Methodology for Calculating Transport and Operational Parameters of Condition of Highways

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Abstract. This article is devoted to methodology of calculation of transport and operational parameters of condition of highways. The technique of determination of parameters of geometrical elements of the road is presented. The technique of definition of strength of road clothes according to statistical and dynamic methods is described. The specifics of measurement of coupling properties and longitudinal flatness of road carpet are presented. The methodology of inspection of engineering arrangement and assessment of parameters of structural elements of highways is concretized.

1. Introduction

Now more and more relevant are problems of increase in transport and operational qualities of highways. The most important are problems of increase in safety, increase in speed of the movement and capacity of the road, hardware and communications, architectural and esthetic registration, drop of consequences of impact of cars on the road and environment and also other tasks making all complex of transport and operational qualities of highways [12].

Operational state - degree of compliance to regulatory requirements of the variable parameters and characteristics of the highway, the engineering equipment and arrangement changing in use as a result of influence of vehicles, weather conditions and level of contents, including strength of road design, condition of road carpet and actually used width of carriageway and road shoulders, coupling qualities and flatness of road carpet, condition of marking, the engineering equipment [15].

According to ODM-218.4.039-2018 of "The recommendation about preliminary treatment and assessment of the technical condition of highways" published on the basis of the order of Federal Road Agency of 04.07.2018 No. 2481-r, the general assessment of transport and operational qualities of highways is made on indicators, the structural elements of roads provided with geometrical parameters and technical characteristics and also existence, arrangement and condition of the road constructions which are technological part of roads [5].

2. Determination of parameters of geometrical elements of the road

When performing field works on determination of spatial arrangement of shaft of the road it is necessary to carry out drives of road laboratory in the direct and return directions according to previously appointed sites:
for two-way roads (congresses from outcomes and ring traverses) – in the middle of each lane (fig. 1);
for three-lane roads – in the middle of extreme right (external) strips (fig. 2);
for four and more lanes – in the middle of extreme left (internal) lanes (fig. 3).
In difficult cases (in the presence of the asymmetrical and (or) strongly carried carriageways on roads of the I technical category on ring traverses, etc.) the center line is traced individually according to the schemes provided on figures 4-6.

![Figure 1](image1.png)
**Figure 1.** Performance of record of spatial arrangement of shaft for two-way roads and congresses from outcomes.

![Figure 2](image2.png)
**Figure 2.** Performance of Record of Spatial Arrangement of Shaft Are Expensive to Three-lane Roads and in Zone of Intersections.

![Figure 3](image3.png)
**Figure 3.** Performance of Record of Spatial Arrangement of Shaft of the Road at four and more lanes.

![Figure 4](image4.png)
**Figure 4.** Tracing of the center line at asymmetrical carriageways.

![Figure 5](image5.png)
**Figure 5.** Tracing of the center line on difficult outcome.

![Figure 6](image6.png)
**Figure 6.** Tracing of the center line on ring outcome.

The general rule of tracing of the design center line should be considered the line between center lines of journey laid according to rules of tracing of roads of the I technical category.
In case the similar line cannot be unambiguously defined (on difficult outcomes, when veering the main title) this line on outcome is broken off; kilometrage on continuation is appointed taking into account length of direct driving through road interchange following title route.
Need of journey for the direct and return directions is caused by the following circumstances: accuracy of measurements increases; control of the executed measurements is exercised - there should not be traverse of models, overlaying and toe-out of models of more admissible; safety conditions of traffic are met [17].
During performance of drives in the massif of coordinates locations of kilometer columns have to be marked with tags, and at their absence – other road objects with unchangeable location: shafts of intersections, deformation seams of bridge constructions, regions of autopavilions of capital type, etc. Frequency of mark of such objects of 1-2 km. At the same time, in the course of performance of drives in the direct and return directions the same objects have to be marked. In case of impossibility of direct driving through the specified trajectories of the movement (in the middle of the required lanes) application of other high-precision methods of the measurements providing the accuracy of measurements of shaft of the road is allowed it is not worse than accuracy, shown to topographic maps of scale 1:2000.

Geometrical elements are expensive (according to GOST 33475-2015) and their parameters are defined by GOST 33383-2015 "Public highways. Geometrical elements. Methods of determination of parameters" on the base: representations of shaft are expensive (including on the restored sheet of angles of rotation, straight lines and curves in the plan); data from the project documentation for road elements which performance of measurements is impossible.

