Concreting in dry hot climate

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Abstract. This article presents the influence of dry hot climate on properties of concrete mix and concrete generally during its production and delivery to construction site. Dry hot climate causes significant water evaporation (i.e. dehydration) of concrete during its setting which can lead to formation of cracks and other deformations of concrete [1÷5]. This experimental research investigating impact of additives on saving workability of concrete mix and on strength of hardened concrete can help in preventing such problems. It was experimentally proved that concrete without additives has significantly lower consistency. A variety of air-entraining additives, superplasticizers, and hyperplasticizers used for preventing loss of mixing water was checked for influence on consistency of concrete mix at high temperature. MC-Techniflow 70 taken as efficient additive is applied in amount of 1,2 % from cement mass, it helps to save workability of concrete mix longer and provides high strength both in 14 days – 29,2 MPa and in brand age of hardening – 35,0 MPa.

1. Introduction

Amount of concrete used in the country as well as in the whole world significantly exceeds amount of other construction materials. Nowadays it is
the most popular material used in various environments including aggressive ones with influence of high or low temperature, salt, acid in soil, air or water.

In summer in some Russian regions with dry and hot climate temperature can reach +25 °C and higher with low relative air humidity (less than 50 %) in daytime. These conditions can cause segregation and high water evaporation of concrete, which have significant influence on consistency and workability of concrete during its transportation and hardening at the construction site.

In this case if temperature increases and exceeds allowable limit, then water intensively evaporates, it results in forming a big amount of empty pores. As a consequence concrete density and strength decreases. In such conditions cement is not hydrated enough, porous structure of concrete is damaged, scales occur on its surface. Hydration of cement is the key element for producing high-quality concrete in dry and hot climate [4÷7].

Impact of high temperature during hardening provides high strength of concrete within first days, but then it changes to the opposite. Samples produced at normal temperature have higher strength. In a range of lower temperatures there is the optimum value at which concrete has highest strength.

There is a need to forecast possible change of concrete properties and make a series of operations for preventing loss of material quality in order to manage its delivery to construction site and further use [8÷11].

Intensive water evaporation during hardening leads to drying of surface; it increases possibility of plastic shrinkage and formation of cracks [5, 6, 12].

Water evaporation from concrete surface can be prevented by covering some materials, but it is necessary to prevent moisture loss during setting and delivery of concrete to construction site [8÷11].

Use of additives for production of concrete can solve these problems. It helps not only to save cement, it also prevents negative impact of high temperature, saves performance properties of concrete mix during its delivery, setting and hardening [13÷22].

This research investigates influence of additives as well as estimates their optimum content in order to save life of concrete mix in conditions of dry hot climate. Moreover it is necessary to clarify the influence of transportation, production conditions and additives on strength properties of hardened concrete.

2. Materials and Methods
Gravel, sand and cement are mixed till reaching homogeneous dry mix. Mixing performed on a metal pan, preliminary wiped with damp cloth in order to prevent overrun of water for watering the pan. Then hole in the mix is done. Then the mix of water and additive is prepared (water in additive-free mix is used without additive) and mixed till reaching homogeneous mix, then dry aggregates and cement is added to the mix, then mix is thoroughly blended within 5 minutes.

Final mix is tested for consistency – that is slump test of each concrete mix assessed before impact of high temperature according to GOST 10181-2000 “Concrete Mixtures. Methods of testing”. Consistency is ability of concrete mix to flow under gravity. Concrete mix workability is estimated by its consistency.

After slump test samples of concrete mix were sent to drying stove imitating hot conditions for 30 minutes. Temperature in stove was 50 ºС. Then slump test was done once again, results being put in laboratory log book. It was necessary to check influence of high temperature (i.e. the rate of water evaporation), and impact of additives on consistency of concrete mix.

After this concrete cubes in size 10x10x10 cm were formed.

Prepared forms filled with concrete mix stayed in drying stove 24 hours at 50 ºС. Then samples were taken out from the forms and placed in the same conditions with high temperature till the moment of strength gain within 14 and 28 days.

When reaching 14 and 28 days strength samples were sent to compression in order to compare strength properties of control samples with properties of final concrete.

3. Results and Discussion

Content of tested concrete samples including control sample per 1m³ of is mentioned in table 1.

Water-cement ratio was not changed.

Applied additives are numbered and mentioned in table 1 with volume (%) and consumption per batch (ml):

1. Centrament Air 202 – air-entraining additive
2. MC-PowerFlow 2695 – hyperplasticizer additive
3. MC-Techniflow 70 – strongly plasticizing additive
4. Centrament N 101 – superplasticizer of MC-generation

**Table 1.** Tested concrete samples.
### 3.1. Workability of tested samples

Results of workability based on cone slump index are presented in Figures 1-4, where initial consistency of concrete is highlighted in blue, consistency of concrete after influence of high temperature is highlighted in red. Result of combined influence of temperature and different additives on concrete mix was analyzed.

