were taken out of the cylindrical molds and placed in a tank for curing. Curing water used were taken from the source water station. Curing period used in this study were 7, 14, and 28 days.

Measurement of Concrete Characteristics

Compressive strength was investigated and measured in this study. Compressive strength as concrete characteristic was chosen as a study variable because it is one of the most significant, one of the most useful, and one of the easiest parameters to measure. The testing for compressive strength were done on all concrete cylinders on each of the curing period in all three river sampling stations. Each of the water percentage category consist of 3 concrete cylinders per station per curing period. The equipment used to measure this parameter was the Universal Testing Machine, with specifications Mitutuyo 12" Serial # 60285757. The compressive strength testing was carried out at the E.B. Testing Center, Inc., a material testing and geotechnical engineering laboratory based in Tacloban City, Philippines.

Data Analysis

Mean values of the 3 concrete cylinders from every curing period taken from each water sampling stations were used in the presentation of results. Approach to data analysis employed similar methods used in various similar research: descriptive statistical analysis and one-way analysis of variance (ANOVA).

RESULTS

Effects of Source and Quality of Water

Figure 3 shows the results of the water quality analysis. Philippine National Standard for Drinking Water (PNSDW) as

Table 1. Previous studies that used seawater in mixing and curing concrete; their reported results and findings

Observations/ Findings on Compressive Strength	Reference
Concrete cast and cured in seawater; the compressive strength increases for all curing days (7, 14, 21, 28, and 90 days) than control samples that used fresh water.	Adeyemi, O.F. and Modupeopla (2014)
It showed rapid increase in compressive strength as compared to plain water mix and cured concrete but ultimately the strength decreases after 180 days' curing period by around 10%.	Islam *et al* (2012)
Concrete mixed and cured with seawater showed strength increments but lower than concrete mixed and cured with fresh water.	Emmanuel *et al* (2012)
The study is confident in the use of seawater in mixing and curing concrete, but recommends the use of counter measures such as corrosion inhibitors, stainless steel, and the use of BFS cement.	Otsuki *et al* (2011)
Use of brackish water resulted in increase of compressive strength from 2 to 10 MPA.	Zainab *et al* (2011)
Concrete mixed and cured in seawater have higher compressive, tensile, flexural, and bond strength than concrete mixed and cured with fresh water in the early periods of curing (7 to 14 days), and started decreasing thereafter, while the fresh water mixed and cured concrete increases;	Wegian (2010)
Used seawater in mixing and curing; compressive strength was not affected up to a period of 17 months.	Ghorab (1989)
Use of seawater is not recommended for use in reinforced, pre-stressed or other structural concrete.	FIP (1985)
Used seawater in mixing and curing; findings showed no sign of harm to the reinforced concrete up to a period of 10 years.	Chen *et al* (1983)
Use of seawater in mixing and curing is not recommended; if circumstances not avoidable, it may be used in plain concrete and concrete structures that are permanently submerged.	IS: 456 (1978)

Table 2. Water-cement ratio and the percentages of water used from source stations (0% for control, 25%, 50%, 75%, and 100%) and the proportions in kilograms of sand, cement, and gravel used in creating the experimental concrete cylinders. Curing days=7, 14, and 28 days

Water/ Cement Ratio	Binahaan Water	Binahaan Water (kg)	Potable Water (kg)	Cement (kg)	Sand (kg)	Gravel (kg)	# of cylinders for the 3 stations/water percentage/curing period
0.45	0%	0	10.44	23.2	34.8	69.65	9
0.45	25%	2.61	7.83	23.2	34.8	69.65	27
0.45	50%	5.22	5.22	23.2	34.8	69.65	27
0.45	75%	7.83	2.61	23.2	34.8	69.65	27
0.45	100%	10.44	0	23.2	34.8	69.65	27