Width of carriageway, the left and right regional strengthened strips strengthened and not strengthened road shoulders, width of dividing strip) measure on each characteristic section of the road, but at least 1 time on 1 km. On sites of rises and descents with additional lanes width of carriageway is measured in alignments of the beginning and end of additional strip of full width and in any alignment on bias [18]. On entrances to bridges (railroad crossings) two measurements of width of carriageway are taken: in alignment prior to the beginning of otgon of width of carriageway on throat or broadening (if that is available) and in alignment of the beginning of the bridge (railroad crossing). In case of lack of change of width of carriageway on approaches to the bridge, measurement of width of carriageway on approaches can not be performed.

Within settlements of rural and city type (cities) width of carriageway is measured in the beginning and the end of building (on approaches – in places of broadening or throat of carriageway), in any characteristic alignment of the road located within the considered site and also in the places of change of its width (if that is available) traced visually.

In the place of measurement of width of carriageway break diameter. Measurements are taken with use automated photo, video systems. It is allowed to use the steel measuring tapes, roulettes, curvimeters, optical range finders, geodetic tools providing the accuracy of measurements of 0.1 m. If necessary prior to measurements from the surface of the carriageway, the regional strengthened strips and the strengthened road shoulders purify dust and dirt that strengthening borders were accurately visible. Width of the main strengthened surface is determined how the sum of width of carriageway and regional strengthening strips.

Determination of extent of the highway, its sites and also calculation of operational kilometrage on the road should be made the shaft of the road which is rather defined in space [14]. The distance of geometrical visibility of road surface in longitudinal cross-section is received as a result of data processing, the longitudinal biases of carriageway of highways and their sites received when determining with use of specialized mobile laboratories. The error of determination of distance of visibility should not exceed 5%. The key indicators of transport and operational characteristics and consumer properties of highways used for determination of the actual category of the existing highway are presented in table 1.

3. Definition of strength of road clothes
Strength of road clothes can be determined by two modes.

Static method. For definition of elastic deflection of road clothes, use the cargo biaxial car at which load of rear axle makes 100 kN with standard air pressure in tires. Measurements carry out according to GOST 32729-2014 "Public highways. Method of measurement of elastic deflection of nonrigid road clothes for strength definition" or ODN 218.1.052-2002 "Assessment of strength of nonrigid road clothes" (instead of VSN 52-89) [3]. The concrete document is defined by the specification on performance of work, depending on the tasks solved at preliminary treatment.
**Dynamic method**, with application of installation of dynamic loading. Measurements of elastic deflection with application of installation of dynamic loading need to be carried out according to GOST 32729-2014 "Public highways. Method of measurement of elastic deflection of nonrigid road clothes for strength definition" and ODM 218.2.024-2012 "Methodical recommendations about assessment of strength of nonrigid road clothes" [4] or ODN 218.1.052-2002 "Assessment of strength of nonrigid road clothes" [3] (instead of VSN 52-89). It is allowed to apply other methods and the equipment having the corresponding metrological support and the results which are not contradicting the existing normative documents allowing to receive. Measurements of elastic deflection of road clothes for strength assessment by static and dynamic mode perhaps only on nonrigid designs of road clothes of the capital and facilitated type.

**Table 1.** The key indicators of transport and operational characteristics and consumer properties of highways used for determination of the actual category of the existing highway [5].

| Parameters of elements of the highway | Highway class | Category of the highway |
|--------------------------------------|---------------|-------------------------|
|                                      | high speed    | ordinary highway       |
|                                      | road          | (not high-speed road)   |
| Total number of lanes, pieces        | IA            | IB                      |
|                                      | 4 and more    | 4 and more              |
| Width of lane, m                     | 3.5 - 3.75    | 3.5 - 3.75              |
| Roadside width (not less), m         | 3.75          | 3.75                    |
| Width of dividing strip, m           | 6             | 5                       |
| Crossing with roads                  | in different levels | crossing in one level with roads with traffic light regulation is allowed not more often than in 5 km |
| Crossing with railways               | in different levels | in different levels |
| Access to the road from the adjoining road in one level | not allowed | allowed no more than 5 km |

Notes:
1. Width of road shoulders of the highway on especially difficult sites of the mountain area, on the sites passing on especially valuable land grounds and also in places with transitional and high-speed strips will also add. strips on rise can make to 1.5 m - for roads of IC, IV and the II categories and to 1 m - for roads III, IV and V categories.
2. On highways of category IB width of dividing strip can be equal 2 m (without protection width at their existence on road shaft).
3. The maximum level of loading of the road by the movement is defined as the size relation move of intensity of the movement to the size of its capacity.
4. It is allowed to classify highways as high-speed highways only by the total number of lanes and types of traverse with automobile and the railroads, at the same time for the specified highway class width of lane should not be less than 3.5 meters

In case of lack of data of tool assessment of strength of road clothes, define probable value of coefficient of strength depending on the size of the average point (formula 1) characterizing condition of road clothes on the characteristic section of the surveyed road on formula (2).

