The aim of these workshops and conference is to help transfer and spread newly appearing design technologies, educational methods and digital modelling supported by information technology in architecture. By organizing a workshop with a conference, we would like to close the distance between practice and theory. Architects who keep up with the new designs demanded by the building industry will remain at the forefront of the design process in our information-technology based world. Being familiar with the tools available for simulations and early phase models will enable architects to lead the process. We can get "back to command".

The other message of our slogan is "Back to command". In the expanding world of IT applications there is a need for the ready change of preliminary models by using parameters and scripts. These approaches retrieve the feeling of command-oriented systems, DOWKRXJKZLWKPXFKJUHDWHUHɋHFWLYHQHVV

Why CAADence in architecture?

"The cadence is perhaps one of the most unusual elements of classical music, an indispensable addition to an orchestra-accompanied concerto that, though ubiquitous, can take a wide variety of forms. By GHȴQLWLRQDFDGHQFHLVDVRORWKDWSUHFHGHVDFORVLQJIRUPXODLQZKLFKWKHVRORLVWSOD\VDVHULHVRI personally selected or invented musical phrases, interspersed with previously played themes – in short, a free ground for virtuosic improvisation."
CAADence in architecture
Back to command
Edited by Mihály Szoboszlai
CAADence in Architecture

Back to command

Proceedings of the International Conference on Computer Aided Architectural Design

16-17 June 2016
Budapest, Hungary
Faculty of Architecture
Budapest University of Technology and Economics

Edited by
Mihály Szoboszlai
Theme

CAADence in Architecture
Back to command

The aim of these workshops and conference is to help transfer and spread newly appearing design technologies, educational methods and digital modelling supported by information technology in architecture. By organizing a workshop with a conference, we would like to close the distance between practice and theory. Architects who keep up with the new design demanded by the building industry will remain at the forefront of the design process in our IT-based world. Being familiar with the tools available for simulations and early phase models will enable architects to lead the process. We can get “back to command”.

Our slogan “Back to Command” contains another message. In the expanding world of IT applications, one must be able to change preliminary models readily by using different parameters and scripts. These approaches bring back the feeling of command-oriented systems, although with much greater effectiveness.

Why CAADence in architecture?
“The cadence is perhaps one of the most unusual elements of classical music, an indispensable addition to an orchestra-accompanied concerto that, though ubiquitous, can take a wide variety of forms. By definition, a cadence is a solo that precedes a closing formula, in which the soloist plays a series of personally selected or invented musical phrases, interspersed with previously played themes – in short, a free ground for virtuosic improvisation.”

Nowadays sophisticated CAAD (Computer Aided Architectural Design) applications might operate in the hand of architects like instruments in the hand of musicians. We have used the word association cadence/caadence as a sort of word play to make this event even more memorable.

Mihály Szoboszlai
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Horizontal Load Resistance of Ruined Walls
Case Study of a Hungarian Castle with the Aid of Laser Scanning Technology

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Abstract: The use of laser scanning technology for surveying historical buildings or ruins is gaining widespread popularity. While the “manual” surveying methods are time-consuming and provide just rough guess about the shape of the investigated complex building, the scanning process is very quick and the point cloud contains the “exact” geometry with the desired accuracy. This paper introduces a method, where by using the “exact” geometry of a ruined Hungarian castle, the stability of the remained walls is checked. With the aid of the point cloud an automated calculation process was developed, that defines the maximum wind load and earthquake ground acceleration as the limit load of the structures. The effect of geometrical precision was also investigated by varying the density of the point cloud.

Keywords: laser scanning, masonry, limit load

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INTRODUCTION
The preservation of the architectural heritage is a crucial issue of our days. Various numerical methods, reinforcing techniques and new materials have been developed for the proper reconstruction of the antique or medieval buildings and structures. The amount of the required reinforcement can be defined just by the good understanding of the structure, which may start with the proper survey of the building. A really edifying research that investigated Michelangelo’s David statue [1] found that the former reinforcement of the masterpiece caused big part of the cracks at the ankle of the body. This reveals that without the deep understanding of the behavior the best preserving aim can be even harmful.

Laser scanning technology and data processing are in the focus of civil engineering researches as well. The advantages of the technology are the non-destructive nature of it, the very quick collection of data and the potential for use in a wide variety of fields. New methods are being presented, where automated segmentation of the point cloud results in a geometric basis for structural analysis [2], detects the cracks of the structure [3] or derives CAD models suitable for structural computations [4]. All these researches show a good way for the geometric pre-processing of the point cloud that can really be hard to manipulate manually. The result of the pre-process is a down-sam-
BRIEF HISTORY OF KANÁZSVÁR

1,2 km away from Mátraderecske a hill is situated that is coped with a fortress. The castle Kanázsvár was built sometime in the 13th century or maybe even earlier [5]. It was a little fortress in the northern part of present Hungary, with a guard tower, whose more than 15 m high ruin remained, Fig 2. The castle was destroyed during the 16th century, and since then the remains have been uncovered, while the wrecking still being going on. No excavations have been made even during the recent decades, resulting in a bundle of guesses about the history of the olden castle.

METHODOLOGY

Our investigations have been based on the following assumptions:
- the structure is homogeneous, so no hidden hollows, no cracks are taken into account
- the masonry does not have tensile strength, the material is elasto-plastic
- based on the non-destructive on-site experiments, the stone is andesite, with a density of approx. 22 kN/m³. The compressive strength of the stone is at least 60N/mm² (strength of the andesite ranges from 60 to 270 N/mm²) and
The point clouds

Figure 3: The point clouds with different data density

when calculating with a weak mortar, the estimated compressive strength of the masonry is ~14,0 N/mm²
- the orientation of the coordinate system: the horizontal plain is the x-y plane, the vertical axis is the z

The survey has been made by MindiGIS Ltd., and we have received a “clear” point cloud that did not contain the vegetation and just showing the main part of the hilltop with the ruins of the tower. While no excavations were done, the level of the foundation is unknown, so we have decided to investigate the stability at the base, where the whole cross-section of the structure is just above the ground. To define the effect of the point cloud accuracy on the results, we were given data with 3 cm, 10 cm, 25 cm and 50 cm grid. The coordinates from the .dxf file were exported to MatLab [7] (Fig 3).

The first question is the stability of the structure for its dead load. To calculate the projection of the centroid of the structure at the base, we cut the structure by m horizontal plains. The cutting planes are at a distance of Δh from each other, which is equal to the average density of the point cloud. The points that are at distances of -Δh/2 and Δh/2 from the reference plane are projected into that plane. Based on the coordinates of these points, the contour polygon of the section is defined at the given level using the built-in boundary command in MatLab [7]. The polygon defines the section, and its area and the coordinates of its centroid can be calculated in each section [8].

\[ A^j = \frac{1}{2} \sum_{i=1}^{n-1} (x_i y_{i+1} - x_{i+1} y_i), \quad (1) \]

\[ c_x^j = \frac{1}{6A^j} \sum_{i=1}^{n-1} [(x_i + x_{i+1}) \cdot (x_i y_{i+1} - x_{i+1} y_i)], \quad (2) \]

\[ c_y^j = \frac{1}{6A^j} \sum_{i=1}^{n-1} [(y_i + y_{i+1}) \cdot (x_i y_{i+1} - x_{i+1} y_i)], \quad (3) \]

where \( A^j \) is the area of the \( j^{th} \) section defined by the polygon coordinates \( x \) and \( y \). The length of vectors \( x \) and \( y \) is \( n \), where \( x_n=x_1 \) and \( y_n=y_1 \). The \( c_x^j \) and \( c_y^j \) are the coordinates of the centroid of the \( j^{th} \) section. Knowing the centroid of the section at the foundation, the origin of the global coordinate system is moved there.

The integral of the areas of these sections along the height gives the volume of the structure. Based on that we can define its weight by assuming the density of the masonry as stated above.

Figure 4 shows the areas of the sections and the volume of the structure. The difference of the results for different density of the point clouds was
almost negligible (there is only 1% difference between the smallest and largest volumes): the volume of the structure for different data density (Fig 3) is 204.2 - 207.5 - 211.1 - 206.3 m$^3$. The result of the second dataset (density: 10 cm) approximates most closely the average, so we choose 207.5 m$^3$, which means $Gk = 4565$ kN weight.

The eccentricity of the dead load of each $\Delta h$ high section can be calculated as follows:

$$N^j = \rho \Delta h A^j,$$

where $N^j$ and $M^j$ are the normal force and the bending moment caused by the $j^{th}$ section respectively. The calculated eccentricity at the foundation is $e_{0} = 0.4$ m.

The next question is whether the point of action of the weight corresponding to this eccentricity is within the core of the section generating just compressive stresses at the foundation and not causing cracks. To find the core of section at the foundation section, we need to calculate the principal axes and the principal moment of inertias. The moment of inertias (also known as second moment of area) of a polygonal shape, about the global x and y axes can be calculated by the following equations [8]:

$$I_x = \frac{1}{12} \sum_{i=1}^{n-1} [(y_i^2 + y_i y_{i+1} + y_{i+1}^2)(x_i y_{i+1} - x_{i+1} y_i)],$$

$$I_y = \frac{1}{12} \sum_{i=1}^{n-1} [(x_i^2 + x_i x_{i+1} + x_{i+1}^2)(x_i y_{i+1} - x_{i+1} y_i)],$$

$$I_{xy} = \frac{1}{24} \sum_{i=1}^{n-1} [(x_i y_{i+1} + 2x_i y_i + 2x_{i+1} y_{i+1} + x_{i+1} y_i)(x_i y_{i+1} - x_{i+1} y_i)].$$
Where \( I_x \) and \( I_y \) are moment of inertias of the polygonal shape about the \( x \) and \( y \) axes, and \( I_{xy} \) is the product of inertia. To find the principal moment of inertias \( I_x \) and \( I_y \), we need to solve the characteristic equation of the \( I \) matrix of tensor of inertia. The eigenvectors of the matrix define the position of the principal axes.