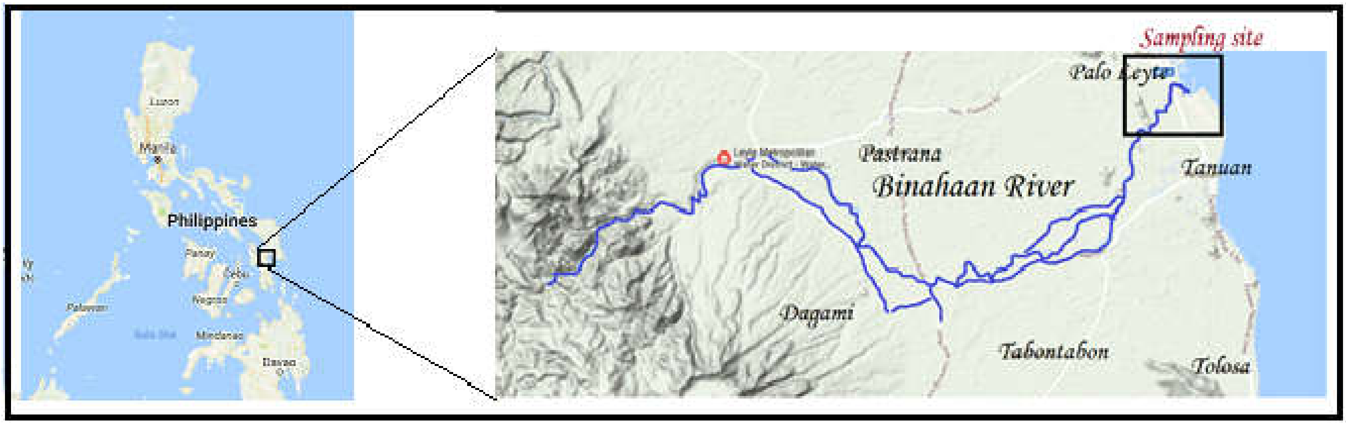


Figure 1. Palo Leyte in Eastern Visayas, Philippines and the Binahaan River

Figure 2. Binahaan River water sampling site. Station 1 was seawater, station 2 was brackish, and station 3, where the water was fresh or not salty

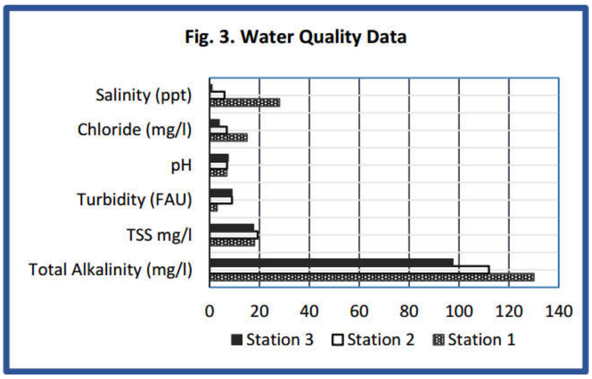
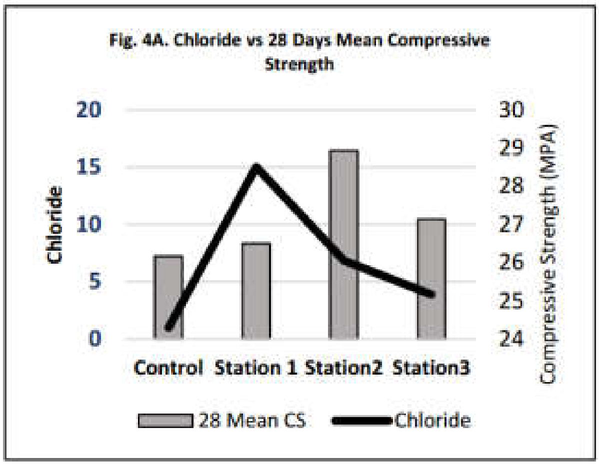
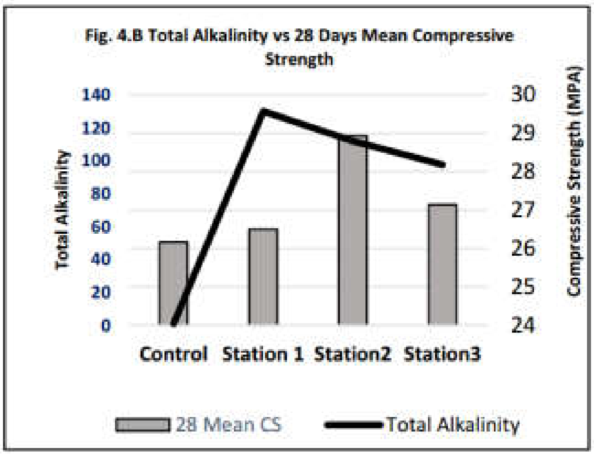
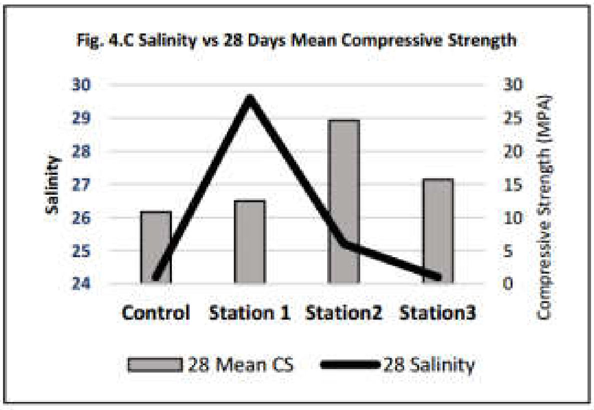


