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Simulation of dam fracture by using HEC-RAS and GIS consolidated models

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Abstract

The produced energy from hydroelectric power plants is the most efficient energy from environmental point of view. Using this phenomenon depends on constructing high dams for storing water and having control and lifting equipment.Dams are primarily built close to where people live and wreckage of one dam is not just harmful economically and environmentally but it is also a big threat for those who live at the downstream of the dam.so we should be really careful in analyzing its calculations and designing and we should also use the most advanced methods and tools which are capable of making and analyzing appropriate models that are harmonized with the geometry of dam's conformation, as much as possible. Despite the great advances of human knowledge in designing, construction, operation and maintenance of dams in a very safe and secure method, dam fracture is still on the agenda of managers and administrators and study about dam fracture in some countries is the integral part of procedures of making dams secure.in this study, after examining the effective factors of dam fracture, we have used the integral methods of HEC-RAS and GIS in order to simulating Sattar Khan's dam fracture. The profile of water level in normal conditions with the rate of 7 cubic meters per second and also in conditions of dam fracture in three ways of Cost, Froehlich and Webby has been compared and Webby method has been used in order to examining the level of water in different sections alongside the river and determining the flood prone areas

Keywords:earth dam, dam fracture, profiles of water level, HEC-RAS, GIS model.

1.Introduction

Throughout history and all over the world , dams that had been built in order to storing water, fractured scarcely and the stored water had been release in downstreams. [6] in some cases the damages caused by such flood was incalculable. The fractured dams were not just include dams which had been designed and constructed according to engineering principals but it also included dams which had been constructed and designed according engineering principals and standards of its time. [4]Nowadays the governing conditions on dams and its surroundings have been changed in the way that has been ruled out the need for examining the events that have been caused by fracturing of dams. On one side we are observing different changes such as the change in climate that in lots of changes they lead to increasing floods and changes in assumptions and data that are used in the construction of the dam and on the other side we are observing the increase in population of dam's downstream area and the rivers beside it.On the other hand, the probable damages caused by dam's fracture, have been increased. Another issue is related to aging dams and its facilities.by increasing the age of these dams and passing many years from the beginning of exploitation, the concerns about probable wreckage of facility and material fatigue will be increase. [7] So the most important reason of dam fracture studies is the high risk of dam fracture or it is at least the efforts for evaluating the rate of this risk.Sang (1996) has been presented the list of reasons about destruction of dams. The most important reasons of dam destruction are:

- About 30 percent is due to the increase of flood more than the capacity of overflow hydraulic conductivity
- About 37 percent is because of the caused problems in (leakage, high pore pressure, piping, motion, displacement and settlement)
- About 10 percent is because of Slippage (soil. Ice masses, rocks and snow devil)
- About 23 percent is because of inappropriate designing and construction, bad quality of materials, war, and exploitation and maintenance problems. [5]

So we can say that issues and problems about dam's following and overpassing are the most important reasons of dam's fracture and destruction. Besides this we should say that the possibility of the fracture of earth dams is much more than the possibility of concrete dam and dams that have been built with building materials. [1]Observing statistics and uneven spatial and temporal distribution of dam fracture in world shows the probability of dam fracture at any place and point of time. Since the experimental models cost a lot and since the measurement effects is so important in dam fracture, lots of methods and models have been proposed in order to estimating theparameters of dam fracture and navigating downstream floods. Although several numerical methods that has been presented for solving Sant and Nant equations are really similar, yet there are inherent differences according to geometry simulation of the river in these models. Beavers (1994) has done his first activities in the field of linking GIS and hydraulic models.so we have provided ARC/HEC2 tool in order to help hydrologists so they can analyze flood zoning. this program is able to extract all the related information about terrain from the surfaces of the map and then will insert data which has been introduced as system's input. Azagara (1999) has used hydraulic model of HEC-RAS besides aerial photos in the project of flood zoning on the catchment of WA river in Austin which is located in Texas one of the state of America in order to providing and analyzing the maps of flood zoning. They concluded that geometric information of river, including the line of water flow, right and left breaches , determining Manning coefficient and information related to cross-sections from the maps of aerial photos will take lots of time whereas by using the appendix of HEC-GeoRAS we can solve the problem easily, promptly and efficiently. Karimian et.al (1384) by zoning the flood by means of HEC-RAS hydraulic model has concluded that integrating HEC-RAS and GIS models in order to zoning the flood of urban rivers will contain acceptable results and in GIS software we can cover the place of human distribution by means of flood prone areas and protecting guidelines. Mignot and Paquier (2005) studied dam fracture of Tous in Spain. They have examined 3 different scenarios of dam fracture and its effect on small town which has been located on 3 kilo meters of downstream, they also have determined the depth of possible flooded that has caused by dam fracture in under study city. Hooshmand Diarjan et.al (1387) anticipated the parameters of Titian's dam fracture and processing caused flood by means of BOSS DAMBRK and HEC-RAS BREACH mathematical methods and they also compared the observed data with one another. [3]

2. Investigating the parameters of dam fracture

In most of the investigations about the way of dam fracture in anticipated the caused flood from it, we assume that dam fracture will suddenly occur, in the way that the body of dam as a barrier in front of water will remove suddenly. According to available experiences, the assumption of sudden fracture of concrete dams is almost acceptable and appropriate.

But this assumption about earth dams is not sufficient method. The fracture in earth dams which are much more applicable in compare to concrete dams will occur gradually and over a certain time period. At beginning of dam fracture, due to various reasons, small breach will occur and output flow from this breach will gradually start to wear it.

This extension will continue until the tank completely evacuated or the erosion of the breach reached to its ultimate point. [8]

According to figure 1 in order to describe the created breaches in earth dams we will use parameters such as breach height-HB and breach width-Bb , the average of breach width which will occur in half of the breach's height (Bavg),the slope of breach's side walls (breach slope-Zb) and the parameter which will express the time of breach development

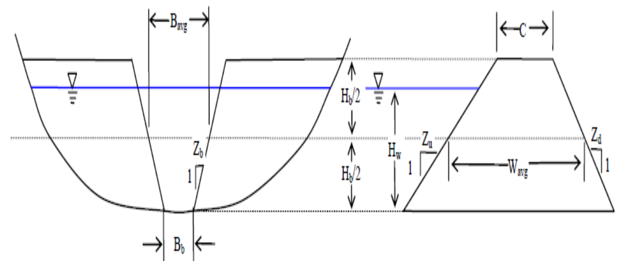

Figure 1.Breach describing parameters in the fracture of earth dams

In order to anticipating breach parameters we will examine 3 main guidelines. These three methods include measurement of breach dimensions according to comparing similar items of fractured dams with under study dam, using anticipating equations which have been obtained from case studies and ultimately, applying detailed numerical methods which have physics and hydraulics base.in most of computerized methods which have been designed for dam fracture simulation, including HEC-RAS model, the user has to introduce the breach describing parameters according to comparing it will similar items or by means of anticipating equations from case studies.More exact models that have physical base are still in investigation phase. [11]

Some useful equations that have been used in this project in order to evaluating breach parameters are as following:

a) Published guidelines by U.S. Army corps of Engineers (COE) in (1980) which is included in table 1 :

Table1: dam fracture parameters according to U.S Army corps of engineers , guidelines:

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Time of breach creation or dam fracture	Side slops $Z\,(H:V)$	Width of breach	Earth dam
0.4 to 0.5 hour	1:1	0.3 to 0.5 times of dam's height	

b) Published guidelines by Fread (NWS) IN 1980 which is included in table2:

Table2

Earth dam	Time of breach creation or dam fracture	Side slops $Z\,(H:V)$	Width of breach
	0.1 to 0.2 hour	1:1	0.3 to 0.5 times of dam's height

c)Published guideline by Froehlich in 2008:

