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Structural health monitoring with UAV

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Structural health monitoring with UAV

M Y Rezk [1], N H Mohamed [1], N M Nagy [1]

[1] Department of Civil Engineering, Military Technical College, Cairo, Egypt

Email: mohamedyosry@mtc.edu.eg

Abstract. In recent years, the use of drones to monitor various types of smart constructions has attracted more attention. Unmanned Aerial Vehicles (UAV) have a number of potential benefits over manual methods for Analyzing construction due to their permit scalable, quick, and affordable solutions to tasks that would otherwise be unsuitable for individuals who are subject to fatigue and measurement uncertainty. In order to better understand how drones can be used in dam monitoring and construction for situation assessment, early warning, and image processing, the current study is studying this topics. High resolution Ierial images that captured by UAV is used to detect the cracks in the dam body structure. Drone-shot images are analyzed by using MATLAB software in order to assess the crack in the dam body and make the correct maintenance.The finite element program Geostudio is undertaken to evaluate a complete numerical analysis of the dam to find out the cause of cracks in the dam body and give solutions to prevent these cracks from happening again depending on the outcome results. This study is applied under two cases seismic and static condition. The results of FEM model concluded that cracks starts to appear at slope change point at downstream and in upstream at dam heel during earthquake action. The current work shows that using drones in dam monitoring is a very effective and fast way to detect cracks in the dam body.

Keywords: reservoir, crack, dam, monitoring, Foundation

1. Introduction

Dams play an important role in the ecological system. Dams have various benefits and advantages, but when exposed to any problem, they may cause problems greater than their benefits. The accumulated problems in the dam may lead to its failure, resulting in damage to the surrounding environment and human loss. There are many causes of dam failure. The most critical one is structural failure caused by earthquake. Therefore, dam must be monitored and maintained to avoid these problems[1].There are phenomena that occur to the dam, which inform us of the existence of problems, such as cracks. Cracks are caused by hydrostatic and dynamic loads. Many researchers have studied the causes of cracks in the dam structure[2–7]. Crack detection is very important and play an essential role in dams monitoring [8]. Manual detection consumes a lot of time and money. Due to the large size of the dam, there are hard-to-reach places, Besides the large number of sensors used in monitoring are placed in fixed points in the structure. Structural monitoring by using visual detection and monitoring sensors in specific spots provide limited readings [9]. It is crucial to use a large-scale, non-contact measurement technique to monitor the health of dams. Numerous studies have been conducted on computer vision-based automatic detecting techniques [7]. The majority of these techniques use machine learning algorithm and image process technology to identify some basic types of structural damage. Vision based techniques by computer and high resolution camera are used to measure the infrastructure response[10]. There are numerous algorithms that can detect cracks at the pixel-level. Cracks in the dam can be detected accurately by using these algorithms. Recently using UAVs specially drones are available. It is used in investigation and inspection of narrow places and high areas and not reachable spots with short time. There are many types of drones, each of them is used for special purpose according to the payload(camera) they carry. Each drone carry camera to generate high-pixel image to increase the accuracy of crack detection[11]. Koyna dam, which is built in india 200 Km far from Mumbai, is used to generate power and in irrigation to that area. Koyna is a gravity dam with 103m height and 70m wide. In 11 December 1967 an earthquake of 6.5 richter is occurred in that area causing damage to the structure of the dam. Cracks propagated along the upstream and the downstream faces. So that static and seismic dam behavior is necessary to be studied. It is found that by using linear analysis the tensile stress is increased and excess the concrete strength at the presence of strong earthquake[12]. After that a lot of nonlinear analysis have been done to the structure of the dam to predicts any possible cracks with earthquakes. In this paper, koyna dam is studied numerically by using Geostudio program in case of static with its hydrostatic load and in case of seismic load to understand the dam behavior through different types of loads.

