систем позволит расширить номенклатуру производимых изделий и обеспечить круглосуточное бесперебойное производство, отвечающее высоким стандартам качества.

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АВТОМАТИЗАЦИЯ СИСТЕМЫ ТРАНСПОРТИРОВКИ РУДЫ

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В промышленности, строительстве и других отраслях промышленности довольно большое распространение получил конвейер. Его установка существенно упрощает проводимые технологические процессы, к примеру, перемещение сыпучих материалов. Простота принципа работы рассматриваемого устройства во многом определяет его распространение.

Рассматриваем систему ленточных конвейеров, которая находится на ОАО «Беларуськалий» 620 горизонта лавы №6 рудника 3РУ. Традиционно работа цепочки конвейеров построена по следующему принципу: последний в цепочке конвейер разгоняется до номинальной скорости, далее предыдущий конвейер и так до первого. Недостаток заключается в том, что даже когда конвейер не загружен рудой на ленте поддерживается номинальная скорость, что приводит к значительным потерям.

Для уменьшения потерь и улучшения энергоэффективности рассматривается система управления транспортировки руды. Система начинает запуск нескольких конвейеров с начала к концу, что позволяет значительно уменьшить время простоя оборудования, добывающего руду. Так же все конвейера без загрузки работают лишь на минимальной скорости, что уменьшает потери и энергозатраты. При подаче руды на конвейер система заранее оповещена и начинается разгон. Когда руда поступит на конвейер сработают оптические весы, которые определяют массу руды и на ленте и подают сигнал контроллеру для увеличения скорости. Последующий конвейер так же заранее разгоняется до необходимой скорости, что исключает завал конвейера.

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PARTHENON FACADE FEA SIMULATION AS SYSTEM OF FREELY PILED SOLIDS JOINED BY GRAVITY AND FRICTION

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Abstract. *Paper concerns to contact task simulation by FEA for "freely piled solids" systems. It may be different dry masonries. The antique façade of the Parthenon temple is taken for simulation as an example. Marble drums and blocks are held together only by friction and gravity. Multiplicity and variability of contact pressure patterns inside columns are disclosed. Surface compression concentrators (SCC) between echinus and top drums are revealed. Such concentrators are proved to be safe for antique marble load-bearing structures. Contact sliding in the column joints is investigated. Slipping localization on the top and bottom of columns is pointed out as a predictor of the uncontrolled movement and falling in the case of the façade inclination. The usefulness of „piled solids" contact tasks for FEA-training of students is stated.*
Keywords: *FEA, contact spots, dry masonry, stone, compression concentration, friction.*

The work concerns the simulation of load-bearing systems (LBS) by the finite element method (FEM, FEA). Special class of LBS – freely piled solids (FPS) – is investigated. Such systems frequently are held together only by some force and friction ("dry masonry" e.g.).

A large number of contact pairs should be modeled for FPS systems. Contact task simulations are relevant for different kinds of technic, including machinery.

A famous antique object, Parthenon temple in the Athen, proved by time for durability, is chosen as example to provide FPS simulation. 3D-model relates to the west Parthenon façade. Columns consist of drums. Echinus and abacus are placed above each column. Columns are tied together by marble blocks of the architrave. The architrave is pressed down by frieze and cornice blocks. There is triangle fronton on top of the façade. Columns are standing on the three-store stylobate (three layers of stone slabs). There is even, the rigid rocky bed under the stylobate.

Parthenon temple had built from the precise marble blocks and drums freely piled on each other. The work aim is to disclose the stress-state state of such unusual object by FEA simulation. The contact task is in the focus. It means disclosing pressure patterns between drums, pictures of the contact sliding, contact opening spots et al.

The main part of the façade is the set of the doric order columns. Each column is 10.425 m height. Its diameter changes from Ø1.46 m (top) to Ø1.884 m (bottom). A column consists of 11 drums, freely and precisely put on each other. Drums will be numbered from bottom to top. Drums mass changes from 3.31 to 5.12 tons. The distance between neighboring column axes is equal 4.3 m.

The full height of the 3D-model is equal 20227 mm. The sum mass of all blocks/drums (excluding stylobate) reaches 1441 tons. 3D-model includes 12 columns. Two rear columns will be named end ones. Eight forward columns create main, façade colonnade. There are two corner columns and two central ones. Looking ahead of FEM results, it should be noted that central column undergoes 1153 kN force from above. Lesser force, equal 692 kN, acts on the echinus of the corner column. Mass of that marble block – 24.5 ton.

Simulation of the given FPS was provided only in the statics. It is possible to enhance the modeling scope onto transient processes, earthquakes e.g. However, Pathenon's load-bearing system has survived many "shock waves". Thus, static analysis may be sufficient to points out the roots of system stability. Façade is taken as carved from marble only.