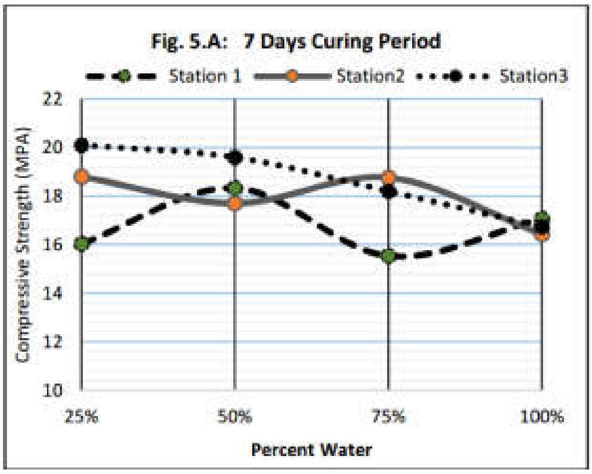
Figure 3. Binahaan River water quality data showing significant salinity and chloride differences among the three stations

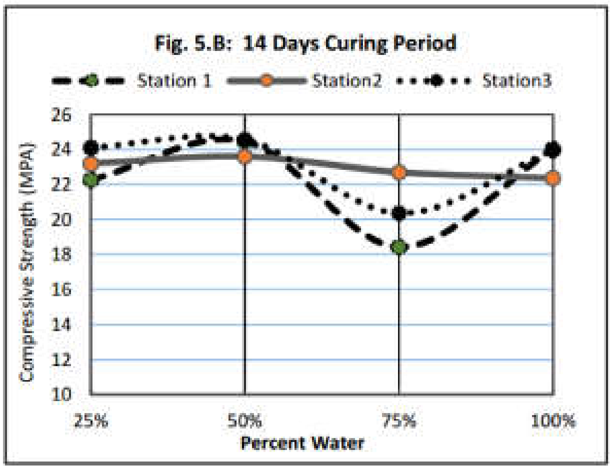






Figures 4.A, 4.B, and 4.C shows the effect of chloride, total alkalinity, and salinity on compressive strength of the cylinders cured for 28 days across the three (3) Binahaan river stations





