Effect of Compressive Strength on Concrete in Hot Weather

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Abstract

In the city of Rajshahi, Bangladesh the temperature of atmosphere is very high during the summer season and there is a fluctuation of temperature throughout the year. In hot weather, it is very difficult to carry out the concrete work. The main problem in hot weather is the increased demand of water. Due to increased temperature, high initial rate of hydration occurs which retards the subsequent hydration and there is non-uniform distribution of products of hydration which effects strength. In this study, the potential effect of high atmospheric temperature on concrete compressive strength is evaluated. To carry out these work, total 96 concrete cylinders were prepared in which 80 cylinders were cast in high environment temperature (summer seasons) and another 16 cylinders were cast in comparatively low temperature (winter season). From the experimental results it is found that the hot weather has an adverse effect on the compressive strength of concrete i.e. compressive strength decreases with the increment of temperature. ASTM type D admixture is suitable for hot weather in 0.60 and 0.65 water cement ratio.

Keywords: Hot weather; environment temperature; compressive strength; admixture; water cement ratio.

1 Introduction

Bangladesh has a subtropical monsoon climate characterized by wide seasonal variations in rainfall, high temperatures and humidity. There are three distinct seasons in Bangladesh: a hot, humid summer from March to June; a rainy monsoon season from June to October; and a cool, dry winter from October to March. In general, maximum summer temperatures range between 30°C and 40°C (Climate of the world, Weather Online). In the last 14 years, Bangladesh Metrological Department recorded the highest temperatures a blistering 42.2°C in its Jessore district and 38°C in the Dhaka city. The highest temperature in 1995 was recorded as 43°C in Rajshahi, and 39°C in the capital Dhaka (Asian Tribune). The summer season in Bangladesh of month from March to June, the maximum temperature this time is greater than 40°C. Relative humidity in hot weather season month March to June varies from 66% to 83.7%, but the average relative humidity from March to May is near about 66% (Chowdhury and Islam, 2008). High plastic concrete temperatures affect important properties of the plastic mixture: increase water demand of the mixture, increase slump loss, reduction in setting times, increase tendency for plastic shrinkage cracking, difficulty in finishing, and reduce control of entrained air content (Properties of Set Concrete at Early Ages, 1981). High mixture temperatures also affect important properties of the hardened concrete such as reduction of ultimate strength, increased tendency for moisture and thermal shrinkage cracks, decrease material durability, and decrease uniformity of surface appearance (Samarai et al, 1983). Suitable precautions must be carried out in situations where high temperatures exist in order to achieve uniformly good concrete quality that will perform adequately in the plastic and hardened states (Schrader, 1987).

It has been found that high early temperature has negative impacts on later strength of concrete. High initial rate of hydration due to increased temperature retards the subsequent hydration and produces a non-uniform distribution of the products of hydration. Its reason is that at high initial rate of hydration, there is insufficient time available for the diffusion of the products of hydration away from the cement particle and for a uniform precipitation in the interstitial space (Husain et al, 2016). ACI Committee – 305 (Farmington Hills, 2010) defines hot weather as any combination of high ambient temperature, high concrete temperature, low relative humidity, wind speed and solar radiation and the maximum allowable fresh concrete temperature is 35 °C and stressed the importance of carefully monitoring conditions to minimize evaporation, especially until proper curing methods have been put in place. They also suggested several methods to reduce the temperature of concrete, including shading aggregate stockpiles, sprinkling water on coarse aggregate stockpiles, using chilled water for concrete

production, substituting chipped or shaved ice for portions of the mixing water and cooling concrete materials using liquid nitrogen. Therefore in this study, the potential effect of high atmospheric temperature on concrete compressive strength is evaluated. To carry out these work, total 96 concrete cylinders were prepared in which 80 cylinders were cast in high environment temperature (summer seasons) and another 16 cylinders were cast in comparatively low temperature (winter season).

2 Experimental Programs

The materials are collected, and then find out the properties of the materials. Mix design of concrete are find out thoroughly and then samples are prepared. After that 28days curing is done properly and then cylinders are tested in the universal testing machine. In this study stone coarse aggregates were used that were collected from Panchagar district. Two types of fine aggregates were used such as coarse sand (domar sand) having F.M. = 2.50 and other fine sand (local sand) having F.M. = 1.35. The domar sand was collected from Panchagar district and local sand was collected from padma river at Rajshahi. Ordinary Portland Cement (OPC) is used to prepare the specimen. In this study, Pozzolith CRP4 admixture was used. Fly ash was collected from Barapukuria coal mining company.