This researcher by means of investigating 63 dams, calculated dam parameters as a function of tank volume, height of breach and the slope of the sides of breach.in this method the distinction has been made between the fracture of top wash and down wash by using the factor of (ko) fracture index.in the case that all data were equal the above wash status will create larger breach section in compare to down wash status.In Fervlich method there is no difference between top wash and down wash status. The estimated extension time has direct relation with tank volume and reverse relation with the height of breach. This means that dams with higher height will result less fracture time for one volume of tank. [10]

$$B_{avg} = 8.239 K_0 V_W^{\;0.32} H_b^{0.04}$$

$$t_f = 3.664 \sqrt{V_w / g H_b^2}$$

the slope of breaches in side walls for overpassing status

$$Z_b(H:V) = 1:1$$

the slope of breaches in side walls for down wash and destruction status $Z_b(H:V) = 0.7:1$

Recognizing hydraulic characteristics of flood flow which is resulted from dam fracture in different situations and according to reaction analyzing Of dam's downstream area and deciding about effective functions on decreasing its effects.

In this study the simulation of Sattar khan's dam fracture and the flood caused by it ,will be done by means of HEC-RAS software.

1.Gathering aerial, satellite photos and topography plans in under study area.

2. Providing plans and cross-sections.

3.Introducing characteristics of the dam in Sattar khan's river,dam's structure and its side structures

4.Determining manning coefficient in dam's downstream

5.Determining border conditions in river's downstream and high stream areas.

6.Performing model and representing the results of hydraulic flow

7.Providing flooded plans that has caused because of dam fracture.

Sattra khan's dam has been located in 15 kilometers of the west of Ahhar city in east Azarbayjan which is respectively located in North West of Iran.By constructing this dam, in addition to controlling and regulating the surface flows of Aharchay's river, the required water for one part of agricultural lands in dam's downstream and also water supply in Ahhar provision will be provide.

The characteristics of earth dam's body and overflow is as following:

- Crest elevation 1459 meters above sea level
- Following the maximum height of 75 meters
- Crest length of 350 m
- Crest width of 11 meters
- Base width of 480 m
- Overflow type : simple tunnel

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- Spillway crest elevation 1451 meters above sea level
- Spillway crest length 14 m
- Spillway tunnel diameter 5.7 m

The volume of dam's tank in normal level is 135 million cubic meter, its useful volume is 120 million cubic meter and the volume of adjusted water is around 90 million cubic meter. Considering that the available plans of under Study Rivers are topographical numeric plans with scale of 1:500 and these plans are also containing main duct of river and flood water and on the other hand the related soft wares to geography information system (GIS) such as Arc view have the capability of information exchanging with simulation mathematical methods in river's one dimensional flow.

So in order to providing cross sections of river in this study, we have used Ark view software.

In order to performing discharge hydraulic studies we've chose return periods of 2 to 100 years in hydrology studies.

Also the flood discharge with 2 years of return period that has 50 percent possibility of occurrence will be consider as the dominated design of flood

3. Simulation of dam fracture:

Hec-2 software has presented around 1990 in order to modeling constant and one dimensional flows with ability of modeling crossing structures such as bridge and calvert.in following by increasing the capability of this software , new models of this software have been located in web site of US Army, engineering group as HEC-RAS software.

Considering various capabilities of this model in designing and performing different calculations, the HEC-RAS model has been chosen and all designing and calculations have been performed by means of this model.

By using these obtained results from the model (the profile of water surface for rates and other calculated hydraulic parameters by this model) we can reach to the followings:

1. Determination of the overflow points of the river banks during flood with different return periods.

2- The maximum capacity of the river at any cross-section

3- Determining flow curves cross the river stage at all levels

4- The possibility of choosing location and direction of flood diversion structures on the river

5- Providing necessary information for the construction of various structures in the river or flooded plain

6-determining appropriate locations for the main drain discharge from plain to river.

In order to inserting river's cross sections in HEC-RAS software we should first provide TIN plan of the area in GIS, and then by means of HEC GEOras software which has linked to GIS software, we should determine the lines of river and its banks and we should also extract all cross sections.

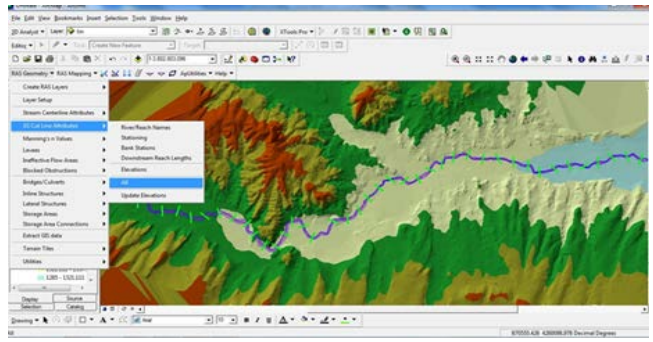

Figure2. presented river's cross sections and make them 3d by means of HEC GeoRas software

After determining middle line of river and right and left banks , the created cross sections in GIS has transformed to output and then has been called in HEC-RAS software.In order to inserting maximum rate after dam fracture we should use relations that have obtained from experimental studies

Costa relation:

Costa (1985) presented following relation by means of obtained results from 31 fractured dam for the maximum output rate.

$$Q_p = 0.763(V_w.H_w)^{0.42}$$

In the above relation, Vw is useful volume of tank and Hw is the height of water which has been stored behind dam.

Froehlich relation:

Froehlich (1995) presented following relation by means of obtained results from 63 fractured dam for the maximum output rate

$$Q_p = 0.607V_w^{0.295}H_w^{1.24}$$

According to Vw is useful volume of tank and Hw is the height of water which has been stored behind dam.

Webby relation:

Webby (1996) performed dimensional analysis by Froehlich's presented data, and represent the following relation

$$Q_p = 0.0443\, g^{0.5} V_w^{0.367} H_w^{1.4}$$

In this relation, Vw is useful volume of tank and Hw is the height of water which has been stored behind dam.

In this research, useful volume of tank is 120 million cubic meter and the height of water behind the tank is 51 meters. According to above mentioned relations, peak rate calculated in each method and the results has shown in table 3.table 3

metod	costa	froehlich	webby
Q_p(m3/s)	9839.2	19228	31453.9

As we have seen in table (3) the rate of Webby's method, in compare to other methods, has the highest amount that will be recognized after inserting peak rate and performing the software of water level in each section.

Discussion and conclusion

After entering necessary information such as cross sections, roughness coefficient of one part of river and right and left banks for each section, data of river flow and border conditions of river such as slope of river and its crisis depth in high streams, we start performing HEC-RAS software.According to the reports, the highest rate which has been entered, was the rate of 7 cubic meters in second.so in order to modeling flood flow in different sections of the rate of 7 cubic meters in second and also for modeling dam fracture ,we have used peak rates which have been included in table 3.

In figure 3, the sections of river and in figures 4 to 7, water level in section of 24600 has been shown.

