AN EXPERIMENTAL STUDY OF THE WATER-CEMENT RATIO AND CONCRETE STRENGTH

A Thesis submitted in partial fulfillment of the requirements for the award of a degree of Bachelor of Science in Civil Engineering

By

ZAHID HASSAN
ID: 192-47-239

TARUN ROY
ID: 192-47-241

SHAHIN ALAM
ID: 192-47-249

Supervised by

Mr. Md Mehedi Hassan Bhuiyan

Lecturer
Department of Civil Engineering
Daffodil International University

DEPARTMENT OF CIVIL ENGINEERING
FACULTY OF ENGINEERING

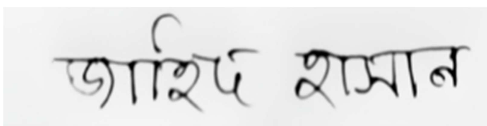
DAFFODIL INTERNATIONAL UNIVERSITY

January – 2023

Certification

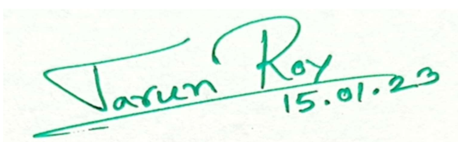
This is to certify that this project and thesis entitled "**AN EXPERIMENTAL STUDY OF THE WATER-CEMENT RATIO AND CONCRETE STRENGTH**" is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the department of Civil engineering under the faculty of engineering of Daffodil International University in partial fulfillment of the requirements for the degree of bachelor of science in civil engineering. The presentation of the work was held on 16th January 2023.

Signature of the candidates



ZAHID HASSAN

ID No: 192-47-239



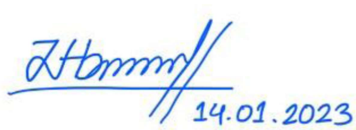
TARUN ROY

ID No: 192-47-241

SHAHIN ALAM

ID No: 192-47-249

Countersigned



Mr. Md Mehedi Hassan Bhuiyan
Lecturer
Department of Civil Engineering
Faculty of Engineering
Daffodil International University.

The project and thesis entitled "**RELATIONSHIP BETWEEN CONCRETE STRENGTH AND WATER-CEMENT RATIO**" submitted **ZAHID HASSAN**, ID No: 192-47-239 **TARUN ROY** ID No: 192-47-241 **SHAHIN ALAM** ID No: 192-47 - 249, Session: summer 2019 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Civil Engineering** on 16th January 2023.

BOARD OF EXAMINERS

18.01.2023

Mr. Md Mehedi Hassan Bhuiyan — Supervisor
Lecturer
Department of Civil Engineering
Daffodil International University

Dr. Miah M. Hussainuzzaman — Chairman
Associate Professor
Department of Civil Engineering
Daffodil International University

Mr. Md. Masud Alom — Internal Member
Assistant Professor
Department of Civil Engineering
Daffodil International University

Mr. Abu Hasan — Internal Member
Lecturer (Senior Scale)
Department of Civil Engineering
Daffodil International University

16/01/2023

Dr. Muhammad Mukhlesur Rahman — External Member
Deputy Secretary
Ministry of Textiles & Jute
Govt. of the People's Republic of Bangladesh

Dedicated to

Parents

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENT

First and probably most important, I express our gratitude to Allah or God. Then I'd want to take this occasion to thank our project and thesis supervisor, **Mr. Md Mehedi Hassan Bhuiyan**, Lecturer in the **Department of Civil Engineering**, for his tireless efforts in helping, encouraging, and mentoring us through this project. Without his helpful suggestions and assistance, my thesis would be impossible to complete. Thank you also for permitting us to select this thesis topic.

I'd like to thank **Dr. Mohammad Hannan Mahmud khan**, Assistant Professor and Head of the **Department of Civil Engineering**, for his assistance, support, and unwavering encouragement.

Apart from that, I'd want to thank all of our friends for sharing their knowledge and experience with us and assisting us with this endeavor. Thank you also for allowing us to use some of your tools and equipment.

I sincerely thank our loving family for their continuous support, as well as their inspiration and encouragement, throughout our time at this university.

ABSTRACT

Water cement ratio is always a burning question for casting concrete. Concrete is the most versatile construction materials and used as a substitute of stone which acts as artificial stone. The strength of this important construction material mostly depends on a proper water cement ratio. A wrong water cement ratio may produce weak concrete in spite of using 1^{st} class ingredients of concrete. Hence determining a proper water cement ratio is one of the important factors of civil engineers worldwide. The first, less frequently mentioned fundamental presumptions for the strength versus water-cement ratio relationship are discussed, namely that (a) the strength of structural concrete is controlled by the strength of the cement paste contained within it; (b) the strength of a cement paste strongly depends on its porosity; and (c) the porosity (capillary) is a function of the water-cement ratio. The connection between concrete strength and water-cement ratio is based on this. For this relationship, many empirical formulations, or "strength formulas," have been established, such as the Abrams formula. These calculations, which often are straightforward but have limited validity, estimate the concrete strength only based on the water-cement ratio. In order to provide improvements, a new class of strength formulas is presented in this study. These formulas include a second independent variable in addition to the water-cement ratio, such as the amount of cement, water, paste, etc. This addition (a) increases the precision with which strength estimates are made (b) demonstrates that, when the water-cement ratio of two comparable concretes is changed, the concrete with the higher cement content will have a lower strength, and (c) demonstrates that the size of changes in concrete strength depends on whether the water-cement ratio is altered by changing the cement content or the water content. These predictions are supported by experimental data. The impact of the other type of porosity, the air content, on the strength of concrete is likewise explained using a formula. When this is combined with any reliable strength formula, the experimental results for both air-entrained and non-air-entrained concretes are well-fitted.

CHAPTER 1
INTRODUCTION

1.1 General

The capacity to bear compressive load is considered as the main function of plain concrete. This capacity is measured by its compressive strength which is dependent on a number of factors. Water cement ratio is on these factors. Actually it is a governing factor of properties of concrete. In this study we have observed the variation in compressive strength of concrete with different water cement ratio. Again water cement ratio may vary with the properties of aggregate used in concrete. Absorption capacity, percentage of void, porosity these are the properties which may alter the value of water cement ratio. That is why a close observation was made on these properties of both coarse aggregate and fine aggregate. The variable of the study was water-cement ratio. A range of 0.30 to 0.60 in water cement ratio was used. 3 number of samples were prepared with each value of water cement ratio. And the average strength of a set of sample was taken as the strength of concrete. Specimen was cylinder of fresh concrete with a dimension of 6 inch diameter and 12 inch height. The specimens were tested using universal testing machine with capacity of 200 kN. The load at which specimen showed cracks on its surface was considered as failure load or crushing load. The value obtained by dividing this crushing load by the sectional area of specimen is considered as the crushing strength of concrete. The study shows that initially the strength of concrete was increasing with the increase of water cement ratio. After some point this strength started to fall. A water cement ratio of around 0.4 was found as the optimum water cement ratio at which the crushing load was found as 13.87 kN.

1.2 Importance of Water Cement Ratio

A lower value of water cement ratio causes lack of workability hence difficult to cast and to give a desired shape. Also it may introduce some voids in the concrete which will reduce the strength of the hardened concrete. Again a higher value of water cement ratio may cause high workability which will cause segregation and bleeding of fresh concrete. Due to bleeding cement will washed out from fresh concrete and the bonding of aggregate will weaken. Thus a low strength concrete will result. Hence an optimum value of water cement ratio is important to produce high strength concrete. And to determine this optimum value of water cement ratio this study works as the foundation. Through this study we will find this optimum value of water cement ratio which will produce maximum strength concrete.

1.3 Application

In this fast growing world concrete is the mostly used construction material. To construct building, bridge, pavement, dam, gravity wall, retaining wall, foundation and other infrastructures concrete is a must use material. The study is concerned about all type of concrete used for constructing structures. Thus the result of this study is applicable for all type of concrete. Specially the concrete used in Bangladesh is under the main observation of the study. However it may also applicable for surrounding countries because of having similarities in environment and other factors.

1.4 Objective of this study

The only objective of this study is to determine an optimum value of water cement ratio which will produce maximum strength concrete.

1.5 Scope of the Study

The study has been performed in Bangladesh perspective using stone aggregate concrete. The only parameter of this study is water cement ratio. Cylindrical specimen of concrete has been prepared with varying eater cement ratio and the compressive strength of specimens were determined.

