CONCRETE WORK AT THE ZAGORSK WATER-STORAGE POWER PLANT

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The Zagorsk water-storage power plant is located in the Sergievo-Posadsk Region in the northeastern Moscow Oblast at the center of three large power systems in an area with a large number of water-storage power plants; this provides it with advantages.

This is the first large-scale test-experimental water-storage plant with a capacity of 1200 MGW in our country.

Construction of the water-storage power plant was begun in 1975 with a small pioneer settlement.

As of 1 January 1992, four units have been placed on line and are in operation. More than 75% of the total volume of concrete has been placed.

**Basic Structural Components of Zagorsk Water-Storage Power Plant.** The Zagorsk water-storage plant consists of an upper (artificial) pool with a capacity of 32 million m$^3$, which is formed by an artificial embankment of morainic clayey soils 9 km long and 40 m high with a concrete lining 0.2 m thick on the inner slope; a water intake; a six-filament pressure pipeline 764 m long and 7.5 m in diameter, which is assembled from sectional pipe elements 4.5 m long with an internal metallic lining and concrete walls 0.4 m thick, the latter being supported on pile foundations connected by longitudinal marginal and transverse beams; a water-storage powerhouse with reversible turbines each with a capacity of 200,000 km; and, a lower storage pool with a capacity of 28 million m$^3$, which is formed by two embankments (downstream and upstream) that partition the Kun' River valley.

The basic concrete structures at the Zagorsk water-storage plant are as follows: water intake (150,000 m$^3$ of concrete); pressure pipelines (145,000 m$^3$ of concrete); water-storage powerhouse with connecting walls (310,000 m$^3$ of concrete); upstream and downstream dams (32,000 m$^3$ of concrete); upper pool embankment (slope stabilization calling for 140,000 m$^3$ of concrete), and other structures with a volume of ≈123,000 m$^3$ of concrete. The overall volume of concrete in the basic structures is ≈900,000 m$^3$.

**Design Requirements for Concrete and Materials Utilized in Its Preparation.** The design calls for more than 20 grades of concrete in the overall 900,000-m$^3$ volume of concrete placed in the basic structures of the Zagorsk water-storage power plant. Fourteen grades of concrete alone are called for in the 310,000-m$^3$ volume of concrete that goes into the powerhouse for the water-storage plant. Five grades of concrete are specified in a single conduit of the pressure pipeline, which will contain 14,000 m$^3$ of concrete: (M200/180 for the piles; M250 Mrz 300 for the transverse beams and pile heads, M250 Mrz 100 for the marginal beams, M300 Mrz 300 for the pipeline elements, M200 Mrz 100 for the shelves, etc.).

Two grades each are called for in certain blocks (part of the structure is concreted without a single interruption). For example, two grades, including 28 m$^3$ of Grade 250 Mrz 300, and 170 m$^3$ of Grade 250 Mrz 100 are called for in the 198-m$^3$ block of the right-bank abutment to the Upr-IX-17 water intake; a total of six grades of concrete (M250, 250 Mrz 100, M200, Mrz 100, M250 Mrz 300, M200 Mrz 300), etc. have been placed in the 1565-m$^3$ abutment.

Due to a lack of coarse aggregate in the construction region around the Zagorsk water-storage plant, designers called for a small-aggregate and fine-grain (sand) concrete for all basic structures.

Compositions containing 0-45% by weight of a crushed 0-20-mm fraction, 100-45% by weight of sand with an $M_{ct}$ of 1.8-2.0, and ground limestone in the amount of 10% of the weight of aggregates with SDB and SP additives within the range of 0.2-0.28% of the weight of the cement. Compositions containing 45% of crushed mass are intended for Grade 300 concrete and sectional reinforced concrete.

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It was specified that the sand and crushed mass be produced from a sand—gravel mix obtained from local quarries 6 and 6a. The sand—gravel mix is separated into a sand and a 5-100-mm gravel fraction at a gravel-grading plant, the sand is then washed on spiral classifiers, and the gravel washed in a trough washer.