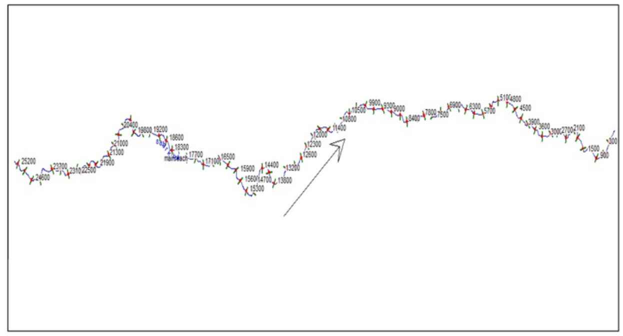

Figure3. river sections

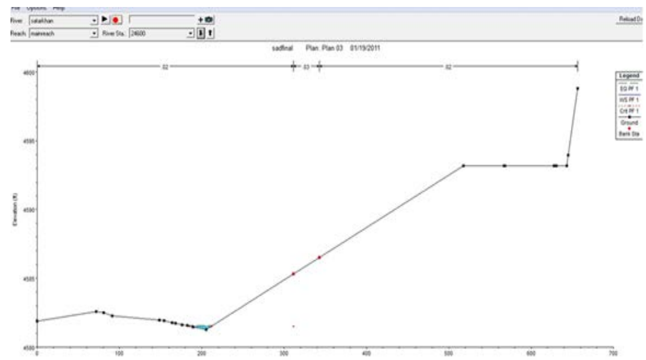

Figure4. the section of 24600 in the rate of 7 cubic meters in seconds

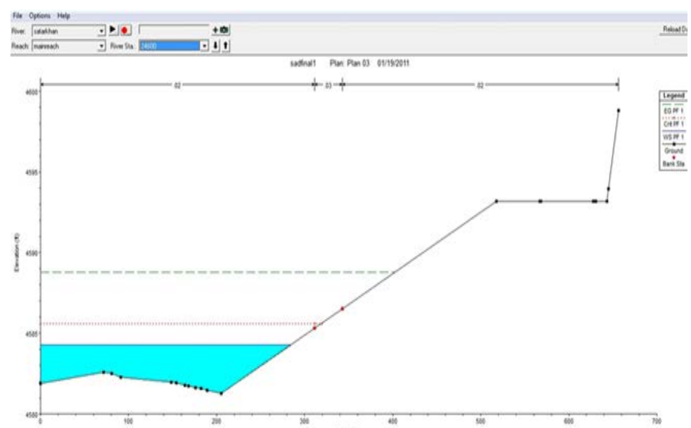

Figure5. the section of 24600 in dam fracture in Costa method

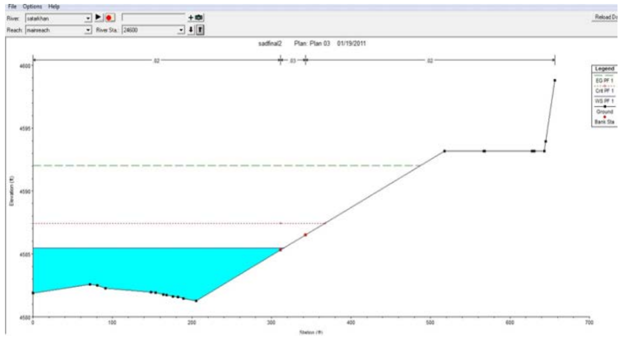

Figure6. the section of 24600 in dam fracture in Froehlich method

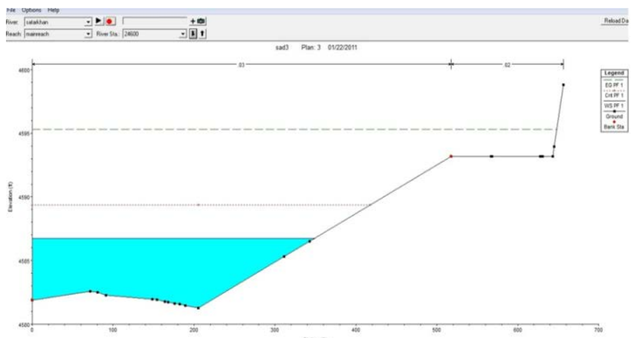

Figure 7. the section of 24600 in dam fracture in Webby method

After evaluating and investigating different sections, the highest level of water was after dam fracture in Webby's method so in the following we have used this method in order to zoning the highest area that flood has allocated to itself.

Figure 8 shows submergible area and figure 9 shows the side effects which have located in submergible area.