3 Test Result and Discussion

Five types of concrete specimens are used in this study. The cylindrical specimen's size is considered as 6" diameter and 12" height. 10 cylinders were prepared by using each number of water-cement ratios like 0.45, 0.50, 0.55, 0.60, 0.65, 0.70, 0.75 and 0.8. Among 10 cylinders 2 cylinders were cast only plain cement concrete, 2 cylinders were cast by using 5% fly ash, 2 cylinders were cast by using 10% fly ash, 2 cylinders were cast by using 7.5 ml/kg cement of admixture, 2 cylinders were cast by using 10 ml/kg cement of admixture. Total 80 cylinders were cast and all cylinders were cast when ambient temperature was above the 35°C. There were five types of specimen in the study which are summarized in the following Table1.

Table 1. Type of Specimen.

Specimen Type	Concrete
Type 1	Normal Concrete with 8 different ratio like as W1-0.45; W2-0.5; W3-0.55; W4-0.60; W5-0.65; W6-0.70; W7-0.75; W8-0.85.
Type 2	Normal Concrete with 5% fly ash with 8 different ratio like as W1F1-0.45; W2F1-0.5; W3F1-0.55; W4F1-0.60; W5F1-0.65; W6F1-0.70; W7F1-0.75; W8F1-0.85.
Type 3	Normal Concrete with 10% fly ash with 8 different ratio like as W1F2-0.45; W2F2-0.5; W3F2-0.55; W4F2-0.60; W5F2-0.65; W6F2-0.70; W7F2-0.75; W8F2-0.85.
Type 4	Normal Concrete with 7.5ml/kg cement admixture with 8 different ratio like as W1A1-0.45; W2A1-0.5; W3A1-0.55; W4A1-0.60; W5A1-0.65; W6A1-0.70; W7A1-0.75; W8A1-0.85.
Type 5	Normal Concrete with 10 ml/kg cement admixture with 8 different ratio like as W1A2-0.45; W2A2-0.5; W3A2-0.55; W4A2-0.60; W5A2-0.65; W6A2-0.70; W7A2-0.75; W8A2-0.85.

Table 2. Compressive strength of the specimens in hot weather for 0.5 water–cement ratio.

Water - Cement Ratio	Tempe-rature (˚C)	Humidity (%)	Type of Cylinder	Machine Load (KN)	Average Machine Load(KN)	Cross Sectional Area(mm^2)	Compressive Strength (N/mm2)	Compressive Strength (psi)
0.5	37.6	56	W2	335.00 327.00	331.000	18232.22	18.15	2632
0.5	37.6	56	W2F1	332.00 335.00	333.500	18232.22	18.29	2652
0.5	37.6	56	W2F2	355.00 345.00	350.000	18232.22	19.20	2784
0.5	37.6	56	W2A1	345.00 362.00	353.500	18232.22	19.39	2811
0.5	37.6	56	W2A2	365.00 385.00	375.000	18232.22	20.57	2982

Table 3. Compressive strength of the specimens in hot weather for 0.55 water–cement ratio.

Water - Cement Ratio	Tempe-rature (˚C)	Humidity (%)	Type of Cylinder	Machine Load (KN)	Average Machine Load(KN)	Cross Sectional Area(mm^2)	Compressive Strength (N/mm2)	Compressive Strength (psi)
0.55	35.9	63	W3	335.00 333.00	334.000	18232.22	18.32	2656
0.55	35.9	63	W3F1	328.00 360.00	344.000	18232.22	18.87	2736
0.55	35.9	63	W3F2	362.00 346.00	354.000	18232.22	19.42	2815
0.55	35.9	63	W3A1	388.00 382.00	385.000	18232.22	21.12	3062
0.55	35.9	63	W3A2	396.00 408.00	402.000	18232.22	22.05	3197

Table 4. Compressive strength of the specimens in hot weather for 0.60 water–cement ratio.

