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OPERATIONAL QUALITY CONTROL METHODS IMPROVEMENT FOR EVENNESS OF ROAD PAVEMENT SURFACE

The influence of road pavement evenness on road complex functional indicators has been discovered. Classification of unevenness's of road pavement surface according to geometric characteristics of its structure is shown. Known methods of operational quality control of road pavement evenness which application has been provided for by current regulations have been considered. Mathematical modeling of road pavement longitudinal profile with different kinds of unevenness has been conducted. On that basis the possibility of application of noted methods of operational quality control for these unevenness's detection has been discovered.

Keywords: *road pavement, surface evenness, macro-texture, micro-texture, operational quality control, leveling, 3-meter straight-edge.*

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УДОСКОНАЛЕННЯ МЕТОДИКИ ОПЕРАЦІЙНОГО КОНТРОЛЮ ЯКОСТІ РІВНОСТІ ПОВЕРХНІ ДОРОЖНЬОГО ПОКРИТТЯ

Установлено вплив рівності дорожнього покриття на функціональні показники автодорожнього комплексу. Наведено класифікацію нерівностей поверхні дорожнього покриття за геометричними характеристиками їх структури. Розглянуто відомі методи операційного контролю якості рівності поверхні дорожнього покриття, застосування яких передбачено діючими нормативними документами. Виконано математичне моделювання поздовжнього профілю дорожнього покриття з різними видами нерівностей, на підставі чого визначено можливість застосування відомих методів операційного контролю якості для виявлення цих нерівностей.

Ключові слова: *дорожнє покриття, рівність поверхні, макронерівність, мікронерівність, операційний контроль якості, нівелювання, триметрова рейка.*

Introduction. The state of road pavement surface is one of primary functional parameters of automobile road. It impacts the safety and comfort of traffic conditions as well as cost-effectiveness of transportations (vehicles maintenance costs and fuel) and environment preservation [1 – 3].

Road pavement surface always has some unevenness (pavement surface deviation from real flat surface) of different forms and scales. Its distribution along the way has casual character. Based on its scale the unevenness might be classified by geometric characteristics of its structure into following types:

– macro-texture – deviations of pavement surface from real flat surface are in the shape of waves with length $\lambda > 5$ m, which as a sum compile longitudinal profile of the road and affect dynamics of car motion but not its oscillation;

– micro-texture – deviations of pavement surface from real flat surface with wave length $0{,}5 < \lambda < 5$ m, which emerge as a result of different deformations occurring on road surface and cause oscillations of car or its parts but don't affect dynamics of car motion;

– roughness – deviations of pavement surface from real flat surface with wave length $\lambda < 0{,}5$ m, which emerge as a result of some compilation of stone material particles on the pavement surface (macro-roughness – $0{,}05 < \lambda < 0{,}5$ m) and caused by the structure of these particles surface (micro-roughness $0{,}005 < \lambda < 0{,}05$ m).

Further we will consider only the questions of macro- and micro-texture determination because pavement surface roughness determination deals with another ways and means of measuring.

Analysis of recent sources of research and publications. Current regulations [7, 8] which deal with quality control works conduction methods in terms of road evenness bases and pavement for construction period, capital repairs and reconstruction. These methods are needed for discovering of macro-texture of road pavement surface and overseeing determination of altitude marks during leveling. It also incorporates determination of gaps under 3-meter straight-edge for discovery of micro-texture.

Determination of macro-texture of road pavement by altitude marks during leveling is carried out according [7] during operational quality control of works for all road bases and pavements by the way of leveling longitudinal profile of route. Its sequence has been described in [8] and it foresees determination of relative deviation for marks h_i of longitudinal profile points (Fig. 1) from project line (except for the first and last points on measurement site) by the formula

$$\delta h_i = \left| \frac{h_{i-1} + h_{i+1}}{2} - h_i \right|, \qquad (1)$$

where h_{i-1} , h_{i+1} – relative marks of previous and further profile points.

