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The Selection of Dams Design Floods: Mistakes and Outcomes

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ABSTRACT

Flood may result from the volume of water within a body of water, such as a river overflows suddenly and takes many lives and causes financial damage. The flood, which is chosen as the basis for the design of a hydraulic structure, is called design flood. In the design of small structures such as bridges, barrages, embankments and small dams, only knowing the maximum instantaneous flow of flood is adequate. In some of hydraulic structures, in addition to the maximum instantaneous flow, flood volume and other properties such as flood continuance are of great importance. Here in addition to the maximum flood discharge, it is necessary to predict design flood hydrograph. Wrong estimation of design flood causes dams failure. In the current research 8 dam failures are studied. The results show that due to the accidental nature of flood amount in dam failure, it can occur in every country with any technology. Also, in some countries such as America some severe rules were made after dam failures. Also, the results show that the amount of victims doesn't depend directly on dam volume or its height and it depends on the regional density, information level, local information and downstream topography of the dams. Earth dams with more than 75% failure are more exposed to failure. Thus, in the design of these dams, low risk should be considered.
KEYWORDS: Design flood; Dam failure; Dam height; the type of dam.

INTRODUCTION

Flood may result from the volume of water within a body of water, such as a river overflows suddenly and takes many lives and causes financial damage. To predict the flood properties at a definite place, it is better to measure and record the number of floods occurred in that place in order to predict the conditions of the floods occurring in future by the analysis of its related data. In the design of small structures such as bridges, barrages, embankments and small dams, only knowing the maximum instantaneous flow of flood is adequate and Hydrograph is not required. Because these installations are mostly sensitive against the maximum flood discharge and it is possible that the volume of flood is not influensive. In this case in addition to the maximum flood discharge, it is necessary to predict hydrograph of design flood. The flood, which is chosen as the basis for the design of a hydraulic structure, is called design flood. The selection criterions of design flood are as the followings:

Structure importance, economical issues, the effect of the failure of structure on downstream regions, technical and economical life service of the structure, population density in the downstream regions, the effect of structure failure on the existing military, local and agriculture installations, social condition and wellbeing of downstream residents. To compute the design flood some methods are used as: The design according to frequency-based flood (FBF), probable maximum flood (PMF), and standard project flood (SPF) and according to flood regional analysis. Design flood analysis is a challenging issue for many years. This is a problematic issued. Most of the dams are failed due to unsuitable capacity of their spillways. Also, the diversity and complexity of the effective factors on the size and creation of flood caused various and different methods to analysis design flood. Design flood for a big dam is a flood whose magnitude and occurrence is considered in a way that dam safety is guaranteed according to a good safety standard of dam design and its failure outcomes. Thus, the selection of design flood is one of the most important decisions that should be taken in the development of dam construction project. This issue is not only dependent upon the design itself as an effective factor with other hydrological factors, but also it is related to a potential risk the causes economical damages and takes many lives if the dam is failed. Design flood is calculated on hydrograph of inflow and under the influence of reservoir in dam site, is used for sizing the spillways and determining storage of reservoir surcharge. Design flood is normally selected by engineering analysis after considering all the information of rainfall amount and the records of river flow. Flood estimation method should be selected in accordance with climate, information and the related country. Bad climatic events not only cause strong floods, but also cause some problems for dam authorities (Such as disconnection, Jammed Gates, power problem, involvement of authorizes in rescue operation etc.) that brings an emergency condition. Some of the events occurred

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due to the low estimation of design flood or operation problems of output structures or spillways in different parts of the worlds are explained in the followings.

As it is shown in chart 1 we can say that most of the failures faced with different errors in the calculation of design flow as error percent was between 15 to 230. In chart (2) among the 3 first countries, 2 countries are developed countries. According to chart 3, we can say that most of the failures in the recent decades are not occurred in developed countries, it means tha these countries obtained the required experience from the initial failures and by making sever law prevented these events. But it cannot by surely said that in these countries there is not dam failure anymore. In chart (4), it is observed that the three countries with the highest dam height had the highest casualties' rate.

RESULTS AND DISCUSSIONS

1- More than 75% of the dams failure is related to earth dams.

