Experimental Research on Dosage of High Range Water Reducing Admixture Influence on the Strength of Mortar and Concrete

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Abstract **–The research emphasizes on "Dosage of high range water reducing admixture influence on the strength of mortar and concrete". Sikament–9 is used as a High Range Water Reducing (HRWR) admixture. In this research, the physical properties of cement, fine aggregate and coarse aggregate are firstly determined according to ASTM procedure. The 1:2.75 cement mortar is used to determine the compressive strength and 1:3 is used for tensile strength. The strength of mortar with cement only and with different dosages of HRWR admixtures are tested at 3 days, 7 days, 28 days and 91 days. To evaluate the dosage influence on strength of mortar, 0.8%, 1.6%, 1.65%, 1.7%, 1.8%, 2%, 2.4% and 2.7% dosages of HRWR are used. Based on w/c obtained from flow table test and normal consistency test, compressive and tensile strengths of mortar are tested. And then, mix design is calculated without and with various dosages of HRWR admixtures for target strength of concrete 34.5 MPa by using ACI method. According to the slump limit, two different w/c ratios 0.396 and 0.346 are used in concrete strength test. After that the samples are tested for 3, 7 and 28 days compressive strength of concrete.**

Keywords- **high range water reducing admixture (HRWR), *compressive strength,* concrete, mortar, Sikament–9**

I. INTRODUCTION

As the technology improved, the building, roads and bridges are built with modern high technology in Myanmar. The main factors that needed to be considered are economy, durability, flexibility, quality of materials and workers comfortability and safety etc. Some admixtures are performed to complete these factors. The effectiveness of an admixture depends on several factors including: type and amount of cement, water content, mixing time, slump, and temperatures of the concrete and air.The term concrete refers to a mixture of aggregates, usually sand, and either gravel or crushed stone, held together by a binder of cementitious paste. The paste is typically made up of Portland cement and water and may also contain supplementary cementing materials (SCMs), such as fly ash or slag cement, and chemical admixtures. Nowadays, admixtures are widely used in many constructions since admixtures can alter one or more properties of the concrete. Among them, high range water reducing admixture can be very beneficial in producing high strength concrete with a low water to cement ratio (w/c). It has long been a concrete technologist's dream to discover method of making concrete at the lowest possible water to cement ratio while maintaining a high workability. So, the objective of the research is to investigate the dosage of high range water reducing admixture influence on strength of mortar and concrete.

II. ADMIXTURES

Admixture is defined as a material other than water, aggregates, and cement that is used in concrete as an ingredient and added to the batch immediately before or during mixing. Admixtures are chemicals which are added to concrete at the mixing stage to modify some of the properties of the concrete mix. Admixtures are almost always used in modern practice and thus become an essential component of modern concrete. The widespread use of admixture is mainly due to the many benefits made possible by their application. For instance, chemical admixtures are mainly used to control the setting and hardening properties for concrete, or to reduce the water requirements.

Superplasticizers are the improved chemical admixture with highly effective plasticizing effects on wet concrete. Superplasticizers result in substantial improvement of workability at a given water-cement ratio. Reduction of water content upto 30% may be achieved by the use of Superplasticizers. Reduction in water cement ratio increases the strength of concrete. This admixture can be used at the higher dosages than conventional Plasticizers in the range of 0.5% to 3% by weight of cement. The properties of Sikament-9 are shown in Table I.

TABLE I PROPERTIES OF SIKAMENT-9

Form	Blended Polymer
Colour	Brown Liquid
Density	1.15-1.17 g/cm^3
pH Value	5.5-7.5
Composition	Solution in water of sodium salt of naphthalene-sulfonate and lignosulfonate

A. Specific Gravity Test of HRWR Admixture (Sikament-9)

Specific gravity of HRWR admixture is determined according to ASTM C-188 which is in the range of 1.15 to 1.17. The test result of HRWR admixture is shown in Table II.