2. Methodology

2.1 Numerical Modelling parameters

Geometry of non-overflow section of koyna reservoir-dam-foundation is illustrated as shown in figure1. The height and width of the dam are 103 m and 70 m, respectively [12]. The upstream face is taken vertical and straight unlike real configuration. Reservoir depth will be taken 91.75m at earthquake time[13]. The dam foundation dimension is set to be 350*140 m and the foundation bottom is assumed to be fixed [14]. In the numerical model,(Geostudio), the length of the reservoir is assumed to be 140m[13]. The material parameters that used in the model are presented in table 1 [14].

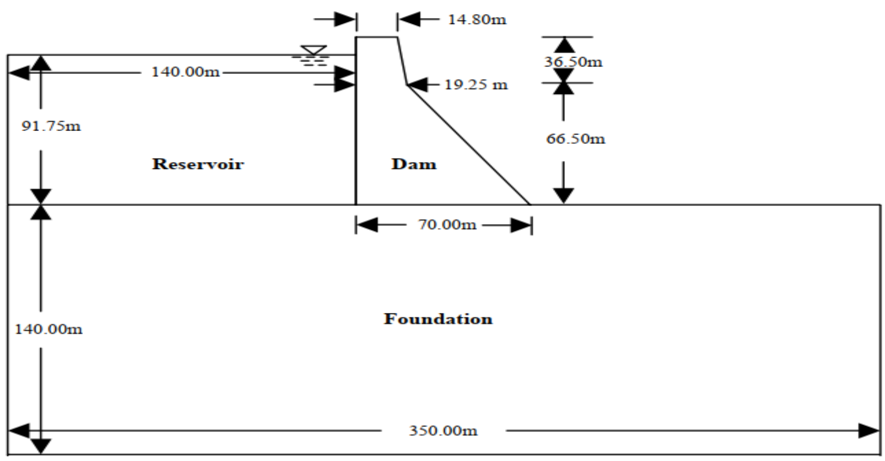


Figure 1. Geometry of cross section of reservoir-dam-foundation system [14]

Table 1. List of material properties

Material	elastic modulus E_d	mass density ρ_c	Poisson's ratio ν_c	dilatation angle ψ_c	compressive initial yield stress σ_{co}	compressive ultimate stress σ_{cu}	tensile failure stress σ_{to}
Dam concrete	31027 MPa	2643 kg/m3	0.2	36.31	13.0 MPa	24.1 MPa	2.9 MPa
Dam foundation	62054 MPa	3300 kg/m3	0.33	-	-	-	-

2.2 stress analysis with Geostudio (SIGMA/W)

In Geostudio software SIGMA/W are used to conduct the deformations and stresses in the dam structure. SIGMA/W calculations are based on two-dimensional (2D) plane strain theory. The analysis uses linear elastic theory. Compression denoted by positive stresses and tension denoted by negative stresses. The model can be seen in figure 2. The base of the foundation is constrained from movement in the X and Y direction and the sides are constrained in the X-direction from moving. The reservoir is applied as hydrostatic pressure. The FEM of tringle and quads mesh was used to simulate the model. The approximate element size is 5 m. The applied loads in the FEM model are hydrostatic pressure at upstream in pink, uplift and self-weight.