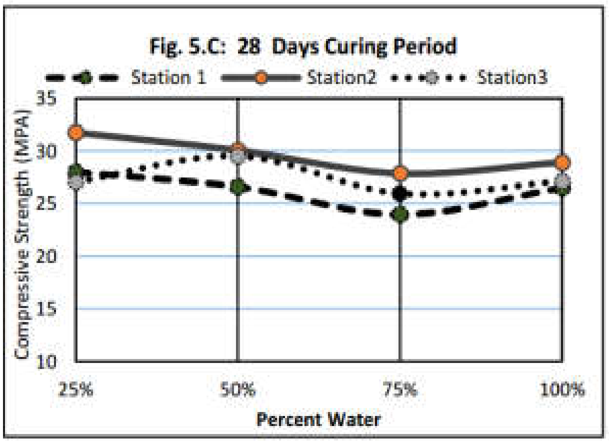
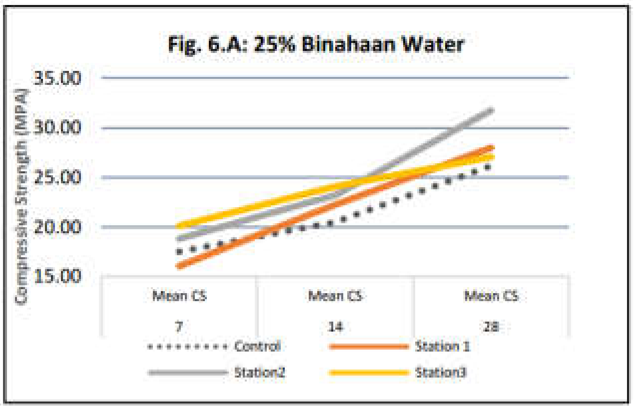
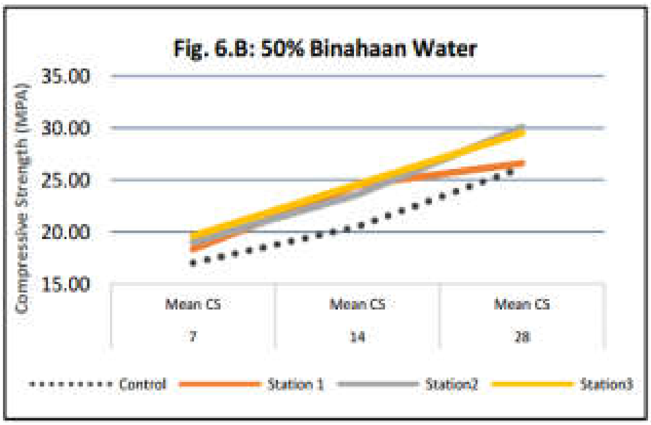
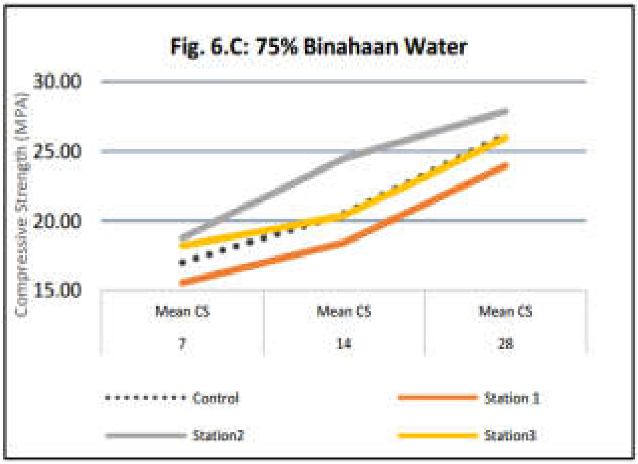


Figure 5.A, 5.B, and 5.C shows the effect of curing days and water percentages on compressive strength of the cylinders cured for 7, 14, and 28 days







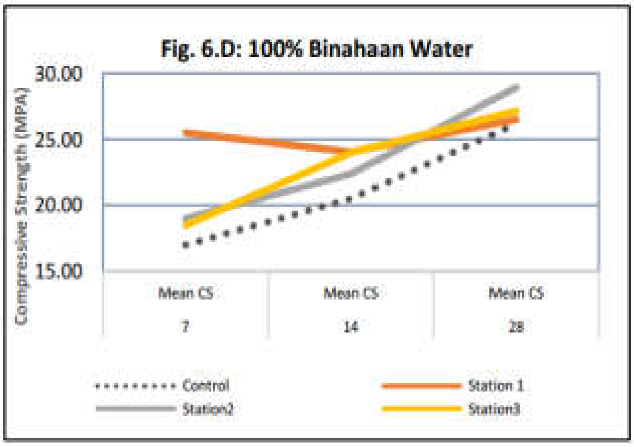
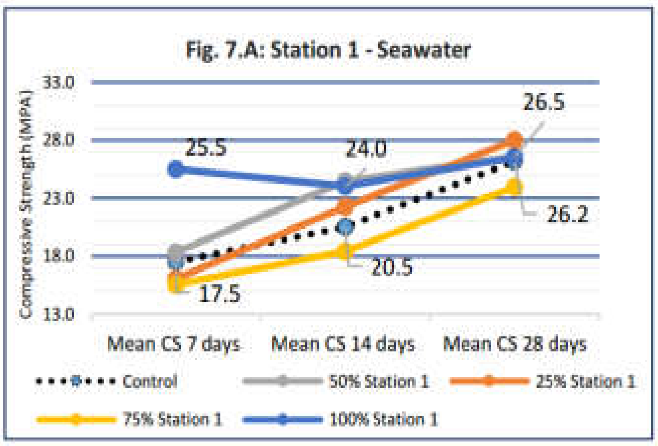
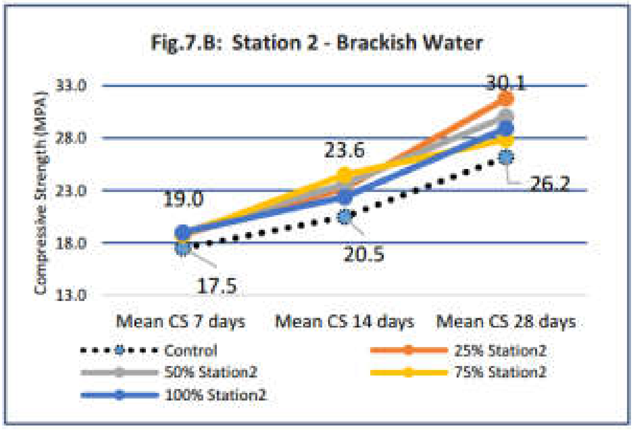