TABLE II SPECIFIC GRAVITY OF SIKAMENT-9

Test No.	1	2	3
Density of Water (g/ml)	0.99681 (25.9°C)	0.99705 (25°C)	0.99705 (25°C)
Weight of Flask + Water (g)	649.2	649.1	649.1
Volume of Flask + Water (ml)	651.28	651.02	651.02
Weight of Flask +Admixture (g)	748.36	748.69	748.50
Density of Admixture (g/ml)	1.149	1.150	1.149
Specific Gravity of Admixture	1.15	1.15	1.15
Average Specific Gravity of Admixture	1.15		

From the result, the specific gravity of HRWR admixture is 1.15 and this value is reached lower range.

B.pH Test of HRWR Admixture (Sikament-9)

pH value is a measure of acidity or alkalinity of water soluble substances. A pH value is from 1 to 14, 7 is the middle point. Values below 7 indicate acidity and values above 7 indicate alkalinity. For admixture, the recommended pH value is from 5.5 to 7.5. The test result for HRWR admixture is 6.8. So, it is reasonable to use.

III. DETERMINATION OF MATERIALS PROPERTIES USED IN CONCRETE

In this paper, the chemical composition of Crown cement and physical properties of cement, fine and coarse aggregates are tested.

A. Chemical Composition of Crown Cement

The chemical composition of Crown cement is conducted in the laboratory of Crown cement factory and analysis result is shown in Table III. According to analysis result, percent contributions of chemical compounds in Crown cement are within the range of composition limit of good Portland cement.

TABLE III CHEMICAL COMPOSITION OF CROWN CEMENT

Chemical Constituents	Approximate Composition Limits of Portland Cement (%)	Composition in Percentage (%)
Silica (SiO_2)	17-25	20.08
Alumina (Al_2O_3)	3-8	5.26
Ferric Oxide (Fe_2O_3)	0.5-6.0	3.15
Calcium Oxide (CaO)	60-67	61.93
Manganese Oxide (MgO)	0.1-4.0	3.39
Sulphur Trioxide (SO_3)	1-3	2.43
Others	1	1.73
Ignition Loss	2	2.03
Total		100

B. Specific Gravity Testof Crown Cement

The purpose of this test is to determine the weight per unit volume of the cement particles. The specific gravity of good Portland cement should be between 3.1 and 3.25. The specific gravity of Crown cement is determined according to ASTM C-188 and result is shown in Table IV.

TABLE IV SPECIFIC GRAVITY OF CROWN CEMENT

Test No.	1	2	3
Wt. of cement (W) (g)	90	90	90
Volume of Kerosene + Cement (V_1) (ml)	29.1	29.2	29.4
Volume of kerosene(V_2) (ml)	0.5	0.7	0.8
Density of cement(g/ml)	3.147	3.157	3.147
Density of water (g/ml) (T°C = 29°C)	0.99595	0.99595	0.99595
Specific gravity of Cement	3.16	3.17	3.16
Average Specific gravity of Cement	3.16		

From the result, the average specific gravity of Crown cement is 3.16 which is within the standard limit.

C. Fineness Test of Crown Cement

Fineness is a vital property of cement. The sizes of cement particles directly affect the hydration, setting and hardening, shrinkage, strength and heat of hydration. This test is carried out according to ASTM C430. Fineness of cement is determined by sieve test. In sieve test, the cement sample weighing 100 grams is taken and sieved for a period of 15 minutes on a sieve of ASTM No.200. The residue by weight on a sieve of ASTM No. 200 shall not exceed 10%. The fineness of Crown cement is shown in Table V.The fineness of Crown cement is 6.5%.

TABLE V FINENESS OF CROWN CEMENT

Test No.	Sieve No.	Shaking Time (min)	Percent Retained (%)
1	ASTM No.200	15	6.7
2	ASTM No.200	15	6.6
3	ASTM No.200	15	6.4
Average			6.5 < 10

D. Normal Consistency of Crown Cement

The consistency of cement is measured by the Vicat apparatus, using a 10 mm diameter plunger fitted into the needle holder. This is considered to be normal, in the meaning of ASTM C187-98, when the plunger penetrates the paste to a point 10±1 mm for 30 seconds from the top of the mould. The water content of the paste is expressed as a percentage by weight of the dry cement, the usual range of consistency being between 26% to 33%.The test results of normal consistency for Crown cement is shown in Table VI. The normal

consistencies of Crown cement and with various dosages of high range water reducing admixtures are tested in laboratory and these results are summarized in Table VII.