One-axis compression dominates in the columns – vectors of minimum principal stress σ_3 are vertically oriented. Architrave blocks undergo bending. Their top faces are compressed – vectors σ_3 are only visible. The bottom architrave faces are, vice versa, tensioned.

Compression is relatively weak (***0.12*** MPa) on the outer sides of the lateral columns. On the contrary, there is strong concentrator ***SCC-2*** on the column's inner side, near "top drum – echinus" junction. It has an arcuate shape. Equivalent stress reaches there ***0.33*** MPa. At the distance of the four drums down, stress concentration disappears. Stress σ_e lowers in 1.65 times (***0.20*** MPa).

For the middle column interesting sequence is observable. The equivalent stress peak (***0.28*** MPa) in the ***SCC-1*** quickly weaken. Stress σ_e became near evenly distributed in the column's section (***0.19*** MPa) at the distance of two drums. Two drums more below one could see slight stress growth (***0.22*** MPa). It is caused by increasing of marble mass upon considered section. Compression stresses in the rounded concentrator ***SCC-1*** (between echinus and 11th drum) spreads at the top of the 8th drum. However, surface concentration appeared again on the 1st and 2nd drums (***SCC-3***). That effect is reflected in the contact spot between column and stylobate.

Distribution of stress σ_3 is near the same as contact pressure p_c. Scheme of events is the next (marks chain ***0.31 – 0.23 – 0.28 – 0.24*** MPa): rounded stress concentration below echinus (***SCC-1***) – stress levelling on the middle heights – rounded concentration above stylobate (***SCC-3***) – compression stress concentration in the center (compression focusing) inside stylobate (***SCC-4***).

All stone parts – blocks and drums – are linked together only by contact pairs with *frictional* status. Status *bonded* (ideal gluing) is used for no one contact junction. It is important to note that the fronton center of mass is placed out of column axes plane. According to the drawing used, that point is moved forward on 20 mm. It creates situation of the eccentric column compression.

Central column bowing in the forward direction. Top forward sides of central columns are the most stressed region (***-1.01*** MPa) in the façade. Rounded concentrators ***SCC-1*** are placed there. However, they acquired arcuate shape due to eccentric compression. As for 11th drum of a central column, minimum principal stress σ_3 is 2.7 times lesser on the rear side than on the forward one.

Corner columns compressed half as weak (***-0.51*** MPa) than central ones. End columns are loaded mainly by their own weight and are just a little stressed (***-0.21*** MPa). A comparison of stress-strain states for different columns points out the importance of the stone fronton gravity.

Openings in the drum junctions are observed only for the end columns. The facade itself is monolithic and stable enough in spite of eccentric loading from above, due to the mentioned shift of the fronton point of mass. That conclusion is relevant only for precisely vertical column positions.

Conclusions:

1. Parthenon's façade was simulated by FEA as a contacts-in-focus load-bearing system of FPS type. Fronton eccentricity (20 mm forward) is taken into account. Stress-strain state is depicted, including smooth lowering (in ~1.35 times) of the average compression stress during descending from echinus to the stylobate.
2. Sequences of the contact openings and slides are described. Different contact interaction patterns are revealed. The adaptive character of the contact slippage picture was considered. The presence of numerous contact gaps in the compressed system is stated as natural feature for FPS.
3. Eccentric compression of the columns caused due to fronton eccentricity is simulated. Drum contact pairs response on eccentricity is discovered.
4. A special class of stress concentrators – surface compression concentrators (SCC) – is depicted. These concentrators are tied to block/drums edges, occupying both free and contact neighboring surfaces. Rounded and arcuate SCC easily transforms into each other. SCC is potentially dangerous for compressed material at least for local overstressing. The significance of that class of concentrators is possibly underestimated.
5. SCC may be compatible (under some conditions) with structure longevity and durability (Parthenon temple e.g.). Column ends, near echinus and near stylobate, are the places for SCC. The periodical transition from SCC to stress leveled regions and back again is revealed along column height. Moderate self-focusing of the compression stress is stated inside stylobate under column.
6. The simulation predicts Parthenon's façade vulnerability to the inclination from vertical. Uncontrollable deformation by sliding and local crashing is expected, beginning from 3° level. Slippage localization on the column bottoms, about abacus, and in the fronton corners is the predictor of the upcoming instability.

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FEA SIMULATION OF THE BIOMECHANICAL STRUCTURE OVERLOAD IN THE UNIVERSITY CAMPUS PLANTING

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Abstract. *FEM investigation of the branch collapse is provided for the huge healthy chestnut tree. Strong wind gust (24 m/s) is assumed. Thus, simulation has as engineering so methodic value to improve the FEM-teaching of students. The geometry was recovered by the photos and sketches. It includes roots, trunk, branch and conditional crown. Static simulation is provided both in the linear formulation and in the geometrically nonlinear one. Branch under-*