APPLICATION OF DIGITAL PHOTOGRAMMETRY AND IMAGE PROCESSING TECHNIQUES FOR HYDRAULIC MODEL EXPERIMENTS

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ABSTRACT:

Stability and suction removal of the sand bed under the rock-armoring layer were exposed under the wave and discharge generated steady flow and coexisting flow investigated at apron area of the open channel discharge system. Determination of the stability of the armoring layer was achieved by micro and macro scale tests focused just sample stone(s) and all armoring area in 1/25 scale laboratory physical model. In this study, two methods are used in order to investigate probable displacement caused by the water flow in a hydrological experimental setup. The setup is a scaled model of an harbor in Omman, UAE, which is already in construction. Both methods are dealing with photos taken with a digital camera. The photos are taken in four epochs. The first epoch of photos has been taken just after the construction of the experimental setup. This causes the first epoch of photos to be the reference set. Between the following three epochs, an hydraulic experiment has been taken place. Comparison these three epochs of photos with reference set and each other results the investigated probable displacement. The data contains all the photos and the terrestrial measurements. The difference of methods is the processing of the data. The first method is the standard photogrammetric method, where the second one deals much more with image processing. The results of these two methods will be compared with each other in order to give accuracy. Image processing techniques was applied at macro scale tests of the armoring area before and at the end of the experiments. Instability was not determined for whole armoring layer after the both image processing processes and photogrammetric approach.

1. INTRODUCTION

One of the methods widely used for scour protection in coastal engineering is rock dumping on a sand bed. When such a rock layer (armoring layer) is exposed to steady current, waves or combined flow their stability are an important issue for engineering design. (Cokgor, et.al., 2004). The design of stable bottom with movable material such as sand, gravel and stones is the most difficult problem of the coastal engineering because of the lack of analytical solution (Kabdasli, 1986) However the definition of critical conditions in which the movable material can be moved by hydrodynamic forces created by current waves or combined effects of them (Kabdasli, 1990), the processes are highly chaotic in nature. For this reason experimental studies are needed in order to obtain the material characteristics such as shape, size, etc. which can be in stable condition under design hydrodynamic conditions.

On the other hand, experimental studies are very difficult and time consuming works because measurements and observation of the material motion are highly complex techniques due to randomness of the material transport. Particularly experimental study for a coastal area is almost impossible by using classic measurements techniques. In that case, alternative methods should be used in order to reach reliable results. It is clear that digital photogrammetry and image processing techniques are the most favorable methods. In order to determine probable displacements or deformations, some methods have been discussed in Altan, 1981.

In this study, stability armouring layer against erosion over the sand bed of open channel thermal discharge system of the power plant in an industrial area in Sohar, Emirate of Oman, was performed. Sohar is located nearly 200 km. North-West of Muscat, capital of Oman.

2. DATA AND METHOD

Hydraulic model of outlet structure was built at 1/25 geometric scale. The wave basin in the laboratory has dimensions of 25x28x1 m. Stone pitching was used at the sea bottom between -0.5 m and –2 m elevations. Discharge channel was constructed of concrete and brick walls (Figure 1). Main issue at the model study was the determination of the stability of stone armour layer on the sand dredging channel in the sea. Various flow measurements and observation techniques were used in the model tests.

For modeling the experimental setup, terrestrial surveys have been done. A terrestrial reference point set has been marked so that they surround the experimental setup and using these points the modeling process has been done. The reason of marking the points surrounding the experimental setup is the inner coverage of the model. The setup is covered with small stones and this would cause the reference points to be displaced by water flow during the hydraulic experiments. Because of that, points have been marked onto concrete bottom, so that they would not be displaced. These reference points will be used control points in photogrammetric evaluation. These points have been colored with red, so that they could be seen clearly without any reflection. Figure 2 illustrates the distribution of the control points with corresponding point numbers where Figure 3 shows an overview with a zoom-view for control point.

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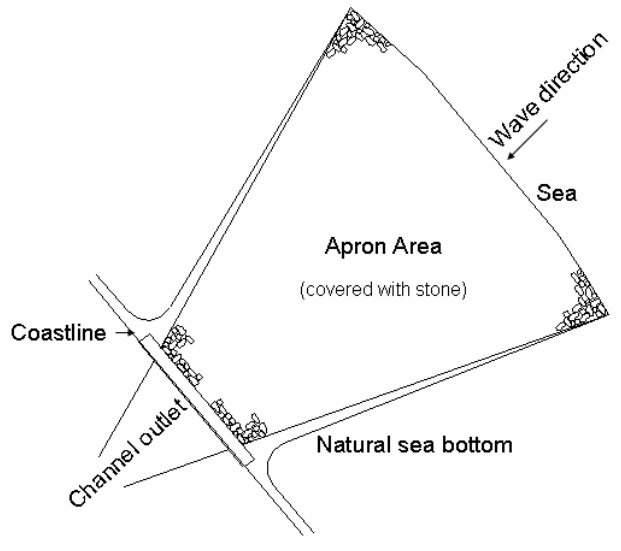

