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NEW CONSTRUCTION OF THE HOLDER OF CONCRETE CYLINDRICAL ELEMENTS

У рефераті представлена нова конструкція захоплення для перевезення бетонних кіл. Його конструкція заснована на використанні фрикційного зчеплення між лапами захоплення і внутрішньою поверхнею круга. Запропонований спосіб запатентований. Захоплення пристосований до застосування зі стандартними навантажувачами. Аналітичні розробки поповнені результатами чисельних розрахунків

Ключові слова: *захоплення, конструкція, запатентований, фрикційного*

Introduction

Several devices for material handling in the building industry are currently available in the market. These devices allow to increase productivity and their wide-spreading is – from the economic point of view – very advantageous. There are several constructional solutions of holders used for transporting coils of wires, metal strips, tubes, plates [1], concrete curbs [3], columns and many other prefabricated concrete products and semi-finished steel products. Also holders of concrete cylinders of a construction presented in fig. 1 are available. When the cylinder is being lifted, one of the holder lug – of a triangle shape – is shifted down on inclined guide-bars, fastened on central bushing of the holder. This causes that lugs are drawn aside, and thereby pressed to the inner cylinder surface.

Fig.1. **Holder of cylindrical elements of the Manhole Company [7]**

Due to an eccentric placement of the axis of rotation of lugs, the friction force acting between the cylinder surface and toothed arched surfaces of lugs causes their self-clamping. However, this solution has some faults. In the first place, surfaces cooperating in joining guide-bars with lugs can be easily contaminated or corroded, which can cause blocking of lugs on guide-bars followed by the lack of matching of the lugs spacing to the cylinder inner diameter. The holder construction presented in Fig. 1 is rather complicated and ensures only a narrow regulation range of the lugs spacing, which can render difficult the holder operating and placing it inside the cylinder. As can be seen in Fig.1, the rotating lugs at the arm ends have arched surfaces, which means that the contact between them and the inner cylinder surface is point wise being the reason of a large stresses in the cylinder material. The maximum force pressing the lug to the ring is limited by the maximum allowable stresses in the cylinder material. Thus, if lugs of a linear contact are applied this, for sure, will allow to increase the range of a down-pressing force.

Analysis of the new construction

Looking for solutions free from the mentioned above faults led to the development of the new holder construction [4]. The scheme of the holder operation is presented in Fig. 2.

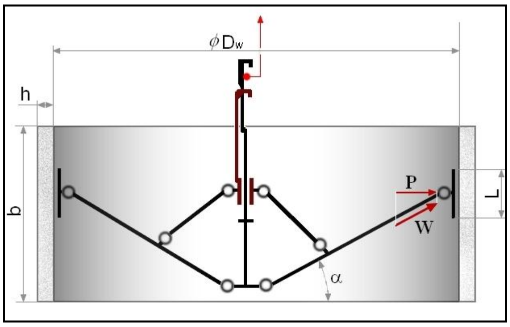

Fig.2. **Schematic presentation of the new holder construction**

In the construction presented in Fig. 2 the effect of the holder self-blocking inside the ring was obtained by changing the angle of arms inclination to the level. This solution enables the application of lugs of a linear contact with the ring surface thus increasing the device operation safety. Due to the fact that joints allowing arms deviations are at a large distance from lugs, small changes of the arm inclination are accompanied by relatively large radial displacements. This makes the holder manoeuvring easier. In addition, joints are less sensitive than guide-bars for eventual contaminations or corrosion. The holder presented in Fig. 2, in a similar way as holders available on the market, allows - by a proper setting of a lifting sling - servicing by a single operator directly from the loading machine cabin. This lifting sling can be attached below the arm holder – during placing the holder in a ring or below the holder central part – during lifting of the ring. The most essential parameter – from the point of view of the holder safety exploitation – is the determination of the allowable range of changes of angle α between holder arms and a level. The highest allowable value of this angle is directly determined by the coefficient of friction between holder lugs and the inner surface of a ring. Making a direct use of the coefficient of friction definition, it can be written:

$$\alpha_{max} = \text{atan}\,\mu \qquad (1)$$

Assuming after [5] the coefficient of friction value between steel and concrete of a rough surface as 0.3, the maximum value of the inclination angle of holder arms is:

$$\alpha_{max} = 16{,}7°$$

The smallest value of angle α depends on strength parameters of concrete used for building cylinders.

Mechanical properties of concrete B30 (C25/30), from which cylinders are built are given in Table 1.

Table 1. **Mechanical properties of concrete B30 [6]**

Guaranteed compression strength $f^{G}_{c,cube}$	30 MPa
Characteristic compression strength $f_{ck} = 0{,}8\, f^{G}_{c,cube}$	25 MPa
Guaranteed tensile strength f_{ctm}	2,6 MPa
Characteristic tensile strength f_{ctk}	1,8 MPa
Elasticity of elongation module *E*	30500 MPa
Poisson’s number ν	0,2

In fact the *Young's* modulus value for concrete of the given strength class depends on the state of stresses occurring there. In the originally isotropic material, anisotropy can develop under an influence of deformations [2]. On account of the fact that, in the considered problem, thermomechanical effects do not occur and loads are of a force nature not of a displacement one, the properties of concrete given in [6] were used in the present paper. On account of the symmetry the considerations can be narrowed to 1/3 of a circle, as shown in Fig. 3. Force *P* is the component perpendicular to the axis of force circle *W* acting along the holder arm (fig. 2).

