To a question of the setting of measures for culvert repair during technical inspection

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Abstract. Culvert pipes are one of the largest categories of engineering structures on roads of both regional and federal significance. During operation, the structure is affected by static and dynamic loads, for example, from the weight of the dam and passing vehicles, temperature changes, melt, and rainwater is directly flowing through the pipe, streams and small rivers, as well as geological factors - earthquakes, shifts, and vibrations ground. Also, over time, the installed reinforced concrete sections of the conduit have a habit of shifting in horizontal and vertical directions under the influence of various kinds of loads, which leads to the formation of gaps and differences between them. Swings reduce the effective cross-section of the pipe, throughput, and lead to silting. Under flood conditions, the presence of discrepancies between the links of the tube leads to significant erosion, leaving voids in the dam, which is fraught with the collapse of the roadbed and road pavement, and in such situation, it is impossible to talk about the possibility of road operation as a whole. The traditional effective solution to this problem is culvert repair. Identifying the need for repair or reconstruction of the structure is the primary purpose of assessing the technical condition during the professional inspection of culverts.

Introduction

Nowadays, a large number of conduits on the road and rail network, which constitute more than half of all engineering structures. The simplicity of their structures promotes the primary distribution of pipes and the lower cost compared to bridges.

A pipe is an engineering structure having a closed ring contour designed to pass a permanent or periodically operating water flow that fits into the body of a highway or railway embankment. Including roads of industrial and agricultural enterprises, roads and streets within cities, towns and rural settlements being built in any climatic conditions, as well as in areas with seismicity up to 9 points. Culvert pipes are designed and constructed in such a way that with final consideration of consumer properties and with proper operation, they have sufficient durability [1]. The minimum service life and the period to the first repair are 50 and 30 years, respectively.

Problem statement
The external load influences the condition of the culvert pipes, depending on the passing traffic, the thickness, type, and state of the surrounding soil, the water-thermal regime of the roadbed. The combination of their effects can cause defects in corrugated metal sections and reinforced concrete pipe links in the form of shape deformation (with longitudinal and transverse cracks and chipped concrete), destruction of the seams of the joints between the links. Violation of waterproofing (Figure 1 a, b) or deformation of the pipe along its length (displacement or sliding rings) due to overhydration of the ground can cause damage to the seams.

The impact of water flows, depending on the degree of its aggressiveness, can cause gradual destruction of the concrete surface or metal corrosion, and if the seams in the pipe tray - washing and overhydration of the soil around the pipe and its deformation. As a result of ground movements, a drawdown of links, displacement of tube ends, undermining of the embankment and its distortion occur (Figure 1 c).

If the design is inadequate at the inlet and outlet of the pipe, the trays and slopes of the embankment are eroded, scour pits are formed, indicating that the design of the tube does not match the water conditions (Figure 1 d). A characteristic defect is also the silting of canals and the exit channel.

Figure 1. Visual inspection of pipe elements to identify shortcomings and defects: a) Input tip. The left face of the approach. Violation of waterproofing pasting and lubricating at links 1, 2, 3. b) Barrel of pipe. Leak between the links at the outlet. Impairment waterproofing. c) Outlet end. Fall of soil on the right side of the collapsed sloping wing. d) Funnel erosion at the outlet of the pipe

A survey of a culvert reinforced concrete rectangular pipe on a highway in the Lysva urban district of the Perm Krai region revealed the characteristic defects presented in Figure 1. The study was
carried out to determine the technical condition of the pipe structures and to determine the suitability of the pipe for further operation \[2-6\].

**Theoretical part**

A water throughput rectangular reinforced concrete pipe with a mouth 4.0 x 2.5 m. The length of the tube is 12.22 m. The number of links - 12 pieces. Design loads - Automobile-8, Caterpillar-60. The width of the roadbed is 8.00 m (Figure 2).

![Figure 2. The longitudinal section along the pipe axis](image)

The entrance tip consists of a portal block and lateral wings. The cap is bell-shaped and at the entrance a link of standard height. A rectangular reinforced concrete link with a hole of 4.0 x 2.5 m performed the role of the portal block. The cordon ledge on it made of solid concrete. Lateral wings composite, consist of two blocks. Barrel of pipe consists of reinforced concrete rectangular blocks with a hole of 4.0 x 2.5 m. The channel at the entrance and exit of the tube is straight and not overgrown with bushes and grass. At a distance of 20 m from the exit tip, the water flow from the pipe flows into the river Kyn. Outlet end is in backwater from the river Kyn (Figure 3).

![Figure 3. River Kyn, Lysva Urban District, Perm Krai, Russia in a) summer, b) winter time](image)

**Practical significance, proposals, and results of the implementation**
According to the survey, the technical condition of the pipe, taking into account the existing defects in durability (D3), safety (S2), carrying capacity (CC0) is unsatisfactory (2 points) (by analogy with road bridges in accordance with ODM 218.4.001-2008 “Guidelines for organization of inspection and testing of bridges on highways” [7]) (table 2).

| The element of the bridge structure | Maximum category                                      |
|-----------------------------------|-------------------------------------------------------|
| Culvert head                      | D3 Destruction and lack of abutment at the exit, cracks, and roll in the lateral wing at the entrance |
| Barrel of pipe                    | D2 The drawdown of the inlet and outlet links, destruction of waterproofing, partial destruction of strengthening of embankment’s cones support, shrubs overgrowing |

Table 1. Pipe technical condition, taking defects into account

To improve the technical condition of the structure, its indicators of durability, and traffic safety, it is necessary to perform repairment of the pipes according to following applicable design standards [9-14].

Repair of the duct is a complex of technological operations, the purpose of which is to preserve (restore) the properties of the pipe. The following types of work performed when carrying out repairs of the pipeline:
- restoration of culvert inlet and an outlet end;
- arrangement of the new cordon block;
- reconstruction of a monolithic tray between the abutments;
- recovery of the strengthening of the embankment slopes and the strengthening of the channel at the inlet and outlet end of culvert;
- restoration of waterproofing and seal joints between rings of the pipe;
- scour backfill;
- for the safe operation of the tube, it is necessary to change the stream canal of the Kyn river by cutting off the island formed in the middle part of the river;
- arrangement of protective flow dam at the exit end of the pipe to organize the Kyn river's water flow.

Repairs of the pipe end through the watercourse on the km 75 + 500 "Lysva-Kormovishche-Kyn" highway are supposed to be carried out without interruption of traffic for the entire period of the repair work, with work carried out in cramped conditions in 2 stages [8]. Each step involves work within one lane, while the passage of vehicles is carried out in another path.

A temporary earth-filled pile coffer installed before starting the repair work. To pass the watercourse, temporarily four metal pipes 1.02 m in diameter with a wall thickness of 12.0 mm are laid; the length of each tube is 12.0 m.

To pass water in the body of the pipe provided a device of 2 metal pipes with a diameter of 1.02 m, with a wall thickness of 12.0 mm and the length of each pipe 22.0 m. These pipes welded to two tubes under earth-filled pile coffer, and on two other pipelines are installed plugs.

After completing the work on one half of the pipe (along), the 2nd metal pipes digested to the other two pipes under earth-filled pile coffer, and on the other two tubes are installed the plugs. The pipes and earth-filled pile coffer dismantled upon completion of the repair work.
When repairing pipe ends, three links are digging up on each side (at the input and the output). Under the body of the pipe pumped cement solution to eliminate the drawdown of the body parts of the pipe. In the drilled holes of 62 mm in the bottom of the canal are installed metal tubes of 57mm, through which injected the M200 solution. On the outer side of the pipe, on the links, the coating and coating waterproofing is restored. From the inside, the caulking of the seams is made and embedded with M200 cement mortar.

An automobile crane with a weight of 16 tons from wheels made the installation of the lateral wings. Surfaces that come into contact with the ground treated with an oblique waterproofing. A tray of solid B20 concrete with a thickness of 200 mm arranged between the lateral wings. Backfilling of the excavation is carried out in layers with compaction by manual pneumatic rammers.

An anti-molded concrete tray B25 arranged on the bottom of the pipe. A 30-cm-wide slot, framed by wooden structures, is provided along the pipe axis.

Backfill of ravines and dumps of soil with compaction and grading of hills made on slopes. Monolithic concrete B20 provided slopes and stream canal strengthening at the pipe. Solid concrete is laid on a layer of 10.0 cm crushed stone and reinforced with A240 steel. The thickness of the solid concrete on the slopes is 8.0 cm, the width of the solid concrete in the stream canal at inlet and outlet end is 12.0 cm. At the base of the hills are arranged monolithic B20 concrete lugs at the entrance with a size of 0.4x0.5x1.75 m, at the outlet - 0.4x0.5x1.0 m.

Stone apron arranged at the end of the fortifications. Filling the bucket is made of stone with a particle size of 150-200 mm.

For the safe operation of the pipe, it is necessary to change the outline of the Kyn river bed by cutting off the island, which formed in the middle part of the river. It is required to arrange a protective flow dam to organize the water flow of the Kyn river at the outlet end of the pipe (Fig. 4). The width of the barrier on top is 3.0 m, height 2.5 m. The slopes of the protective flow dam and the hills of the straightened coast are reinforced by sketching.

![Figure 4. Protective flow dam](image)

**Summary**

The technical condition, as a set of qualitative and quantitative indicators, characterizes the operational suitability of engineering structures and their constructions. In comparison with the permissible values, it is the main characteristic of the ability of pipes to provide a normal operating mode associated with the safe passage of transport at set speeds and uninterrupted passage of water through the embankment body [18]. Improper implementation of a set of operational measures,
including regular inspection of culverts on the roads, can lead to deterioration of the technical condition of the road pipes and destruction of the roadbed.

Therefore, a complex of measures, by definition and assessment of the actual values of the monitored parameters characterizing the performance of the culvert pipes, should be given increased attention. Based on the information obtained during inspections, surveys, and monitoring, recommendations developed for eliminating the detected defects.

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