N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 3, Number 429 (2018), 197 – 207

UDC 539.3.6:621.01.03
Code of MRNTI 30.19.51

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FINDING ALLOWABLE DEFORMATION OF THE ROAD ROLLER SHELL WITH VARIABLE CURVATURE

Abstract. The article examines a new mechanic and mathematical model for the conditions of the roller flexible shell of the road roller assessing its load bearing capacity, reliability and strength and making it possible, depending on the properties of the material to be compacted, to select abroad roller with the required performance of rollers before the work is started. It also reviews issues related to the acceptable transformation of the flexible shell circular surface and allowable displacementlimit while exceeding ofthe latter may lead to a failure of the road roller capability. The article is aimed at giving scientific evidence and finding feasibility of using flexible shells in the road roller design and determining their parameters that are sufficiently accurate to be used for engineering purposes. It also describes the experimental equipment used to investigate the parameters of flexible shells and presents practical effect in the form of schematics and full-scale structures, as well as an experimental roller of a road roller with a flexible steel shell. The results complement and integrate into previous studies and they are compared with analytical and elemental solutions of similar tasks from the scientific literature [7, 9, 13, 14].

Key words: Cylindrical shells, Elastic Deformation, elastic bending of a circular ring, flexible shell of roller of road roller, load bearing capacity, strength, kinematic parameters.

1. Introduction. Compulsory compaction of soil, crushed stone and asphalt in the road sector is actually the main operation to ensure their strength, stability and durability [6].

The main compacting equipment is a road roller which can be equipped with rollers of various shapes and dimensions.

Analysis of the available experimental data shows that the increase in the roller weight without adjustments in the roller diameter does not make it possible for the standard roller to adapt to the current properties of the compacted materialbecause the pressure applied to the contact area may exceed the material strength and this will lead to over-compaction and loosening of the material.

To remedy the situation and adapt to the properties of the compacted material using its optimum and compaction-friendly parameters is possible only by the application of road rollers with flexible rollers [1-3] which, given permanent static weight of the roller, allow for changing its linear pressure on the material in the area of their contact by varying the curvature radius of the roller.

The radius of flexible rollers is changed by their forced deformation along the entire perimeter and local deformation in the area of contact with the ground [1, 4, 5].

The economic significance of the problem is so high that even its partial solution will have a noticeable effect on the efficiency of road construction and their operation reliability [8, 10, 12].

2. Problem. Modern compaction equipment is marked by more advanced technologies and compaction effect that provides a change in the pressure at the supporting surface contact area due to variation in the shell curvature radius. However, given the roller weight and its pressure on the shell, an

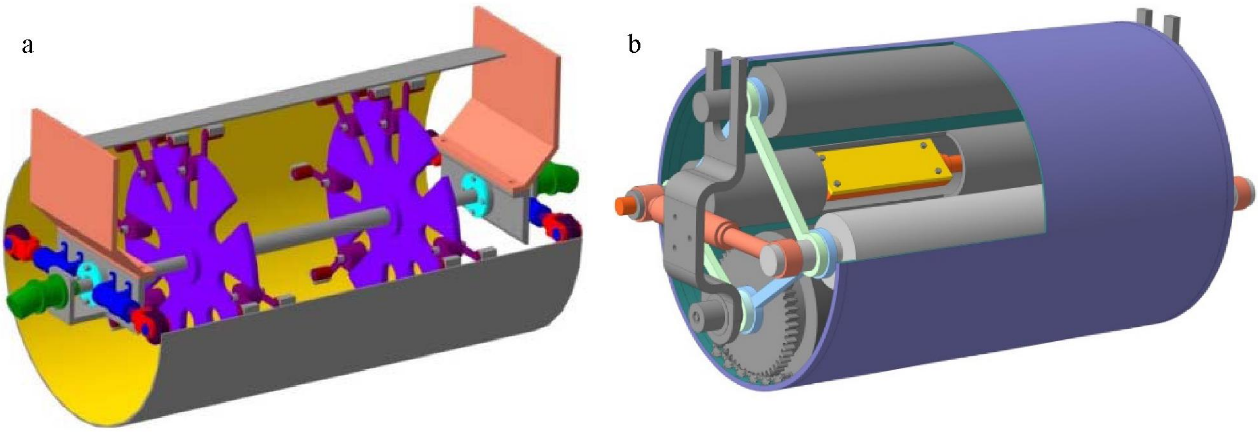

Figure 1 – Rollers of road rollers withflexible shells under provisional patents of Kazakhstan No. 18131 (a) and No. 21592 (b)