1.6 Outline of Thesis

In chapter 1 Basic idea of the work that has been done under this research.

In chapter 2 The next section mentions what has been done before and what kind of work has been used in preparing concrete cylinder.

In chapter 3 What we analyzed and how we accomplished.

In chapter 4 The data obtained from the study was analyzed and interpreted. The results such as load-water cement ratio, stress vs strain compared with the experimental data.

In chapter 5 This chapter contains major findings of the research and recommendation for future work.

CHAPTER 2
LITERATURE REVIEW

2.1 General

The water cement ratio is provided in different proportions at the construction site. It provides different strength of concrete. The water cement ratio is determined to obtain the maximum strength using a certain amount of water. A lot of research has been done on this previously. And different results have been found. A discussion of the results is provided in Section (2.2).

2.2 Literature Review

(Singh et al., 2015b) It has been noted that cement mortar is also subject to Abrams' law. The Portland Pozzolana Cement (PPC) and river sand are mixed in variable ratios in the cement mortar, such as 1:3, 1:4, 1:5, 1:6, 1:7, and 1:8 with various w/c ratios. The empirical relationship between the split tensile strength and compressive strength of cement mortar has been established. The results demonstrate that when the w/c ratio increased, cement mortar's compressive strength and split tensile strength declined. It has been shown that a 0.5 minimum w/c ratio is needed to make cement mortar workable.

(Vu et al., 2009) The porosity and strength of the cement matrix of cured concrete are significantly influenced by the water/cement ratio (W/C), which enters the concrete mix. This article's goal is to measure this ratio's impact on specific behavior under very constricted circumstances. Two more concretes have been created from the materials of a reference "ordinary" concrete (W/C=0.6) with W/C ratios of 0.4 and 0.8, respectively.

(Varma, 2017) In a laboratory, concrete was created in accordance with nominal mix specifications while maintaining constant proportions for all other constituents except water. A variety of mixes were created in the lab by varying the water to cement ratio. All of these concrete mixtures were generated utilizing a shift in water cement ratio from 0.5 to 0.6, and wet density, workability, and compressive strength were measured for each one. The compressive strength of the concrete mixes was seen to be significantly reduced when the water-cement ratio was above 0.55. In contrast, the performance of concrete mixtures consistently shows a decline in compressive strength when the water-to-cement ratio rises.

(Popovics & Ujhelyi, 2008) When making concrete, the more compact the mixture is, the less porosity the concrete will have. As a result the concrete will be more dense. The more accurate the water-cement ratio is applied during field application, the higher the concrete's workability will be.

(Rao, 2001) The w/c ratios ranged from 0.35 to 0.50 with a consistent 0.05 increase. The percentage of silica fume ranged from 0% to 30%. In plain cement mortars, it has been found from test results that, regardless of mortar age, mortar strength diminishes as the w/c ratio rises. The strength of mortars containing silica fume declines with w/c ratio up to 0.45 at young ages of 3 and 7 days. The strength has been seen to rise with w/b ratio between 0.45 and 0.50 w/c ratio. The strengths of mortars at w/c ratios of 0.35, 0.40, and 0.50 were seen to be roughly the same at ages 28 and 90 days, though.. But, at w/c ratio of 0.45, the strength has been observed to be the lowest at any silica fume content. However, for all silica fume contents, the strength has been shown to be lowest at a w/c ratio of 0.45.

(Liu et al., 2016) On the relative viscosity of the cement paste, pore structure, and strength of the hardened foam concrete, effects of the water-cement ratio were discussed. Results shown that the size, distribution, and connectivity of pores in foam concrete can be affected by the water-cement ratio. With a rise in the water-cement ratio, the compressive strength of foam concrete displayed an inverted V-shaped variation law. A greater w/c ratio would lead to a lower relative viscosity and a poorer ability for cement paste to keep bubbles at the same density of foam concrete. The size, shape, distribution, and connectivity of pores in foam concrete are affected by the water-cement ratio. With varied w/c ratios, the power exponential relationship between the foam concrete's dry density and 28-day strength changes.

(Kaplan, 1959) It was discovered that the ratio of changes in compressive strength and pulse velocity caused by a change in water/cement ratio is often different from that caused by a change in age. As a result, age and the amount of water to cement cannot be assumed to have no effect on the relationship between pulse velocity and compressive strength. However, it seems that the relation can really be taken to be true for compressive strengths up to around 4,000 lb/in2. Low pulse velocity at an early age predicts low strength at a later age for concrete with the same aggregate:cement ratio, researchers have discovered.

(Albano et al., 2009) With different water/cement ratios (0.50 and 0.60), PET contents (10 and 20 vol%), and particle sizes, this work aimed to investigate the mechanical behavior of concrete containing recycled Polyethylene Therephtalate (PET). Additionally, when the mixes were exposed to various temperatures (200, 400, and 600 _C), the effect of PET's thermal deterioration in concrete was investigated. Results show that water absorption increased in PET-filled concrete, though. On the other hand, the temperature, water-to-cement ratio, PET content, and particle size all had a significant impact on the flexural strength of concrete-PET when it was exposed to a heat source. Additionally, the temperature, the placement of the PET particles on the slabs, and the water-to-cement ratio all had an impact on the activation energy.

(Singh et al., 2015a) According to Abrams equation it was recommended to keep the w/c above to 0.4 . In practice, it has been observed in our work that water cement ratio above 0.4 results in workable concrete.

2.3 Summary

We refer to the process of selecting the right mix ingredients and their amounts in a concrete mix as mix design. The mix design includes the calculation of the quantity of cement, fine aggregate, and coarse aggregate, as well as the relationship between water/cement ratio and the desired strength.

CHAPTER 3
METHODOLOGY

3.1 General

Experimental works were conducted in a laboratory with concrete cylinder of dimension 4 inch diameter and 8 inch height. Molding was removed after 2 days of casting. Then a curing period of 28 days was maintained in the laboratory. Specimens were removed from water the day before testing. Axial load was applied along the longitudinal axis of the specimens and failure was observed.

3.2 Experimental Setup

Cylindrical mold was cleaned and arranged together. Then a lubricating liquid was applied inside of the cylinders so that hardened specimens can be removed easily. An identifying number was given to each cylinder to differentiate different specimens.

Fig 3.1: Cylindrical mold for casting concrete

3.3 Aggregate

3.3.1 Coarse Aggregate

Crushed stone was used as coarse aggregate in this study. Absorption capacity, Fineness Modulus, Dry Rotted Unit Weight, Gradation tests were conducted for coarse aggregate. Following test results were obtained (Fig.3.2)

Fig 3.2: Coarse Aggregate (Crushed Stone)

Fig 3.3: Fineness Modulus test of coarse aggregate

3.3.2 Fine Aggregate

Sylhet sand has been used as fine aggregate material in this study. Before using this material in concrete a few tests were conducted to find the properties of the material. Fineness modulus, specific gravity, absorption capacity, dry rotted unit weight tests were performed. Following test result was obtained :(Fig.3.3)

3.3.3 Cement

Cement is the only binding material usually used in concrete. Portland Composite Cement (PCC) is used in this study. Coarse Aggregate gives the bulk of the concrete and fine aggregate fills the inter particle void of coarse aggregate. Whereas cement binds the aggregates and make a strong bond among the aggregates. Hydration is the most important property of cement. A few tests like setting time, consistency test, compressive and tensile strength test were performed of the cement used in this study. Following are the test results obtained of cement:

Table 3.1 : Chemical Composition of Portland Composite Cement

Constituent	Chemical Composition (%)_ PCC
SiO_2	20.60
Al_2O_3	4.74
Fe_2O_3	3.28
CaO	64.82
MgO	1.84
SO_3	2.4
Na_2O	0.21
K_2O	0.38
LOI	1.73

3.4 Working Procedure

Total working procedure of this study is divided into two parts. One is making cylinder and the other one is measuring the crushing strength. Specimen cylinder size was of 4 inch diameter and 8 inch height. All aggregates were blended in required proportion before mixing. (Fig.4)

Fig 3.4: Mold Preparation

First coarse aggregate, fine aggregate and cement are mixed in dry condition by hand (Fig.5). After 2-3 minutes dry mixing, water is added and mixed thoroughly. Water cement ratio is increased in every new set of specimens. Amount of water need to be mixed is measured by the weight of cement added times water cement ratio.