Water - Cement Ratio	Tempe-rature (˚C)	Humi-dity(%)	Type of Cylinder	Machine Load (KN)	Average Machine Load(KN)	Cross Sectional Area(mm^2)	Compressive Strength (N/mm2)	Compressive Strength(psi)
0.6	37.8	67	W4	380.00 368.00	374.000	18232.22	20.51	2974
0.6	37.8	67	W4F1	383.00 395.00	389.000	18232.22	21.34	3094
0.6	37.8	67	W4F2	387.00 380.00	383.500	18232.22	21.03	3050
0.6	37.8	67	W4A1	430.00 415.00	422.500	18232.22	23.17	3360
0.6	37.8	67	W4A2	445.00 437.00	441.000	18232.22	24.19	3507

From Table 2, it is seen that the ambient temperature was 37.6˚C, humidity 56% and water-cement ratio 0.5. The concrete mix was not workable due to hot environment weather. During the casting plain concrete, it was not possible to compact thoroughly, and for this reason these concrete cylinder was not obtained desired strength. Fly ash delay the setting time and help to gain strength of concrete, while these concrete mix are not workable, however little bit strength gain in these concrete. Admixture delay the setting time and help to gain strength, while these concrete mix are not workable, however little bit strength gain these concrete.

From Table 3, it is seen that the ambient temperature was 35.9˚C, humidity 63% and water-cement ratio 0.55. At hot environment, after few minutes of mixing the raw mix concrete became dry little bit. During the casting plain concrete, it was not possible to compact thoroughly, and for this reason these concrete cylinder was not obtained desired strength. Fly ash delay the setting time and help to gain strength of concrete, while these concrete mix are not workable, however W3F2 type concrete gain little bit strength. Admixture delay the setting time and help to gain strength, while these concrete mix are not workable, however admixture mix concrete gain little bit strength because of admixture help for gain strength.

The ambient temperature was 37.8˚C, humidity 67% and water-cement ratio 0.6 that is shown in Table 4. During the casting plain concrete, it was possible to compact correctly, and for this reason these concrete cylinder was obtained desired strength. Fly ash delay the setting time and help to gain strength of concrete, while these concrete mix was fully workable, however these concrete gain strength. Admixture delay the setting time and help to gain strength, while these concrete mix are totally workable, however these concrete attain appetency strength.

From Table 5, it is seen that the ambient temperature was 39.2˚C, humidity 51% and water-cement ratio 0.65. At hot environment, during the casting plain concrete cylinder, it was possible compact properly and for this reason these concrete are obtained desired strength. Fly ash delay the setting time and help to gain strength of concrete, while these concrete mix was fully workable, however these concrete gain strength. Admixture delay the setting time and help to gain strength, while these concrete mix are totally workable, however these concrete attain appetency strength.

Table 5. Compressive strength of the specimens in hot weather for 0.65 water–cement ratio.

Water - Cement Ratio	Tempe-rature (˚C)	Humidity (%)	Type of Cylinder	Machine Load (KN)	Average Machine Load(KN)	Cross Sectional Area(mm^2)	Compressive Strength (N/mm2)	Compressive Strength (psi)
0.65	39.2	51	W5	374.00 364.00	369.000	18232.22	20.24	2935
0.65	39.2	51	W5F1	350.00 400.00	375.000	18232.22	20.57	2982
0.65	39.2	51	W5F2	380.00 385.00	382.500	18232.22	20.98	3042
0.65	39.2	51	W5A1	426.00 415.00	420.500	18232.22	23.06	3344
0.65	39.2	51	W5A2	425.00 444.00	434.500	18232.22	23.83	3456

Table 6. Compressive strength of the specimens in hot weather for 0.7 water–cement ratio.