issue of the flexible shell operability, reliability and ability to recover its original shape becomes highly relevant [6].

Cylindrical shells with different thickness and made of different materials behave differently when forcibly deformed by external or internal forces. After the cylindrical shape is changed in order to achieve the desired contact area, if the allowable deformation limit is exceeded, the steel roller shell may not recover its original shape and remain flattened or stretched. Then the capability of the roller or the road roller as a whole will be completely broken, limited or terminated.

It is required to conduct a research and find scientific evidence of the allowable vertical and horizontal displacements of the roller shell after which the shell will guaranteedly retain its initial cylindrical shape. It is also needed to complete the previous studies of the roller flexible shell [6], combining them with the findings of experimental test of its stress and strain state.

3. Analytical Model. The goal of this research is to do an experimental test, complement and complete earlier analytical linear connection of displacement u, v [6] for a scale-down model of a cylindrical shell made of engineering alloy steel30ХГСА (GOST 4543-71) with modulus of elasticity E=2,11$\cdot 10^5$ MPa (N/mm^2), Poisson's ratio μ=0,282, yield limitσ_T=830 MPa (N/mm^2) and dimensions R=152,15 mm; B=399,3 mm; δ=1,98 mm - outside radius, width and thickness respectively, (figure1) frequently used for various operating elements of road and screening equipment [6-8, 15, 16].

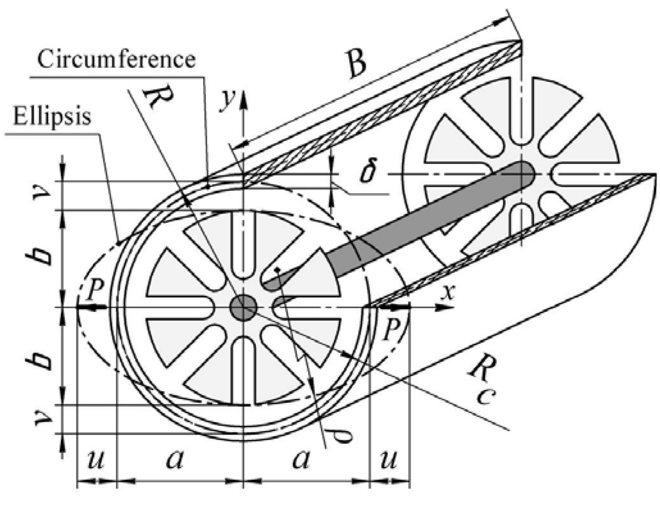

Figure 2 – Theoretical and calculation schematics of cylindrical shell

Let usintegrate the analytical model of the roller stress and strain state presented earlier [6]and the new calculated and force linear connections:

For the ellipsis curvature radius $\rho = \rho(x)$ (figure 2), upon replacing arbitrary size of bodies a, b with their allowable values $a_п$, $b_п$, the function $\rho_n = \rho_n(x)$ was obtained [6] at the highest change of the deformed shell contour expressed in terms of R_c:

$$\rho_n = \rho_n(x) = 1{,}333\mathrm{R_c}\left(1 - 0{,}2708\frac{\mathrm{x}^2}{\mathrm{R}_c^2}\right)^{3/2}, -a_п \leq \mathrm{x} \leq a_п \tag{1}$$

where,when$x=0$,

$$\rho_{max} = \rho_n(0) = 1{,}333R_c, \tag{2}$$

and when$x = \pm a_n = \pm 1{,}09537$

$$\rho_{min} = \rho_n(\pm a_n) = 0{,}7394R_c. \tag{3}$$

Functional width of flexible shellδ, should fall into the ranges

$$\delta \leq \delta_{max} = 2{,}18\ cm \tag{4}$$

When this condition is fulfilled (4), the given physical and mathematical model will be sufficiently correct with an error value allowable for engineering calculation below 5% [12, 14].

