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METHODOLOGICAL PROPOSAL OF IMAGE PROCESSING WITH FREE SOFTWARE TO EVALUATE THE ROUGHNESS OF MASONRY PIECES

Florentino M. Jose[1], Sanchez T. Sulpicio[1]

[1]*Facultad de Ingeniería, Universidad Autónoma de Guerrero (UAGro)*
Av. Lázaro Cárdenas s/n, Ciudad Universitaria, 39070, Chilpancingo, Guerrero, México
josefl orentino@uagro.mx , *sstizapa@uagro.mx*

Abstract. Masonry is widely used in a large number of constructions around the world. However, these register severe damages in seismic areas. An important parameter to guarantee adequate structural behavior is the adhesion between the piece and the mortar, which has two origins: a) chemical, b) mechanical. The latter is related to the fineness of the mortar components and the roughness of the piece. Under this consideration, a proposal is presented to calculate the roughness of the faces of a concrete masonry block made with cement and fine sand, using photographs taken with a 24 megapixels camera capacity and processed with three free software applications. The procedure has four steps: a) calibration of the camera and taking of photographs, b) three-dimensional reconstruction of the piece using the Visual SFM software, c) obtaining the points of both faces with the Meshlab software from the three-dimensional model, d) construction of a point cloud using the CloudCompare software, where it is possible to visualize the crests and valleys of the faces, and therefore it is possible to measure the average roughness. For the piece under study, 25 images were taken and processed for each face, the average values of roughness were 0.06 mm and 0.23 mm for the smooth and rough faces, respectively; the references show values of 0.08 and 0.32 mm measured in red clay brick. For the lightweight concrete block and the same order, there are references of 0.45 and 0.77 mm. In the case of concrete, average values of 0.3 mm on smooth surfaces and between 0.3 -1.0 mm on standard surfaces are reported. The proposed methodology, in the experimental phase, provides values of roughness in the range defined in other investigations of similar materials with two additional advantages: it does not require special equipment, and the computer applications are free software. This tool can be used to evaluate the influence of the roughness of masonry faces on the resistance to lateral loads generated by earthquakes.

Key words: Masonry, roughness y seismic

1 Introduction

The Mexican Pacific coast (from Colima to Chiapas) is the most seismically dangerous area [1]. In this zone, confined masonry is frequently used as a structural system in low and medium height constructions destined in more significant for housing use [2]. Pacheco and García [3] found that in some cities in this area, 85% of the houses are made of confined masonry.

The resistance to lateral seismic forces of the masonry is a function of the adhesion between the piece and the mortar, which has two components. The mechanical adhesion is generated by the roughness of the surfaces of different materials in contact; the chemical adhesion is produced by the formation of compounds and chemical interaction between molecules and shows in smooth or non-absorbent surfaces. The average mechanical roughness of a surface is the valleys' depth or ridges' height to a baseline [4].

Except for the works of Pacheco [5], Gómez [6], Mayo [7], and Florentino [8], who calculated the roughness in different types of masonry pieces by photogrammetry, there are no additional references. Regarding the roughness in concrete surfaces, Grzelka, Majchrowski, and Sadowski [9] used a 3D scanner to obtain a correct image of two concrete surfaces. 3D models are generated where the triangulation of the irregularities is shown. The surface I recorded values from 1.039 mm to 0,430 mm; in the same order, the surface II recorded 2.494 mm, and 2.702 mm.

Also, Courard [10] investigated two different techniques to evaluate the surface roughness of the concrete. Surphometry is performed by sliding a stylus on the surface, and opto-orphometry uses the bases of the Moire method to develop the interferometric measurement. In another investigation, Leising [11] analyzed the surface roughness of concrete using a portable profilometer model JR25, which automatically calculates the roughness over a length of 25 mm. The average value was 0.1259 mm, with a height variation of 0.2047 mm.