TABLE VI NORMAL CONSISTENCY OF CROWN CEMENT

Test No.	Wt. of Cement (g)	Wt. of Water (g)	Normal Consistency (%)
1	400	112	28
2	400	110	27.5
3	400	108	27
	Average (%)		27.5

TABLE VII NORMAL CONSISTENCY OF CEMENT WITH DIFFERENT DOSAGES OF HRWR

Percentage Dosage of HRWR by Wt. of Cement	Normal Consistency (%)	Percentage of Water Reduction
0	27.5	-
0.8	26	5.45
1.6	25	9.09
1.65	24.75	10
1.7	24.65	10.36
1.75	24.55	10.73
2.4	24.25	11.82
2.7	22.25	19.09

According to the test results, increase in dosage of HRWR by weight of cement decreases the normal consistency and amount of water.

E. Setting Time Test

The setting time of cement is very important in the construction projects. This test is to determine the time required for cement paste to harden. The setting time of cement is determined according to ASTM C 191 and is measured by Vicat apparatus. Setting is divided into initial and final set. The initial setting time should not occur in less than 45 min and the final setting time should not be greater than 375 min according to ASTM standard. The results of setting time of Crown cement and cement with various dosages of HRWR admixtures are described in Table VIII and illustrated in Figure1.

TABLE VIII SETTING TIME OF CROWN CEMENT WITH DIFFERENT DOSAGES OF HRWR

Percentage Dosage of HRWR by Wt. of Cement	Initial Setting Time (min)	Final Setting Time (min)
0	62	140
0.8	150	270
1.6	170	290
1.65	180	310
1.7	230	335
1.75	240	345
2.4	290	435
2.7	325	495

The initial and final setting times of cement alone and cement with different dosages of HRWR admixtures are within standard limit except those for greater than 1.75% of admixture by weight of cement.

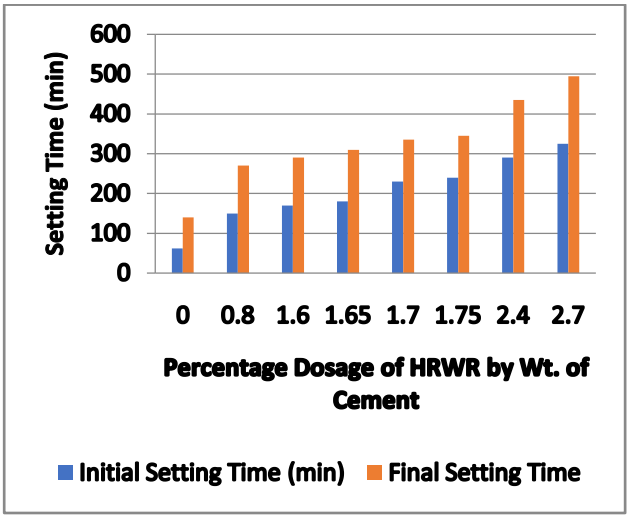

FIGURE 1.SETTING TIME OF CEMENT WITH HRWR ADMIXTURE

F.Soundness Test

The soundness of cement refers to the stability of the volume change in the process of setting and hardening.The soundness test is performed with the help of Le-Chatelier apparatus. The expansion exhibited by the Le-Chatelier mould should not exceed 1 mm for any type of Portland cement. This test is carried out according to ASTM C151-00.The test results of Crown cement and with various dosages (0.8%, 1.6%, 2.4%, 2.7%) of HRWR admixtures are summarized in Table IX.

TABLE IX SOUNDNESS OF CROWN CEMENT WITH DIFFERENT DOSAGES OF HRWR

Percentage Dosage of HRWR by Wt. of Cement	Soundness (mm)
0	0.9
0.8	0.33
1.6	0.53
2.4	0.6
2.7	0.87

It is found that the lowest value of soundness is achieved at 0.8% of HRWR admixture but the increasing the

dosage of admixture, the soundness value is increased and all of these are within the ASTM limit and also still lower than that of cement only. Therefore, the expansion of concrete can be reduced by using HRWR admixture and also reduced the cracking of concrete.

