MECHANIZATION OF FINISHING OF PNEUMATIC-CONCRETE TUNNEL LININGS, ENSURING LOWER ROUGHNESS

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For tunnels constructed in rock wide use should be made of progressive types of linings in which the bearing capacity of rock of medium and high strength is utilized to the maximum possible extent. Such linings include, in particular, a new type made of a cavitation- and wear-resistant material — pneumatic concrete with a geometrically accurate and smooth surface. The formless technology for construction of such linings makes it possible to obtain high-quality permanent linings of practically any small thickness (5-20 cm). This type of lining may have a minimal thickness, it is characterized by absence of contact grouting, and it has high density, strength, and imperviousness, as well as better conditions for joint operation with the rock.

The use of permanent pneumatic-concrete linings is possible in tunnels driven by the shield and combined methods, as well as by the drilling—blasting method with smooth breaking of the outline; and in combined linings, when pneumatic-concrete or reinforced Gunite shells are constructed on primary linings made of prefabricated, cast-in-place, and cast-in-place—pressed concrete. However, the basic condition for applicability of such linings in hydraulic tunnels is the solution of the problem of building them with regular geometric shapes and a smooth surface characterized by a roughness coefficient of 0.011-0.012.

At the Kazakh Branch of the Gidroproekt Institute, for several years comprehensive design and research work has been carried out to develop flow-line techniques and equipment for construction of permanent tunnel linings of pneumatic concrete, having regular shapes and smooth surfaces. During 1968-1969, under test area conditions, use was made of an experimental installation to establish the feasibility of mechanical finishing of pneumatic concrete surfaces, which ensured the construction of such a lining with a roughness coefficient \( n = 0.013 \) [1]. During 1974 industrial tests were performed on the first Soviet installation with a remote-controlled handling of pneumatic concrete and integrated mechanization of all auxiliary processes. The tests, performed at the construction sites of the Inguri and Zhinvala hydroelectric plants, confirmed the possibility of obtaining high-quality support of rock excavations by means of pneumatic concrete, with a significant increase in the labor productivity and a reduction of labor costs [2]. During 1976, a system of automatic nozzle control, using suitable contactless elements which ensured high reliability of the control system, was developed, fabricated, and tested under test area conditions. This system made it possible to operate the nozzle in both the automatic and remote-control regimens; the motion of the nozzle during the process of applying the pneumatic concrete is easily and quickly corrected; also, the system permits applying a continuous and uniform pneumatic concrete layer. During 1977 work was continued to determine and define more precisely, from tests, the technical and construction parameters of shaping devices using a different principle of mechanical finishing of pneumatic concrete and Gunite.

A way to increase the effectiveness of tunnel linings lies in improvement of their hydraulic regimen through reduction of the roughness coefficient of the internal surfaces. The geometric characteristics of lining surfaces which affect the roughness coefficient are the mean height of the irregularities, waviness, bumpiness, changes in height along the tunnel, individual defects of the pneumatic concrete layer, etc. Surfaces of pneumatic concrete and nonsmoothed Gunite applied by the current techniques, even on originally uniform surfaces, have high roughness values in comparison with concrete surfaces obtained by using metal or wooden forms [3, 4]. Smoothing of Gunite surfaces substantially reduces their roughness coefficient from \( n = 0.016-0.018 \) to \( n = 0.012 \) [3]. At the present time Gunite smoothing is car...
Fig. 1. Basic schematics of shaping and smoothing devices for: a) cylindrical linings; b) linings of complex shapes. 1) Primary lining (prefabricated or cast-in-place); 2) first-stage pneumatic concrete lining (invert); 3) the same, second stage (walls and roof); 4) drive of shaping device; 5) working element of shaping device; 6) guide plate for lining surface; 7) carriage; 8) shell for trapping waste.

Fig. 2. Basic schematics of live elements used for shaping and smoothing pneumatic concrete and Gunite: a) cutting; b) "anklepf" action; c) smoothing. 1) Drive; 2) milling cutter; 3) rings freely mounted on shaft; 4) rotating roller.

ried out by hand, which is extremely labor-consuming and reduces only the mean height of the irregularities, the other surface indices remain unchanged. Pneumatic concrete is not smoothed.

The Kazakh Branch of the Gidroproekt Institute proposed a technique for mechanized finishing of tunnel linings made of pneumatic concrete, as well as for mechanized finishing of plain or reinforced Gunite coverings in combined linings, which includes the following processes: a) shaping of the internal surface of the lining in order to basically eliminate the roughness caused by waviness, bumpiness, changes in diameter along the tunnel, and individual defects of the surface; b) smoothing of the internal surface to eliminate roughness caused by the mean height of sharp "short-wave" irregularities; c) use in pneumatic concrete linings of a last covering layer of sand-material—Gunite, which facilitates shaping and smoothing such a lining.

For shaping pneumatic concrete or Gunite surfaces it is proposed to use a milling cutter or freely rotating shaft-mounted ring, while for smoothing them it is proposed to use a fast-rotating cylinder-roller. The technical operations performed by the above live elements are called milling, "anklepf" (rotating ring), and smoothing. Figure 1 shows the basic schematics of shaping and smoothing devices for tunnel linings with cylindrical and more complex types of surfaces. Figure 2 depicts the basic schematics of the live elements of the shaping and smoothing devices used in the experiments. Figures 3 and 4 show, respectively, the devices used in the automated method for applying pneumatic concrete and Gunite, and the shaping live element used in the "anklepf" method.

Through previous studies and experiments carried out at the Branch, it had been found although it is possible to shape surfaces of pneumatic concrete containing aggregates 10-20 mm in size, this cannot be permitted since such a surface, on acquiring a geometrically regular shape, contains holes larger than the coarse particles of the aggregates removed during shaping. In this connection it was decided to adopt the rule that permanent pneumatic concrete linings for hydraulic tunnels should consist of the pneumatic concrete proper, of the required thickness, and of a final sand-layer covering (Gunite), which is more amenable to shaping and ensures a geometrically regular as well as smooth surface with an acceptable roughness coefficient \( n = 0.011-0.012 \). In this connection the shaping and smoothing experiments were performed primarily on cement-sand material. Use was made of coarse river sand having a fineness modulus \( M_f > 2.5 \).