A Case Study of Engineering Ethics on Sultan Mizan Zainal Abidin Stadium Roof Collapse and Teton Dam Failure

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***Abstract*—A year after Sultan Mizan Zainal Abidin (SMZA) Stadium was officially opened, the nation was shocked by the collapse of the stadium's roof in 2th June 2009. There were no injuries reported but the stadium which had been built in conjunction with SUKMA in MAY 2006 had declared unsafe. Almost 60% of the roof structure with a cost of RM 25 million was collapsed including above the royal box at the grand stand. This is the one of the shocking accidents occurred in Malaysia beside the "the highland tower collapse". A committee established by Public Works Department to investigate this incident and based on the investigation report, the main reason that lead the roof to collapse was a faulty design with failure to consider the support condition of the roof structure. The committee also noted that the management team had failed to conduct a design analysis, considering that the complex architectural shape and large spans made the structure very sensitive to any movement in the supporting structures. In May 1975, there was a similar incident occur where a dam located at Idaho, United States was failed to hold the water pressure. Designed and built by the authorized agency, Teton Dam however failed and reported to cause about 14 deaths where 11 was killed directly and the others died from heart attack. The main reason for the dam construction is to control flood and irrigation at the certain area as well as to capture unused water from the Teton River for agriculture purpose performed by the local farmers. However, local farmers extract benefits from Teton Dam service for only one year before it was failed due to lack of material quality used to build the dam. From the both two cases, it is crucial for engineers to take more attention on important parameters in designing part in order to avoid any incident that can harm people life.**

Index Terms—Stadium Sultan Mizan Zainal Abidin; roof collapse; Teton Dam; failed; design.

I. INTRODUCTION

SMZA stadium is a multi-purposed stadium which located at Jalan Engku Omar Kuala Terengganu, Terengganu Malaysia. The stadium which can accommodate 50 000 peoples and is named after the reigning Terengganu ruler, Sultan Mizan Zainal Abidin was constructed by a South Korean construction firm. During the construction, the stadium consumed amount of RM 300 million and makes the stadium the pride of the state at that year. The stadium that was built in conjunction with SUKMA in May 2016 however had declared unsafe just a year before it was opened due to the one side of the stadium roof collapsed. The roof of the left wing of the stadium that cost around RM 25 million had ravaged after the iron frame structure supporting the 300 meter roof destabilized, causing it to fold. The affected area includes the main entrance, royal podium and the public seating area. There were no injuries reported but the incident had attracted the nation attention and the stadium was immediately declared unsafe. Even though there was no one inside the stadium during the incident, but such incident could easily harm many people and here the credibility of the responsible consultant engineer needs to be questioned.

In other hand, there was a similar incident occur also on May but in 1976 where a dam located at Idaho, United States was failed to hold the water pressure. The dam, named as Teton dam was fully designed and built by one of the eight federal agencies that has the authorization to construct a dam in US. The main reason for the dam construction is to control flood and irrigation at the certain area as well as to capture unused water from the Teton River for agriculture purpose performed by the local farmers. However, a year after the dam finished its construction, it failed that lead to 14

death and James Sherard, who participated in post-failure discussion claim this incident as one of the most important single events in the history of dam engineering. Teton Dam failure share the same main reason as failure of SMZA stadium where the material used in the construction does not meet the requirement and lack of quality. In this incident, the quality of the rock in the surrounding canyon wall is not good enough to bear the huge pressure.

II. OBJECTIVES

The objectives of this case study are as follows:

A To perform a critical analysis on the roof failure of SMZA stadium
B To study and analyse Teton Dam failure
C To relate and critic about these two cases in term of professional engineering ethics
D To highlight the lesson that can be extracted from both case

III. SMZA STADIUM ROOF COLLAPSE

A) Plot

Stadium Sultan Mizan Zainal Abidin was built in the year 2006 and finish in 10th May 2008. It is multi-purpose stadium in Kuala Terengganu with capacity up to 50, 000 people constructed by South Korea construction company. Cost for constructing this stadium is RM 290 million. This stadium was name after reigning Terengganu ruler which is Sultan Mizan Zainal Abidin. This stadium will be used for SUKMA (Malaysian Games). The architect who design the structure of this stadium is Raja Datuk Kamarul Bahrin Shah.