The function of internal [6] bending moment $M=M(x)$:

$$\frac{M}{H} = \frac{1}{\rho} - \frac{1}{R_c} \tag{5}$$

where H is rigidity of the shell rectangular section core [8]:

$$H = \frac{EB\delta^3}{12(1-\mu^2)} \tag{6}$$

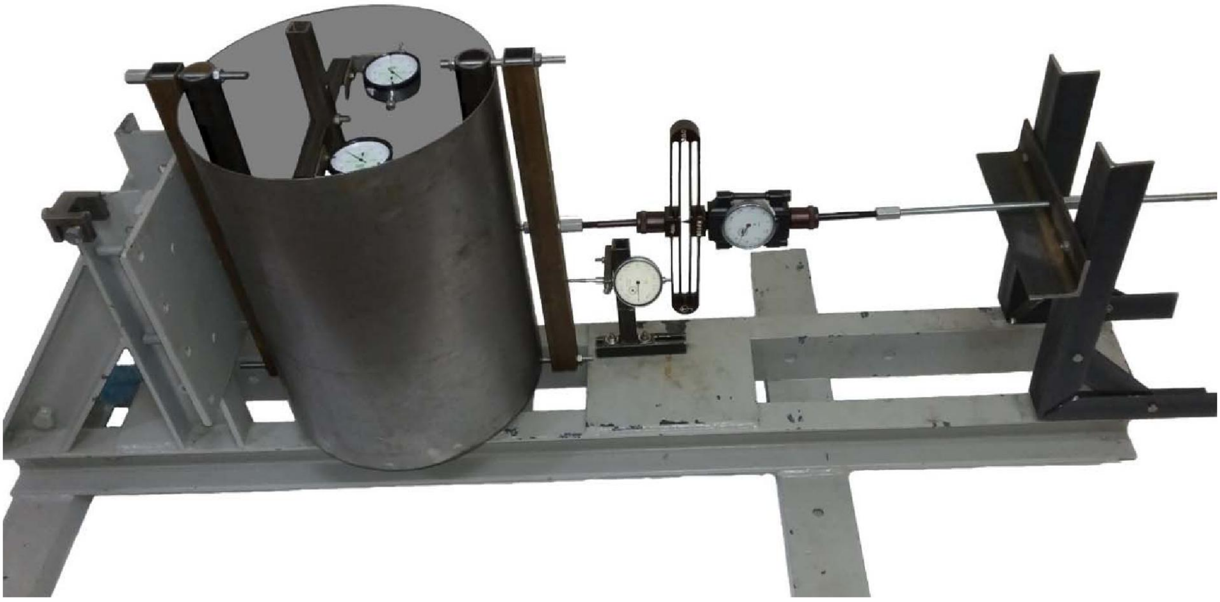

Figure 3 – Test stand for finding allowable displacement of flexible shell and its instruments

The rule of the moment sign$M$is derived from equation (5), meaning that the parameter $H>0$: if the core curvature increases, then $M>0$ and $M<0$ – if it decreases. The difference change sign is also considered ${}^{1}/_{\rho} - {}^{1}/_{R_c}$, i.e. the positive value $M>0$ corresponds to ${}^{1}/_{\rho} - {}^{1}/_{R_c} > 0$ and vice versa.

Changing the symbols $M \Rightarrow M_n$, $\rho \Rightarrow \rho_n$ and substitutingρ_n, based on (1), in the ratio (5), let us obtain a linear connection for the function of the ultimate bending moment $M_n(x)$: