Mechanical properties of hardened concrete in hot and dry climate

Vasiliy Korovyakov¹, Polina Reshetneva² and Vadim Solovyov²

¹Research Institute Mosstroy, 105066, Moscow, Russian Federation  
²Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia

E-mail: polinaresh@mail.ru

Abstract. Concrete is the most popular material in construction industry. Recycling of waste and their application in the construction industry are the main purpose in the world economy. The concrete working in dry and hot climate are exposed to high temperatures in the summer. The temperature can increase up to 50 °C while the relative humidity drops to 10-15% and lower. Climatic conditions lead to decrease the performance properties (strength and modulus of elasticity). The basic tasks of region with dry and hot climate are improve resistance and efficiency of concrete. An extreme daily change in temperature, low humidity, soil salinity are the main cause of erosion of concrete. One of the way of optimizing of cracking resistance of the concrete is to increase the amount of cementitious components. The dependencies of experiment with similar climatic conditions based on sulfate resistant cement were conducted. The results of experiment show that the optimal content of materials in concrete included 530 kg of cement; 833 kg of quartz sand; 873 kg of coarse aggregate; 1.5 liters of plasticizer and 176 liters of water. The designed mixture had the following characteristics: the density 2414 kg/m³, the compressive strength in 28-day at the range of 47 MPa, water permeability - W4, with water cement ratio equal to 0.34.

1. Introduction

Concrete is one of the main types of building materials due to the presence of objective factors. There are satisfaction of architectural requirements in the design of various functional purposes; low energy intensity of raw materials and technological processes for obtaining concrete; favorable ecological and economic indicators of production and use of concrete and uniqueness of physicochemical properties [1]. Reinforced concrete structures can be destroyed in a few months after its creation due to the violation of the anfollowed rules of raw material work, and the technology of concrete production is disrupted. Status of concrete and reinforced concrete structures, constructed and operated in hot climates, it is extremely dissimilarity. Along with structures that have operated for more than 20 years and are in satisfactory condition, new designs often require repair or restoration.

For many construction companies this climate is atypical and complex. During the operation of the structure, the harmful effect of increased shrinkage of concrete in hot dry climate conditions is manifested. Shrinkage and shrinkage macro- and microstructural stresses cause the formation of macro- and microcracks in concrete.

Internal cracking causes not only shrinkage, but a thermal deformation also as well. Large fluctuations in the temperature of the medium contribute to a difference in the dilatometric properties...
of the concrete components; aggregate and cement. Special attention should be given to the thermal compatibility of the constituents of concrete [2].

Corrosion of sulfate is appears in violation of selection of concrete. Such destruction is typical for the southern regions with saline soils. Usually this destruction occurs not in the summer, but in the autumn, because the anhydrous salt absorbs moisture and forms an aqueous salt. The mandatory condition for the use of reinforced concrete structures in hot dry climate is their protected of corrosive environments.

External processes here have an important role. Including the effect of temperature on the strength and density of cement concrete, prepared in dry hot climate. Studied an effect of casting temperature on strength and density of plain and blended cement concretes prepared and cured under hot weather conditions. The optimum casting temperature for OPC and SF cement concrete is 32 °C. The optimum casting temperature for fly ash, very fine fly ash, natural pozzolan and blast furnace slag is 38 °C [3].

In Facts, that cement which has less C₃A and C₃S is more sulfate resistant. Type CEM I-SR 5 [4] is used in case where sulfate resistance is important. The cement substitute (CR) is very sensitive to the absence of aging in a humid environment. In the opposite case, a cement substitute leads to a poor quality of concrete. Microsilica (SF) should be used to replace conventional Portland cement (OPC) within the maximum ratios as follows [5]. Replacing 10% of conventional portland cement with silica fumes that meet the chemical and physical properties. The replacement of 11% of conventional Portland cement with microsilica, taking into account the water-cement ratio and the minimum cement content according to the standard [6].