2- Dam failure can occur in any country with any technology level, and that is due to the sudden natural phenomenon such as rain and flood and the weakness in the exact prediction of flood.

3- Today, by technology advance by satellite images and data, climate forecast and determination of critical and dangerous phenomenon is getting better. Thus, by high precision, we can design the dams but achieving very high reliability is impossible yet.

4- In most of the countries and Iran in the designs due to dam failure, consider the highest scientific image of a dam. While in most of the cases, these constructions are very costly and most of the capital is taken out of the country. For example, 15Khordad dam in Iran.

5- Regarding 45000 large dams and the number of failed dames, we can say that the dams' failure statistics is very good in comparison with other social issues.

6- Alarm system of dams downstream is very important. As it is seen in the above statistics, in two equal failures the number of casualties in advanced countries are much less than other countries. This should be considered in dam construction. Also, by holding some classes in downstream zones of the dam, casualties risks will be reduced.

7- In Iran considering the dam failure statistics of Zero, except for Farazband dam or other small dams during operation, it is necessary to overview the design flood standard. This reduces capital wastage in the country. It seems that it is about the time that dam construction engineers consider high risk.

8- It is interesting that most of the dam failures are occurred when there was considerable progress in the science of dam construction. (After 1960). This caused the change of standards.

9- Observing good reliability coefficient (Excess reliability coefficient increases the unnecessary costs)

10- Considering the importance of structure and analysis of economical risk

Table 1- The dams' failures due to the mistaken determination of design flood

1-	Dam	SOUTH FORK (USA)	May 31, 1889
2-	Dam	BRISEIS (Australia)	April 4, 1929
3-	Dam	SELLA ZERBINO (Italy)	August 23, 1935
4-	Dam	GIBSON (USA)	June 8, 1964
5-	Dam	EUCLIDESDA CUNHA (Brazil)	January 19, 1977
6-	Dam	MACHHULL (India)	August 11, 1979
7-	Dam	NOPPIKOSKI (Sweden)	September 7, 1985
8-	Dam	SPITSKOP (South Africa)	February 23, 1988

Dam and country	SELLA ZERBINO (Italy)	MACHHULL (India)
construction goal	Electricity production	Irrigation of farms with the area of about 7000ha, water supply
Year Completed	1919 to 1925	1967 to 1972
Type	Concrete dam	Earth fill
Height (m)	The main dam BRIC ZERBINO 46.75 m Secondary dam SELLA ZERBINO, 16.50 m	59.25 m
Basis of design flood	Design flood of experience 810 m^3 / s	6180 m^3 / s
Inflow flood	History of flood as 2280 to 2500 m^3 / s	14000 m^3 / s
Hydrological properties	- Basin 141hm^2- Annual rainfall (1930 to 1934) 1500mm- Mean annual flow in dam site (1925 to 1934) 5.75 m^3 / s	The maximum historical rainfall in one day: 291 mm (August 1968)- Daily rainfall in a 50 years period is varied from 200 to 415 mm and in a 100yeras period from 220 to 475 mm
Cause of Failure	Unsuitable selection of design flood	Unsuitable selection of design flood
Outcome	Flood led into flooding of urban and agricultural areas and the death of more than 100 people especially in OVADA city. SELLA ZERBINO Dam was not rebuilt and ORBA river flow is now passing from the previous dam site. SELLA ZERBINO Dam is located in the center of the country and there is no reservoir such as ORTIGLIETO.	2000 People were died in the flood. In this area, the damage costs were 15 million dollar to agricultural products. Also, 12700 houses and huts were destroyed and 6700 houses were little damaged. In Morby city 153000 people were damaged and 68 villages were damaged along MACHHULL river around Morby and Malia. MACHHULL River is flowing to the north and from MARSHLAND of Kuch creek finishes.