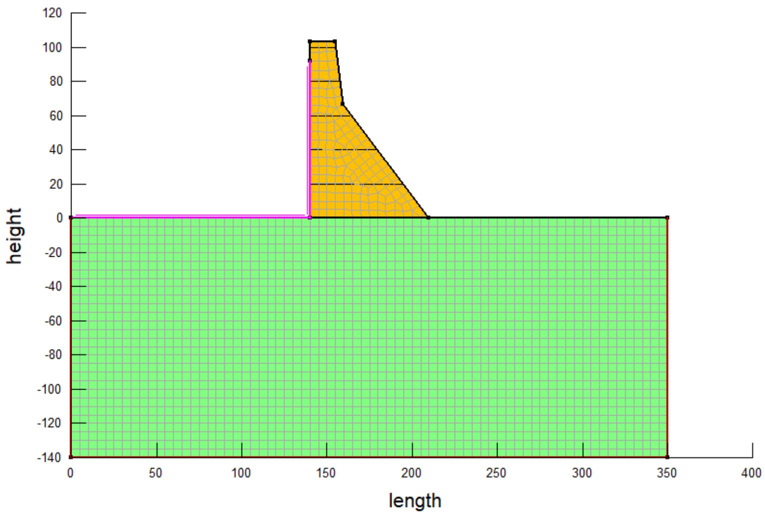


Figure 2. Finite element mesh of koyna dam with Geostudio

2.2.1 Displacements-Deformed grid

The dam is tilted towards downstream and pressured downwards into foundation direction as shown in figure 3. The displacement is magnified with factor (350) to see the deformation significantly. Therefore, the structure will be subjected to some settlement.

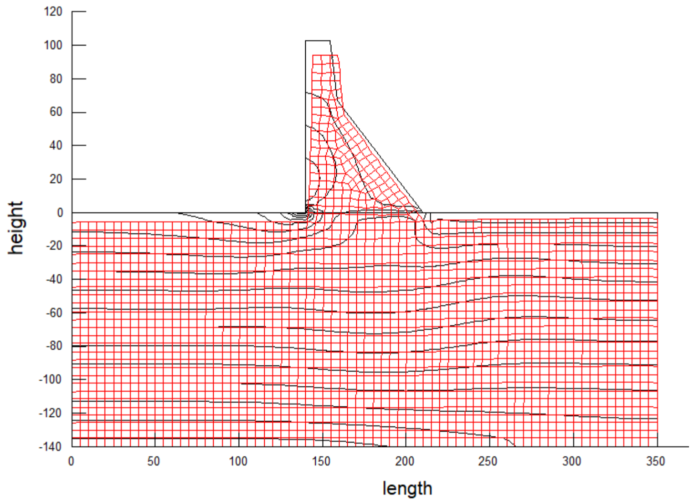


Figure 3. Deformed grid at static condition of the dam

2.2.2 Maximal stresses

The maximum stresses during static condition can be seen in figure 4. The stress contours show the change in stresses through the dam body and foundation. The maximum stresses were 4 MPa compression along the dam toe, and in the foundation under the dam reach up to 3 MPa. In the heel of the dam is reached 1.5 MPa.

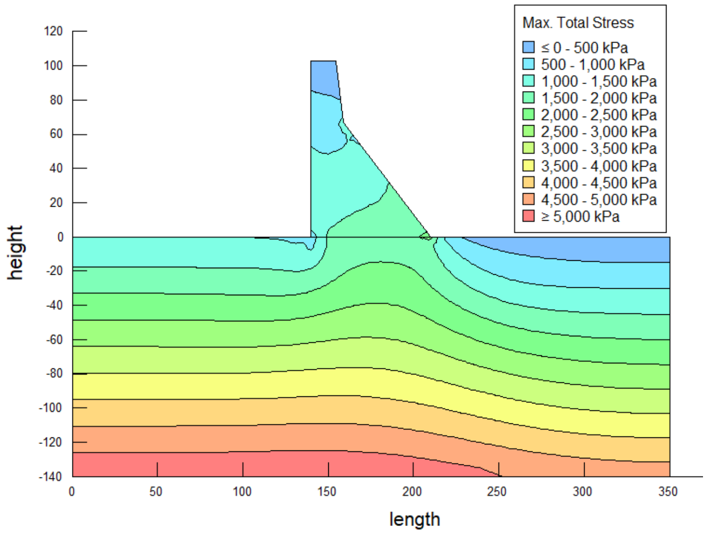


Figure 4. The maximum stresses during static condition

2.2.3 Minimal stresses

The minimum stresses during static condition can see in figure 5. Minimal stresses contours used to show the tension areas in the foundation and dam structure. The minimum stresses reach to -0.4 MPa tension in dam toe and in the foundation under the dam reach up to -1.5 MPa. In dam heel is reached -1 MPa. Higher tensile stresses lead to crack appearance in the concrete surface of the dam.