On each same site in cameral conditions calculate the average point $B_{mid}$

$$B_{mid} = \frac{B_1 \cdot l_1 + B_2 \cdot l_2 + \ldots + B_n \cdot l_n}{l_1 + l_2 + \ldots + l_n}$$  \hspace{1cm} (1)

where:
$B_i$ and $l_i$ – the corresponding point and extent of (i) of private microsites of each strip with almost identical condition of road clothes in points; $n$ - the number of private microsites as a part of the same site.

$B_{mid}$ is defined:

$$K_{str} = \frac{B_{mid}}{10} + 0.5$$ \hspace{1cm} (2)

where:
$K_{str}$ - probable size of coefficient of strength.

The actual module of elasticity on each characteristic site is determined by formula (3)

$$E_f = E_{aggr} \cdot K_{str}$$ \hspace{1cm} (3)

where:
$E_{aggr}$ - the general settlement module of elasticity installed for the total estimated number of applications of loading from the moment of construction of road clothes or the previous construction of layer of strengthening until tests, MPa.

4. Measurement of coupling properties and longitudinal flatness of road carpet

At assessment of coupling properties of road carpets carry out measurements according to GOST 33078-2014 "Public highways. Methods of measurement of clutch of wheel of the car with covering".

Measurements of coupling properties of road carpets carry out on the left strip of setup of each lane by means of mobile installation of PKRS or its analog according to Section 9 GOST 33078-2014. At impossibility to provide safe measurement on the left strip of setup (two band are expensive, extreme left strip of the multiband road) it is allowed to make them on the right strip of setup. In case of need averagings on one kilometer take arithmetic-mean value of the received measurements.

It is allowed to take measurements of coupling properties of road carpet by means of the PPK-MADI-VNIIBD portable device or analog according to the Application In GOST 33078-2014. Measurements of coupling properties of road carpet by means of portable devices carry out on the left strip of setup of each lane in number of not less than 3 (three) measurements on 1 km of the road. At the uniform roughness of covering (the site, characteristic of this parameter) defined visually it is allowed to perform one measurement on one characteristic site which length should not exceed 5 km. Previously, by performance of 3-4 measurements, it is necessary to be convinced that clutch coefficients on such covering do not change.
At impossibility to perform safe measurement on the left strip of setup (the two-way road, extreme left strip of the multiband road) it is allowed to make them on the right strip of setup [10]. In case of need averaging on one kilometer take arithmetic-mean value of the received measurements.

Coupling qualities of covering are estimated by the coefficient of longitudinal clutch measured on the humidified covering at the design air temperature of 20 °C. Moistening of road carpet, is carried out by means of the autonomous system of artificial moistening mounted on road laboratory [16].

When using portable devices it is necessary to humidify road carpet with water on trajectory of the movement of simulators, at the rate from 0.15 to 0.25 l under each simulator. It is not allowed to perform measurements of coupling qualities of road carpet during rain and also during 2-3 h after it.

At measurements of coefficient of clutch fix air temperature. The received values of coefficient of clutch lead to the design temperature of 20 °C by their summation with the amendments specified in Section 10 GOST 33078-2014.

At assessment of longitudinal flatness of road carpets carry out continuous or selective measurements according to GOST P 56925-2016 "Public highways. Methods of measurement of roughnesses of the bases and coverings". Continuous measurements carry out at inspection of sections of roads more than 1 km long, selective – less than 1 km. It is recommended to use pro-phyllometric devices to assessment of longitudinal flatness and to measure longitudinal microsurface profile of covering on the main lanes and to carry out calculation of the international index of flatness of IRI (International Roughness Index). The IRI index needs to be calculated for sites 100 m and 1 km long (between kilometer columns). Length of sites for which calculate IRI indicator can be changed by the specification on performance of work and is specified directly or the reference to the normative document. In the Specification the order of measurement of longitudinal flatness on outcomes has to be specified.

It is allowed, at the corresponding justification, use for measurement of flatness of surface three-meter lath or level.