Microsilica is a very small pozzolanic material consisting mainly of amorphous silica (non-crystalline), manufactured using an electric arc furnace, as a byproduct of the production of simple silica or alloys containing silicon. Used as a replacement of cement to a certain percentage to improve the properties of concrete.

In hot climate experiments are also conducted. Using HSFC in hot climate slightly increases the compressive strength and reduces concrete permeability. Materials used as partial replacement of cement include class C and class F fly-ash, ground granulated blast furnace slag, and silica fume [7].

Experiments were conducted to determine the effect of climate on the durability of concrete structures. In this work experiment conducted in the Bukhara region (Uzbekistan).

An extreme daily change in temperature, low humidity, soil salinity are the main cause of erosion of concrete. Fig.1, 2, 3 show following disruptions occur If non-compliance and violation of technologies for concreting in a dry hot climate.

![Figure 1](image_url)

**Figure 1.** Open concrete surfaces with microcracks, point holes and small shells.
Macro-structural stresses occur due to the no uniform distribution of temperature or humidity in the concrete volume, under conditions preventing free deformation from shrinkage, swelling and temperature.

Numerous studies and experience [2, 3, 7, 8] of local construction have taken a number of measures on the technology of erecting concrete conglomerates. The maximum permissible temperature of the concrete mixture in the installation area should be 35 °C [9]. Using cooling water for mixing and heat reflective coatings. Use a previously recommended water-reducing additive-retarder, meeting type D [10].

Concrete surfaces should be kept constantly moistened for 24 hours in order to avoid loss of water as a result of evaporation and rapid rise in concrete temperature by performing the following actions: the watering or continuous spraying, maintaining the absorbent mat or material when wet, continuous protection from sunlight. Suggest using of waterproof paper for hardening concrete [11]. Care of freshly laid concrete should be started immediately after the end of the placement of the concrete mix and carried out until, as a rule, 70% of the design strength is achieved.

The right choice of raw materials such as cements, aggregates, water and additives, according to their characteristic compositions and chemical properties, is necessary for the production of high-performance, durable concrete, which should be most suitable for use in construction/design conditions and environmental conditions. Should not use additives containing chlorides or other corrosive substances acting on the valve.

2. Materials and methods
The technical requirements for structural concrete were as follows. Concrete is heavy structural concrete C30 [12]. Freeze thaw resistance should be assigned to structures exposed to the effect of alternating freezing and thawing of F50 in a humidified state (in practice, F75). Waterproof brand should be assigned to structures to which the limitations of the permeability W4 are required. The total content of sulphates in concrete from all sources, expressed as SO3, when tested in accordance [13], should not exceed 4% by weight of dry cement, including cement substitutes. Water mixing and water used for ice must be potable or otherwise tested for suitability according to the standard.

All components were cooled to normal temperature.
2.1. Cement

Weight of cement is 2400 kg/m$^3$, type of cement is CEM I-SR 5 42.5N with content of MgO less than 4%. Specific surface is 291 m$^2$/kg, content of sulfuric arid anhydride (SO$_3$) is 2.1% and specific efficiency of natural radionuclides – 81.0. There are specifications of Portland cement in Tables 1, 2.

**Table 1.** The chemical composition of cement.

| Component | Mass (%) |
|-----------|----------|
| SiO$_2$   | 21.88    |
| CaO       | 61.64    |
| Fe$_2$O$_3$ | 4.81    |
| Al$_2$O$_3$ | 4.33    |
| MgO       | 3.10     |
| free CaO  | 0.22     |

**Table 2.** The mineralogical composition of the cement.

| Component | Mass (%) |
|-----------|----------|
| C$_3$S    | 43.7     |
| C$_2$S    | 30.4     |
| C$_3$A    | 3.8      |
| C$_4$AF   | 14.5     |

2.2. Coarse aggregate

Coarse aggregate consists 5-20mm mixture fractions, real density 2.67 g/ cm$^3$. The granulometric of coarse aggregate show in Table 3.

