AUXILIARY ELEVATOR ACTIVATED WITH A TRANSLANTING CAM MECHANISM USED FOR SERVING AN OVERGROUND SMART PARKING LOT ABOVE THE DAMBOVIȚA RIVER. CALCULATION OF THE BUCKLING CRITICAL LOAD OF A ROD PERTAINING TO A ROLLER TRASLATING FOLLOWER

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ABSTRACT: The overground parking lot including a robot-driven elevator has the advantage of complete automation. The parking lot can be attended to, in case of an emergency, by auxiliary elevators that operate several small-sized side platforms that can transport vehicles between the parking floors. These elevators can be operated by mechanisms provided with translating cams and roller translating followers. In order for the follower rod to withstand buckling, it is required that we be in the elastic field and the Euler formula be applicable. Calculation of the buckling critical load of a rod pertaining to a roller translating follower

Key words: elevator, cam and a roller translating follower, the buckling critical load

1. The need to adopt a device for the evacuation of cars from the parking lot. Components and working phases of the device

For the circular overground system, one considers the design of a mechatronic system for evacuating the vehicles located in the parking (fig.1), which is made up of the following elements:

- A translating cam mechanism with a roller translating [1], [2] follower that would elevate the vehicle together with the platform on which it is parked at a certain height
- A robot provided with a platform that takes the vehicle elevated by the cam mechanism, and transports it outside the parking.

In figure 4, one can see the components of the system. These are the following:

1) Translating cam 1 that can alternatively move from left to right by elevating or lowering roller follower 2
2) Roller follower 2 that is driven by translating cam 1, which is in a rigid connection to platform 4 [1] ,[3] ,[4], [6]
3) Guide 3 of translating follower 2 that is fitted by means of non-demountable (welding, riveting) or demountable (using screws) assembling to the metallic structure of the parking

(the structure is not represented in the figure) [1], [3]

4) platform 4 that elevates vehicle 5 to a higher level than the sum between its ground clearance and the thickness of platform 6 of robot 7

5) the parked vehicle

6) the platform of robot 6 that acts in the second phase of elevating vehicle 5 located on platform 4

7) robot 7 that alternatively moves from left to right and removes vehicle 5 from the parking by means of platform 6

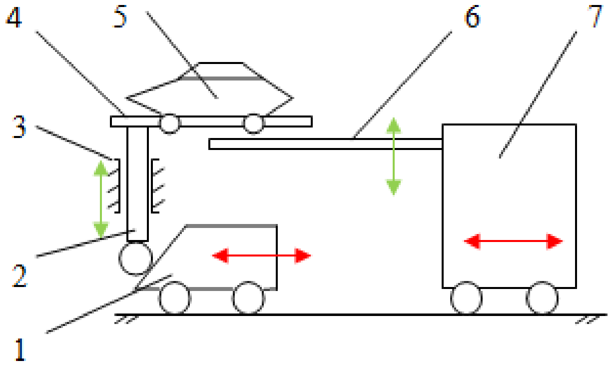


Fig.1 The mechatronic system for removing vehicles from the parking in case of emergency – first elevation phase [6]

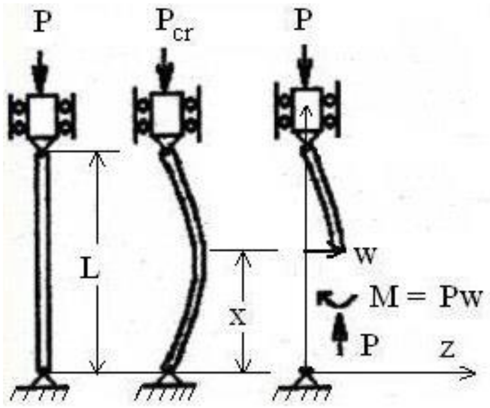
An essential element that generates the modernity of a capital is transportation and traffic fluency in that capital.

By reviewing the existing specialty literature and the policy documents of the large cities, it can be said that, at present, the parking policy aims at contributing to a better accessibility and mobility of the urban areas.

Further to an impact study for the modernization and development of parking lots in the Romanian capital, it was concluded that a smart overground parking lot located above the Dâmbovița river would solve a part of the problems caused by the small number of parking lots.

2. Verifying the translating follower rod with buckling roller

The elastic buckling of the straight bars was first approached by L. Euler who calculated the Pcr buckling critical load in 1744. One considers a bar having the cross-sectional area A and rigidity EIy, both constant along it. The bar is articulated at both ends and compression strained by a force P (fig. 2). The buckling occurs at a certain P = Pcr value of this force. In a deformed position of the bar, it is noticed that, in any certain section at level x, with the bending displacement w (on the axis Oz), besides the axial stress P, a bending moment M also occurs.



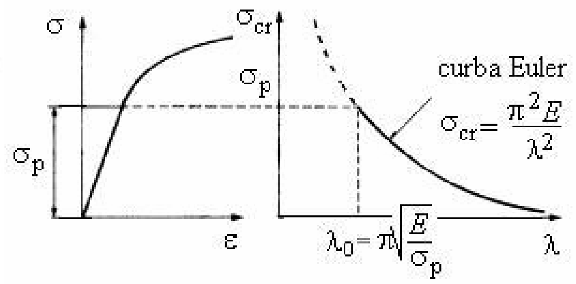


Fig. 2 The buckling of double-articulated bar

Fig. 3 Euler's Hyperbola

The bending moment in section x is $M = Pw$ and, consequently, the equation of the deformed average fiber is:

$$EI \frac{d^2 w}{dx^2} = -M = Pw \quad (1)$$

The characteristic equation of this differential equation is:

$$r^2 + \alpha^2 = 0 \quad (2)$$

where $r_{1,2} = \pm \alpha i$ and, consequently, the solution of the differential equation is in the form of:

$$w(x) = A\sin \alpha x + B\cos \alpha x \quad (3)$$

The limit conditions at the two ends are:

a) If $x = 0$, $w = 0$ and $A\sin 0 + B\cos 0 = B = 0$ follows.