Figure 6.A, 6.B, 6.C and 6.D. The effect of water percentages on compressive strength on the three (3) Binahaan river stations





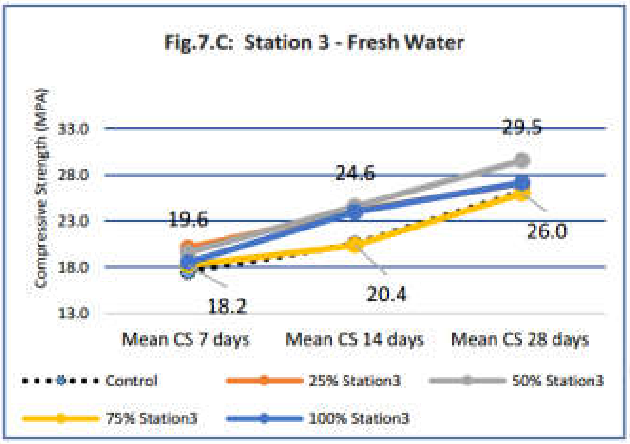


Figure 7.A, 7.B, and 7.C. This shows the effect of water source stations on compressive strength of the cylinders cured for 7, 14, and 28 days. Indicated data labels are: highest MPA values (top), and the control MPA values (bottom)

prescribed by the Department of Environment and Natural Resources (DENR), Department of Health, and /or the Department of Science and Technology (DOST) was used in classifying the laboratory results of the water samples taken from the 3 stations in Binahaan River (all values are within range except the salinity values of station 1(seawater) and station 2 (brackish)). Further, Figure 3 shows station 1 (seawater) having the highest salinity and chloride values; units are as follows: salinity is ppt, chloride is mg/l. It also shows significant alkalinity and turbidity differences among the three stations; station 1 (seawater) having the highest alkalinity and lowest turbidity values. Figures 4.A, 4.B, and 4.C shows the effect of chloride, total alkalinity, and salinity on compressive strength of the concrete cylinders, respectively; while Figure 7.A, station 1 (seawater), and Figure 7.B, station 2 (brackish water), and Figure 7.C, station 3 (fresh water) shows the effects of water stations and percentages on compressive strength on the experimental concrete cylinders. ANOVA for the effects of water stations and percentages are shown in Table 3 and 4.

Effects of Curing Period and Water Percentages

The result of the testing for compressive strength done on each of the curing period in every river sampling station are presented in the Figures 5.A, 5.B, and 5.C. Figure 6 shows effects of the water percentages used in creating the experimental the concrete cylinders, while Table 5 shows the ANOVA for the effects of curing period.