\[
\det \begin{bmatrix}
I_x - \lambda & I_{xy} \\
I_{xy} & I_y - \lambda
\end{bmatrix} = 0 \quad [11]
\]

Core of section of a cross section is a locus where applied compression force causes just compressive stress over the whole section. In this case the neutral axis does not intersect the cross-section. We can find the corner points of this convex polygon by solving the following equation for every side of the convex contour of the cross section.

\[
-\frac{1}{A} + \frac{k_y^i}{l_1} P_y + \frac{k_x^i}{l_2} P_x = 0, \quad [12]
\]

where \( k_x^i \) and \( k_y^i \) are the coordinates of the \( i^{th} \) point of the core of section corresponding to the \( i^{th} \) edge of the convex contour of cross section. The \( P \) points are arbitrary points on the edge.

**RESULTS**

Figure 5 shows the core of section at the foundation and the eccentricity of the self-weight. It is clearly seen that the resultant force is within the core of section, so the whole area is under compression. This means, that there are no stability problems with the structure for the self-weight.

The next question is the effect of horizontal loads: what is the maximum wind load the structure can take? We wish to find the load, where the eccentricity is about to reach the contour of the core of section. For this, an optimization process was developed in MatLab with two parameters: the magnitude of the uniform wind load, and the angle of the wind (i.e. wind direction). The loaded area is assumed to be the contour of the structure that faces the wind. For arbitrary angles the area and the centroid of the vertical plane were calculated and the related destabilizing moment at the foundation was determined as well.

The results can be seen in Figure 6. The load that causes tension stresses at the foundation is 1.5 kN/m². The wind load need to be considered [9] is \( w_k = 1.155 \) kN/m² based on the \( q_{ed} = 1.05 \) and the shape factor, that is \( c_{pe} = 1.1 \) for polygonal buildings with this slenderness [10]. This shows that as the result of the design value of the wind load \( (w_{ed} = 1.73 \) kN/m²), there are tension stresses on the section, so just a certain part of the cross section is under compression. Assuming plastic stress state, at least a 0.35 m² compressed zone is required to balance the dead load of the structure. This is less than 2.5% of the base area, and would result some 1.6 m eccentricity at the most dangerous point.
The effect of the earthquake can be investigated by assuming the followings, using the response spectrum method [11]:
- the first mode shape of the building is considered
- the structure is rigid, so \( T_a < T_c < T_e \)
- behavior factor of the masonry is taken to be \( q = 2.5 \)
- the structure is in the northern part of Hungary, where the base acceleration on rock is \( a_{g,R} = 0.1 \text{ g} \)
- the castle was built on rock, so the soil class is \( A \), so \( S = 1.0 \)

Based on this data, the resulting base shear force is \( F_b = 456.5 \text{ kN} \), which causes \( M_{\text{destab}} = 3350 \text{ kNm} \) moment at the base, and 0.74 m eccentricity. This results 1.14 m total eccentricity, which is still less than the above stated limit eccentricity 1.6 m.

**CONCLUSION**

In this paper we have investigated the stability of the remaining part of an old castle tower. While the structure needs to be renovated, a survey of the masonry has been performed using laser scanning technology. The original point cloud was made at a 1 to 2 mm accuracy resulting over 200 million points which was unmanageable for our studies. We found that the point cloud with an accuracy of 10 cm still gives accurate results, and the amount of the data permits fast calculations. It was an interesting experience, that the point cloud with accuracy values of 25 cm and 50 cm gave also acceptable results (less than 2% difference in the volume of the structure).

The structure was found to be safe against the dead load and the probable horizontal loads. We could define the limit eccentricity, for which the whole section is under compression. We defined the ultimate eccentricity for which the structure is safe. The developed method is automated, and it can be easily adopted to other point clouds of structures.

In our investigations it was not considered that the structure can fall down due to inner cracks or hollows. Therefore, the preservation of the surface against the wind, rain and snow and the pointing of the masonry are necessary to ensure that the structure remains safe for the following decades and centuries.

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The aim of these workshops and conference is to help transfer and spread newly appearing design technologies, educational methods and digital modelling supported by information technology in architecture. By organizing a workshop with a conference, we would like to close the distance between practice and theory.

Architects who keep up with the new designs demanded by the building industry will remain at the forefront of the design process in our information-technology based world. Being familiar with the tools available for simulations and early phase models will enable architects to lead the process. We can get “back to command”.

The other message of our slogan is <Back to command>.

In the expanding world of IT applications there is a need for the ready change of preliminary models by using parameters and scripts. These approaches retrieve the feeling of command-oriented systems, although, with much greater effectiveness.

Why CAADence in architecture?

"The cadence is perhaps one of the most unusual elements of classical music, an indispensable addition to an orchestra-accompanied concerto that, though ubiquitous, can take a wide variety of forms. By definition, a cadence is a solo that precedes a closing formula, in which the soloist plays a series of personally selected or invented musical phrases, interspersed with previously played themes – in short, a free ground for virtuosic improvisation."