Kraków, dnia 20 czerwca 2022 r.

Tytuł pracy doktorskiej: STATECZNOŚĆ CIĘŻKICH MASZYN ROBOCZYCH PRACUJĄCYCH NA PODŁOŻU SŁABONOŚNYM

Autor: mgr inż. Mateusz RICHTER

Promotor: dr hab. inż. Aleksander URBAŃSKI, prof. PK

Summary

This research work concerns the stability of heavy machinery moving on caterpillar tracks on weak subsoil. Taking up this topic is caused by many accidents related to overturning of heavy machines, about which the media from time to time inform, pointing to their potential danger both to the immediate environment (construction workers and the site of construction works) and bystanders. One of the examples is the incident that took place in May 2003 in Great Britain, which resulted in a pile driver falling over onto an active railway line. Although no one was injured, a passenger train passed through the scene two minutes earlier.

One of the basic issues related to the stability of heavy machinery is to determine the basic parameters of a machine (its vertical load *Q*, caterpillar track dimensions: length - *L*, width - *B* and their axial distance between tracks - *D*) and the limited bearing capacity of the soil on which the machine is suppose to move or perform work. In case of insufficient bearing capacity of the subsoil, reinforcement is required in the form of a temporary strengthening structure which is a working platform.

In this research work, a synthetic decomposition of the interaction problem was made: construction machine - working platform - subsoil, isolating the problems related to the construction machine (e.g. the influence of the eccentricity of the machine's center of gravity on its stability), the working platform (e.g. determination of the limited bearing capacity) and subsoil (e.g. determination of the ultimate bearing capacity of a multilayered subsoil). An important element of this work is a review of the existing solutions for determining the bearing capacity of a multilayered subsoil, which is the basis for formulating theoretical solutions for the bearing capacity of the subsoil under the load of a caterpillar track machine. At the beginning of the work, the theoretical basis for the interaction of the caterpillar track - working platform - subsoil was developed. In the next stage, a three-dimensional computer model with only one caterpillar was made due to the use of system symmetry (3D Model ½). Results obtained from the 3D Model ½ for different values of the dimensionless eccentricity of the position of the resultant gravity force *e* create the basic characteristics: the angle of rotation $\varphi(e)$ and the displacement $w(e)$ calculated in the center of the running gear. From the obtained characteristics, it can be concluded that at a certain limit value of the eccentricity, there is a sudden increase in the angle of rotation $\varphi(e)$ and displacement $w(e)$, which indicate the beginning of the loss of a machine stability. All computer models were made using the finite element method (FEM) using the ZSoil 2016 v16.03 x64 program.

Then the results of the 3D Model ½ were approximated by the derived approximating equations (Approximation Model) in a calculation script specially written for this purpose. Using the results of the 3D Model ½ and the Approximation Model, and taking into account the time-consuming computer calculations related to the time needed to prepare the computer model and the time needed to obtain the results (due to the large number of equilibrium equations), an attempt was made to create a closed solution allowing to obtain the characteristics of $\varphi(e)$ and $w(e)$ in a purely analytical manner (Analytical Model). Then, the results obtained from the 3D Model ½ were compared with the results of the Analytical Model, demonstrating quantitative and qualitative compliance. In the next stage of the research, a three-dimensional computer model was made, taking into account two caterpillars and allowing for a full simulation of the behavior of the caterpillar track machine on the ground (3D Model). The results obtained from the 3D Model compared with the results of the Analytical Model finally confirmed the correctness of the Analytical Model. Apart from the possibility of obtaining the basic characteristics of $\varphi(e)$ and $w(e)$, the Analytical Model allows for the drawing of interaction curves. They define the permissible space of a pair of eccentricities e_X, e_Y, which allow to maintain the stability of the caterpillar track machine. The presentation of the interaction curves (e_X, e_Y) in the form of nomograms enables their practical use by engineers in the design procedure of working platforms.

Additionally, the most common related problems were analyzed with the performance of work by caterpillar track machines on the construction site: diversified bearing capacity of the subsoil under each caterpillar (e.g. as a result of one of the caterpillars running outside the area of the working platform) and the permissible slope of the terrain when the construction machine descends (e.g. as a result of a slope on the site construction).

At the end of the research work, on the basis of the multi-model analyzes (3D Model ½, Approximation Model, Analytical Model and 3D Model) and the interpretation of their results, the consolidation was accomplished, concerning performed in the initial phase of the research decomposition of the interaction problem - construction machine - working platform - subsoil, presenting the proposed algorithm for designing working platforms.

....

podpis