Figure 1. Plan of the Application Project

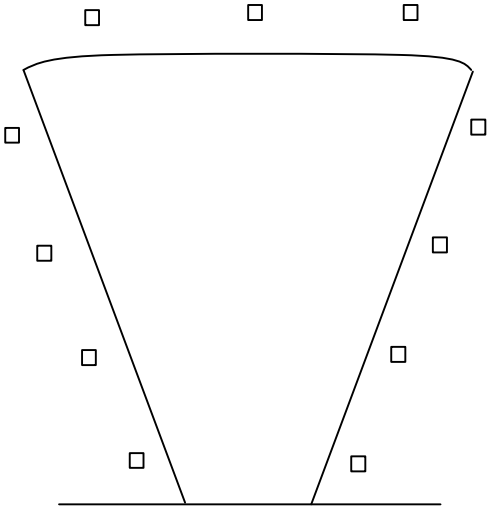

Figure 2. Distribution of Control Points

In terrestrial surveys, a local geodetic coordinate system has been established and all the coordinates are computed in this coordinate system. Coordinates of control points are given in Table 1. By all the terrestrial surveys; Pentax ATS 102 Total station has been used.

Another important point is to establish a point set, which would be used by displacement investigation. These points must be on the experimental setup, with other words, on the probable displacement area. They also had to be marked so that they act with the bottom of setup. All this needs caused to strip the bottom of the setup with white color, which gives a good contrast and would be an advantage by photogrammetric and image processing works. Corners of these strips could be used as measurement points (Figure 3).

Point	X (m)	Y (m)	H (m)
1	1020,716	5007,553	10,005
2	1018,619	5009,362	9,948
3	1015,738	5011,850	9,932
4	1012,885	5014,396	9,896
5	1010,723	5011,632	9,883
6	1009,551	5008,775	9,858
7	1008,320	5005,530	9,855
8	1008,376	5002,950	9,850
9	1012,035	5002,726	9,882
10	1015,969	5002,480	9,924
11	1018,730	5002,265	10,018

Table 1. Coordinates of Control Points

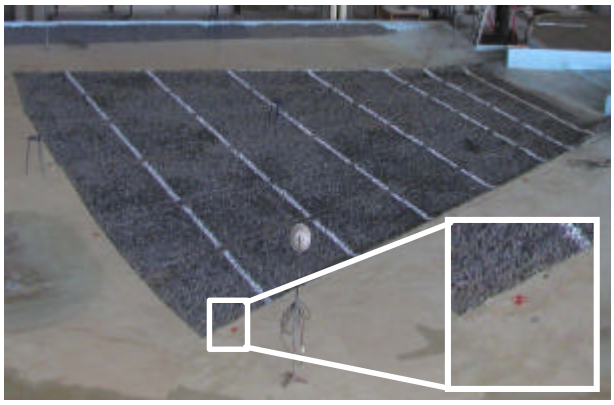

Figure 3. Experimental Setup With Control Points and Strips

As mentioned above, four epochs of photographs have been taken. By all the epochs, Olympus Camedia C-4040 Zoom digital camera has been used. Nowadays it is very difficult to get high-resolution digital cameras with fixed focus lens. It was a must to use one of the extreme values, either the small angled or the wide angled setting of the lens. The Camedia is known for its good quality and sharpness of the images, resolution is just one aspect.

Image acquisition has been done from the inner balcony of the laboratory, which is approx. 8 m. above the experimental setup. This causes an oblique photo, which is a disadvantage for photogrammetric works. But using digital photogrammetric systems, this disadvantage has been eliminated.

3. APPLICATION

For each epoch, three projection centers have been used. As it is well known, for a standard three-dimensional photogrammetric evaluation, at least two photos of an object from different projection centers must be used (Altan, 1979). Third projection center is used for increasing the accuracy and controlling the results.

Using the control points and the photos from the first epoch, the first photogrammetric evaluation was done. This epoch was not only used for detecting probable displacement on the

experimental setup but also checking the reliability of the control points for the work. The coordinates of control points were taken as true value during the exterior orientation. After building the model, the corners of strips were digitized. The coordinates derived, were used for building the reference set for the experimental setup. All photogrammetric work was done using Pictran-D/E software and monitoring the results was done by using the coordinates, obtained from photogrammetric evaluation, using AutoCAD (Figure 4). After deriving the coordinates of all the strip corners, the reference model was created. This model was used as a basic of probable displacement investigation (Figure 4).