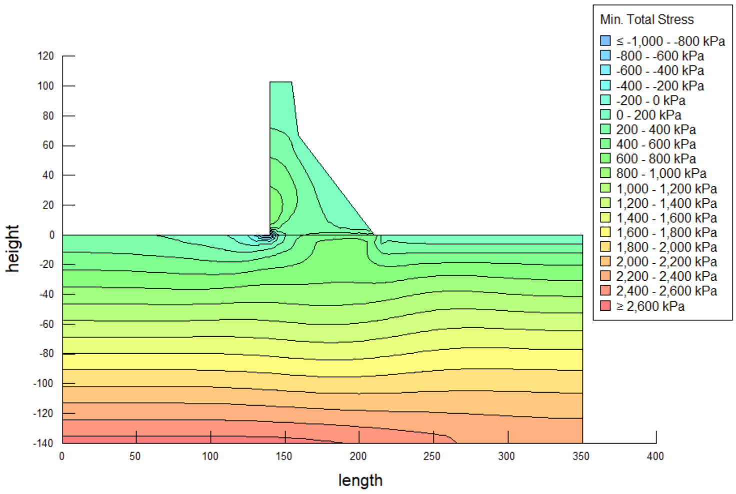


Figure 5. The minimum stresses at static condition

2.3 Seismic analysis with Geostudio (Quake/W)

In Geostudio program (Quake/W) seismic response through dam body during and after earthquake action are introduced. The boundary condition is the same as (SIGMA/W) except the sides of the foundation constrained in the Y-direction from movement to restrict vertical movement and allow the foundation to sway presented in figure 7[15]. The vertical and horizontal accelerations record of koyna earthquake that happened in 1967 have been added to finite element model presented in figure 6.

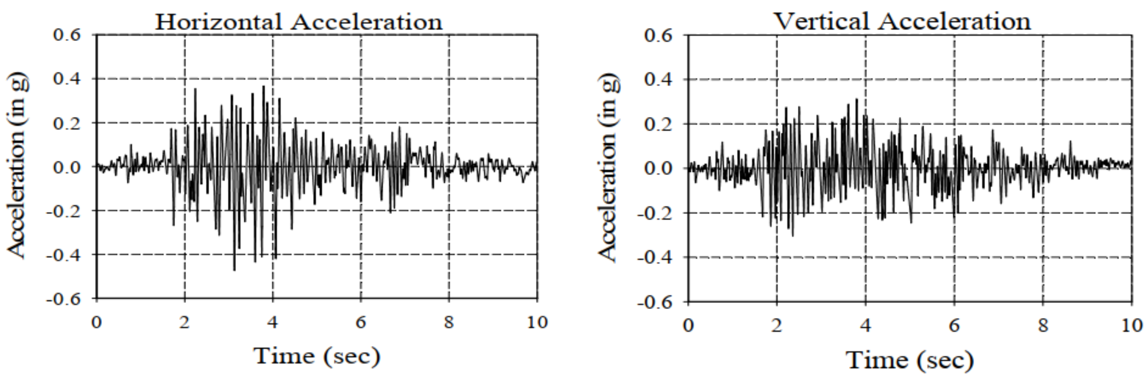


Figure 6. accelerations of koyna earthquake[13]