Consequently: $w(x) = A\sin \alpha x$ *(4)*

b) if $x = L$, $w = 0$ and so $A\sin \alpha L = 0$

In order to meet this condition, there are the following two possibilities:

$A = 0$ that implies the common solution $w = 0$, or $\alpha L = k\pi$, where $k = 1, 2, ...$

Remark: $k = 0$ would mean $P = 0$ or $L = 0$. Consequently, a non-zero solution is obtained from

$$\alpha^2 L^2 = k^2 \pi^2 \quad (5)$$

$$\alpha^2 = \frac{P}{EI} \quad (6)$$

Further to the two equations, this follows

$$P = \frac{\pi^2}{L^2} EI\, k^2 \quad (7)$$

The smallest value of the buckling critical load is obtained for $k = 1$, i.e.

$$P_{cr} = \frac{\pi^2}{L^2} EI \quad (8)$$

known as Euler's formula.

If the bar has $I_y \neq I_z$, P_{cr} has the smallest value when, in the calculation, the minimum value of the inertia moment $I = I_{min}$ is considered.

The importance shows the buckling in the fundamental case $k = 1$, which leads to the smallest value of the force that causes the buckling, given by the relation:

$$\lambda P_{cr} = \frac{\pi^2}{L^2} EI_{min} \quad (9)$$

For other propping cases (other limit conditions), the relation that gives the buckling critical load:

$$P_{cr} = \frac{\pi^2}{{L_f}^2} E I_{min} \qquad (10)$$

where $L_{f=}kL$ is called buckling length, and is the distance between two consecutive inflexion points of the bar shape in the buckled state. For the bar articulated at both ends $L_{f=}L$.

The bar compressive stress, adequate for the buckling critical force P_{cr} is:

$$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{\pi^2 E}{\lambda^2} \qquad (11)$$

Where with $\lambda = \frac{L_f}{i_{min}}$ (12)

a dimensionless coefficient called *slenderness ratio* or *fineness ratio* has been noted.

Curve σ_{cr} (λ) is called Euler's hyperbola (see fig. 3).

Euler's formula is valid in the linear-elastic field where the material is subject to Hooke's law. Consequently, $\sigma_{cr} < \sigma_p$ (the proportionality limit). For

$$\sigma_p = \frac{\pi^2 E}{{\lambda_0}^2} \Rightarrow \lambda_0 = \sqrt{\frac{\pi^2 E}{\sigma_p}} \qquad (13)$$

Coefficient λ_0 only depends on the bar material. Euler's formula is valid if $\lambda > \lambda_0$ (for slender bars). If the loss of stability occurs for $\lambda < \lambda_0$, the phenomenon is called plastic buckling

3. CALCULATION OF THE BUCKLING CRITICAL LOAD OF A ROD PERTAINING TO A ROLLER TRASLATING FOLLOWER

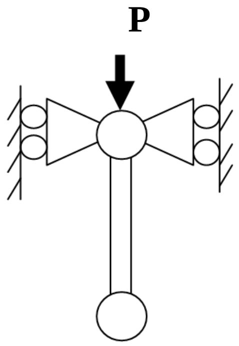


Fig.4 Bar model articulated at both ends

The follower rod is considered as a bar model articulated at both ends.

Data

- The force acting on the rod is F= 20000 N
- The length of the rod l= 2.5 m= 2500 mm
- The material of the steel rod with σ_r = 520 N/ mm^2 having σ_c = 360 N/ mm^2
- Steel elasticity module E= 210000 N/mm^2
- The slenderness ratio characteristic for steel λ_0= 105
- The safety coefficient c= 15

- The material features *E*, σ_c, σ_p, λ_0, λ_1 and *a*, *b* (from the Tetmajer-Iasinski formula).

Calculation

1.Buckling length

l_f = l= 2.5 m (articulation at both ends)

2.Inertia moment

$I_{min} = I = \pi d^4/ 64$

$I = Fcl^2/ \pi^2 E = 20000*15*2500^2/ 10* 210000= 89.28*10^4$ mm^4

3.Bar diameter

$d= \sqrt[4]{\frac{64*I}{\pi}}$ = 65.3 mm. d= 70 mm is chosen

4.The applicability of Eulerformula is verified

i= d/ 4 = 70/ 4 = 17.5 mm

5.Slenderness ratio

λ= l/ i = 2500/ 17.5 = 142.8 > 105

Euler's formula is applicable, so we are in the field of elastic buckling. We are in the field of slender bars. The follower withstands buckling.

6.The rod section area

Considering the chosen safety coefficient, d= 70 mm follows.

The section area is:

$A= \pi d^2/ 4 = 3.14* 70^2/ 4 = 3846$ mm^2

4. CONCLUSION:

Euler's formula is applicable so we are in the field of elastic buckling. We are in the field of slender bars. The follower withstands buckling.

The parking lot shall be executed and exploited so that the regular operation does not generate noises or vibrations which might affect the health and peace of the users from the surrounding. [8]

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