Water - Cement Ratio	Tempe-rature (˚C)	Humidity (%)	Type of Cylinder	Machine Load (KN)	Average Machine Load(KN)	Cross Sectional Area(mm^2)	Compressive Strength (N/mm2)	Compressive Strength (psi)
0.7	36.9	64	W6	340.00 318.00	329.000	18232.22	18.04	2617
0.7	36.9	64	W6F1	360.00 340.00	350.000	18232.22	19.20	2784
0.7	36.9	64	W6F2	345.00 380.00	362.500	18232.22	19.88	2883
0.7	36.9	64	W6A1	382.00 400.00	391.000	18232.22	21.45	3110
0.7	36.9	64	W6A2	395.00 408.00	401.500	18232.22	22.02	3193

The ambient temperature was 36.9˚C, humidity 64% and water-cement ratio 0.7 that is shown in Table 6. At hot environment, during time of mixing the raw mix concrete became little bit liquid. During the casting plain concrete cylinder, it was possible to compact properly but the mix was little bit liquid, and for this reason these concrete cylinder was not obtained desired strength. Fly ash delay the setting time and help to gain strength of concrete, while these concrete mix was little bit liquid, however little bit gain strength these concrete. Admixture delay the setting time and help to gain strength, however strength gain these concrete.

From Table 7, it is seen that the ambient temperature was 37.8˚C, humidity 63% and water-cement ratio 0.75. At hot environment, during time of mixing the raw mix concrete became little bit liquid. During the casting plain concrete cylinder, it was possible to compact properly but the mix was little bit liquid, and for this reason these concrete cylinder was not obtained desired strength. Fly ash delay the setting time and help to gain strength of concrete, while these concrete mix was little bit liquid, however little bit gain strength these concrete. Admixture delay the setting time and help to gain strength, however strength gain these concrete.

Variation of compressive strengths with different water-cement ratio for different types of concrete cylinder is shown in Figure 1. With the increase of water-cement ratio, the compressive strength is increasing too. But at 0.6 and 0.65 water-cement ratio, the compressive strength is found to be the highest in case of all type concretes. After increasing water-cement ratio above 0.6 and 0.65 the compressive strength keeps decreasing. The concrete containing Admixture has the most compressive strength at all water-cement ratio. Using fly ash in concrete decreases compressive strength by a little.

Table 7. Compressive strength of the specimens in hot weather for 0.75 water–cement ratio.

Water - Cement Ratio	Tempe-rature (˚C)	Humidity (%)	Type of Cylinder	Machine Load (KN)	Average Machine Load(KN)	Cross Sectional Area(mm^2)	Compressive Strength (N/mm2)	Compressive Strength (psi)
0.75	37.8	63	W7	265.00 294.00	279.500	18232.22	15.33	2223
0.75	37.8	63	W7F1	325.00 370.00	347.500	18232.22	19.06	2764
0.75	37.8	63	W7F2	355.00 345.00	350.000	18232.22	19.20	2784
0.75	37.8	63	W7A1	395.00 368.00	381.500	18232.22	20.92	3034
0.75	37.8	63	W7A2	420.00 383.00	401.500	18232.22	22.02	3193

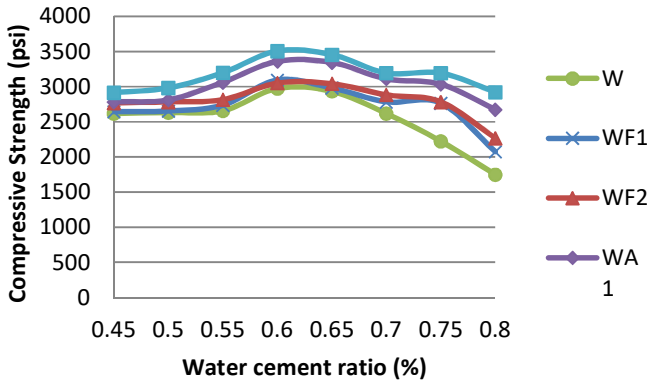

Figure 1. Compressive strength for different type concrete with different w/c ratio.

Table 8. Compressive strength of the specimens in cool weather.

Water - Cement Ratio	Temper-ature (°C)	Humidity (%)	Num. of Cylinder	Machine Load (KN)	Average Machine Load(KN)	Cross Sectional Area(mm^2)	Compressive Strength (N/mm2)	Compressive Strength (psi)
0.45	23.4	86	1 2	405.00 430.00	417.500	18232.22	22.90	3320
0.5	23.4	86	1 2	425.00 390.00	407.500	18232.22	22.35	3241
0.55	23.4	86	1 2	390.00 410.00	400.000	18232.22	21.94	3181
0.6	23.4	86	1 2	400.00 385.00	392.500	18232.22	21.53	3122
0.65	22.1	88	1 2	395.00 370.00	382.500	18232.22	20.98	3042
0.7	22.1	88	1 2	360.00 380.00	370.000	18232.22	20.29	2943
0.75	22.1	88	1 2	385.00 350.00	367.500	18232.22	20.16	2923
0.8	22.1	88	1 2	360.00 355.00	357.500	18232.22	19.61	2843