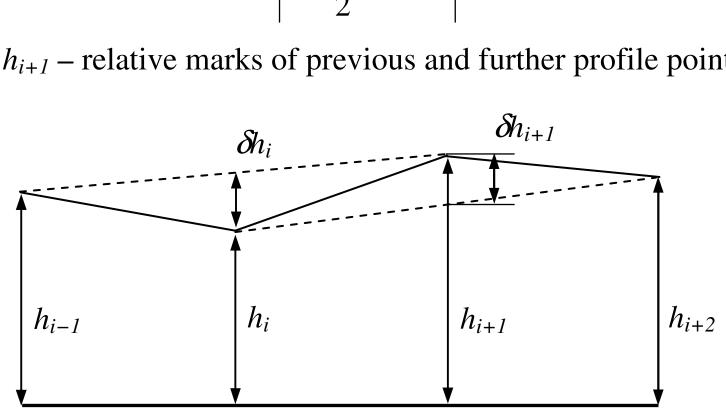

Figure 1 – Scheme for determination of deviation δh_i from project line

Basic values of relative marks difference during longitudinal leveling of longitudinal profile of automobile road are taken from table 21.4 [7]. For example if the distance between leveling points is 5, 10 and 20 m for roads of I – II categories then basic values of relative marks difference are being taken as 3 (5), 8 and 16 mm.

According to paragraph 38, table 27.1 [7] «not more than 10% of height measurements might have deviations from project values within the limits of ± 20 mm, for the rest of them ± 10 mm». Aside from that «at least 1 measurement should be taken per a 100 m».

Determination of micro-texture of road pavement surface under 3-meter straight-edge should be conducted according to paragraph 21.2 [7]. It is performed during works quality operation control for layers of base and bottom of the pavement. Its sequence is shown in paragraph 4 [8]. The essence of the method is that using wedge meter the gaps between bottom edge of straight-edge and pavement surface are being measured after each 0,5 m in longitudinal direction.

Allowable deviations of gaps measurements under 3-meter straight-edge for bases and pavements (apart from asphalt concrete and cement concrete pavements) according to paragraph 8.8, table 21.1 [7] «not more than 5% of measurements might have deviations from project values within the limits of 20 mm, for the rest of them – 10 mm».

According paragraph 89, table 21.7 [7] for the asphalt concrete and cement concrete pavements «... not more than 5% of measurements might have deviations from project values within the limits of 10 mm, for the rest of them – 5 mm», aside from that «... at least 150 measurement should be performed per a 1 km for each lane».

Identification of general problem parts unsolved before. Analyze of noted modern theoretical investigations and practical guidelines relating to assessment of road pavement evenness show that unevenness formation starts at longitudinal profile designing stage (up to 15 – 20% of road pavement designed evenness indicators), unevenness progress occurs during construction period (reconstruction) during road coating installation (including pavement top layer), unevenness accumulation takes place during road exploitation process as a result of transport loadings and climate conditions [9 – 11].

Construction period is the most responsible here since at this stage designing mistakes still could be properly corrected but technological violations correction is almost impossible. [12 – 14]. Since regulations [7, 8] do not contain detailed guidelines for execution sequence of operative quality control of road pavement evenness this question requires further consideration.

Formulation of the problem. Improvement of methodic for operative quality control of road pavement evenness by means of its longitudinal profile modeling and its evenness assessment by noted measurement instrumentation are the goal of this research.

Basic material and results. Usually the reproduction of designed longitudinal route profile on site is carried out using a guide string in a shape of steel supports-suspended rope. Thanks to that all minor unevenness of base surface or pavement's bottom layer, which were left for the moment of next layer installation, shouldn't affect designed pavement's profile quality [11 – 14]. The guide string represents flexible cable of constant section [16] that under its own weight q in the middle of the span l has its bending deflection f (Fig. 2)

$$f = \frac{ql^2}{8N}, \qquad (2)$$

where q – flexible cable's own weight, kg/m;

l – flexible cable's span, m;

N – flexible cable's horizontal tension, kg.