Table 3. Analysis of Variance (ANOVA): Two-Factor Without Replication on water percentages (25%, 50%, 75% and 100%) and curing periods (7,14, and 28 days) effects on concrete compressive strength. Alpha=0.05

Station	P –value % water	P –value Curing Period	Interpretation % water	Interpretation Curing Period
Station 1 (Seawater)	0.1192701	0.016940785	Not significant	Significant
Station 2 (Brackish)	0.6522082	4.10118E-05	Not significant	Significant
Station 3 (Freshwater)	0.0366452	5.37964E-05	Significant	Significant

Table 4. Analysis of Variance (ANOVA): Two-Factor Without Replication (alpha=0.05). Effects of water source station and water percentages on compressive strength of concrete cylinders cured for 7,14, and 28 days

Curing Period	Between Stations (P-value)	Between Water Percentages (P-value)	Between Stations (Interpretation)	Between Water Percentages (Interpretation)
7 days	0.00800	0.35914	Significant	Not significant
14 days	0.67007	0.29172	Not significant	Not significant
28 days	0.00943	0.03842	Significant	Significant

Table 5. Analysis of Variance (ANOVA): Two-Factor Without Replication (alpha=0.05). Effects of curing period (7,14, and 28 days) and water source stations on compressive strength of the concrete cylinders mixed with 25%, 50%, 75% and 100% water from Binahaan River

Water Percentage	Between Stations (P-value)	Curing Period (P-value)	Between Stations (Interpretation)	Curing Period (Interpretation)
25%	0.33133	0.00509	Not significant	Significant
50%	0.35656	0.00113	Not significant	Significant
75%	0.01300	0.00113	Significant	Significant
100%	0.58691	0.08659	Not significant	Not significant***

DISCUSSION

Water quality analysis. This study's sampling station 1, which is the seawater station located just outside the mouth of the river has a salinity of 28 ppt (Figure 3); this lower salinity values is not surprising compared to the expected standard seawater or oceanic water salinity of 35 ppt (Bella and Fabuss, 1989) as the water sample was perhaps diluted by the river discharges making it less saline than the salinity of seawater offshore. Water salinity for station 3, which is the inside portion of the river not encroach by the sea during high tide has a salinity of just 1 ppt, while Station 2, the brackish section has a salinity of 6 ppt. This distribution pattern for salinity follows the same pattern for total alkalinity with station 1 having the highest value at 130 mg/l, and 112 mg/l for station 2, and 97.6 mg/l for station 3; while chloride content, station 1 has a value of 15.03 mg/l, and for station 2, 6.83 mg/l, and station 3 has 3.89 mg/l. Other water parameters such as turbidity, TSS, and pH have small non-significant variations see Figures 4.A, 4.B, and 4.C. *Water quality effects on concrete compressive strength.* This can be observed through Figures 4.A, 4.B, and 4.C where this study graphed the compressive strength at 28 days curing period with significant water parameters that have high variations across the three stations. Relevant observations, perhaps, show that lower salinity, lower chloride, and lower total alkalinity probably results in higher compressive strength. These variations in water quality values reflects the stratification of the water sampling stations.

Water stations and water percentages effects on concrete compressive strength. Figure 6 shows that in all stations the concrete cylinders passed the compressive strengths (either close enough or better than control) test values. Water station effects on concrete compressive strength is presented in Table 4 where its effects are statistically significant (ANOVA) at 7 days curing period (*P*=0.00800) and 28 days curing period (*P*=0.00943). Further, ANOVA indicated that water percentage significantly affects compressive strength of concrete cylinders at 28 days curing period (*P*=0.03842). Interestingly, it can be observed that station 2 showed the highest compressive strength at 28 days curing period at 31.8 MPA from 25% brackish water percentage (Figure 7.B). These results, perhaps, at first take, shows that the Binahaan riverine water, all stations, particularly, the brackish station 2 are useable in concrete construction, however, these initial findings should be treated with caution as the longest curing period in this study is just 28 days, and thus, perhaps, not long enough to make any definitive conclusions much less definitive recommendations.

Seawater effects on concrete compressive strength (Station 1). Figure 7.A shows that the 100% sea water percentage sourced from station 1 obtained the highest compressive strength values at 7 days curing period only and it eventually decreased during the 14 and 28 days curing periods, respectively. In station 1, the 28th day curing period was dominated by the 25% seawater and 50% seawater percentages. At Station 1, the effects of water percentages on compressive strength were not statistically significant ANOVA (*P*= 0.11927), (Table 3); and this is perhaps because the water components and its concentration are still too dynamic to be reflected in the compressive strength values given that this study's longest curing period is only 28 days.