On 2nd June 2009, an undesired event occur which involve the roof of the stadium collapsed. Almost 60 percent of roof collapsed on the east wing of the stadium. Even though no one was injured during the incident, total damage estimated around RM250 million. On 9.00 am, based on the morning worker where they are doing some cleaning and maintenance, a huge crashing sound was heard. The support of the roof outside of the stadium had failed. Luckily, no worker was under the roof when its collapse. However, a vehicle outside the stadium were damaged by debris.

Four years later, on 20th May 2013, the collapsed roof had been removed and the rest was being dismantled. In 2015, it is partially opened to the public in condition it can only be used during the day light as the light were installed to the roof. Base on Persatuan Bola Sepak Negeri Terengganu (PBSNT), they are allocating some money for the renovation in 2019.

Figure 1: SMZA stadium collapse

B) Analysis

Based on the journal report written by Fahad Ali Gul and Chauhdry Mehr Ali, the incident occurs due to the design error. It was reported that the design was inadequate and insufficient safety measure was used. In addition, the skill of the construction worker hired were inadequate as the design structure is complex. Defective wielding was found in steel compound indicates poor workmanships.

Besides that, there is not enough support used to handle the weight of the roof itself. Huge gap was made which 30 meters wide between last concrete stump and the concrete buttress. In addition to that, buckling happen to the inclined pole shows that the load exceeds the buckling capacity.

Other factor that cause the incident is the condition where the strength of the material used must achieve the design requirement did not pass the preliminary test which cause the mechanical strength of the structure reduce. Poor project management also contribute to this incident because of the lack quality control and safety measurement. Also, SUKMA will be held in that stadium causing them fast pace the schedule to finish on time making them do the work while neglecting the quality control and safety measurement.

Based on professional opinion like Ir. Azhar bin Ahmad, Senior Lecturer in School of Civil Engineering in UTM, when the construction company construct the roof, the assumption they made on paperwork must same when they are doing it on sites. Meaning that, the company should follow the plan so that no problem will occur. Also, it is a job of civil engineer to ensure to the project would not become a failure. Crack on the building is also consider as failure even though the building is not collapse. From safety design perspective, it is responsibility of consultant engineer to ensure that his design would not go towards failure.

C) Critics and Lesson Learnt

There are two main reason for the SMZA roof collapse. Firstly, is due to design error while the second reason is due to poor management. This incident can be avoided if all parties have adhered to the rules and regulations. Besides that, as an individual, one should have sticked to their professional ethics. The mischief act of certain individuals had violated few codes of ethics and laws. The following are the list of code of ethics that has been violated under design error:

IEEE Code of Ethics

1. To hold paramount, the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment.
7. To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others.

IEM Code of Ethics

6. Members shall take all responsible steps to inform themselves, their clients and employers and the community of the social and environmental consequences of the actions and projects in which they are involved.
7. Members shall express opinions, make statements or give evidence with fairness and honesty and on the basis of adequate knowledge.

These ethics emphasize on the safety of publics. The engineers should have considered all safety aspects when designing the stadium. They should not have taken the critics on their design for granted. Instead, they should have taken responsibilities to improve and deliver a better project.

The following are the list of code of ethics that has been violated under poor management:

IEEE Code of Ethics

3. To be honest and realistic in stating claims or estimates based on available data
6. To maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations

IEM Code of Ethics

3. Members shall offer services, or advise on or undertake engineering assignments, only in areas of their competence and shall practice in a careful and diligent manner

These ethics focuses on the reliability in completing a project. The engineers should have been honest and realistic in designing the stadium. One should have assisted colleagues in their professional development by enforcing the safety measures.

Apart from that, there are few laws under the Occupational Safety and Health Act 1994 that has been breached. For example, Occupational Safety and Health (Control of Industrial Major Accident Hazards) Regulations 1996. The law enforces the safety features in a project to avoid any misfortunes.

There are few precautionary steps that could be taken to avoid the stadium roof collapse such as line drawing technique, flowcharting and risk benefit analysis. These steps consider all the possibilities in a project and based on the analysis, the best method is chosen to be implemented.