Fig 3.5:Concrete mixing dry conditions

As 1st set of specimens, a water cement ratio of 0.30 is used and 3 cylinders are prepared with this water cement ratio. A label of 0.30 is added to this set. On the next specimen a water cement ratio of 0.35 is used and 3 sample cylinders are prepared. A label of 0.35 is added to this specimen set. Similarly set of specimens are prepared with varying water cement ratio of 0.40, 0.45, 0.50, 0.55 and 0.60.(Fig.6)

Fig 3.6: Concrete casting in the cylindrical

Newly casted concrete cylinders are placed in the laboratory at room temperature (Fig.7). On the day after casting, specimens were removed from mold. After another day the specimens were immersed under water for curing purpose.

Fig 3.7: Concrete casting finishing works in the cylindrical

On the 27th day the specimens were removed from water and kept in normal temperature. On 28th day the specimens were tested by universal testing machine.

Specimens were placed vertically under the upper yoke of the UTM. Using fine motion screw both yoke of the UTM are placed in touch with the specimen (Fig.8). Then compressive load was applied gradually until visible cracks of failure are formed. Any visible crack like this is assumed as the failure of the specimen and corresponding load is recorded as the crushing strength of the specimen. Along with the crushing load failure mode was also observed whether it was aggregate failure or bond failure or combined failure. Aggregate failure indicates strong bonding between aggregates whereas bond failure indicates lack of strong bond which may be due to void or impurities in the freshly cast concrete.

All set of specimens were tested gradually and the result obtained are recorded. Succeeding calculations are then done to find the ultimate compressive strength of concrete which will indirectly determine the value of optimum water cement ratio.

Fig 3.8: Concrete cylindrical compression Test

Calculate the specimen's compressive strength by dividing the greatest load borne by the specimen during the test by the average cross-sectional area and rounding up to the closest 10 psi (69 kPa). If the length-to-diameter ratio of the specimen is 1.75 or below, multiply the obtained value by the appropriate adjustment factor provided in table-2

Table 3.2: Multiplying Factor of Concrete Strength

L/D	1.75	1.50	1.25	1
Factor	0.98	0.96	0.93	0.87

At work our cylinder was 4 inches in diameter and 8 inches in height. The ratio of which is 2. So, we didn't have to use any factor.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

Several experiments were conducted to examine and validate the research aims. Water cement ratio and concrete strength have been summarized in this chapter. It has been highlighted that using less than required and more than required water in concrete reduces the amount of strength. Finally the mechanical effects and properties of water cement ratio are discussed.

4.2 Evaluation the results/ Analysis

Table 4.1: The Result of Compressive Strength for Different mixed of water-cement ratio after 28 days.

W/C	d(inch)	H (inch)	L/D	P (kN)	Area (mm^2)	Stress	Average	Failure Type
0.3	4.3	8	1.86	98	9369.02	10.5		T3
0.3	4.2	8	1.90	120	8938.32	13.4	13.4	T3
0.3	4.3	7.9	1.84	74	9369.02	7.9		T3
0.35	4.3	8	1.86	95	9369.02	10.1		T2
0.35	4	7.8	1.95	93	8107.32	11.5	11.5	T3
0.35	4.3	8	1.86	85	9369.02	9.1		T3
0.4	4.2	8	1.90	106	8938.32	11.9		T3
0.4	4.2	8	1.90	90	8938.32	10.1	13.9	T3
0.4	4.2	7.9	1.88	124	8938.32	13.9		T3
0.45	4.2	8	1.90	87	8938.32	9.7		T3
0.45	4.2	8	1.90	70	8938.32	7.8	10.6	T3
0.45	4.2	8	1.90	95	8938.32	10.6		T3
0.5	4.3	7.8	1.81	100	9369.02	10.7		T2
0.5	4	8	2.00	80	8107.32	9.9	10.7	T2
0.5	4.3	8	1.86	65	9369.02	6.9		T3
0.55	4.3	7.9	1.84	95	9369.02	10.1		T2
0.55	4.1	7.9	1.93	85	8517.75	10.0	10.1	T2
0.55	4.3	8	1.86	58	9369.02	6.2		T3
0.6	4.3	8	1.86	45	9369.02	4.8		T3
0.6	4.1	7.8	1.90	61	8517.75	7.2	7.2	T3
0.6	4.3	8	1.86	60	9369.02	6.4		T3

After completing all processes, we finally reached analysis part. After the analysis, we find out the concrete strength and w/c ratio and other parameters. The compressive strength results are introduced in Table-3 and Table-4

Compressive strength result in 28 days for w/c ratio 0.3, 0.35, 0.4, 0.45, 0.5, 0.55 & 0.6 is 13.4MPa, 11.5MPa, 13.9MPa, 10.6MPa, 10.7MPa, 10.1MPa& 7.2MPa, After observe we find the compressive strength for 0.4 w/c is highest value that is 13.9MPa.(normal specimen).