In other studies, (Michael and Adam Kuwairi, 1978; Stark, 2001; Tibbetts, 1968); among others, that used seawater as mixing or curing water in concrete, findings of these researches are largely conflicting. For example, Wegian, (2010) reported that concrete mixed and cured in seawater have higher compressive, tensile, flexural, and bond strength than concrete mixed and cured with fresh water in the early periods of curing (7 to 14 days), and started decreasing thereafter, while the fresh water mixed and cured concrete increases. These findings of Wegian (2010) is very similar to results of this study i.e. that the compressive strength afforded by the use of seawater in mixing concrete is temporal and only occurs in the first or second week of its curing. However, Ghorab (1989) reported that the use of seawater in mixing and curing does not affect compressive strength up to a period of 17 months, and similarly, Chen *et al* (1983) reported that the use of sea water in mixing and curing showed no sign of harm to the reinforced concrete up to a period of 10 years. While other studies do not recommend the use of seawater in concrete mix IS: 456 (1978), FIP (1985). This study surmises that perhaps there are other factors that affect the concrete compressive strength apart from salinity, and these parameters should be investigated. Further, the conflicting results may be caused by other parameters such as sand, gravel, or perhaps temperature, and humidity.

Brackish water effects on concrete compressive strength (Station 2). Figure 7.B shows that the compressive strength variations at 7 days curing period were not evident or high enough across the four water percentages in station 2, however, on the 28th days curing period, compressive strength was dominated by the 25% brackish water and 50% brackish water sourced from station 2, respectively. At Station 2 the effects of water percentages on compressive strength were also not statistically significant ANOVA (P= 0.65220) (Table 3). This non-significance, perhaps, maybe attributed to the short period of curing, and conceivably the brackish waters' salinity, chlorides and other components, and its concentration are still too dynamic to be reflected through the compressive strength values, and perhaps could only be revealed through a longer curing period. On the other hand, a separate study by Zainab *et al*. (2011), where brackish water was used in concrete mixing and curing, findings indicate that it increased the compressive strength of the experimental concrete from 2 to 10 MPA. These findings of Zainab *et al*. (2011) has similar findings to this study; indeed, this research reports that among all the water stations investigated, the use of brackish water in concrete mixing and curing yielded the highest compressive strength values compared to control, seawater, and fresh water.

Freshwater effects on concrete compressive strength (Station 3). Figure 7.C shows that the compressive strength variations at 7 days curing period were also not evident as well, however on the 28th days curing period, compressive strength was dominated by 50% fresh water and 25% fresh water sourced from station 3 whose values were almost similar or close enough to the control cylinders' compressive strengths values. At station 3 the effects of water percentages on compressive strength were statistically significant (P= 0.03664). The ANOVA shows that water percentages (only on station 3) and curing periods (in all stations) significantly affects the compressive strength values (see Table 3).

Curing periods effects on concrete compressive strength. Table 3 and Figures 5.A, 5.B, and 5.C shows that the concrete compressive strength consistently increases as curing period increases. Also, the compressive strength increase is consistent regardless of the water source, be it from the sea (station 1), or brackish (station 2), or in the deemed fresh water section of the river (station 3). Curing period impact on compressive strength were statistically significant for all stations ANOVA for station 1 (P=0.01694), at station 2 (P=4.10118E-05), and at station 3 (P=5.37964E-05), alpha 0.05. Further, across water percentages curing period effect on compressive strength is consistent as shown in Table 5.

In summary, this study showed that Binahaan riverine samples from seawater, brackish, to fresh water stations maybe used in concrete mix without affecting much the tolerable limitations set forth by the control cylinder compressive strength values. The various components of the water such as salinity, chlorides, and total alkalinity may be affecting the compressive strength of concrete cylinders, thus should be taken into consideration. This study cautions to make any definitive conclusions and recommendations as the maximum curing period in this study was only 28 days, perhaps, not long enough to establish definitive results and experimental outcomes confidently. These findings, including the literature review of the many other similar studies shows conflicting results in so far as the effects of seawater on compressive strength of concrete structures are concerned; thus, a thorough and longer study may be needed to resolve these conflicting results.