After modeling the reference set, following epochs of photos were taken. Each epoch was taken just after each hydraulics experiment. For each of the epochs, same process was applicated. This process contains same steps like the modeling of the reference set. In that way, differences between sets would be the data for displacement analysis.

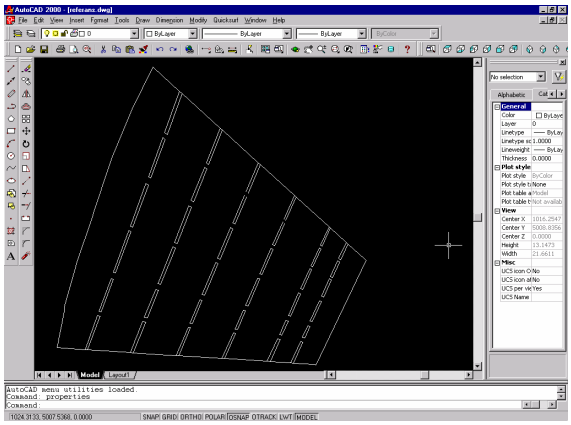

Figure 4. Reference Model Used as a Basic for Probable Displacement Analysis

Figure 5. Evaluation of the first epoch photos

After evaluating all the epochs, maximum displacement was detected in coordinates as -0.002 and 0.002 in meters. These values appear in positional displacement as ±0,003 m. These results were interpreted as “there were any displacement in the experimental setup causing by the experiments done”.

3.1 Image Processing

An additional investigation of probable displacement was done using image processing techniques. All the photos have been georeferenced onto the reference set of photos. As in the first investigation, the first epoch of photos was taken as non-displaced. The histograms of following three set of photos are equalized. In this process, the photos were grayscaled. After that, each set of photos has been placed in one channel of an RGB image, so that true color image could be obtained. By this process, In Figure 5, the photos from 2nd, 3rd and 4th epochs can be seen. 2nd epoch was placed in red, 3rd epoch in green and 4th epoch in blue. As a result, a true-color photo was obtained (Figure 6).

As it can be seen from the Figure 6, the experimental setup is clearly visible without critical movement between the channels. The surrounding such as columns and pipes in the laboratory,

which are out of the experimental setup, seem not so clear. This is an expecting results since these objects were not taken into account during georeferencing process. Figure 7 illustrates a monitoring of the results in another unusual way.

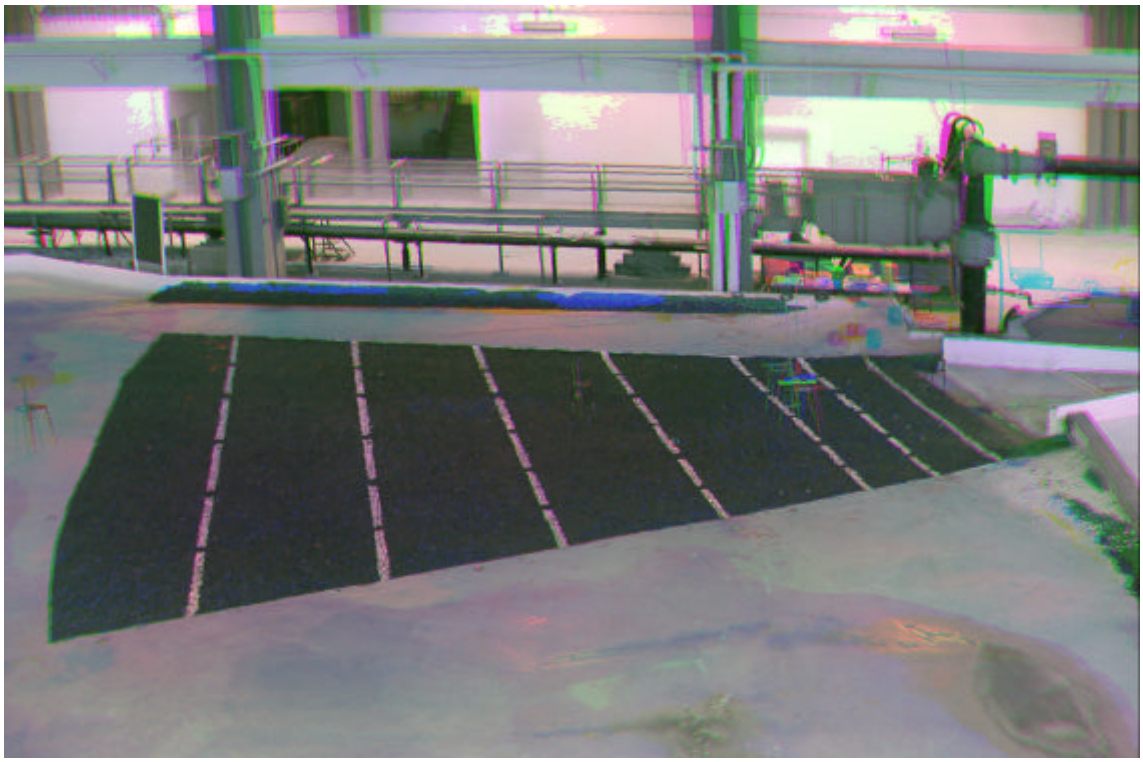

Figure 6. Obtained true-color photo by setting each epoch in one channel RGB: 2nd/3rd/4th epochs