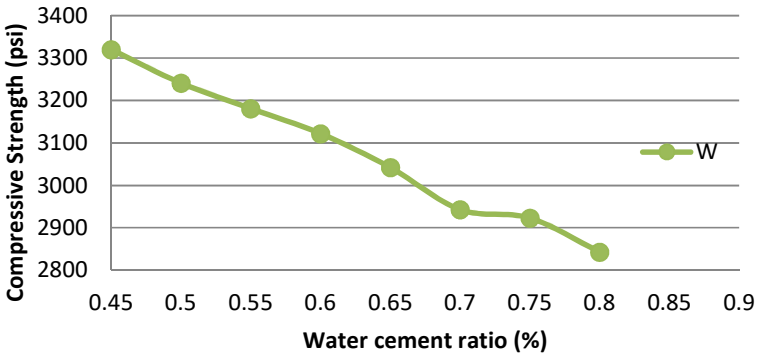

Figure 2. Compressive strength – water cement ratio plain concrete with different w/c ratio in cold weather.

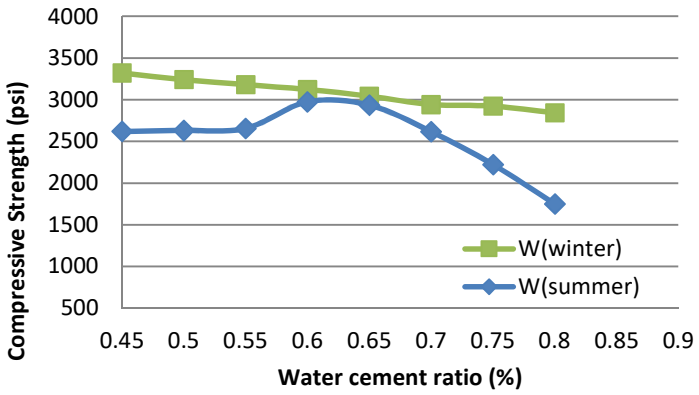

Figure 3. Compressive strength for plain concrete in summer and winter season.

From Table 8, it can be observed that the first four type concrete cylinder were casting when environment temperature was 23.4˚C; humidity was 86% and another four type concrete cylinder were casting when temperature was 22.1˚C; humidity was 88%. Concrete cylinder made with 0.45 water cement ratio obtained more strength than other concrete because in winter season of 0.45 water cement ratio concrete mixes thoroughly, workable and do properly compaction. On the other hand made of 0.80 ratio concrete obtained less strength than other concrete cylinder because in winter 0.80 ratio concrete mix thoroughly workable and done poorly compaction and concrete mix become liquid.

From Figure 2, it can be observed that the compressive strength of the concrete decreases with the increase in w/c ratio. Compressive strength for plain concrete in summer and winter seasons are shown in Figure 3. All number of water-cement ratios concrete gets much strength in winter season than the summer season except 0.6 and 0.65 water-cement ratio strength. However in summer seasons, concrete strength up to 0.55 water cement ratio are smaller, because of concrete mix is dry due to quickly evaporate of water in hot weather seasons. Concrete strength of 0.6 and 0.65 water-cement ratios approximately same in both season because in summer season in those water cement ratio concrete has no extra water required.

4 CONCLUSIONS

Compressive strength of concrete decreases with increase in water-cement ratio and decreasing the water-cement ratio increases compressive strength up to certain limit. The water cement ratio of 0.6 and 0.65 are very effective for hot weather. Used 10 ml/kg-cement admixture in the concrete then get average 26% more compressive strength than the plain concrete in hot weather. ASTM type D admixture very suitable for hot weather for 0.6 and 0.65 water cement ratio. Hot weather has an adverse effect on compressive strength i.e. compressive strength decreases with the increase of temperature. In hot weather it is very difficult to carry the concrete work because increased amount of water is needed in concrete which results in decrease of strength.

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