Table 2- Failure of table 1 dams

Dam and country	BRISEIS (Australia)	SOUTH FORK (USA)
construction goal	Electricity production , Potable water	Recreational goals
Year Completed	1924to 1928	1838 to 1852
Type	Granite earth fill dam with concrete upstream cover	Earth fill
Height (m)	24 m	22 m
Basis of design flood	Design flood of experience during 6 hours 125 mm and during 24 hours 250mm	130 m^3 / s
Inflow flood	In sum, during 48 hours rainfall reached to 483 mm	Between 200 to 300 m^3 / s
Hydrological properties	Average annual rainfall 1350mm- Average annual flow of the river 0.48 m^3/ s via experience	No definite information
Cause of Failure	Unsuitable selection of design flood	Unsuitable selection of design flood
Outcome	Dam failure caused the death of 14 people including 8 mine workers. Some of the mine horses were drown in these floods. Also, some of the mine buildings and houses, documents, machineries were destroyed and the estimated costs (In March 1930) were 62000 pound sterling that was a considerable cost on that time.	2209 People were died in the flood. And 100 houses and administrative buildings were destroyed. The estimated damages costs were more than 17 million dollar or by the current value was more than 500 million dollar (1989).
Dam and country	**GIBSON (USA)**	**NOPPIKOSKI (Sweden)**
construction goal	Electricity production	Production of Hydroelectric, basin dam
Year Completed	1929	It was started in 1964 and the first hydration was done in 1967.
Type	Concrete arch	Earth fill
Height (m)	60.7m	The height of 18.5 m of the foundation
Basis of design flood	850 m^3 / s	140 m^3 / s
Inflow flood	1700m^3 / s	**600** m^3 / s
Hydrological properties	Average annual rainfall 470mm annual runoff 3947hm3-The maximum experienced flood was occurred on June 21, 1916 in the related measurement station during the above period and its maximum flow was recorded as 850 m^3 / s	Basin is with the area of 520 km2, a reservoir called Vasinoksemi is located in this area, climatic condition is continentality, annual rainfall is 700mm, and evaporation is 400mm. The snow cover is permanent. The maximum observed rainfall during 24 hours in the zone with the area of 1000 km^2 is 97mm.
Cause of Failure	Unsuitable selection of design flood	Unsuitable selection of design flood
Outcome	It is not failed but water overflow as 2 m on the spillway is revised. Revision in the design flood of maximum flow is 4390 m^3 / s- The corrective actions for guaranteeing the safety of GIBSON dam under the design flood are including the following alternatives: 1-Revision in Alternatives operation methods 2- Structural modifications to avoid flood overflow. Alternative 3: The necessary modifications for flood overflow. Alternative 4: The construction of Alternative dams (Alternative)	It caused damage to 20 km along the river. In some of the places a new river bed was created along the river. Power plan, dam and entry channel in Hansjo power plan were damaged on that day and about 100000 m^3 soil was eroded due to this flow. The design of new NOPPIKOSKI dam was started immediately after the dam failure. This design was done within a week and constructional operation was started in less than 2 weeks after dam failure. The new dam was completed during 7 months and operation of the dam began on April 1986.
Dam and country	**SPITSCOP dam (South Africa)**	**EUCLIDES DA CUNHA (Brazil)**
construction goal	Fixing river flow for farms irrigation	Creating a reservoir and water height for underground power plan of 94800 KW
Year Completed	between 1970 to 1974	Between 1958 to 1960
Type	Earth fill	Homogenous earth fill dam
Height (m)	The maximum height of the river bed 13.1 m	40 m
Basis of design flood	1700 m^3 / s	1840 m^3 / s
Inflow flood	2400m^3 / s	2000 m^3 / s
Hydrological properties	Basin is with the area of 26914 Km2 and average annual rainfall is 480mm	This dam controls a basin with the area of 4366Km2 and its average annual rainfall is about 1500 mm
Cause of Failure	Unsuitable selection of design flood	Unsuitable selection of design flood
Outcome	Gradual destruction of the dam didn't increased flow in downstream. The river slope is very little and adequate and gradual increase of the level above downstream decreased flow through breach. The failure of dam did not take any life and flooding of downstream farms were occurred even the dam didn't failed. The maximum damage is about the dam repair costs that was exceeding 5 million US dollar (Price of 1990)	No death is recorded in this event. The hydrological studies resulted into the determination of a new design flood 3100 m^3 / s and on January 19, 1977 , strong raining was observed in Pardo river in the upstream of EUCLIDES DA CUNHA dam especially as densely in an area about 1700 Km2 exactly in the upstream of the dam. Rainfall mean in 24 hours in the above area of the river was recorded as 180mm. due to this rainfall, river flow increased on January 19 at noon until midnight of the same day 200 m^3 / s. Water increase speed was high in reservoir. The dams doors were not opened on time due to opposite interpretations of the related staff about the intensity of the flood. About midnight during more than 7 hours water height reached 1.2 m from crest level. The dam failed when a 100m breach was created from the right support and the right side of the dam was destroyed. (Picture 2) the main outcome of this event in the downstream of the dam was overtopping of Armando Salles de Oliveira dam in the 10 km distance of the downstream of the dam due to the flood flowing. No death was recorded in this event.