**Table 3.** Granulometric (grain compositions).

| Hole diameter | 1.25 D | D | 0.5(D+d) | d |
|---------------|--------|---|----------|---|
| particular remainder,% | 25 | 20 | 15 | 10 | 5 |
| full remainder, % | - | 8.7 | 45.4 | 44.2 | 1.7 |
| regulatory value of the indicator | - | 8.7 | 54.1 | 98.3 | 100 |

Based on granulometric content of the crushed rock complies with requirements standard [14].

2.3. Fine aggregate

Fine aggregate consists density in natural condition – 1.44 g/cm$^3$, real density 2.75 g/ cm$^3$, humidity – 3.11%, content of grain is more than 5 in sand 10.15%.

**Table 4.** Grain composition.

| Sieve size | Particular | Full |
|------------|------------|------|
| 2.5        | 29.94      | 29.94|
| 1.25       | 18.97      | 48.91|
2.4. Supplement
Since the experiment conducted in the summer was used retarder plasticizer SikaPlast520N in respect of 0.28% by weight of cement.

3. Results
The results of experiment show that the optimal content of materials in concrete included 530 kg of cement; 833 kg of quartz sand; 873 kg of coarse aggregate; 1.5 liters of plasticizer and 176 liters of water. The designed mixture had the following characteristics: the density 2414 kg/m³, the compressive strength in 28-day at the range of 47 MPa, water permeability - W4, with water cement ratio equal to 0.34.

In the zone of laying the concrete mix, samples were taken for Slump tests, temperature of the concrete mix. The results of the research are: slump 130 mm, temperature of the concrete was equal to 30.5 °C, ambient temperature was equal to 35.6 °C.

Shaping of concrete has occurred in hot and dry climate. Than the samples were left for days in the environment. After was left in concrete moist room.

The samples 1-2-3 were tested in 7 days and 4-5-6 in 28 days respectively. The results are shown in the Table 5.

| Age in days | Weight, g | Sample size, mm³ | Breaking load with account of 1 kgf/cm² | Strength, MPa | Growth of Strength |
|------------|-----------|------------------|-----------------------------------------|--------------|--------------------|
| 7          | 2404      | 100x100x101      | 453.7                                   | 42.6         | 105%               |
|            | 2373      | 100x990x101      | 431.5                                   | 40.9         |                    |
|            | 2408      | 100x100x100      | 406.2                                   | 38.5         |                    |
|            | 2455      | 100x100x102      | 458.7                                   | 44.9         |                    |
|            | 2380      | 100x102x100      | 430.0                                   | 42.1         |                    |
|            | 2370      | 100x102x101      | 492.5                                   | 47.8         |                    |
| 28         |           |                  |                                         |              |                    |

4. Conclusion
The obtained data show that research presented concrete obtain high-quality concretes suitable for operation in hot dry climate conditions, which satisfy high strength indicators. Get the material with the desired properties.

In 7-day strength of concrete was already above the design strength. This indicates a high rate of strength development, which gets the concrete in hot and dry climate with a specified composition.

The strength of concrete at 28 days showed 20% more than the design strength. It is possible to reduce cement to silica fume to improve performance.

Anchoring durability of concrete in hot dry climate with its structure it is necessary to consider all the factors. Under certain conditions of service of the structure, the structure of the concrete can play a crucial role in its destruction. This situation is well illustrated by the analysis of the types of concrete.

Sand belongs to the group of sand with increased coarseness, grade II [15].

Table 5. Strength of concrete class CEM I-SR 5 42,5N.
destruction under the action of cyclic changes of temperature. Using the same initial materials durability of concrete is determined by the characteristics of its macrostructure.

These studies provide a new platform for discussion. There are fights against sulfate corrosion in regions of dry hot climate, the use of mixed cements based on AMA in an alternative to Sulphate-Resistant Portland Cement.

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