# DESIGN OF DIVERSION DITCHES FOR HIGHWAY ROADBEDS

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During construction of highway roadbeds at zero elevations, and of small embankments, the ditches are being constructed in excavations and they are the roadside diversion ditches. The purpose of these structures is to drain the roadside area and the roadbed soil.

However the role the ditches play in order to facilitate the roadbed construction operation is insufficiently studied. This statement can be confirmed by the fact that mostly often designing of roadside ditches is quite a formal process - shape and sizes of the roadside ditch cross sections are specified in compliance with standard plans, trapezoidal shape with 0.3m bottom width and 0.4m depth, with slope inclination of 1:1.5. Hydraulic calculations for ditches are usually not done. Currently valid standards and recommendations / 1 / suggest that hydraulic calculation be done for the ditch lined with concrete slabs (fig. 1), and as a rule there are no ditch liners of such kind on flatland highways and on those ones in semi-rough terrains.

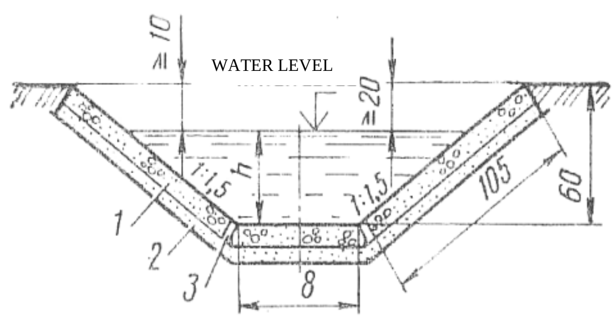


***Fig 1.*** *Structural model of a roadside ditch*

*1 - concrete slab; 2 - sand-gravel bedding for slabs; 3 - longitudinal seams filled with mastic*

The fact which confirms the above statement is that roadside ditches are shutoff when ramps are being installed, especially in inhabited localities. In these cases a culvert (usually its diameter does not exceed 0.5m) is placed in the ditch and the area around is filled with soil or concrete. The ditch cross-sectional area decreases by several times. As the result there appears a block for water flow in the ditch which causes water accumulation on the upstream side. These ramps are also the spots where different litter accumulates too and it blocks the water flow in the ditch even more.

Another confirmation of insufficient study of role the ditch plays in facilitating the highway roadbed operation and consequently of not understanding their significance is the maintenance of roadside diversion ditches in the highways operation period. In warm season of a year ditches become overgrown with tall grass and bushes and are not being cleared out of them (the grass is not mowed in the ditches) (fig. 2). The ditches are the most choked up sections of a road's right-of-way.

Technogenic litter, scrapped automobile parts (old tires, rags, etc.) are being accumulated there.

And as a result the ditches turn from being lotic systems to being water detention basins. Water is removed from them only by infiltration into soil and into roadbed too and it is also removed by evaporation. In temperate climate conditions of middle Russia still water in a ditch in summer season of a year may be observed up to 1 - 2 weeks (in rainy years even longer), in spring during snow melt period and in autumn during rain period it can be observed up to several months. In the monsoonal climatic regions (the Far East of Russia, Vietnam, the south of China, the Indochinese countries) in the rainy period of the year water stagnation in the ditch system (fig. 3) may be observed during some months.

***Fig 2.*** *The ditches overgrown with grass and bushes. Roads of Vietnam Republic, Russia, Poland*

***Fig 3.*** *Slack-water in a ditch*

Stagnation of water for a long time in a roadside ditch results in an increased humidity of roadbed soil. By infiltration water penetrates into roadbed soil and under it (fig. 4) overwetting it and thus decreasing roadbed stability and subbase load-carrying capacity under it.

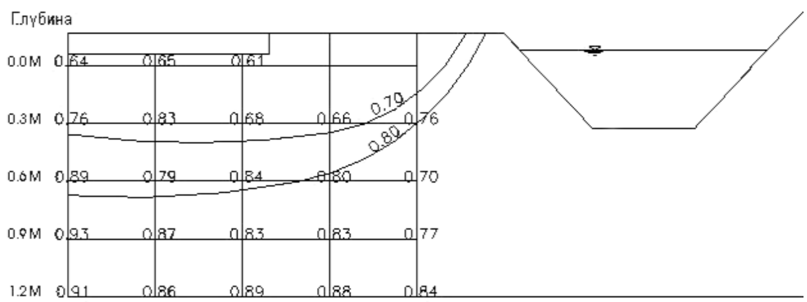


***Fig 4.*** *Relative humidity of roadbed soil under the impact of ditch slack-water*

*at State Highway №1A, Lang Son, Vietnam.*

***Note:*** *numbers on a cross profile show relative humidity of the earth roadbed*

In figure 4 it is seen that in case of a long period of slack-water in a ditch, the water gradually infiltrates and penetrates into the roadbed body over wetting its soil. Under the road pavement relative humidity of soil has reached 60-65% gradually increasing with the depth and reaching 80% at the depth of 30cm (from the pavement bottom), and over 80% at the depth of 70cm, i.e. already in the soil, at the embankment base it is over 80%. Relative humidity optimal for ensuring maximum soil density is 50-60% on the road №1A

Figure 4 illustrates the case of overwetting the roadbed soil which had been constructed in zero elevation or in excavation. When stagnating for a long time in a ditch the water gradually reaches the bottom of a road pavement. By definite combinations of water level and duration of its stagnation in a ditch, soil water permeability, relative humidity of soil may reach 100%.

Little by little in roadbed soil under the pavement a free water level is being formed which is dependent on the ditch water level. Under certain conditions there might appear a situation when under the road pavement a certain water head is being formed. It is in upright position and is equal to difference in the heights of ditch water level and road pavement b ottom elevation.

When a roadbed is in the form of an embankment of small height, the scheme of soil wetting shown in Figure 4 is accompanied by soil wetting which is performed by an upward capillary rise of water. In this situation sufficiency of the em bankment height depends on soil water permeability and its degree of compaction during the construction process. However a possibility of overwetting and decreasing of the embankment load -carrying capacity is preserved.

In the above considered operating conditions of roadbed and ditches (in case of water stagnation) the decisive factor for estimating the degree of soil wetting in the embankment body and under it becomes the factor of time during which water remains in a ditch. This factor is determined by quickness (velocity) of water evaporation.

In operating conditions, i.e. in a situation when water flows along the ditch, the water too is being infiltrated into soil. Water in ditches is observed during rains and some time after. This is caused by the water runoff coming from water catchment areas adjacent to the road a nd also the one coming from carriageway surface. The depth of water stream depends on hydrometric parameters of rain and water catchment area. In most cases the rains intensity is much le ss than that of a designed one and the water stream depth in a ditch is not big (in observations made by the author the depth varied from 2 - 4 up to 10 - 12 cm). However under these conditions water is being infiltrated into soil and overwettens it. Figur e 5 represents soil humidity data, obtained during rainy period on the highways of Vietnam Republic. It is seen in the diagrams that an active water infiltration into soil of the embankment body and its base is going on.

It appeared that when ditches ar e in operation, i.e. when they ensure rainwater runoff along them, soil humidity is much less inspite infiltration process, than in the case when water stagnates in the ditches.


***Fig 5.*** *Relative humidity of roadbed soil*

Water flow duration in a ditch beside the hydrometric parameters of rain and water catchment area depends on conditions of water flow. If there exists any obstacle the water flow velocity decreases and the flow depth increases.

Thus when designing the roadside diversion ditches it is necessary to take into account their "operating" condition, i.e. the presence of any obstacles for water flow in ditches - things that litter ditches both of man-made and of natural origin (grass and bushes vegetation). This can be done by improving the hydraulic calculation of a ditch.

Hydraulic calculations for the ditch are being done on the basis of the classical hydraulic equation: $Q = w.v$

where "Q" is capacity (flow rate), "w" is flow area,

"v" is the flow velocity.

In this formula flow velocity appears to be the key factor.

According to the Chezy equation $v = C\sqrt{R \cdot i}$

where "i" is the longitudinal flow inclination, "C" is the coefficient, "R" is the hydraulic radius the value of which is determined by cross-sectional parameters of water flow in a ditch:

$$R = w/\chi$$

where $\chi$ is the wetted perimeter.

The hydraulic radius R is the overall index of geometrical sizes and shape of the ditch cross section (in the limits of cross section of the streamflow going along this ditch).

An important indicator reflecting conditions of water streamflow is the coefficient C in the Chezy formula. The value of this coefficient in the present time is determined by a series of empirical formulas. There exist up to 136 of such formulas (for different conditions of water streamflow) but the main ones are:

For turbulent conditions of water movement (which is typical of the situation with water flow in a ditch) the coefficient C may be determined by formulas of different types. For open channels with absolutely rough walls and for open natural beds the most used formulas are:

- The Basen formula: $C = 87/(1 + n_1/\sqrt{R})$

where $n_1$ is the Basen's hydraulic roughness coefficient. The Basen formula is used when calculating water diversion ditches.

- The N.N. Pavlovsky formula: $C = R^{y}/n_2$

where $n_2$ is the N.N. Pavlovsky's coefficient of hydraulic roughness.

$$y = 2{,}5\sqrt{n_2} - 0{,}13 - 0{,}75\left(\sqrt{n_2} - 0{,}1\right)\sqrt{R}$$

This formula is to be the main one at calculating beds with absolutely ro ugh sides.

- The Manning formula: $C = R^{1/6} / n_3$

where $n_3$ is the Manning's coefficient of hydraulic roughness.

- The I.I. Agroskin formula: $C = 4\sqrt{2g}(k + \lg R)$

where "k" is the coefficient which characterizes absolute roughness both qualita tively and quantitatively, i.e. according to its type and sizes.

Values of the hydraulic roughness coefficient differ considerably based on data obtained by the authors mentioned above. For instance, Basen's $n_1$ depending on channel sides and bottom roughness is $n_1$ = 0.50…4.00; N.N. Pavlovsky's and Manning's $n_2 = n_3$ = 0.012…0.150; I.I. Agroskin's k = 3.15…1.90.

Research data of Basen, N.N. Pavlovsky, Manning, I.I. Agroskin and of other authors / 3 / show that:

1. Bed and sides roughness (i.e. the degree of their overgrowing with grass and bushes, littering with stones and etc.) has a great impact on water flow velocity (up to 7 -8 times and more).

2. When designing the ditches and doing hydraulic calculations it is necessary to carefully estimate the future operating condition of ditches and in connection with that to choose value of the design coefficient of bed sides roughness.

Obstructions found in ditches and blocking water flow in there may be divided to two groups (according to character and degree of im pact on water flow in a ditch). One group is the grass growing on the bottom and on the slopes of a ditch. It might be considered to be the roughness of bottom surface and bed sides and in this case its impact is to be estimated according to the hydraulic roughness value of bed. The other group are things of technogenic origin (automobile parts, tires, and other kind of litter) and bushes growing on the bottom and on the walls of ditches. In this case, depending on location, quantity, character of things th at choke up the bed and their impact on water flow may be considered when doing calculations as for the case when streamflow comes over a threshold or also when it comes through one or several holes in the wall and etc.

The most frequent (practically c ountrywide) thing which chokes up a ditch is the grass (it has different height in various periods of warm season of a year). Technogenic litter is sooner or later being cleared out of ditches by the road maintenance services. Usually this is performed once a year before road spring acceptance (except bushes which are cleared out very seldom; but bushes grow not so often).

Taking into consideration all the facts mentioned above a conclusion should be made that the improvement of ditch design method must in clude:

- An obligatory determination of runoff volume on the designed section of a roadside diversion ditch (for runoff coming from terrains of natural water catchments the well -known methods are to be used / 3 /, for runoff coming from carriageway surface s of highways the M.V. Nemchinov formulas are to be used / 4 /);

- Hydraulic calculations for a ditch considering its maintenance peculiarities: overgrowing with grass and bushes vegetation (in a varying degree) or in conditions of periodic mowing when grass is not taller than 2 - 5cm and doesn't influence considerably the flow velocity of water; when doing calculations the Basen formula is to be used as the one which reflects to the fullest extent the conditions of streamflow in the roadside diversion di tches (it follows from the fact that the Basen formula was in the first place obtained for conditions nearest to the roadside diversion ditch conditions).

- Determination of cross-sectional parameters of a ditch with consideration of character and degree of roadbed soil wetting;

- Specifying the operating mode of a roadside ditch - whether it should be a detention structure (perhaps on road sections located in the rural inhabited localities where there exist numerous access ramps to the adjacent agricultur al lands or absolutely no ditch maintenance works are conducted) or it should be a structure for transferring the collected runoff to a discharge point.

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