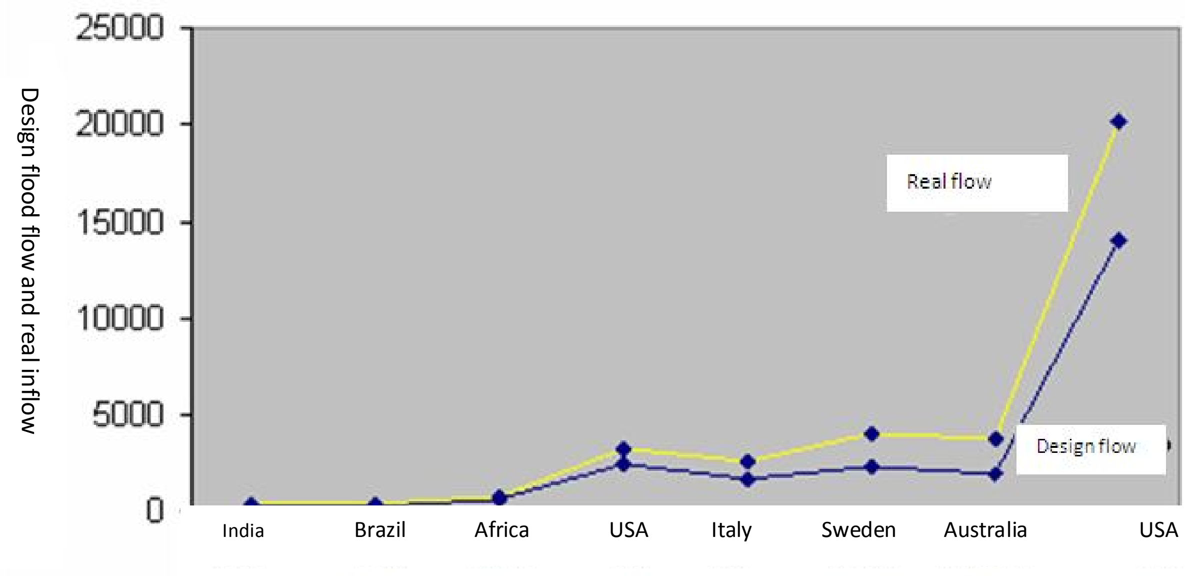

Chart 1: Dam failure chart according to design flow

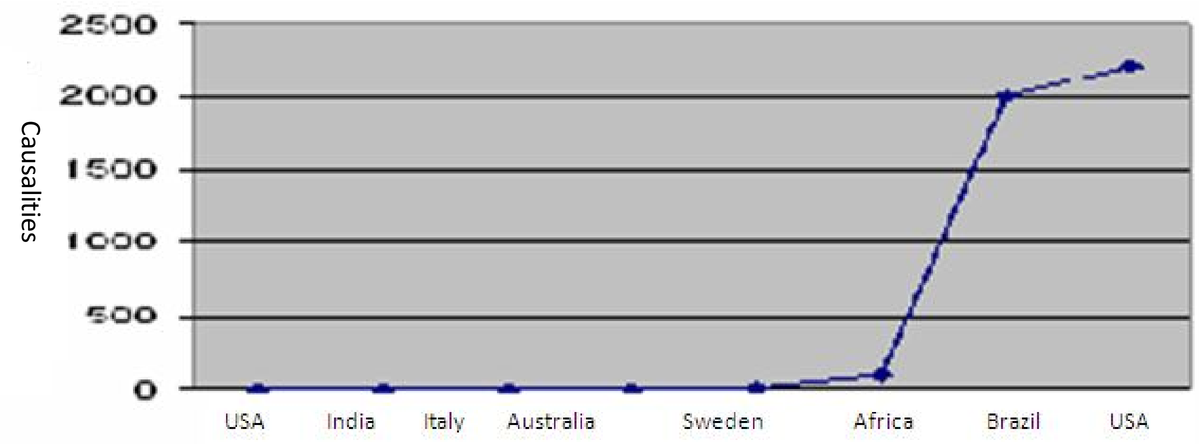

Chart 2: The number of casualties in Dam failure