On the other hand, Courard [10] conducted an investigation using two different techniques to evaluate the surface roughness of concrete. Surformatics is performed by sliding a stylus on the surface and opto-morphometry uses the bases of Moire's method to perform an interferometric measurement. Results in two tests were 0.005 mm and 0.014 mm

The roughness of the pieces influences the adhesion of the joint and the diagonal compressive strength. Ramos and Sánchez [12] obtained different values for adhesion and collapse failures in two types of adhesion piles as a function of the roughness of the masonry unit, using the same mortar in both cases. The specimen is formed by three bonded pieces to which axial load is applied. The units used were: a) massive block (cement and sand from rock crushing, piece A), b) lightweight block (cement and volcanic stone, piece B). Due to the granulometry of the material, the first piece has smooth surfaces, while the second has higher roughness. The piece A has a higher compressive strength than the second one. Figure 1a shows the failure of the piles made with pieces A, as it can be seen, the low roughness generates the failure in the joint. Figure 1b shows the failure model of prims made with pieces B; in this case, the higher adherence of the joint combined with the lower compressive strength causes the fracture of the intermediate piece.

a) b)

Figure 1. Failure forms in two adhesion piles with different roughness in the parts [12].

This document presents a methodological proposal to evaluate the roughness of a masonry piece using the basic principle of photogrammetry applied on a reduced scale. The main advantage is the low cost because it does not require specialized equipment, in addition to using free software.

2 Metodologia

The process consists of four steps described in Figure 2.

HOME

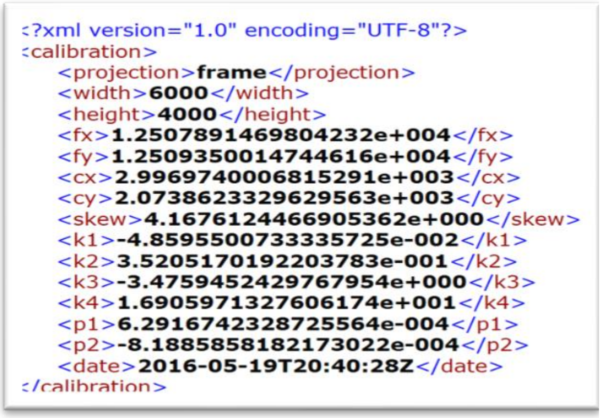
a) Camera Calibration using Agisoft PhotoScan and Shooting
The Agisoft PhotoScan software is used to calibrate a Nikon camera model D3400 with a capacity of 25 MPa, five pictures of a board provided by the software are used. This way gets the focal radius and vectors in the X- and Y-direction to correct the taken pictures [13].
Afterward, the piece is placed on a turntable and 25 photographs are taken of the top face for different angles of the piece until finishing one turn. The procedure is repeated with the bottom side taking another 25 pictures.

b) Obtaining the point cloud with Visual Structure from Motion System (SFM)
The software allows the construction of the 3D model. The process integrates the execution of toolchains developed by Furukawa [14]. The 25 photographs and the calibration data are inserted into the program, which generates a 3D point grid of each unit face. Figure 4 shows the point cloud formed by the 25 photographs.

c) Excess point cleaning by Meshlab software
The software can edit, clean, inspect, represent and convert unstructured triangular meshes of points obtained in the scanning. In this step, the unnecessary points were deleted, leaving only those corresponding to the surface to be analyzed [15].

d) Roughness measurement on 3D model with CloudCompare
This program allows the processing of 3D point clouds. The file obtained in the previous step is edited, and the triangulation of the analyzed face is obtained, figure 6. The roughness is measured by using the tool Rouhgness. The process is repeated on the remaining side [16].