Table 4.2: Determine the strength of concrete for w/c ratio

W/C	Stress (MPa)
0.3	13.4
0.35	11.5
0.4	13.9
0.45	10.6
0.5	10.7
0.55	10.1
0.6	7.2

We used an equation (eqn-1) from a code approved by the American Concrete Institute (ACI). We have analyzed the maximum strength of concrete by establishing that equation water cement ratio. We have tried to reconcile the obtained data with the ACI approved equation. And after analysis a graph is drawn which is given in 3.1. This is an empirical formula, so that if water cement ratio is applied, the strength of concrete will be found in MPa.

$$\frac{w}{c} = 1.1734e^{-0.025\ '_c}$$

Table4.3: Data calculation for equation number-1

W/C	Test(MPa)	Calculation(MPa)
0.3	13.43	52.66
0.35	11.47	46.71
0.4	13.87	41.55
0.45	10.63	37.00
0.5	10.67	32.94
0.55	10.14	29.26
0.6	7.16	25.90

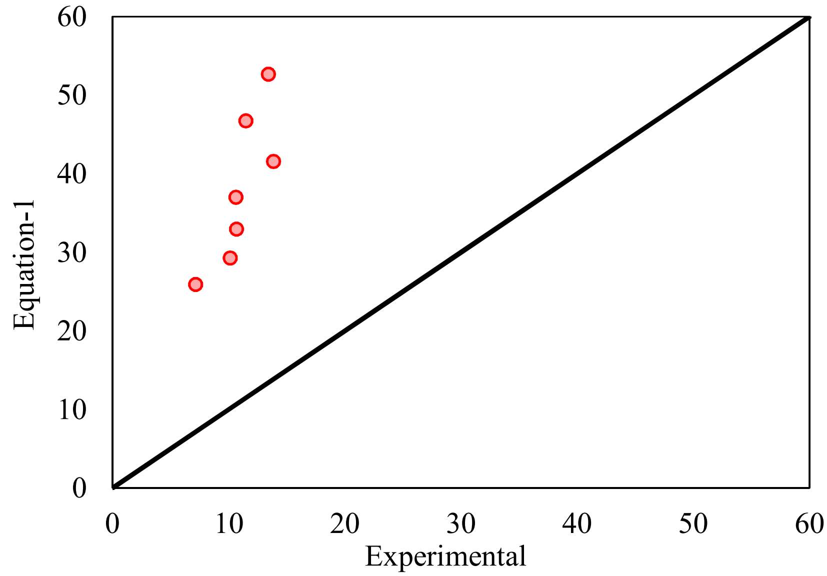


Fig-4.1: Calculating result for ACI Equation.

And from a literature “Contribution to the Concrete Strength versus Water-Cement Ratio Relationship” by Sandor Popovics, Ph.D., P.E., F.ASCE1 ; and Janos Ujhelyi, Ph.D.2 we got a equation(eqn-2). Equation 2 is an imperial formula. which have fixed values of A=97.93MPa and B=7.226 which are With this equation we get the strength of concrete by applying the ratio of water cement ratio used during our work. Which did not match with the standard concrete strength. As a reason we can say that we have not been provided with the correct proportion of water cement ratio. A lot of water remains in the fine aggregate due to rain. Which did not work by drying in the oven.

$$f'_c = {}^{A}/_{B^{(W/C)}}$$

Table 4.4 Data calculation for equation number-2

W/C	Test (MPa)	Calculation (MPa)
0.3	13.43	54.11
0.35	11.47	49.01
0.4	13.87	44.40
0.45	10.63	40.22
0.5	10.67	36.43
0.55	10.14	33.00
0.6	7.16	29.89