G. Sieve Analysis of Fine and Coarse Aggregates

Fine aggregate is defined as aggregate, which passes entirely through a 9.5 mm sieve and passes through a 4.75 mm sieve with more than 85%.Fineness modulus test is carried out according to ASTM C136-01.The standard specification of fineness modulus in fine aggregate is between 1.6 and 3.Coarse aggregate is defined as aggregate which is retained on a 4.75 mm sieve with more than 85%. Tables X and XI show the test results of sieve analysis of fine and coarse aggregates respectively.

TABLE X SIEVE ANALYSIS OF FINE AGGREGATE

Sieve No.	Sieve Opening (mm)	Wt. Retained (g)	Percent Retained (%)	Accumulated Percentage Retained (%)	Finer (%)
4	4.75	-	-	-	100
8	2.36	10	2	2	98
16	1.18	96.2	19.24	21.24	78.76
30	0.595	178.0	35.60	56.84	43.16
50	0.297	153.7	30.74	87.58	12.24
100	0.149	56.2	11.24	98.82	1.18
Pan		5.9	1.18	-	--
Total		500.0	100.00	266.48	-

According to the test result, the fineness modulus of fine aggregate is 2.66 and it is within typical range.

TABLE XI SIEVE ANALYSIS OF COARSE AGGREGATE

Sieve No.	Sieve Opening (mm)	Wt. Retained (g)	Percent Retained (%)	Accumulated Percentage Retained (%)
11/2 in	37.5	-	-	-
3/4 in	19.0	927.9	927.9	92.79
3/8 in	9.5	72.1	72.1	100
No.4	4.75	-	-	100
No.8	2.36			100
No.16	1.18	-	-	100
No.30	0.595	-	-	100
No.50	0.297	-	-	100
No.100	0.149	-	-	100
Pan		-	-	-
Total		1000	100	∑= 792.79

From the test result, the fineness modulus of coarse aggregate is 7.93. Limit for fineness modulus of coarse aggregate is range from 5.5 to 8. So, the result is within the limit.

H. Specific Gravity and Water Absorption of Fine and Coarse Aggregates

The saturated-surface-dry aggregate is defined as the aggregate whose pores are completely filled with water, but have no water adhering to the outside surface. The fine aggregate loses all uncombined water when it is dried at a temperature of 110 ± 5°C for a sufficient period. These tests are carried out according to ASTM C128. The test results for water absorption of fine and coarse aggregates are shown in Tables XII and XIII respectively.

TABLE XII WATER ABSORPTION OF FINE AGGREGATE

Test No.	1	2	3
Wt. of container + Wt. of wet fine aggregate (g)	160.5	161.7	160.2
Wt. of container + Wt. of dry fine aggregate (g)	159.6	160.8	159.3
Wt. of container (g)	68.0	67.9	68.2
Wt. of water (W_w) (g)	0.9	0.9	0.9
Wt. of dry fine (W_d) (g)	91.6	92.9	91.1
Absorption (%)	0.98	0.97	0.99
Average (%)	0.98		

TABLE XIII WATER ABSORPTION OF COARSE AGGREGATE

Test No.	1	2	3
Wt. of saturated surface dry sample, B (g)	4000	4000	4000
Wt. of oven dry sample, A (g)	3986.5	3987.2	3985.2
Absorption (%)= B-A/A x 100	0.34	0.32	0.37
Average absorption (%)	0.34		

Table XIVand Table XV show the test results of specific gravity of fine and coarse aggregates.