Recommendation

This study recommends the following: (1) a similar study should be undertaken but should consider a longer curing period to ascertain the effect of water source on compressive strength; (2) to conduct further study so as to determine the higher compressive strength resulting from water source station number 2 or brackish station; and find out why it is offering strength better than control and better than the fresh water station of the river, and whether the quality of the water source offers advantages and disadvantages in both shorter and longer term; and devise a thorough and robust methodology so as to resolve the conflicting results of various similar studies. Despite the limitations of this study, the researcher would somehow recommend that if Binahaan riverine water is used in concrete mix for any compelling reason, the brackish and fresh water stations of the river should be used, in order of preference based on its delivered compressive strength values.

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REFERENCES

Adeyemi, O.F. and Modupeopla, A.G. 2014. The Effect of Sea Water on Compressive Strength of Concrete. *International Journal of Engineering Science Invention*, ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726 www.ijesi.org Volume 3 Issue 7 ǁ July 2014 ǁ PP.23-31

Bella, M. and Fabuss, T. 1989. Properties of Seawater. 1st Edition Academic Press Boston, p 766-771.

Chen, B. *et al*. 1983. Ten-year field exposure test on the endurance of reinforced concrete in harbor works, *Cement and Concrete Research*, 13, 603-610

Emmanuel, A.O., Fatokun Ajibola Oladipo & Ogunsanmi Olabode E. 2012. Investigation of Salinity Effect on Compressive Strength of Reinforced Concrete. *Journal of Sustainable Development*, Vol. 5, No. 6; 2012

FIP 1985. The Design and Construction of Concrete Sea Structures, 4th edition FIP Recommendations, London.

Ghorab, H.Y *et al*. 1989. Effect of mixing and curing waters in the behavior of cement pastes and concrete, Part 1, Macrostructure of Cement Paste, *Cement and Concrete Research*, 19, 88-878

http://nro8.neda.gov.ph

IS: 456 1978. Code of practice for plain and reinforced concrete. Indian Standards Institute, New Delhi.

Joo-Hwa Tay and Woon-Kwong. 1987. Use of reclaimed wastewater for concrete mixing, *Journal of Environmental Eng*., 113:1156-116NRMCA, 2016

Kim, Y. Y., K. M. Lee, J. W. Bang, and S. J. Kwon, 2014. Effect of w/c ratio on durability and porosity in cement mortar with constant cement amount, Advances in Materials Science and Engineering, Article ID 273460.

Kucche, K. J., S. S. Jamkar, P. A. Sadgir. 2015. Quality of Water for Making Concrete : A Review of Literature. *International Journal of Scientific and Research Publications*, Volume 5, Issue 1, January 20151 ISSN 2250-3153

Michael A.T. and Adam Kuwairi, 1978. Effect of ocean salts on the compressive strength of concrete and concrete Res., Pergamon Press Inc. (USA) pp:491-500.

NRMCA, 2016. www.nrmca.org/aboutconcrete/downloads/Tip10w.pdf

Olaf, N. *et al*. 2008. Community-Based Flood Management Program (BFMP). Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)

Otsuki, N. and Kubota, Masato. 2011. Chloride penetration profiles in existing harbor structures constructed with blast furnace cement concrete. 36th Conference on Our World in Concrete & Structures. 287-292

PAI, 1999. Sustaining Water: Population and the Future of Renewable Water Supplies. http://www.cnie.org/pop/pai/h2o-toc.htmL

Perante, WC. 2016. Validity and Reproducibility of Typhoon Damage Estimates using Satellite Maps and Images. *Asian Journal of Applied Science and Engineering*, 5, 105-116.

Stark, D.C. 2001. “Long Term Performance of Plain and Reinforced Concrete in Seawater Environments”, Portland Cement Association, RD 119, Retrieved December 01, 2010, from http://www.cement.org/tech/cct_pca_research_tech.asp.

Tibbetts, D. C. 1968. “Performance of Concrete in Seawater”, Canadian Building Series, No.2, pp. 159 – 180.

United Nations, 2013. http://www.unwater.org/water-cooperation-2013/water-cooperation/en/int

Wegian, F.M. 2010. Effects of Seawater for Mixing and Curing on structural concrete studies. *The EIS Journal Part A; Civil and Structural Engineering*, Vol.3 No.4, and November 2010, pp 112-115.

Zainab *et al*. 2011. Utilization of Cement Kiln Dust in Concrete Manufacturing. *Jordan Journal of Civil Engineering*, Volume 7 No. 2013

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