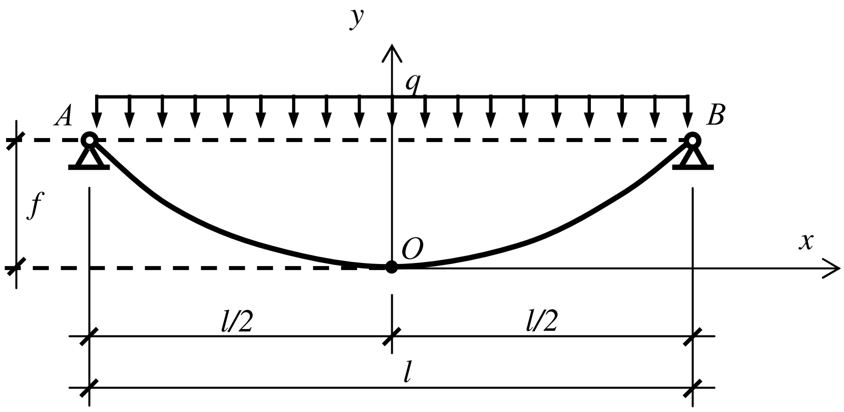

Figure 2 – Calculation scheme for symmetric flexible cable ($H_A = H_B$)

If suspension points of guide string will be fixed at one level (Fig. 2) then flexible cable will be of a symmetric shape. The lowest point of flexible cable (point O at Fig. 2) in this case will be situated in the middle of the span, that's why $x_O = l/2$ and $y_O = f$.

If suspension points of guide string will be fixed at different levels (Fig. 3) and flexible cable will be of an asymmetric shape the bending deflection for each point of fixation f_i might be calculated by the formula

$$f_1 = \frac{ql^2}{8N} + \frac{Nh^2}{2ql^2} + \frac{h}{2} , \qquad f_2 = \frac{ql^2}{8N} + \frac{Nh^2}{2ql^2} - \frac{h}{2} , \tag{3}$$

where h – altitude levels difference of suspension points (see Fig. 3).

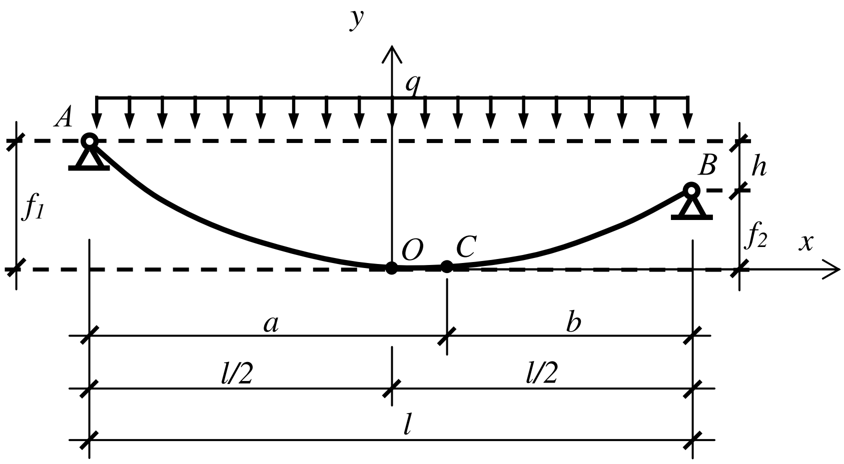

Figure 3 – Calculation scheme for asymmetric flexible cable ($H_A > H_B$)

The lowest point of flexible cable (point C at Fig. 3) in this case will be situated at some distances a and b from suspension points, which might be calculated using difference of altitude levels of suspension points

$$h = f_1 - f_2 . \tag{4}$$

If values f_1 and f_2 from expression (2) will be substituted into expression (4) and converted with condition $a + b = l$ we'll obtain following expression:

$$h = \frac{qa^2}{2N} - \frac{qb^2}{2N} = \frac{q}{2N}(a^2 - b^2) = \frac{ql}{2N}(a - b) \tag{5}$$

from which

$$a = \frac{l}{2} + \frac{Nh}{ql}, \qquad b = \frac{l}{2} - \frac{Nh}{ql}. \tag{6}$$

Using MS Excel we'll carry out longitudinal profile of road pavement with different unevenness's types modeling for clarification of results objectivity of road pavement evenness assessment during operational quality control execution with noted methods taking into account calculations shown above and results of [9].