TABLE XIV SPECIFIC GRAVITY OF FINE AGGREGATE

Test No.	1	2	3
Wt. of fine aggregate (g)	500	500	500
Wt. of bottle, W_1 (g)	151.6	154.0	152.8
Weight of bottle + water, W_2 (g)	652.2	649.9	649.6
Weight of bottle + water + sand, W_3 (g)	962.0	958.9	958.3
Specific Gravity	2.63	2.62	2.61
Average	2.62		

TABLE XV SPECIFIC GRAVITY OF COARSE AGGREGATE

Test No.	1	2	3
Wt. of SSD aggregate, B (g)	4000	4000	4000
Wt. of saturated sample in water, C (g)	2552	2592	2556
Specific gravity= B/ (B-C)	2.76	2.84	2.77
Average specific gravity	2.79		

From the test results, it is found that the specific gravity of fine aggregate is 2.62 within the standard range of 2.5 to 2.7 and that of coarse aggregate is 2.79 which is between 2.6 and 3. Water absorption of fine and coarse aggregates are 0.98 and 0.34 respectively. These values are within 0.2% to 4%. So, all test results are within the standard limits.

IV. TESTING ON STRENGTH OF MORTAR AND CONCRETE

To evaluate the dosage of HRWR admixture influence on strength of cement mortar and concrete, the strength tests for mortar and concrete are carried out according to ASTM procedures. The compressive strength of mortar is tested with cement alone and with HRWR admixture 0.8%, 1.6%, 1.65%, 1.7%, 1.8%, 2%, 2.4% and 2.7%. The tensile strength of mortar is tested with cement alone and with HRWR admixture 0.8%, 1.6%, 1.65%, 1.7%, 2.4% and 2.7%. The samples are tested for 3, 7, 28 and 91days compressive strength of mortar using w/c obtained from flow table test and tensile strength using w/c obtained from normal consistency.

A. Compressive Strength Test for Mortar

The purpose of this test is to determine the compressive strength of (1:2.75) mortar composed of the cement and sand. In this test w/c ratios for various dosages of HRWR admixture are determined based on constant flow 110%. Required amount of material for compressive strength of mortar with various dosages of HRWR admixture based on constant flow 110is shown in Table XVI. Compressive strengths of mortar with various dosages of HRWR admixture are summarized in Table XVII and illustrated in Figure 2.

TABLE XVI

REQUIRED AMOUNT OF MATERIAL FOR COMPRESSIVE STRENGTH OF MORTAR

Percentages of Admixture by Weight of Cement	Wt. of Cement (g)	Wt. of Admixture (g)	Wt. of Sand, SSD (g)	Wt. of Water (g)	w/c	Percentage of Water Reduction (%)
0	1000	-	2729.375	600	0.6	-
0.8	1000	1.6	2729.375	570	0.57	5
1.6	1000	3.2	2729.375	550	0.55	8.33
1.65	1000	3.3	2729.375	545	0.545	9.2
1.7	1000	3.4	2729.375	540	0.54	10
1.8	1000	3.6	2729.375	535	0.535	10.8
2	1000	4	2729.375	520	0.52	13.3
2.4	1000	4.8	2729.375	500	0.5	16.7
2.7	1000	5.4	2729.375	485	0.485	19.2

TABLE XVII

COMPRESSIVE STRENGTH OF MORTAR WITH DIFFERENT DOSAGES OF HRWR

Percentages of Admixture by Weight of Cement	3 days Strength (MPa)	7 days Strength (MPa)	28 days Strength (MPa)	91 days Strength (MPa)
0	10.92	16.03	22.21	23.59
0.8	28.32	29.93	36.49	37.91
1.6	31.54	33.47	39.77	41.26
1.65	30.92	33.12	39.21	40.32
1.7	30.94	33.07	38.93	40.24
1.8	30.36	33.02	38.4	39.78
2	29.35	31.28	36.46	37.55
2.4	14.03	17.38	24.46	25.15
2.7	11.46	16.35	22.14	22.87