5. Inspection of engineering arrangement

Traverses and railroad crossings, technical means of the organization of traffic (protections, signs, marking, guiding devices, networks of lighting, traffic lights, the systems of automated management of the movement, calling communication), gardening, platforms of rest, advertizing, small architectural forms, etc. belong to engineering arrangement of roads [13].

At inspection check existence and compliance of parameters, designs and seating of elements of engineering arrangement of highways to regulatory requirements. At assessment of existence and condition of engineering arrangement it is necessary to be guided by requirements of normative documents. When determining elements of engineering arrangement one of modes is used: pointed field measurements by means of the satellite GLONASS/GPS systems; measurements of linear coordinates of objects through road laboratories; vectorization of clouds of points of laser scanning; fotogrammetriya on video filming materials (video series with binding of shots to geographical or linear coordinates); on materials of executive shooting; on materials of large-scale aerial photography, including with use of unmanned aerial vehicles; the different ways yielding the required result.

When coordinating the dot objects (having the area less than 0.1 sq.m. on the horizontal plane) as point of coordinating the point at the base from the front face at the movement in forward direction of the road is defined. Accuracy of determination of coordinates of such objects has to be no more than 1 m. When coordinating the linear objects (having the expressed extent along the direct, broken line or curvilinear forming and the cross size less than 0.4 m) the provision of object is fixed as set of points forming. The number of points has to be necessary and sufficient for providing deviation forming no more than 1 m from true position of object. When coordinating vulgar objects the provision of object is fixed as set of points of its external circuit (circuits) [11]. The number of points has to be necessary and sufficient for providing deviation of circuit no more than 1 m from true position of object.

Data on methodology of assessment of parameters and characteristics of structural elements of highways and road constructions on them are presented in table 2.
Table 2. Data on methodology of assessment of parameters and characteristics of structural elements of highways and road constructions on them.

| Specification               | Normative document | Justification of need of change                                                                 |
|-----------------------------|--------------------|-------------------------------------------------------------------------------------------------|
| The width of the roadway    | table 3 GOST R 52399-2005 for the corresponding category [2] | Need of increase arises in case the actual value less standard values at the size exceeding 0.5 m |
| Roadside width              |                     |                                                                                                |
| Width of dividing strip     |                     |                                                                                                |
| Size of radiuses of curves  | table 5.3 SP 34.13330.2012 for the corresponding design speed [8] | Need of increase arises in case the actual value less standard values for 20%, curve length more than 50 m and also the condition on existence of dangerous turning movements is satisfied |
| Size of longitudinal bias   | table 1 GOST R 52399-2005 for the corresponding rated speed [2] | Need of change arises in case the actual value more standard values for 20%, and site length more than 200 m |
| Longitudinal flatness of road carpets (IRI indicator) * | after construction, reconstruction or major repairs: item 16.5 (table 11a) SP 78.13330-2012 [8] after repair works and during operation: item 5.2.1 (table 5.1) GOST R 50597-2017 [1] | Need of improvement of flatness of carriageway arises in case the actual value of indicator of flatness exceeds standard value |
| Rutting of covering of carriageway ** | paragraph 5.2.4. (table 5.3) GOST R 50597-2017 [1] La appropriate category | In case of excess of the actual values of depth of track over permissible values works on elimination of rutting are appointed |
| Coupling properties of covering of carriageway *** | paragraph 5.2.2. GOST R 50597-2017 [1] | Need for holding actions for increase in coupling properties of covering arises when actually measured coefficient of clutch of wheel with covering of carriageway of less admissible on paragraph 5.2.2. GOST R 50597-2017 |
| Strength of road clothes **** | position ODN 218.1.052-2002 [3] and ODM 218.2.024-2012 [4], as well as methods of ODM 218.6.002-2010 [7] | Need for holding actions for strengthening of road clothes arises when the coefficient of strength of road clothes matters less than 1.0 |

6. Conclusions
Assessment of parameters and characteristics of structural elements of highways and road constructions on them is carried out for the purpose of definition of degree of compliance of the actual values of parameters and characteristics of structural elements to standard values. Toe-out degree assessment between the actual and standard values of parameters and characteristics of structural elements allows to draw conclusions on need of purpose of repair and recovery actions.

For each estimated parameter the admissible range of deviation of its actual values from standard at which excess there is need of purpose of repair and recovery actions is established. In case of hit of the
actual value of parameter in the admissible range, such parameter it is considered inappropriate, but need of purpose of repair and recovery actions does not arise.

7. References

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