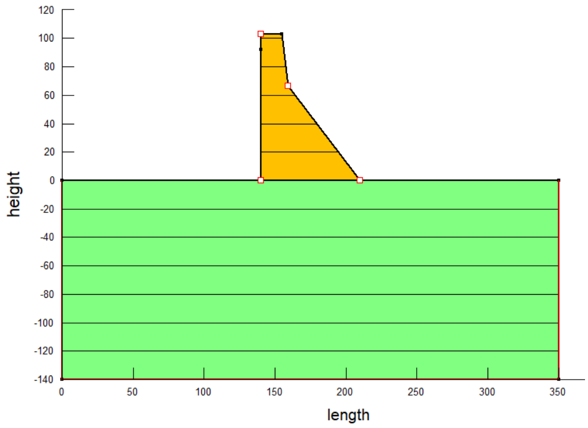
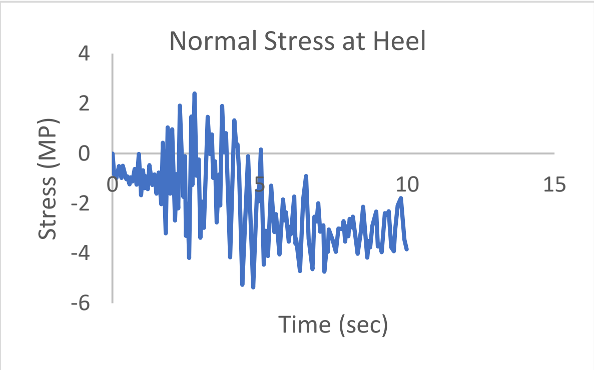
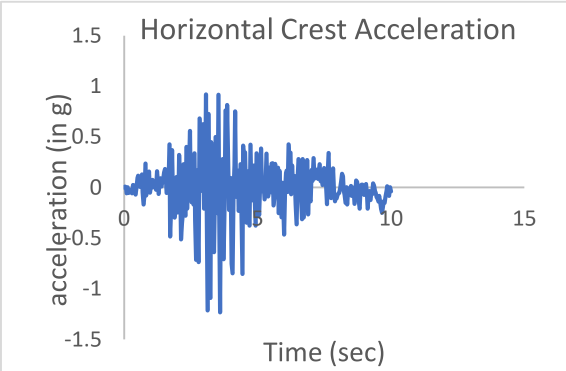


Figure 7. (FEM) model with Geostudio

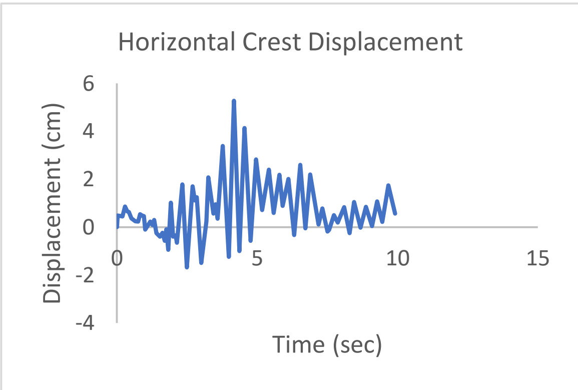
2.3.1 Dam seismic response diagrams

By solving the finite element model, the horizontal crest acceleration diagram, crest horizontal displacement and heel normal stress diagrams are introduced during 10 seconds duration of the earthquake are introduced in figure 8. History points are taken at the heel and the crest to show the change of values through the time and get the peak values. Figure (8-a) shows the normal stresses at dam heel through time. Figure (8-b) show the horizontal acceleration at dam crest through time Figure (8-c) show the horizontal displacement of dam crest at the same period of earthquake. The peak response values are estimated. The peak acceleration at the crest is 11.772 m/s^2, peak normal stress at the heel is 7.89 MP, and the peak horizontal stress at heel is 5.83 cm.





a) Normal Stress at Heel b) Horizontal Crest Acceleration



c) Horizontal Crest Displacement

Figure 8. Reservoir-dam-foundation response quantities

2.4 Crack detection by UAV

After making the numerical analysis to the dam body at static and seismic condition with history area earthquake parameters the most possible areas that have high tensile stress are known that have or will expose to cracks. By using drones with high-pixel camera to make monitoring to the dam by taking photos to the surface of the dam structure specially the spots that have high tensile stresses as shown in numerical analysis as shown in figure 9 [3]. The techniques of image processing are used to detect automatically and report the crack data without man use. The input data in that processes is the RGB image (colour images in Red, Green and Blue colour space), camera distance from the surface and the effective pixels of the camera. The output data is the area and the length of the crack.

Figure 9. Example of drone used in monitoring

The type of drone for each mission is chosen according to specific information such as camera lens, light condition, wind speed, total time collection and collection distance to get accurate information and images of the structure[7]. Many software is available to make image processing like LEAR and MATLABE. Edge detection is an algorithm and one of image processing techniques used to identify the points in the image taken from camera by drone that present in figure 10.