Figure 2. Proposed methodology for assessing roughness in masonry pieces



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<calibration>
    <projection>frame</projection>
    <width>6000</width>
    <height>4000</height>
    <fx>1.2507891469804232e+004</fx>
    <fy>1.2509350014744616e+004</fy>
    <cx>2.9969740006815291e+003</cx>
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    <skew>4.1676124466905362e+000</skew>
    <k1>-4.8595500733335725e-002</k1>
    <k2>3.5205170192203783e-001</k2>
    <k3>-3.4759452429767954e+000</k3>
    <k4>1.6905971327606174e+001</k4>
    <p1>6.2916742328725564e-004</p1>
    <p2>-8.1885858182173022e-004</p2>
    <date>2016-05-19T20:40:28Z</date>
</calibration>
```


Figure 3. Data vector for correction of photos obtained by Agisotf PhotoScan [8]

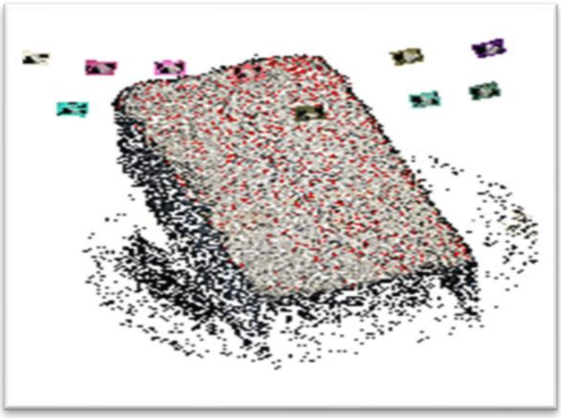
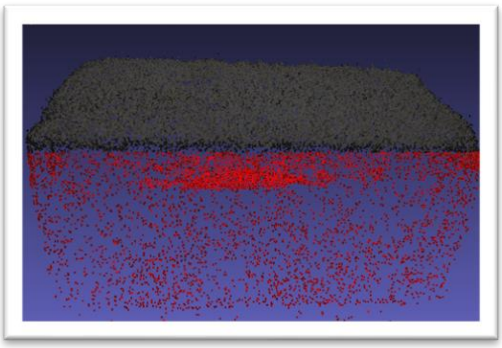
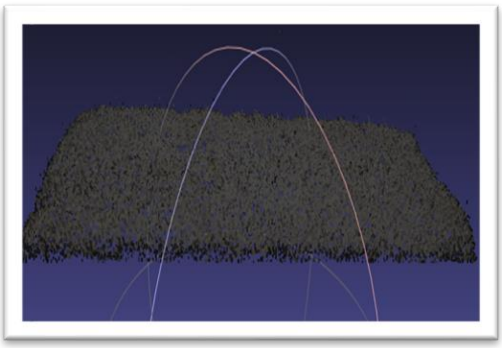


Figure 4. Point cloud display obtained with SFM [8]



a)



b)

Figure. 5 Cleaning of excess points: a) selection of unusable points, b) points to be used

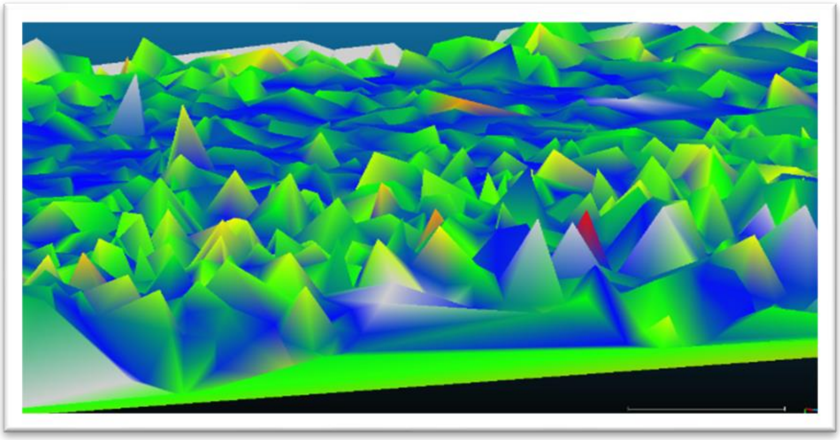


Figure 6. 3D model using triangulation obtained in Cloud Compare, top side

3 Results

With the CloudCompare Roughness tool, a histogram of each surface of the masonry unit is obtained, figures 8 and 9. The average roughness values on the upper face of the piece were 0.06 mm from the lowest point to the highest point and 0.23 mm on the lower face. Roughness value is equal to the distance between this point and the best fitting plane computed on its nearest neighbors [16].