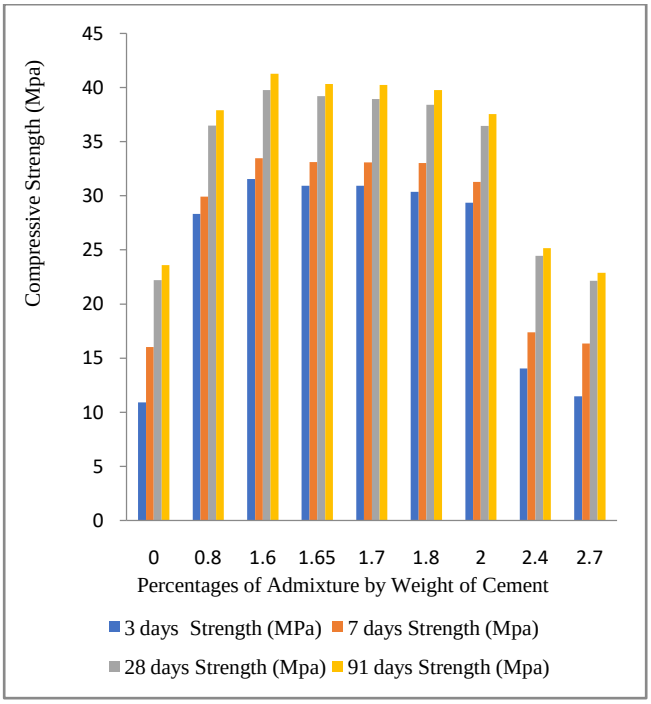

FIGURE 2. COMPRESSIVE STRENGTH OF MORTAR WITH DIFFERENT PERCENTAGES OF HRWR ADMIXTURE

According to the test results, the highest compressive strength of mortar is 41.26 MPa at 91 days when 1.6% dosage of admixture by weight of cement is added. At this dosage, 8.33% of water can be reduced when compared to without admixture condition. The strength of mortar with 2.4% of HRWR admixture is slightly greater than cement only mortar. Therefore, 1.6% dosage is selected as the optimum dosage for compressive strength of mortar.

B. Tensile Strength Test for Mortar

The objective of this test is to determine the tensile strength of the (1:3) cement-mortar composed of the cement and fine aggregate. The tensile strength of mortar with different dosages of HRWR admixture are tested by using various water to cement ratio based on normal consistency of cement and with HRWR admixture. The specimens are tested after 3, 7, 28 and 91 days. Standard limit of tensile strength of mortar for 7 and 28 days are

1.96 MPa and 2.46 MPa respectively. Required amount of material for tensile strength of mortar is expressed in Table XVIII. The test results are summarized in Table XIX and illustrated in Figure 3.

TABLE XVIII

REQUIRED AMOUNT OF MATERIAL FOR TENSILE STRENGTH OF MORTAR

Percentages of Admixture by Weight of Cement	Normal Consistency (%)	Wt. of Cement (g)	Wt. of Admixture (g)	Wt. of Sand, SSD (g)	Required Water (%)	Wt. of Water (g)	Percentage of Water Reduction (%)
0	27.5	480	-	1440	11.08	213	-
0.8	26	480	3.84	1440	10.83	208	2.35
1.6	25	480	7.68	1440	10.67	205	3.76
1.65	24.75	480	7.92	1440	10.63	204	4.23
1.7	24.65	480	8.16	1440	10.61	203	4.69
2.4	24.25	480	11.52	1440	10.54	202	5.16
2.7	22.25	480	12.96	1440	10.21	196	7.98

According to the test results, the highest tensile strength of the mortar is achieved at 1.6% dosage of admixture by weight of cement and beyond this dosage; the tensile strengths are gradually decreased. At this dosage, 3.76% of water can be reduced when compared to without admixture condition. In addition, all 7 days and 28 days strength are greater than the standard limit except 2.7% dosage of HRWR.