Cone slump of control sample without additives was 13 cm, after placing in drying stove its consistency decreased to 1 cm.

| Additive | Volume, % | № of sample | Consumption per 1 m³, kg |
|----------|-----------|-------------|--------------------------|
|          |           |             | Cement | Concrete | Gravel | Sand | Additive, ml |
| Control sample | - | 0 | 380 | 230 | 1320 | 590 | - |
| 1        | 0,2       | 1           | 380 | 230 | 1320 | 590 | 0,76 |
|          | 0,25      | 2           | 380 | 230 | 1320 | 590 | 0,95 |
|          | 0,3       | 3           | 380 | 230 | 1320 | 590 | 1,14 |
| 2        | 0,4       | 4           | 380 | 230 | 1320 | 590 | 1,52 |
|          | 0,5       | 5           | 380 | 230 | 1320 | 590 | 1,90 |
|          | 0,6       | 6           | 380 | 230 | 1320 | 590 | 2,28 |
| 3        | 1,0       | 7           | 380 | 230 | 1320 | 590 | 3,80 |
|          | 1,2       | 8           | 380 | 230 | 1320 | 590 | 4,56 |
|          | 1,4       | 9           | 380 | 230 | 1320 | 590 | 5,32 |
| 4        | 0,6       | 10          | 380 | 230 | 1320 | 590 | 2,28 |
|          | 0,8       | 11          | 380 | 230 | 1320 | 590 | 3,04 |
|          | 1,0       | 12          | 380 | 230 | 1320 | 590 | 3,80 |
Figure 1. Cone slump of concrete mix with additive Centrament Air 202. After influence of aggressive environment with high temperature Centrament Air 202 additive didn’t save required properties of concrete. Moreover, workability of concrete significantly decreased. Samples 1, 2 and 3 saved only 20 % on average of their consistency within mentioned volumes.

Figure 2. Cone slump of concrete mix with additive MC - PowerFlow 2695. Additive MC-PowerFlow 2695 in samples 4, 5 and 6 also didn’t help to save required consistency under the influence of high temperature. Initial cone slump decreased by 74 % on average after applying this additive in three different quantities.
Samples 7, 8 and 9 managed to save most of concrete consistency; it is 93% on average, cone slump decreased by 1 cm. MC-Techniflow 70 additive helped to save concrete workability (decrease of this value was not significant), each batch of additive had equal influence on consistency of concrete mix.

According to received results samples 10, 11 and 12 with Centrament N 101 additive saved on average only 74% of consistency. Influence of this additive is little worse than influence of additive 3, but it is more efficient than sample with additives 1 and 2.

Properties of concrete with additives were better than properties of control sample. Sample 3 showed best results and it is more appropriate to...
use additive 3 in case of transportation of concrete mix in dry and hot conditions.

3.2. Compressive strength

Influence of additive 1 on compressive strength of concrete mix 1, 2 and 3 is showed at Figure 5. According to results this additive gives high strength properties at 14 days age as well as at 28 days (-brand age). Maximum properties are 31,9 and 35,2 MPa (sample 2), though it does not help to save necessary consistency at high temperature, the mix loses big volume of water and its workability decreases almost to zero.

![Figure 5. Test results of samples 0, 1, 2 and 3 for compressive strength at 14 and 28 days age.](image)

![Figure 6. Test results of samples 0, 4, 5 and 6 for compressive strength in 14 and 28 days age.](image)
According to results (Figure 6) samples 4, 5 and 6 had significant decrease of compressive strength by 37% on average each of them. Additive applied in tested samples did not help to save required consistency at of high temperature; it means that it is unprofitable to use it in such conditions.

![Compressive strength chart](attachment:image.png)

**Figure 7.** Test results of samples 0, 7, 8 and 9 for compressive strength in 14 and 28 days age.

Test results (Figure 7) of sample 7, 8 and 9 for compressive strength showed that compressive strength stays the same when applying additive 3 with volume 1.2% of adhesive; compressive strength of the concrete decreases if volume of additive is changed. Moreover, use of this additive at high temperature helped to save initial compressive strength and required workability of concrete.

Maximum approached compressive strength at early and branded age of concrete hardening with volume of additive 1.2% is 29.2 MPa and 35.0 MPa accordingly, which saves compressive strength in comparison with control sample (concrete mix without additive).
Figure 8. Test results of samples 0, 10, 11 and 12 for compressive strength at 14 and 28 days age.

Samples 10, 11 and 12 showed decrease of compressive strength (Figure 8) in early (by 20 %) as well as in branded concrete (by 19 %), that means this additive is not efficient for use at high temperature. Effect from use of this additive was a little worse than from the additive 3, but better than use of additives 1 and 2.

Sample 8 had the highest compressive strength (35,0 MPa), which complies with compressive strength of B25 concrete.

4. Conclusion

Tested additives showed that use of chemicals for mixing concrete helps to regulate its properties. Each additive has different influence on consistency of concrete mix prepared in high temperature conditions. Additives Centrament Air 202 and MC-PowerFlow 2695 did not save consistency of concrete in conditions of dry hot climate. Centrament N 101 additive saved consistency almost completely, though MC-Techniflow 70 saves consistency most efficiently.

Centrament Air 202 additives used in different quantities shows different compressive strength (32,5 MPa at content of 0,25% in branded age of hardening), but in condition of dry hot climate consistency of mix decreases almost to zero, that is why it is not possible to use it in high temperature conditions.

Use of MC-PowerFlow 2695 caused significant decrease of compressive strength (by 37 %) and did not save required consistency of concrete.

Use of Centrament N 101 showed decrease of compressive strength (by 19 %), but it was more efficient in saving concrete in dry hot climate in comparison with two previous additives.
MC-Techniflow 70 is taken as the most effective additive, its compressive strength complies with compressive strength of control sample (35.0 MPa) with 1.2% of additive, consistency stays the same.

Tested additives are efficient for use of concrete mix in dry hot climate, but it is necessary to compare consumption of additive and its efficiency.

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