Fly ash of thermal power plant - micro fill for hydro technical concrete

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Abstract. The article presents the option of using ash - fly ash of the New-Angren Thermal Power Plant (NATPP) as micro filler of a raw mix of hydraulic concrete, as the most appropriate solution to the economic and environmental problems of the Tashkent region, Republic of Uzbekistan. The total amount of utilized ash and slag waste for the 9th month of 2019 is 45,630 tons, ash disposal 2554 tons in the NATPP. These figures show that, annually, only 12-13% of ash and slag waste is used by consumers for various purposes, the remaining 87-88% of ash and slag waste accumulate in ash and slag dumps and pollute the environment of the region. The chemical composition of fly ash as a part of the raw mix of hydraulic concrete was studied, in comparison with the chemical composition of Akhangaran cement grade M400, its physical and mechanical properties were determined. We have carried out several laboratory experiments, we obtained a quantitative dependence of the effect of the ash - cement ratio on cement consumption to obtain hydraulic concrete of the required strength. According to the test results, it was found that the heat of hydration released during the setting process decreases in proportion to the ash content. This property is of great interest when concreting massive hydraulic structures in the hot season. Experiments show that when replacing part of the cement with fly ash on the first day, the set of strength slows down, and after 7 days it accelerates by 12-15%. With the use of fly ash in an amount of 40% by weight of Portland cement of grade 400, heat dissipation during hydration is reduced by almost 30-35%, which is very important for hydraulic concrete, which increases crack resistance and resistance in an aggressive environment. Summarizing the above, it can be concluded that the use of large-tonnage fly ash of the NATPP in concrete technology is a big state task, solving the priorities of the further development of the national economy and one of the strategic ways to solve the environmental problem in the NATPP zone.

1. Introduction
Wastes from the heat and power industry of Uzbekistan are among the cheapest and most widespread types of local artificial mineral raw materials suitable for construction, including in concrete technology. Their reserves currently amount to several tens of millions of tons and their reserves are growing from year to year [1, 2, 3, 4]. In this regard, we have carried out studies on the rational use of ash and slag mixtures in the NATPP in hydraulic engineering. In 1984, at a distance of 4 km from the TPS, the first stage of the ash and ash slag dump was built with the launch of the first power unit. The design capacity of the ash and ash slag dump (ASD-1) amounted to 4.7 mln.m at the design level of the crest of the enclosing dam 712.0. Currently, ASD-1 is filled with ash and slag deposits. Its capacity is completely exhausted. In this regard, work is underway to reclaim the bowl.
However, in connection with the decision of the Cabinet of Ministers of the Republic of Uzbekistan on increasing brown coal burning at the NATPP, “an additional task for the design of a new ash and ash slag dump” is visible. The working volume of the capacity of the ASD-2 bowl is more than 12.8 million tons [5]. For 9 months of 2019, the total amount of ash sent to ASD_2 is 335.241.5 tons. Including for September, these figures were 12.766 tons. Currently, only 15 enterprises receive ash and slag waste for various purposes. The total amount of utilized ash and slag waste for the 9th month of 2019 is only 45.630 tons, ash disposal 2554 tons. These figures show that, annually, only 12-13% of ash and slag waste is used by consumers for various purposes, the remaining 87-88% of ash and slag waste accumulate in ash and slag dumps and pollute the environment of the region (Fig. 1).

Figure 1. Ash disposal site of NATPP

With the goal of utilizing ash and slag waste, it is a task of national importance dictated by the economy and ecology of industrial regions. The use of fly ash in concrete technology is a vivid example of the appropriate solution to this problem since fly ash is not only disposed of but also serves as a valuable raw material that improves the properties of concrete. However, widespread use became possible after conducting research in the field of concrete technology [6, 7, 8].

A thorough analysis of the condition was given on the use of ash and ash slag mixtures in concrete technology are given in [9, 10, 11]. Considering the options for using ash in concretes, the most promising type of ash from the point of view of the main technological processes and the properties of the resulting concrete is to recognize ash removal of dry removal. The normative basis for the use of fly ash in concrete was the State Standard of Uzbekistan (O’zDSt) 11024-84, as well as for instructions for the use of dry fly ash in the manufacture of heavy concrete structures [12, 13]. Analysis of published materials and studies shows the high technical and economic efficiency of the mass use of ash in concrete [14, 15]. This is since fly ash significantly affects some properties of concrete and allows them to be purposefully changed to a small extent. Available data suggest that fly ash is a multifunctional component of concrete, which meets the requirements of the State Standard of Uzbekistan (O’zDSt) 25813-83 [15, 17]. The multifunctionality is that it can serve as a filler, an active mineral additive, a plasticizer, and a filler. The significance of these functions depends on the properties of fly ash and the conditions for its use.

2. Method
The domestic and foreign published materials on the problems of using fly ash in concrete technology are analyzed. In as a research method, a system analysis was selected, based on state standards State Standard of Uzbekistan (O’zDSt) and other regulatory documents, approaches, methods, and ways of solving the scientific problem posed in the study. Portland cement of grade 400 of the Akhangaran plant with a limit on compressive strength after 28 days hardening under normal conditions $R = 39.0 -$
41.2 MPa was used as a binder; The natural sand of the Sergeli deposit was used as a fine aggregate, the sand property was investigated according to the method of State Standard of Uzbekistan (O’zDSt) 8735-75, State Standard of Uzbekistan (O’zDSt) 9758-77: bulk density 1420 kg/m³. The density of sand particles is 2.62 g/cm³. Coarse modulus Mₚ=1.65-1.72; During the experiments, crushed granite with grain sizes of 5 - 20 and 20 - 40 mm was used as a large aggregate.

As a micro filler, ash of the NATPP with a specific surface area S = 0.378 m²/g with a density of 2.38 g/cm³ was used. The chemical composition of fly ash of the NATPP is shown in table No. 1. The mineralogical composition of the ash of the NATPP is represented by hematite, quartz, feldspar and mulita. The ash contains 34.2% of the crystalline, 65.5% of the vitreous, and amorphous phases. According to its physical properties and chemical composition, fly ash of the NATPP meets the State Standard of Uzbekistan (O’zDSt) 25818-83.

3. Results
The chemical and phase-mineralogical compositions of fly ash are determined by the mineral composition of the combusted fuel, the mineral part of the ash and slag of almost all types of fuel consists of 97-98% of free aluminum and titanium, iron, calcium, magnesium, sodium and potassium oxides bound into chemical compounds. In addition to those indicated in it, there may be other elements from the table of D.I. Mendeleev. The chemical and phase-mineralogical compositions of fly ash obtained at the same thermal power plant during coal combustion in the same basin can vary at certain intervals (Table 1), which are usually neglected and considered to be stable in practical applications. The chemical composition of the fly ash of the NATPP (Table 1) indicates that the content of individual oxides, as well as fuel in the ash obtained from the pulverized combustion of various types of coal, has significant deviations. This determines the properties of fly ash and the area of its rational use in the technology of hydraulic concrete.

| Intervals | Al₂O₃ | TiO₂ | SiO₂ | MgO | Fe₂O₃ | CaO | MnO | Na₂O |
|-----------|-------|------|------|-----|-------|-----|-----|------|
| Day-1     | 7.5   | 0.5  | 64.3 | 3.3 | 2.8   | 0.2 | 2.4 | 8.4  |
| Day-5     | 7.5   | 0.33 | 64.3 | 1.6 | 4.3   | 0.17| 2.4 | 5.6  |
| Day-10    | 11.3  | 0.66 | 64.3 | 3.3 | 4.3   | 0.17| 2.4 | 11.2 |
| Day-15    | 7.5   | 0.5  | 64.3 | 3.3 | 2.8   | 0.17| 2.4 | 14   |
| Day-20    | 5.7   | 0.16 | 42.8 | 3.3 | 8.6   | 0.33| -   | 5.6  |
| Day-25    | 7.5   | 0.33 | 42.8 | 3.3 | 2.8   | 0.07| 1.2 | 11.2 |
| Day-30    | 11.3  | 0.5  | 42.8 | 5   | 2.8   | 0.1 | 2.4 | 8.4  |
| Av.ind.   | 8.32  | 0.42 | 5.51 | 3.3 | 3.95  | 0.17| 1.88| 8.80 |

Currently, various methods are known for selecting the consumption of fly ash in the technology of heavy and light concrete [18, 19, 20]. Considering the ash as a micro filler for hydraulic concrete, it can be assumed that as much ash should be introduced into the concrete to the total consumption ash and cement was equal to the optimal content of fine particles in concrete. Of course, ash also plays other functions in concrete, therefore, the found flow rate should be considered approximate, which will be specified in the experimental batches depending on the chemical activity of the ash and its water demand. In the experiments, fly ash of the NATPP of dry removal was used.

To establish the dependence of the effect of ash-cement ratio on cement consumption. Typically, the composition of ash-containing concrete is currently determined by experimental selection. However, it is possible to prescribe the composition of ash-containing heavy concrete with a given strength and workability of the concrete mixture using the traditional calculation and experimental method, modified taking into account the peculiarities of the influence of the addition of fly ash as an active micro filler. Carrying out several laboratory experiments, we obtained a quantitative
dependence of the effect of the ash-cement ratio on cement consumption to obtain hydraulic concrete of the required strength (Fig. 2).

![Figure 2](image-url)

**Figure 2.** Dependence of the influence of the ash-cement ratio on cement consumption. 1 – Class Concrete B 22.5 c OK=1...4 cm, 2- Class Concrete B 15 c OK=1...4 cm.

In the first section of the curves, a slight decrease in glue quality due to dilution of cement with ash was compensated by an increase in the total volume of the binder, which allowed a decrease in cement consumption [21, 22, 23, 24, 25].

When the required strength for concrete reaches the optimum thickness of the adhesive layer on the aggregate grains, a further increase in the volume of the binder does not increase the strength of the concrete. The increase in this ash cement ratio affects the quality of the adhesive increases the water content of the mixture and reduces the strength of concrete. The provision of the required concrete strength, seen in the second section, is offset by an increase in cement consumption (Fig. 2.)