In a nutshell, accidents in a project is mainly caused by the poor act of an individual. Adhering to the professional code of ethics could somehow reduce the number of accidents occur. To further decrease the accidents, precautionary steps should be taken into consideration throughout the project.

IV. TETON DAM FAILURE

A) Plot

The teton dam was build 305 feet high tall from river. This high is equivalent to 30-storey building. The dam consists of 5 layers of different material. The mixture of the material will form of mound of fine silt which is consist of sand, gravel, and cobbles. These 3 mixtures are used to cover silt core. While another 2 substances are earth and rock are used to form additional shells.

In 3 June 1976, there was 2 small seeps observed at the downstream. These 2 small seeps resulting released clear seepage with less than ¼ cfs. In 5 June 1976 (7.30am-8am), muddy water flowing from the rock in the right abutment about 15 ft above stream bed. Water flow rate about 20-30 cfs. This scenario noticed by project supervisors during that time. 5 June 1976 (9.00am), water flow rate had increase with 40-50 cfs. Besides that, other leaks

were found in the right abutment. During this time, supervisor in charge did not aware that the dam was in danger.

In 5 June 1976 (9.30am-10 am), presence of wet spot appeared on the downstream face (15-20 ft from right abutment). Then, the spot became flowing seepage & started washing out the embankment material. At 11am, dozers were sent in an unsuccessful attempt to fill the resulting eroded area nearby the dam. Then, two bulldozers slid resulting banks collapse. Finally, the crest of the dam collapse and fall in the water.

Figure 2: Teton dam failure

B) Analysis

1. **Too much reliance on the grout curtain**

The design of the Teton Dam should include provision to prevent any leaks. This is because, any small leaks of the dam can result of other parts dam leaks. This will slowly make the dam collapse. Any defective part of the dam should be address correctly and immediately.

2. **Inadequate quality of trench fill and silt used in the core.**

The trench fills below the dam should be well build so that any water flow from the dam can go through the trench provided. The quality silt used in the core should be highest possible in order to withstand high pressure of the dam. Material chosen for the silt also can contribute to the strength of the dam and prevent erosion and cracking.

3. **Inadequate provision made for handling leakage.**

The gravel and rock surrounding the dam should carry away any leakage water. This is important to make sure there is no water slip of the dam occur. However, none of these found in teton dam.

4. **Trenches in the canyon walls narrow & steep**

Trenches in the canyon narrow can result of high-pressure water flow from the dam. This can also lead to cracking, hydraulic fracturing and erosion of the silt used to fill the trenches. The trench should be bigger so that the pressure is reduced.

5. **Inadequate instrumentation to monitor conditions in the dam's embankment & surrounding canyon walls.**

The dam should be installing a system that can monitor condition of the dam. This feature can be used to monitor any early cracking and erosion of the dam. Teton dam had deficiency instrument that can help monitor the dam. This resulting no clue can be detected earlier of the teton dam faced. The problem detected just a few hours before the collapse occur.

C) Critics and Lesson Learnt

Code of Ethics

Since the event of Failure of Teton Dam that occurred in Idoha in 5th June 1976, there are lot of perspective views that has been point out through investigations that has been made at Teton Dam. This event not only has given effects to the natural habitat, but it is also involved with public's safety that live near to the Teton Dam.

The failure of Teton Dam has been releasing millions gallon of water into Snake River. This case has caused 14 deaths and some damage of infrastructure which cost around $1 billion. In other word, the cost of damage for this dam is very high. In this section, explanation on code of ethic that involved in this case.

It has been responsibility for engineers and architect to ensure that the construction of an infrastructure is safe to use by making some periodic check at the site and the quality of work is done well. One of conventional method to make sure the structure is safe and meet specifications that required is doing test on the compressive strength of material that provide by the supplier.

There are two standards where engineers may follow these two standards. The standard that engineers and architects may referred are BS EN 13791:2007 and BS 6089:1981. These two standards have provided guidelines for the reason of:

- when an existing structure is to be modified or redesigned;

- to assess structure adequacy when doubt arises about the compressive strength in the structure due to defective workmanship or the deterioration of concrete due to fire or other causes;
- when an assessment of the in-situ concrete strength is needed during construction;
- to assess structural adequacy in the case of non-conformity of the compressive strength obtained from standard test specimens;
- assessment of conformity of the in-situ concrete compressive strength when specified in a specification or product standard.