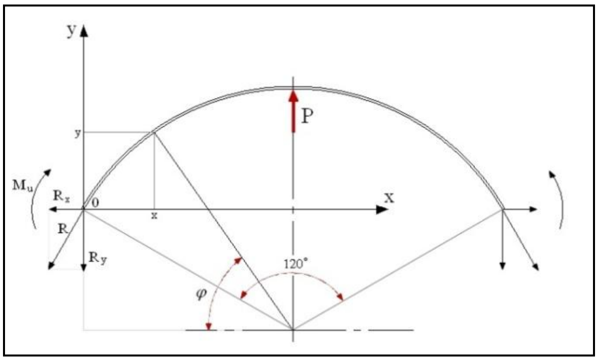

Fig.3. **Model of the sector of the analysed concrete circle loaded with force P**

The smallest allowable value of angle α can be expressed as follows:

$$\alpha_{min} = \operatorname{atan}\frac{G}{3 \cdot P} \tag{2}$$

where *G* is the weigh of the lifted cylinder. Moment M_u is the hyperstatic reaction resulting from the symmetry condition. The *Menabrea's theorem* was used for the determination of the force P maximum and thus the angle α minimum. Initially, for the simplification, the co-ordinate system shown in Fig. 3 was assumed. Parameters of the lifted cylinder: inner diameter: D_w=1500 mm; wall thickness: *h* =150 mm; cylinder height: *b*=1000 mm; weight: *G*=19130 N, mean radius of the cylinder r = ½ (D_w + h) = 825 mm. The bending moment as a function of coordinate *x* equals:

$$M(x) = R_y \cdot x - R_x \cdot y - M_u \tag{3}$$

where $R_x = {}^{1}/_{3}\, P\sqrt{3}$; $R_y = {}^{P}/_{2}$. Expressing the bending moment as a function of angle φ:

$$M(\varphi) = R_y \cdot r \cdot (\cos 30^\circ - \cos\varphi) - R_x \cdot r \cdot (\sin\varphi - \sin 30^\circ) - M_u \tag{4}$$

The ratio of the mean radius of the cylinder to its thickness is 5.5. Thus, it was assumed that it can be modelled in a form of hyperstatic bar slightly bended. The elastic strain energy, in the considered case, will be:

$$U = \int \frac{M^2(\varphi) \cdot r \cdot d\varphi}{2EJ} \tag{5}$$

Substituting (4) into (5) we obtain:

$$U = \int_{30^\circ}^{90^\circ} \frac{(R_y \cdot r \cdot (\cos 30^\circ - \cos\varphi) - R_x \cdot r \cdot (\sin\varphi - \sin 30^\circ) - M_u)^2 \cdot r}{2EJ} d\varphi \tag{6}$$

Using the *Menabrea's theorem* :

$$\frac{\partial U}{\partial M_u} = \int_{30^\circ}^{90^\circ} \frac{-(R_y \cdot r \cdot (\cos 30^\circ - \cos\varphi) - R_x \cdot r \cdot (\sin\varphi - \sin 30^\circ) - M_u) \cdot r}{EJ} d\varphi = 0 \tag{7}$$

From where:

$$M_u = \frac{P \cdot r(4\pi\sqrt{3} - 18)}{12\pi} \tag{8}$$

The highest normal stresses originated from bending and stretching occur for φ = 90º (fig. 3):

$$\sigma\left(\varphi = \frac{\pi}{2}\right) = \frac{P}{bh}\left(\frac{1{,}132r}{h} + 0{,}288\right) \le k_r = 1{,}5\ MPa \qquad (9)$$

The allowable stresses for tensile failure were assumed from the condition $k_r = 0.8 f_{ctk} \approx 1.5$ MPa due to the fact that the analytical model does not take into consideration the concentration of stresses related to a small lug length (in comparison with the cylinder height), to the spatial stresses distribution, cylinder curving, and dynamic over-loads. Hence the highest force P = 34539 N and the smallest allowable angle α_{min} = 10.5º. Calculations of stresses in the cylinder were performed with several simplifying assumptions. One of them was the assumption that holder lugs are in contact with the cylinder at its whole height. In fact, these lugs can be of various length L and width. In order to verify the calculation correctness several Finite Element Method analysis were performed. The first one was the analysis at the assumed lug length L = 1000mm and width being 10mm. The normal stress pattern in the cylinder material in the direction x for this case is presented in Fig. 4a. Maximum tensile stresses did not exceed 1.4 MPa which means that simplifying assumption performed in the analytical model slightly increased the calculation safety. In successive analyses the lugs length L was shortened, while the width remained the same, up to the moment of obtaining the maximum tensile stress equal f_{ctk}. This value was obtained already at L = 500 mm. This case is shown in Fig. 4b.