For concrete of certain strength, made from a mixture of given mobility, the optimum possible $C/B$ corresponds to the minimum possible $C/C$. With an increase in the mobility of the concrete mix and the strength of concrete, the $C/B$ increases, and the $C/C$ decreases. This yields equality:

$$\frac{(C/W)_1}{(C/W)_2} = \frac{(A/C)_1}{(A/C)_2}$$

(1)

Where $(C/W)_1$ and $(A/C)_1$ are the cement-water and the ash-cement ratio for concrete of one class, $(C/W)_2$ and $(A/C)_2$ are the cement-water and the ash-cement ratio for concrete of another class.

So for a certain concrete strength

$$\frac{C}{W} \cdot \frac{A}{C} = \text{const}$$

(2)

If the water demand of concrete mixtures is identical, then it follows from condition (1) that

$$\frac{C_1}{C_2} = \frac{(A/C)_2}{(A/C)_1}$$

(3)

An analysis of the results indicates that the optimal ash consumption for concrete of class B15 .... B25 varies slightly and depends mainly on the mobility of the concrete mix and the conditions of concrete hardening (Fig. 2)
When replacing part of the cement with fly ash from the NATPP, in the beginning, a decrease in strength is proportional to the percentage of ash and after a day and later fly ash behaves as an active material, participates in the set of concrete strength and the portland effect of fly ash is observed. (Fig. 3)

![Figure 3](image3.png)

**Figure 3.** Portland effect of fly ash depending on time. 1 is without additives, 2 is with the addition of 20% fly ash, 3 is portland effect.

Fly ash improves the workability of the concrete mix. The effect of sols is greater, the finer the particles. In each case, there is an optimal dosage of ash, which allows you to get the best workability. In this case, the plasticity of the mixture was determined by a melt test using a shaking table. According to the test results, it was found that at a W/C from 0.45 to 0.63, the optimum ash content is in the range of 18 ... 32% of the mass of cement. For hydraulic concrete, Portland cement, slag, in some cases, sulfate – resistant cement is usually allowed. Portland cement is characterized by low heat during hardening, a higher density of cement stone, and a lower tendency to water separation. But ordinary Portland cement does not have such properties. At the same time, to reduce the consumption of cement, and consequently, heat and volumetric deformations of concrete, while maintaining the necessary plasticity of the concrete mixture and the density of concrete, micro fillings are introduced into it. As such an additive, fly ash of the NATPP in the amount of 20 and 40% by weight of cement was used.

A comparison of the adiabatic heat release of conventional Portland cement and cement with a content of 20 and 40% ash is shown in figure 4.

![Figure 4](image4.png)

**Figure 4.** Comparison of heat during the hydration of Portland cement M400 with the addition of fly ash, 2 is with the addition of fly ash 20%, 3 is with the addition of fly ash 40%.
According to the test results, it was found that the heat of hydration released during the setting process decreases in proportion to the ash content. This property is of great interest when concreting massive hydraulic structures in the hot season. Fly ash in one lengthens the crack formation time and reduces hydraulic shrinkage in concrete. This can be explained by the fact that cement contains soluble alkalis \((Na_2O + K_2O)\) which increase the shrinkage of concrete, and ash absorbs these alkalis, forming stable and insoluble alum inosilicates. It can be stated that the introduction of fly ash in the amount of 20 – 30% of the mass of cement in the concrete mixture to increase the resistance of concrete in an aggressive environment. At the same time, the increase in resistance is due to the finely dispersed ash, an increase in the total binder volume, the presence of lime in small amounts, and most importantly, a decrease in the content of three-finger clinker aluminate, which contributes to destruction under the influence of sulfates.

4. Conclusions
The possibilities of using fly ash of the NATPP as a micro filler for hydraulic concrete have been substantiated:
- according to static data, the technical and environmental conditions of the Angren region were studied, the total amount of ash accumulated at Ash and Slag dumps located near the residential areas of Angren was determined.
- the chemical composition of fly ash has been studied as a micro filler for hydraulic concrete, and their physical and mechanical properties have been determined.
- the possibility of efficient use of fly ash as a micro filler is substantiated, that it can change some physicists of the mechanical and operational properties of hydraulic concrete.
- the change in cement consumption from the ash of the cement ratio was established and the optimum ash cement ratio (A/C) for concrete B15 ... V25 was determined, which is (0.48 ... 0.62) by weight of the cement.
- the portland effect of fly ash was revealed and changes in concrete strength over time were justified. Experiments show that when replacing part of the cement with fly ash on the first day, the set of strength slows down, and after 7 days it accelerates by 12-15%.

With the use of fly ash in an amount of 40% by weight of Portland cement of grade 400, heat dissipation during hydration is reduced by almost 30-35%, which is very important for hydraulic concrete, which increases crack resistance and resistance in an aggressive environment. Summarizing the above, it can be concluded that the use of large-tonnage fly ash of the NATPP in concrete technology is a big state task, solving the priorities of the further development of the national economy and one of the strategic ways to solve the environmental problem in the NATPP zone.

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