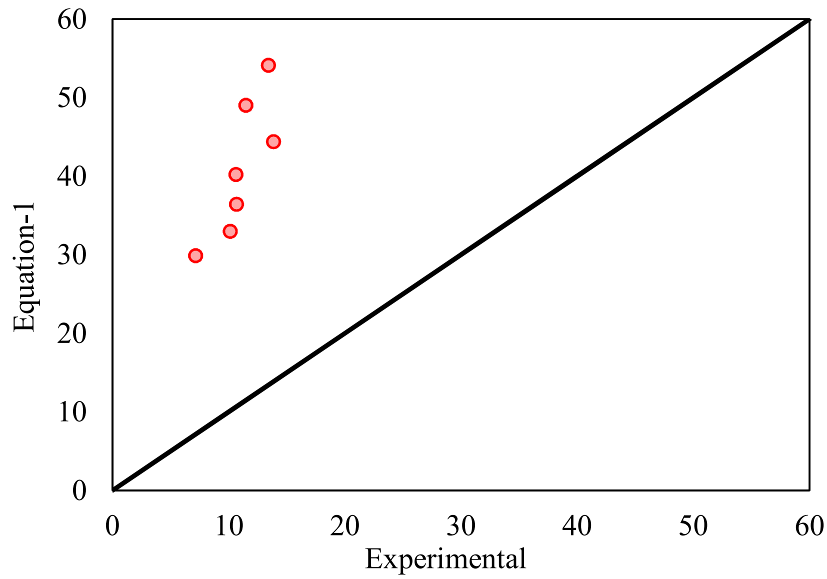


Fig4.2 : Calculating result for Equation-1

Finally from a literature "Contribution to the Concrete Strength versus Water-Cement Ratio Relationship" by Sandor Popovics, Ph.D., P.E., F.ASCE1 ; and Janos Ujhelyi, Ph.D.2 we got a equation(eqn-3). We have also drawn graph 5.1 to cross-check our work and which do not match the given equation. This is an empirical formula that, applying the ratio of water to cement, gives the concrete strength in psi. PSI is divided by 145 to convert to MPa.

$$\log f'_c = 4.159 - 0.8589\left({}^{W}\!/_{C}\right)$$

Table 4.5 Data calculation for equation number-3

W/C	Test (MPa)	Calculation (MPa)
0.3	13.43	54.95
0.35	11.47	49.78
0.4	13.87	45.09
0.45	10.63	40.84
0.5	10.67	37.00
0.55	10.14	33.51
0.6	7.16	30.36

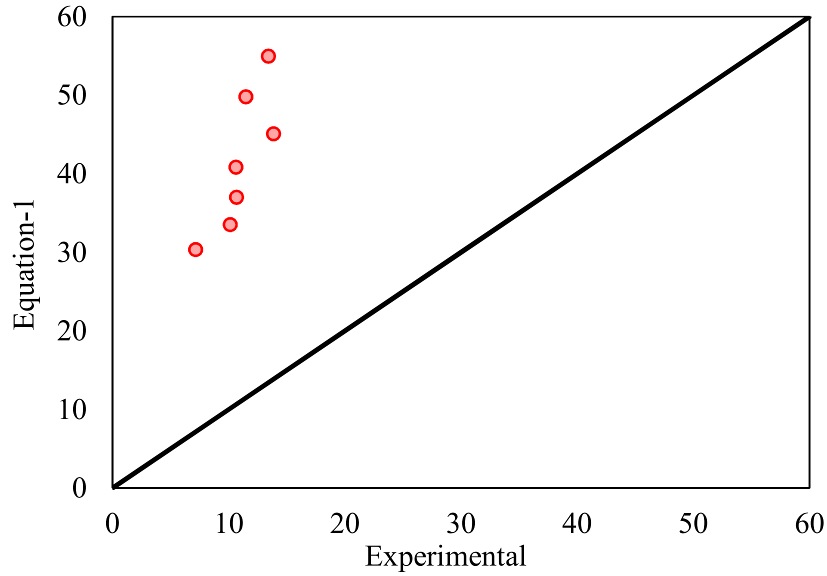


Fig.4.3 : Calculating result for Equation-2

4.3 Summary

In this chapter the complete results of the research are discussed in detail. Research data and information are presented through tables and graphs. The chapter is divided into different parts. Each part is explained separately. Results are conceptually presented through graphs