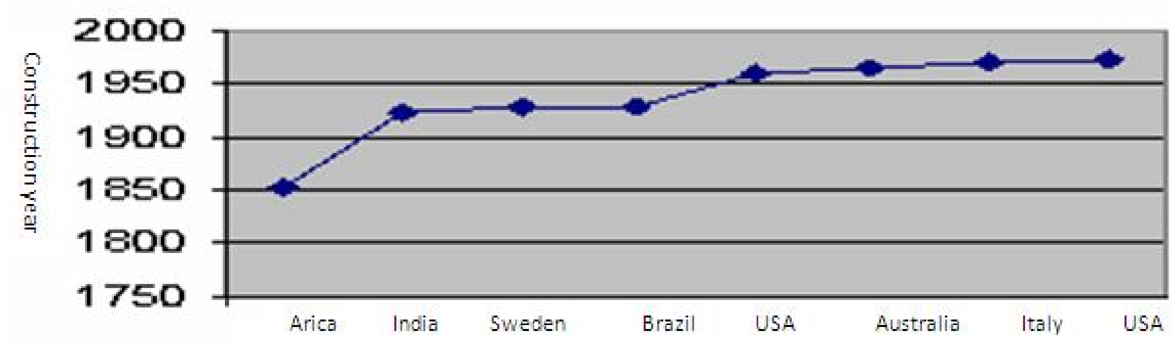

Chart 3: Construction year of dams

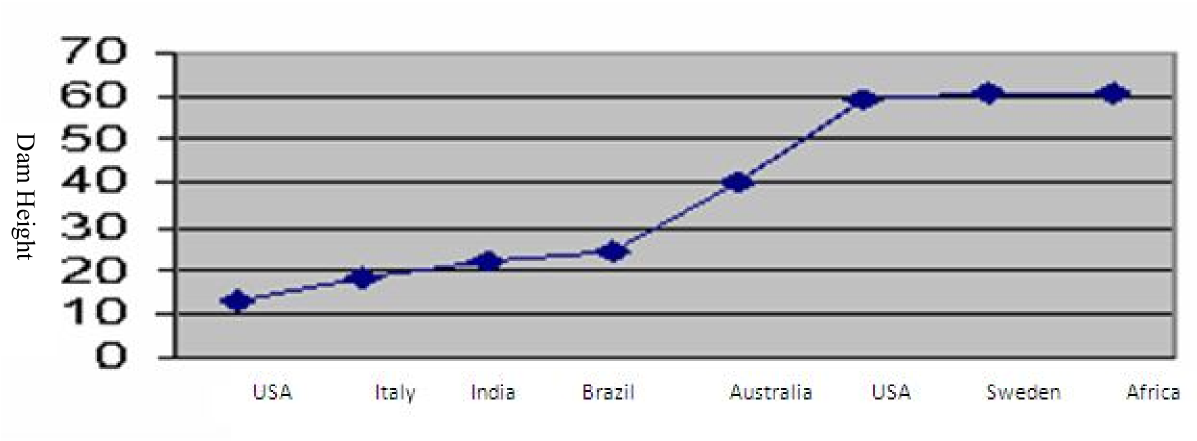

Chart 4: Dams height

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