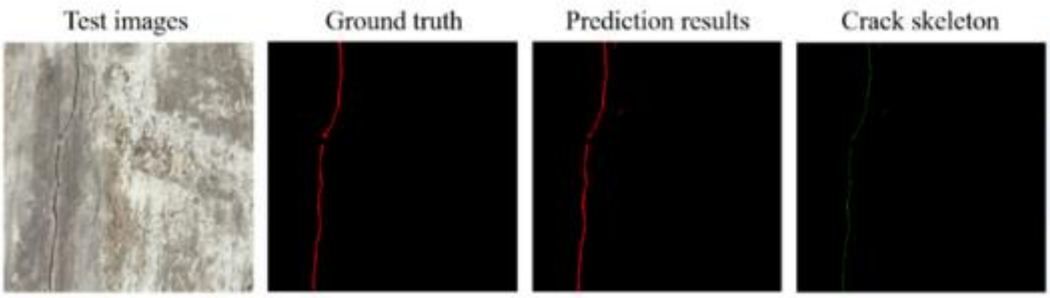


Figure 10. Example of extraction of crack skeleton by using LEAR software [2]

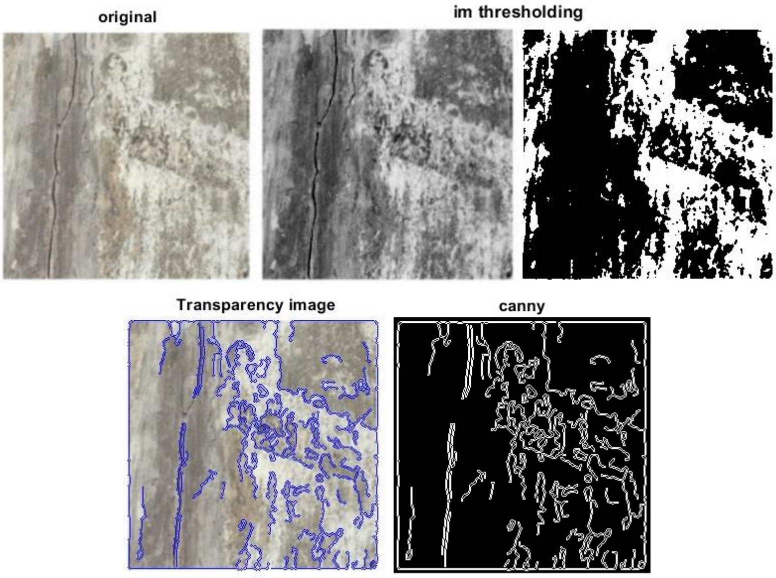


Figure 11. Example of extraction of crack skeleton by using MATLAP software

3. Conclusion

In this study, numerical analysis is done by using GEOSTUDIO (SIGMA/W, QUAKE/W) programme to koyna dam in two cases at static condition and seismic condition to detect the possible area for cracks and find the reason of crack to find the most appropriate way for maintenance, the following results are concluded:

- The results of non-overflow section of koyna dam at static condition ensure that the dam is safe against compressive stress, tensile stress and overturning. Because of the dam high self-weight is safe against sliding.
- Figure 5 shows the dam-reservoir-foundation response. The crest displacement response and the heel stress response are beginning from some initial values. This is due to the static loading initial values before dynamic loading. The stress plots at the heel show that after time interval, stresses have sudden reduced due to the tensile damage at dam heel for concrete nonlinearity. It is concluded from stress plots that concrete has lost its strength at those damaged areas to let the tensile load make action due to the dynamic loading of the system.
- The behaviour of the dam body under earthquake shows an initiation of cracks at the heel and change slope point duo to high tensile stresses.
- Structure health monitoring by using UAV increase the corrective action possibility earlier than any failure occurrence by making the inspection, monitor and analyzing faster.
- Numerical analysis is helpful in determining the locations of high stresses that properly have or expose to crack through the life time of the dam.

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