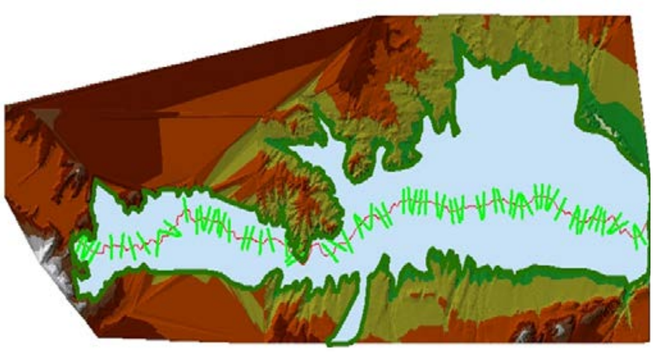

Figure 8

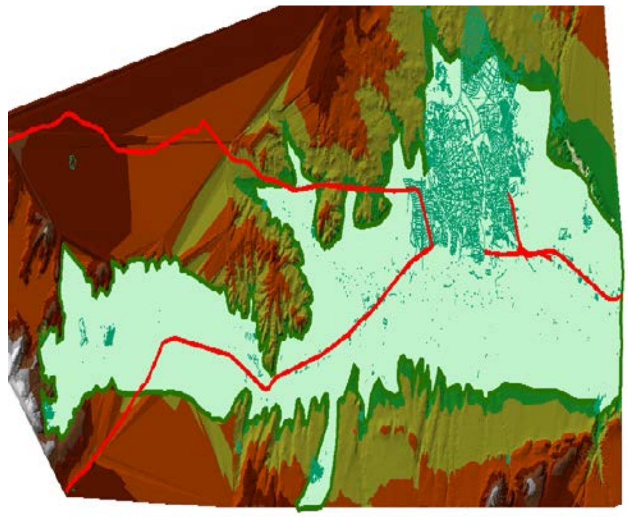

Figure 9

4.Conclusions

After evaluating and investigating flow depth in different sections with 3 different methods of Costa, Webby and Froehlich, the highest water level after dam fracture and the highest submergible zone, was in Webby's method.

Flood zoning in area shows that the part of main road and Ahhar city, after dam fracture has been located in submergible area.

We can use the obtained results from model in determining overflowing points of bank at the time of flood occurrence, determining the maximum capacity of river in each cross sections, determining Ashel rate curves in every section, determining structure's position and the path of flood divergence on river and also deciding about appropriate places for discharging main drains from plain to river.

We can provide secure points for Sattar khan's dam, by means of plan.

We can use zoning plan in designing main roads, main highways and hospitals

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References

[1] Kharghani, Saeed and Fakhari, Naser. Earth dam engineering, Publications Department of Energy, 2009
[2] M.Soltani and Rahimi Asl, " computational fluids dynamics by means of Fluent Software" published by Jahad Daneshgahi, 2003
[3] B Abbasi investigating numerical and experimental methods of hydraulic fracture of dam with considering the effects of shower and sediments, civil MA thesis, hydraulic structures, Ferdoosi Mashhad engineering university, 2008
[4] A .Alizadeh applicable hydraulic principals, published by Emam Reza Mashhad University, 1998
[5] Sadr Nejad. A, earth dams and their numerical analysis, published by Shahid Rajaei university, 2004Shafaei Bejestan principals and applications of hydraulic-physical models, published by Ahvaz Shahid chamran university, 2010
[6] Power ministry publication leakage in foundation and methods for controlling that. Iran committee of large dams (ICOLD), 1996
[7] K Behnia and A.M Tabatabaei, earth mechanic ,ninth publication of Tehran university, 2009S.M Haeri principals of earth dam designing ,published by civil engineering department of Tehran university, 1984
[8] Ghobadian. Rasool, effects of dam's wall on the position of free leakage line and the rate of leakage in earth dams by means of limited and numeric volumes,sixth national congress of civil engineering, 2011
[9] Collection of regulations and standards of aquiferous and natural sources, 2012
[10] Shafaei Bejestan.M, principals and applications of hydraulic-physical models, published by Ahvaz Shahid chamran university, 2010
[11] S. Haeri, principals of earth dam designing,published by civil engineering department of Tehran university, 1984

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