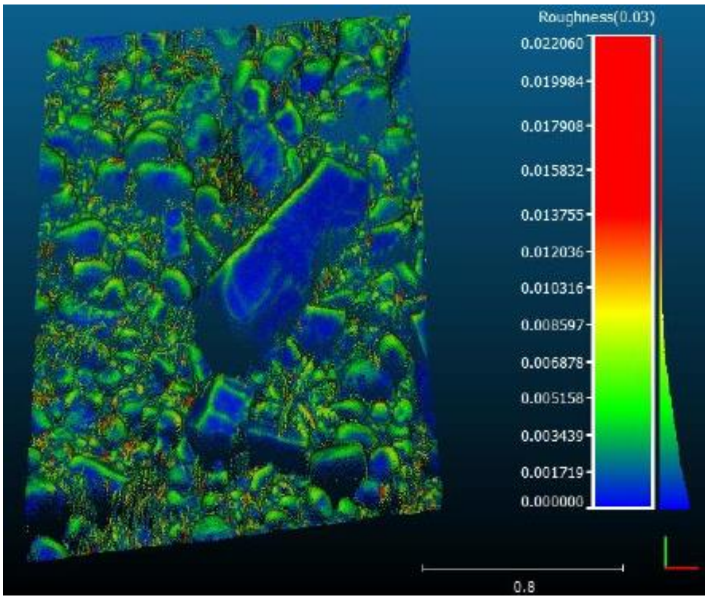


Figure 7. Roughness ouput

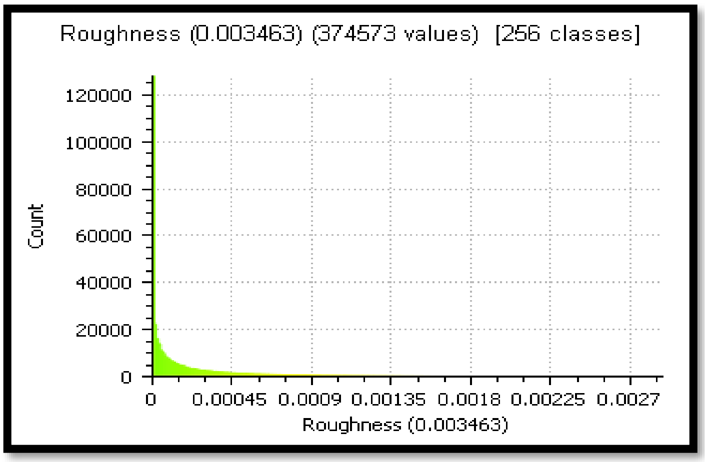


Figure 8. Histogram of the upper face of the Tabiton piece

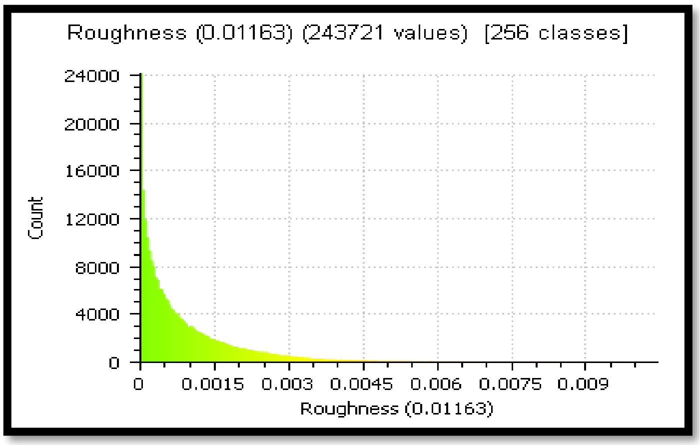


Figure 9. Histogram of the lower face of the partition

4 Conclusions

Confined masonry constructions are widely used throughout the world. However, earthquakes have caused severe damage to these constructions, so it is necessary to ensure proper performance in the integral elements: mortar and pieces. Between these two materials, adherence is an essential factor to provide adequate mechanical behavior, so the piece's roughness helps to support the forces generated in the earthquake.

The average values of the roughness in the masonry unit are 0.06 mm in the upper face and 0.23 mm in the lower face. The references show values in red clay brick of 0.08 mm and 0.32 mm, in lightweight masonry unit were 0.45 mm and 0.77 mm. The roughness of the concrete is 0.3 mm in the smooth side, and 0.3 - 1.0 mm in rough side, the comparison of values shows a correspondence.

There are research works about the roughness, but special equipment with higher cost are used. The proposed methodology evaluates the roughness of masonry pieces, using the basic principle of photogrammetry through free software with low-cost equipment. The knowledge of this variable will guarantee the masonry's adequate behavior under seismic forces.

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