The crushed mass is produced from the 5-100-mm gravel fraction, passing through jaw and cone crushers installed at the concrete plant. The entire mass of the 0-20-mm fraction is delivered to an aggregate stockpile and is used for the concrete without grading. In separating the sand, it was assumed that the dirt, mud, and silt particles finer than 0.14 mm were washed away on the hydraulic classifiers.

Use of Low-Gravel and Fine-Grain Concrete for Construction of Zagorsk Water-Storage Power Plant. The design scheme for the production of aggregates for the concrete in the basic structures of the Zagorsk water-storage plant was, by itself, unjustified.

The actual reserves of the sand—gravel mix in the local quarries was found to be half of the planned reserves. There is also no correspondence of qualitative characteristics between the actual and design mixes. The actual content of gravel amounted to 15-20% on average, instead of the 30-35% based on reconnaissance data; the content of washed particles (mud, slime) amounted to 20-30% in stead of the projected 10% value. As compared with projected data, the aggregate yield was reduced due to heavy contamination with mud particles and every kind of discrepancy in the set up of the plant containing the gravel-grading equipment, and its productivity was reduced by half. As a result, the gravel-grading plant supplies only half the required amount of aggregates for the concrete. All of the washed sand is used for the concrete, while the gravels go into drainage and filters for the most part.

The crushing plant is not operated due to a lack of material for crushing, and to faulty operation of the cone crusher. The crushing plant, which is assembled at the concrete plant, was disassembled in 1987; the shop is used for other purposes.

As of 1 October 1985, all mix reserves in local quarries 6 and 6a were essentially exhausted. The construction site was left without aggregates and filter materials.

Since 1986, the project has survived on imported materials. A gravel bank owned by the Kama-Volga Steamship Company and partly granite crushed stone supplied by the Gavrilovsk Quarry in the Leningrad Oblast or from Zaporozh'ye have been used as coarse aggregate. In 1985-1986, sand was imported partly from the Petrovsk Quarry and was recovered from local quarry Nos. 17 and 9 and from various suitable excavations. None of the local quarries could supply the construction site with quality sand in the amount required.

The Parfenovsk Quarry located 12 km from the Zagorsk water-storage plant has been mined since 1986. The mixture from the quarry is delivered by motor transport to a gravel sorter and separated into sand and gravel. The sand is washed through classifiers, and the gravel is run through a trough washer and is graded by size.

Hydraulic classifiers were successfully installed at the construction site so that mud and clay is washed away, and silt particles finer than 0.14 mm are retained; their content of 8-12% in the sand made it possible to eliminate scarce additives and ground limestone introduced to the concrete as an additive-filler, and to lower the consumption of cement by ≈10%.

The sand in all exploited quarries has a fineness modulus of 1.8-2.0. Due to a lack of design aggregates, the compositions issued by the Gidroproekt were not used to prepare the concrete. The concrete is produced on the basis of compositions selected by the construction laboratory. The basic concrete compositions, which were selected by the laboratory, conform with that issued by the design organization.

The low-gravel and fine-grain concretes are adopted as basic compositions. No classical concretes are used at the Zagorsk water-storage plant. The consumption of corresponding grades of cement for the compositions employed does not exceed that for the design mix. The silt fraction finer than 0.14 mm, which is retained in the sand during its separation, is used as an additive-filler in lieu of ground limestone. Use of sands without silt or sands with a silt content of less than 6% result in an increased cement consumption ranging from 10-20%.

For the wide variety of concrete grades placed in the project (≈20 grades), selection of the concrete compositions was difficult.

The concrete plant is designed to produce four grades in a semiautomated mode, but is forced to deliver 8-11 grades of concrete and grout per shift.

The laboratory is forced to blend several grades into a single composition, for example, Grades 250 Mrz 100, 250 V-6, 200 V-8, 200 Mrz 200, and 250 are introduced to composition G-4, i.e., five grades of concrete are blended into one composition.

Moreover, the procedure developed for the placement and transportation requires different compositions with respect to concrete plasticity. A slump of 10-20 cm is required when the concrete is placed by concrete pumps or is transported via mixers,