Macro-textures determination of road pavement surface via altitude marks during leveling in accordance with [7, 8] will be carried out at the interval of road pavement longitudinal profile of 100 m length (the start of an interval is at the PK 0+000, and the end is at the PK 0+100). It's marked on site with guided string in intervals of 10 m length each. Divergence of suspension points of guided string relatively to interval start within the range of ± 1 mm

We've taken in calculation that guide string is manufactured of steel cable ∅3,1 mm according to regulations [17] (mass q = 0,0492 kg/m, cross section area is F = 5,66×10-6 m^2). The cable will have bending deflection f = 3,075 mm if the span is l = 10 m and tension force is N = 200 kg and fixation points will be located at the same level according to expression (2).

Distribution of vertical deviations of longitudinal profile from real flat surface is shown at Fig. 4. This deviations are obtained by the way of altitude marks leveling with the step of 0,5 m.

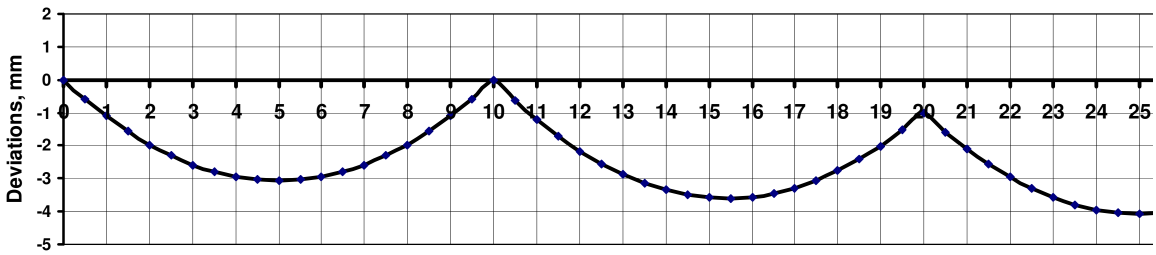

Figure 4 – Diagram of vertical deviations of longitudinal profile of pavement according to leveling results (PK 0+000 – PK 0+025)

Assessment results of road pavement longitudinal profile macro-textures by its vertical deviations obtained via leveling have shown that due to divergence of suspension points marks relatively to the start of the interval within the range of ± 1 mm vertical deviations δh_i of 3,83 mm emerge in longitudinal profile during route leveling after each 5 m. Vertical deviations make up 1,50 and 0,75 mm during leveling after each 10 m when leveling straight-edge installed above and between guide string fixation points respectfully. Thereby a more precisely assessment of road pavement evenness by macro-textures could be obtained in results of longitudinal leveling after each 5 m.

Micro-texture determination of road pavement surface under 3-meter straight-edge according to [7, 8] is carried out at the interval of road pavement longitudinal profile of 100 m length (the start of an interval is at the PK 0+000, and the end is at the PK 0+100). Its reproduced on site with guide string by intervals of 10 m length each taking into account assumptions that guide string suspension points are situated at the same level.

It was taken in calculations that longitudinal micro-textures have emerged on the surface of road pavement during its installation (wave length λ = 0,5 m, its amplitude A = 0,5 mm).

Distribution of vertical deviations of road pavement longitudinal profile from real flat surface, obtained by the way of determination of gaps with wedge meter under 3-meter straight-edge along the route with the step of 0,5 m is shown at Fig. 5. Fig. 5a shows the case of 3-meter straight-edge is laid on the road surface from the very beginning of interval at PK 0+000, at Fig. 5b – 3-meter straight-edge is laid on the road surface in 0,5 meters after route start at PK 0+000,5.