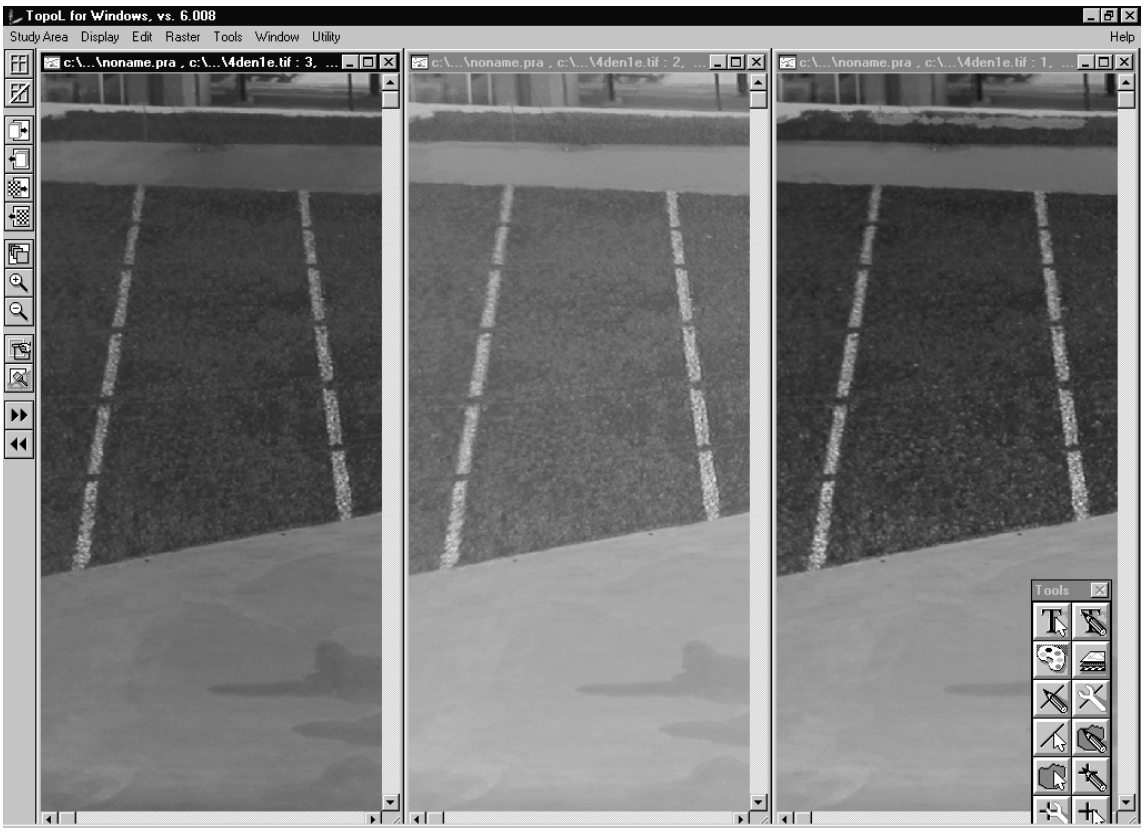

Figure 7. Channels of true photos, left-red, middle-green and right-blue

4. RESULTS AND CONCLUSIONS

Stability of stone covered armoring layer under the waves and currents also both were investigated during this study by experimentally. Given stones sizes for armoring layer are satisfied the design criteria and there is no possible damage occurred under the mentioned flow conditions.

This study figures out of an application of digital photogrammetry and image processing for engineering purposes. The first investigation is widely used and well-known technique with its instruments, measurements and methods. The originality of the study is the second investigation and monitoring of probable displacement of the armor stone. This method must be supported with advanced image processing techniques and the displacement analysis must be set onto a mathematical basis. In that way, a new method for photogrammetrical displacement and deformation analysis, which is full-automatic, can be developed.

The characterization of the sea bottom stable conditions in the large coastal area is almost impossible by using classical experiment techniques done in the laboratories. If it is consider that there are many stone with different sizes. It is possible to say that the reliability of the results obtained by classical methods may be very low. In this study, it has been shown proposed and verified method in order to solve an important design problem in coastal areas.

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