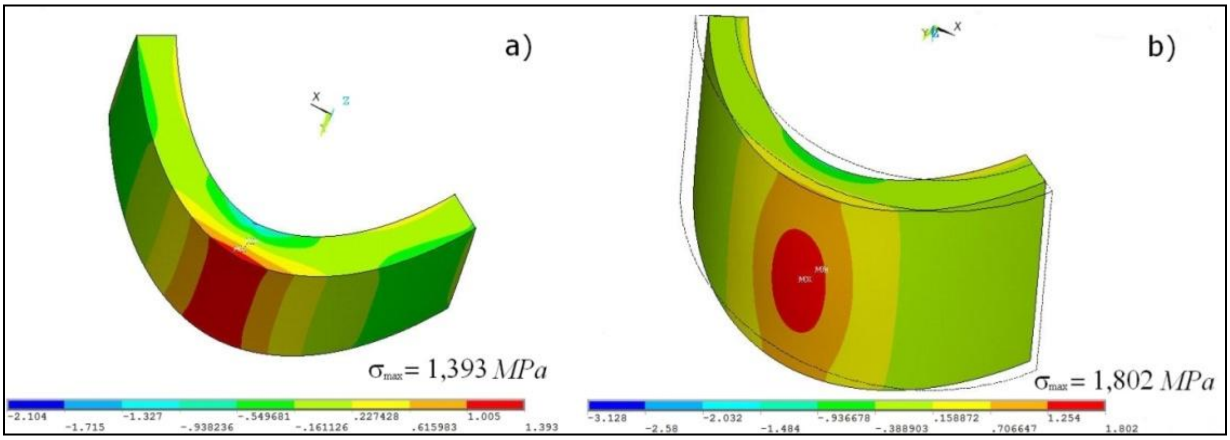

Fig.4. **Stress distribution in the cylinder in direction *x: a*) for lug length 1000mm, *b*) for lug length 160mm**

As can be seen in Fig. 4 the length of holder lugs has an essential influence on stresses in the cylinder and thereby on the minimum allowable value of the arms inclination angle. This confirms the superiority of the new construction over solutions available currently on the market. This is a result of a linear contact of the lug with the cylinder surface while the point wise contact is applied in the currently available solutions. The FEM analyses confirmed the correctness of the assumed analytical model and simultaneously allowed to select properly the geometric parameters of clamping lugs. The presented calculation results bore fruits in the new holder construction, which is the subject of the patent application [4]. Fig. 5 presents this new holder. Currently works on the implementation of the presented solution for production and sale - are under way.

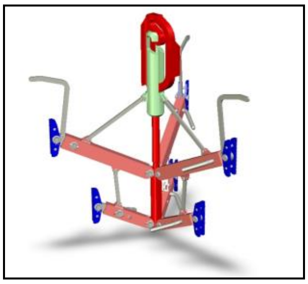

Fig.5. **Construction of the new holder [4]**

REFERENCES

1. Kosakowski K., Dudek R.: Projekt samozaciskowego uchwytu do pionowego transportu blachy. Postępy Nauki i Techniki. – 2011. No 7, – Pp 149–156,
2. Litewka, A., Bogucka, J., Dębiński, J.: Analytical and experimental study of damage induced anisotropy of concrete. Foundations of Civil and Environmental Engineering . – 2002.– No.2, pp. 101–124.
3. Patent PL 389906 A1: Manual, self–clamping grapple for building elements. – 2011
4. Patent PL 389968 A1: Device for translocating cylindrical elements, especially concrete rings. 2011
5. PN-82/B-02003 Obciążenia budowli – Obciążenia zmienne technologiczne – podstawowe obciążenia technologiczne i montażowe, Grupa ICS 91.080.01
6. PN-B-03264:1999 Konstrukcje betonowe, żelbetowe i sprężone. Obliczenia statyczne i projektowanie.
7. WWW.lifting-equipment.co.uk

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Новая конструкция захвата для перевозки бетонных кругов

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В реферате представлена новая конструкция захвата для перевозки бетонных кругов. Его конструкция основана на использовании фрикционного сцепления между лапами захвата и внутренней поверхностью круга. Предложенный способ запатентован. Захват приспособлен к применению со стандартными погрузчиками. Аналитические разработки пополнены результатами численных расчетов.

Ключевые слова: захвата, конструкция, запатентован, фрикционного.

New construction of the holder of concrete cylindrical elements

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The new construction of a holder of cylindrical elements, made of concrete, was presented in this paper. The holder allows to handle concrete cylinders, thanks to the frictional contact between holder lugs and the cylinder inner surface. The way of the holder operation was patented. The holder can be maneuvered by the operator of a loader cooperating with the holder. Analytical calculations presented in this paper were supplemented with the results of numerical calculations.

Keywords: holder, construction, patented, frictional.