Research of traffic-flow speed on weaving sections of freeway intersections

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Abstract. This article contains: groundwork base’s drainage of rigid and flexible permanent road revetments conceptual issues; drainage systems operational schemes; underlayer’s working layer hydration types; groundwork drainage measures; drainage systems design calculation criterias; recommended production methods are offered; the most commonly used drainage structures components; criteria for choosing the most suitable material; reasons of road revetments’ drainage systems underperformance; comparison of normative and proposed methods for designing drainage systems in the bases of pavement; a forecast of possible changes in normative framework (in order to improve roads’ groundwork bases and revetments durability, using modern design calculation methods); drained road revetments durability data; economic feasibility of using drainage systems in the base of pavement.

1. Introduction

Excessive moistening protection of road revetments is crucial challenge in its design, construction and maintenance. Moistening degree defines motorway’s durability and load-bearing capacity. Road revetment’s drainage system efficiency is shaped by correct and rational engineering and technical solutions, proper construction and repair, as well as by season drainage maintenance works.

In the regulatory and methodological documents in force in Germany [7], the requirements for the weaving sections length are in tabular dependence on the estimated design speed of the traffic and the weaving section type have implemented. Rules and regulations review of the Russian Federation [8,9,10,11] has indicated that there are no rules for assignment parameters for weaving sections of traffic flows in our country. Considering the foregoing, the author set the task of studying the operation modes of weaving sections. The present research is devoted to the identification of the functional dependence of the motor vehicle speeds on the weaving sections length of traffic flows in relation to road traffic conditions in the Russian Federation.

2. Relevance

Drainage systems’ performance directly affects road revetment’s traffic capacity properties, set by reference documents (durability, road life, load-bearing capacity etc.) [1].
As the issue of improving drainage systems design calculation quality is urgent, it was necessary to carry out additional researches as well as to combine Russian and foreign best practices of maintenance and construction of such systems.

The heaviest impact to road’s framework sustainability is brought by free water moved under pressure of wheels in its pavement layers. Free water in road groundwork base’s granulated bed experiencing dynamic loads can decrease its durability more than by 25%.

Brief and heavy summer rains can’t dramatically increase road’s framework moistening due to insufficient air humidity and high evaporation. However, as temperature lowers, bound water in different layers of freezing soil is pulled up to surface.

3. Problem statement

Drainage system development studies for I to III class motorways in Russia were started by Soyuzdorproekt in 1967. These researches were used to develop intercity public motorways drainage systems generic solutions in 1976 and 1984 [2]. Standardized design for road revetments’ drainage systems was also based on these researches. However, despite the demonstrated standardized feasibility of drainage engineering solutions there is still a list of questions of standardized and individual design to be studied with best practices to be combined and used.

Usual road structures containing granulated layers on poor-filtering soil roadbed (dust sand, normal sand with soil permeability less than 0.5 m/day, clay) require drainage blanket and catch-water systems for every working layer moistening type in road-building climatic zones II and III, and for type #3 in zones IV and V (Table 1) [3].

| Working layer moistening type | moistening source                                      |
|------------------------------|-------------------------------------------------------|
| I                            | atmosphere precipitations                              |
| II                           | Short-term (up to 30 days) surface runoff, atmosphere precipitations |
| III                          | subterranean water or long-term (more than 30 days) surface runoff, atmosphere precipitations |

Road revetments drainage is necessary if the water going to groundwork frequently overfills revetment’s bugholes, decreasing its traffic load resistance capacity.

4. Theoretical

Road revetment’s drainage system includes: plane horizontal drainage, reinforced in appropriate cases with edge drainage and subsurface transverse drainage.

Subsurface cross drainage is installed for transverse interception of the water moving along drainage blanket on the road sections that have: longitudinal slope over 20%; continuous longitudinal slopes exceeding transverse ones; sag vertical curves; decreasing transverse slopes.
Figure 1. Transverse drainage cuts layout

Combined plain drainage is universal component for most of motorways.

Water removing drainage blanket should be made of sandy soil or highly permeable open-type (unfilled bughole) aggregate (ballast stone or gravel) satisfying a list of water-resistance requirements. This layer should be spread at full road revetment’s width [4]. Also, this layer should be linked with road slope. Drainage blanket can also be equipped with drain tubes to collect and remove water outside the roadbed more rapidly. Drainage blanket and drains should be provided with flood protection. Drainpipes’ outputs should be protected from water freezing [5]. Drainpipes and drainage geocomposites should be laid at the depth that’s 0.2m lower than soil frost zone. If such a displacement is impossible, drainage system should be frost-protected with heat insulating materials layer or geoplates.

Road revetment drainage design is carried out in the following order:

1. The road is divided in homogeneous sections with similar longitudinal profiles and environmental conditions (ground form, waterways crossing the road etc.) considering roadbed (height of the road body meeting SP 34.13330.2012 [1] requirements; earth cut; landmarked road body lower that [1] requires; transition from road body to earth cut) and road revetment (solid-cast groundwork base layers, frost-protecting or heat insulating layers made of reinforced materials) features, as well as road framework drainage and supply of draining blanket materials, draining pipes, geotextiles [6];

2. Daily and base period amounts of water for homogeneous sections are calculated, with road framework drainage taken into account;

3. Drainage systems types are designated;

4. Necessary drainage blanket thickness is justified through calculations or drainage material permeability is defined for approved drainage system.

Drainage system should be designed considering the base period amount of water passing to groundwork base, draining blanket material permeability and roadbed structure.

Road revetments’ draining design in seasonal earth freezing zones should take into account two estimated functional periods:

1. Roadbed in the middle of the road is already defrosted, whereas draining blanket at the sides of the road is still frozen, so catch-water systems don’t work.

2. Draining blanket is completely defrosted, so catch-water systems work normally.
5. Practical relevance

Depending on specific conditions, draining system can be designed for one of these three operating modes:

- draining mode
- soak-up mode
- delayed catch-water draining mode

Depending on moistening conditions, ODM 218.2.055-2015 “Road structures’ draining systems design guidelines” [7] differs three types of road revetments. However, as this research is studying draining components of rigid and flexible permanent road revetments, further information will be related to type #3: Road revetment with waterproof surface and additional solid base layer. This certain road revetment type is recommended for modern roads that have only solid layers reinforced by cementsitious materials (asphalt-grouted macadam, roller-compacted concrete roadbed, soil-cement etc.). This type of structure is the thickest, as water penetration from the surface or roadbed is barely possible. That allows using for intermediate layers thick low-waterproof non-frost-resistant materials, which somewhat reduce road revetment’s cost.

As the range of draining materials is quite wide, this article will review only draining materials used for building road revetment drain lines.

Longitudinal and transverse drain lines construction uses 50-100 mm asbestos-cement pipes (perforated or saw cut), ceramic or plastic pipes or filter drain pipes. Claydit filter drain pipes can be used only if the ground water isn’t concrete-corroding.

Drain pipes should meet following basic requirements:

- Drain pipes should have sufficient water-carrying capacity in order to withdraw incoming water in time
- Draining blanket particles shouldn’t pass pipes’ intake openings
- Pipes should resist road revetment’s pressure as well as temporary loads
- Pipes should be frost-resistant

Pipes’ diameter should be more than 60mm with soil freezing depth less than 0,8 mm and not less than 80 mm with more deep frost penetration.

Nowadays plastic pipes are the most advanced. [8]. Commercial plastic flexible pipes have long length (8-200 m) and low weight, which reduce the amount of joints. These pipes are corroding water resistant, easy to set without heavy machines, and therefore cheaper to use [9]. Drainage requires pipes with openings smaller than 5 mm, whereas saw cuts shouldn’t be longer than 25 mm. To avoid silting-up and blockage of the openings, perforated drain pipes should have a drain fill around them (made of expanded clay) or geotextile wrap.

Filter drain pipes don’t require any of these measures. To withdraw large amounts of water (more than 0,005... 0,007 m3/(m2 per day)) as well as on low height road body sections it’s recommended to set transversal drain pipes with transversal outlets on road edges (figure 2) [7].
1 – surface; 2 – roadbed; 3 – reinforced area; 4 – draining blanket; 5 – longitudinal drain pipe (d=50…100 mm) or filter drain pipe; 6 – transversal outlet; 7 – concrete portal; 8 – rock bed; 9 – water outlet reinforcement; 10 - drain fill or solid fill

Figure 2. Draining system, withdrawing water from draining blanket with transversal outlet pipes

Figure 3. Draining system, withdrawing water from draining blanket with longitudinal drain pipes set on the edges of the road

Transversal drain pipes with drain fill or filter unwoven wraps (d=80…100 mm, transversal subsurface drainage cuts) are set in 15…20 cm deep pits on the sections that have long longitudinal slopes exceeding transversal ones to catch the water moving in the draining blanket along the road. The distance in the drainage cuts is from 10 to 20 m.

ODM 218.2.055-2015 “Road structures’ draining systems design guidelines” [7] shows design calculation methods of flat horizontal and transversal drainages, as well as how to define full draining blanket thickness.

The final choice of drainage solutions for the roadbed is made through feasibility study with estimated road life and materials supply taken into account. The primary choice or estimation of possible application of any solution is made depending on specific requirements and intentions (reducing separate layers’ thickness, extending road revetment’s or surfaces’ life) [10]. To reduce layers, draining blanket in the roadbed is replaced by drainpipes. But as their maintenance and replacement is somewhat more difficult than setting up sandy drainage layers, it’s necessary to make a draining system’s life forecast to understand the cost advantages of such solution.

6. Summary

Improving and maintaining road revetment’s draining system working capacity is an important task. Existing researches and calculations prove that drainage improvement as well as its maintenance is quite cost effective, especially when road destruction is related with insufficient drainage. Nowadays, providing a modern and in-time drainage is one the main concepts of safety, environment and quality factors improvement in Russia.
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