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

The study was mainly focused to find a relationship between water cement ratio and the compressive strength of stone aggregate concrete. The study was performed with stone aggregate concrete because in Bangladesh it is very much popular. And the study was performed on Bangladesh perspective. At the same time in Bangladesh there is a lack of awareness in maintaining a proper water cement ratio which directly affect the properties of the concrete. The study was started with a water cement ratio of 0.30. And the study shows that the compressive strength of concrete increases with the increase of water cement ratio up to a certain limit. And after this limit value of water cement ratio, the compressive strength of the concrete started to fall. This limiting value of water cement ratio is the optimum value of water cement ratio. This value may differ at different weather and exposer condition due to the variation in humidity of atmosphere. Thus the value obtained from this study should be used only in the locality which has weather condition similar like Bangladesh.

And for Bangladesh perspective an optimum value of water cement ratio has been obtained as 0.45.

5.2 Recommendation.

The study was performed only for stone aggregate concrete and Bangladesh perspective. Thus following recommendations should be followed by the readers.

1) For weather condition other than Bangladesh, a similar study should be performed to find the optimum value of water cement ratio in that environment.
2) The study was performed only using stone aggregate, so for other aggregate like brick a similar study may be performed. Researchers are recommended to make study with varying the parameters used in this study.
3) In this study only the compressive strength of concrete was observed. There are other properties like modulus of elasticity, Poisson's ratio, tensile strength and so on which also may be studied through a similar study.
4) Any research always has some limitations which are inevitable. We also face some limitations too like freedom to choose materials, availability of local materials, quality of local materials and so on. Hence a researcher should keep in mind these important factors before starting a study. In fact every study has some positive outcomes irrespective of a lot of limitations. Hence a researcher is always encouraged to find a way to start a new project. stone aggregate

5) Concrete production techniques and effective use of self-compacting concrete are improving day by day. The mixing ratio of concrete is one of the main keys to adjusting the water cement ratio. The Self Compatibility Test Method is not a condition it is a universally accepted rule. The degree of tolerance depends on the type and variety of the engineering judgment material. However, much research is needed to establish it properly.

References

Albano, C., Camacho, N., Hernández, M., Matheus, A., & Gutiérrez, A. (2009). Influence of content and particle size of waste pet bottles on concrete behavior at different w/c ratios. *Waste Management*, *29*(10), 2707–2716. https://doi.org/10.1016/j.wasman.2009.05.007

Kaplan, M. F. (1959). The effects of age and water/cement ratio upon the relation between ultrasonic pulse velocity and compressive strength of concrete. *Magazine of Concrete Research*, *11*(32), 85–92. https://doi.org/10.1680/macr.1959.11.32.85

Liu, Z., Zhao, K., Hu, C., & Tang, Y. (2016). *Effect of Water-Cement Ratio on Pore Structure and Strength of Foam Concrete*. *2016*.

Popovics, S., & Ujhelyi, J. (2008). Contribution to the Concrete Strength versus Water-Cement Ratio Relationship. *Journal of Materials in Civil Engineering*, *20*(7), 459–463. https://doi.org/10.1061/(asce)0899-1561(2008)20:7(459)

Rao, G. A. (2001). *Role of water ± binder ratio on the strength development in mortars incorporated with silica fume*. *31*, 443–447.

Singh, S. B., Munjal, P., & Thammishetti, N. (2015a). Role of water/cement ratio on strength development of cement mortar. *Journal of Building Engineering*, *4*, 94–100. https://doi.org/10.1016/j.jobe.2015.09.003

Singh, S. B., Munjal, P., & Thammishetti, N. (2015b). Role of water / cement ratio on strength development of cement mortar. *Journal of Building Engineering*, *4*, 94–100. https://doi.org/10.1016/j.jobe.2015.09.003

Varma, M. B. (2017). *Effect of Change in Water Cement Ratio on Wet Density , Dry Density , Effect of Change in Water Cement Ratio on Wet Density , Dry Density , Workability and Compressive Strength of M-20 Grade Concrete*. *December*.

Vu, X. H., Malecot, Y., Daudeville, L., & Buzaud, E. (2009). *Effect of the water / cement ratio on concrete behavior under extreme loading*. *April*, 1867–1888. https://doi.org/10.1002/nag