TABLE XIX

TENSILE STRENGTH OF MORTAR WITH DIFFERENT DOSAGES OF HRWR

Percentages of Admixture by Weight of Cement	3 days Strength (MPa)	7 days Strength (MPa)	28 days Strength (MPa)	91 days Strength (MPa)
0	1.19	1.72	2.43	2.53
0.8	1.72	2.08	2.86	3.03
1.6	1.94	2.19	3.06	3.28
1.65	1.83	2.01	2.81	2.84
1.7	1.61	1.81	2.50	2.55
2.4	1.57	1.78	2.46	2.48
2.7	1.27	1.68	2.09	2.11

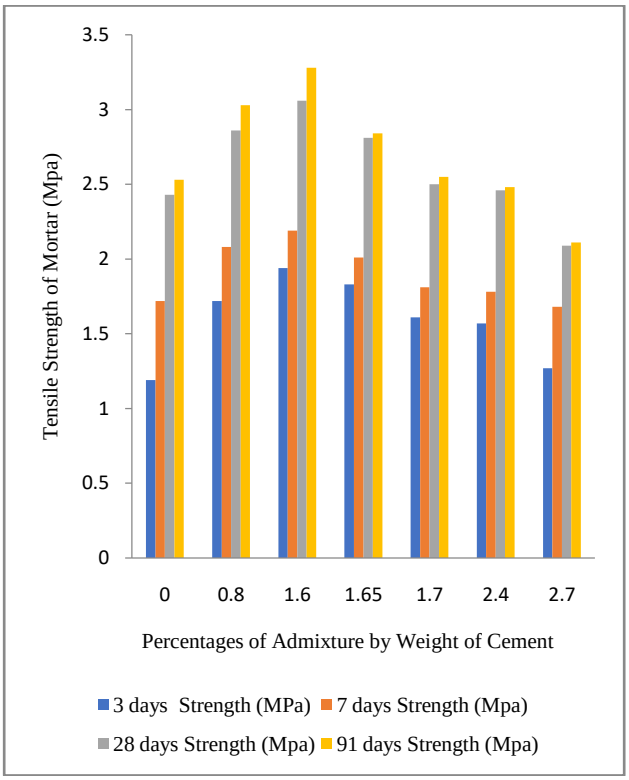

FIGURE 3. TENSILE STRENGTH OF MORTAR WITH DIFFERENT PERCENTAGES OF HRWR ADMIXTURE

C. Compressive Strength Test for Concrete

In this paper, target strength of concrete is considered as 34.5MPa. To achieve the target strength, the mix design is calculated by ACI method. In order to use HRWR admixture, the amount of water is reduced 5% and 10% from the mix design w/c. For w/c 0.396, 0.6%, 0.8%, and 1% dosages and

for w/c 0.346, 0.8%, 1.2% and 1.4% dosages of HRWR admixture are used to determine the strength of concrete. The compressive strength is tested at 3, 7 and 28 days. The test results of compressive strength with two different w/c ratios for cement alone and with various dosages of HRWR admixture are described in Tables XX and XXI and illustrated in Figure 4 and 5 respectively.

TABLE XX

COMPRESSIVE STRENGTH OF CONCRETE WITH W/C 0.396

% of Admixture	Compressive Strength of Concrete (MPa)			Remark
	3 Days	7 Days	28 Days	
-	16.23	24.33	33.96	Target Strength 34.5MPa
0.6	21.41	27.24	38.92	
0.8	23.03	29.61	41.12	
1	24.22	31.31	41.75	