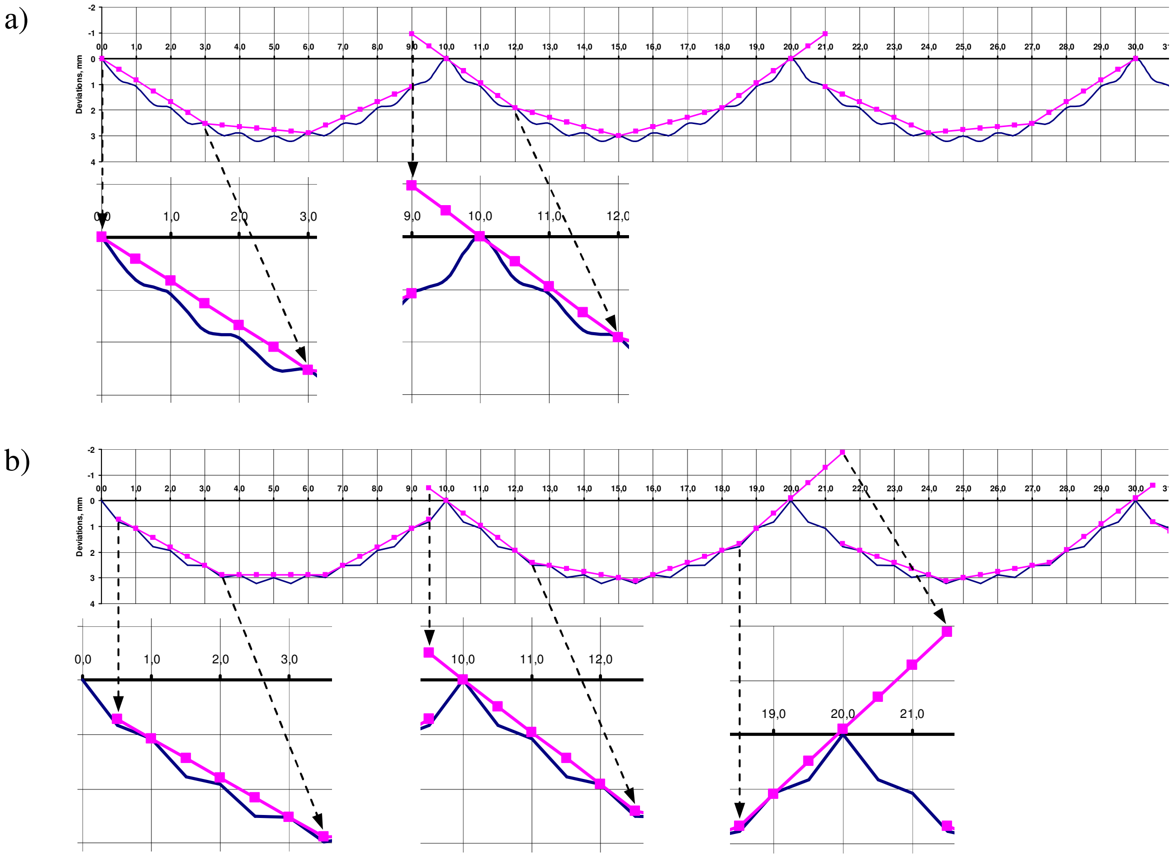

Figure 5 – Diagram of vertical deviations of longitudinal profile of road pavement by gaps under 3 meter straight-edge (straight-edge location is represented with marked intervals)

Results of assessment of micro-textures of road pavement longitudinal profile by its vertical deviation (gaps) under 3-meter straight-edge have shown that result could depend on situation of the straight-edge along metering route. For example, in case of straight-edge location on the road pavement from the start of an interval, maximum value of gap on metering interval will be 2,04 mm when average gaps value is 0,37 mm. If 3-meter straight-edge is located on road pavement after 0,5 m from the start of route then maximum value is 3,66 mm when average gaps value is 0,31 mm. Thereby a more accurate evenness assessment of road pavement by micro-textures might be obtained during 3-meter straight-edge location between suspension points of guide string.

Conclusions. Results of road pavement longitudinal profile modeling with different kinds of unevenness's show that for macro-textures discovering leveling straight-edge should be placed at suspension points of guided string during operational control of road pavement evenness quality 3-meter straight-edge with wedge meter for micro-textures discovering should be placed above suspension points of guided string (at maximum deflection points).

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