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Figure 3: Quality Management System

Lesson Learned

There are many lessons that ca be taken from this case where failure of dam to hold million gallons of water to supply water and generate electricity for Idoha's people that live nearby the Teton Dam.

From what has been described, the moral values that can be obtained, the design that has been proposed should meet the specification based on what the client's need. The raw material should be checked first especially the durability and strength which may differ for different purpose of construction method. Besides, the geographical factors must be taken into consideration when designing an infrastructure.

Furthermore, consultant or engineers that has been tasked to take care of the project should do more supervising on site. This is because the proper supervise will help worker to get inform earlier in order to prevent disaster that may affected the people who live near to the construction site. They should follow the guidelines that has established so that the unpleasant incident can be avoid in future.

In short, engineers must take the moral values on what happen to the Teton Dam, where this incident has become a nightmare to the people, who live nearby. Engineers should know the guidelines of work. They are responsible to ensure the safety of public when doing the projects or constructions. The safety of public must be prioritized so the benefit will be gain to everyone.

V. RELATIONSHIP BETWEEN SMZA STADIUM ROOF COLLAPSE AND TETON DAM FAILURE

In this section, the relationship in term of similarities and differences between both cases is discussed.

A) Design Specification

Table 1: Relationship in-terms of design specification

SMZA Stadium	SMZA Stadium is designed to have two shell-like roofs supported by concrete buttress and space trusses along the roof. At its two ends, a concrete buttress at each is implemented. Between the end of the steel column and the buttress there exists a wide gap spanning more than 30m. The truss consists of tubular and steel ball joints.
Teton Dam	The height is 305 feet high tall from river to top which is equivalent to 30-storey building. It consists of 5 layers of different materials. The core of the dam is built by a mound of fine silt. The core is about half of the volume of the dam. It is the compacted in order to make it impervious to the flow of water. The silt core was covered with, sand, gravel and cobbles. The layer of other materials are earth and rocks and form of additional shells.

B) Reasons of Failure

Table 2: Relationship in-terms of reason of failures

SMZA Stadium	Teton Dam
Inappropriate choice of materials	Too much reliance on the grout curtain
Design did not have enough support	Inadequate provision made for handling leakage
Work quality was not up to the standard	Inadequate quality of trench fill and silt used in the core
Change of design in last minute	Trenches in the canyon walls were narrow and steep
Poor management • Incompetent staff were involved	Poor management • Inadequate instrumentation to monitor conditions in the dam's embankment and surrounding canyon wall

In both cases, we can relate that both has similarities the cause of the incident was because of inappropriate choice of materials and lack quality of supervision or for Teton Dam's case; inadequate instrumentation to monitor the condition. In addition, SMZA's case, the quality of work was not up to standard and caused the roof to collapse while in Teton Dam's case, the geological factors could contribute the dam to fail.

The effects and damages for both cases has caused a large impact to some parties. It was not only affected in terms of money, but lives of several members too.

Figure 4: Damages due to SMZA collapse

Figure 5: Damages due to Teton dam failure

There are two standards where engineers need to follow as mentioned in C in Chapter III and C in Chapter IV It can be said that the parties involved might have breached the code of ethics as the code emphasizes on the safety of the publics. The engineer should have considered all the safety aspects and all possible outcomes when designing and planning a project. The accident that happened probably because of the poor act of an individual. If the party involved followed all the guidelines, the situation can be avoided.

VI. CONCLUSION

In conclusion, even though both of the cases is not similar in term of design specification, but the root cause of the incident is the same; the engineers and designers. These issues can be avoided if the parties involved comply with the ethical guidelines and prioritize the public safety instead of individual importance. The parties involved should have been more responsible in making decision and considered every aspect involved very seriously as it affected many lives. We also think that all parties involved should communicated well with each other and be honest about their opinions or professional judgements. As an engineer, we must be responsible and put aside our individual importance as every decision we make will cause huge consequences in the future.

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