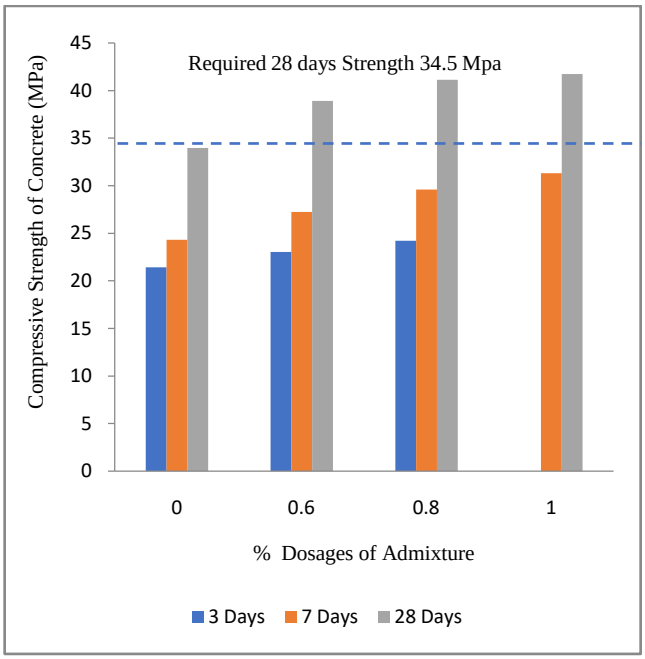

FIGURE 4. COMPRESSIVE STRENGTH OF CONCRETE WITH DIFFERENT DOSAGES OF HRWR ADMIXTURE FOR W/C 0.396

TABLE XXI

COMPRESSIVE STRENGTH OF CONCRETE WITH W/C 0.346

% of Admixture	Compressive Strength of Concrete (MPa)			Remark
	3 Days	7 Days	28 Days	
-	17.68	24.11	35.46	Target Strength 34.5MPa
0.8	22.93	29.48	40.95	
1.2	25.77	32.64	42.95	
1.4	26.5	35.63	43.45	

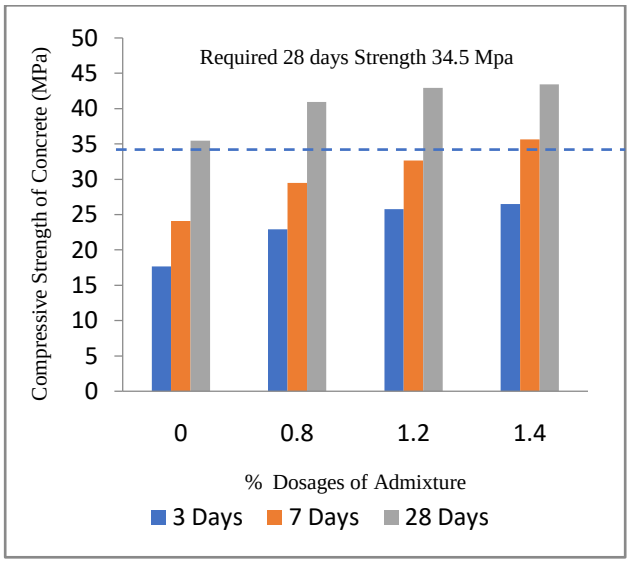

FIGURE 5. COMPRESSIVE STRENGTH OF CONCRETE WITH DIFFERENT DOSAGES OF HRWR ADMIXTURE FOR W/C 0.346

V. CONCLUSION

Based on the laboratory research carried out for this investigation, the following conclusion can be pointed out.

1) First dosage of 0.8% HRWR admixture, the tensile and compressive strength of mortar increased 1.4 and 2.5times at 3 days strength respectively, and increased about 1.15 and 1.5 times that of cement alone for other durations respectively.
2) Maximum compressive strength of mortar is obtained with the dosage of HRWR 1.6% and adding greater amount of dosage up to 1.8% achieved the approximately same amount of compressive strength.
3) Although increase the reduction of water, the strength of mortar can't increase as increase the dosage of HRWR admixture.
4) Increase the dosage of HRWR admixture; increase the strength of concrete in all durations. Target strength of concrete can be reached at 28days when w/c 0.396 and 0.6% dosage of HRWR admixture are added. To achieve target strength at early duration (7days strength), 1.4% dosage of HRWR with w/c 0.346 can be used.
5) At the same dosage of HRWR, the w/c ratio ±5% changes can't influence on the compressive strength of concrete.

REFERENCES

[1]. Finn, O.: Manufactring Portland Cement, Civil Engineering, Concrete Technology, (2011)
[2]. Bhavikatti, S.S.: Basic Civil Engineering, (2010)
[3]. Irving, K.: Engineering Concrete: Mix Design and Test Methods, Concrete Technology Series, (1999)
[4]. Nyi, H. N.: Properties of Concrete and Steel Design Concepts in Concrete Engineering, (1992)

[5]. Nevile, A. M., Brooks, J .J.: Concrete Technology, English Language Book Society, (1990)
[6]. Ramachandran, V .S., and Malhotra, V .M.; Concrete Admixtures Handbook: Properties, Science, and Technology, Noyes Publications, Park Ridge, New Jersey, (1984)