RCC DAM DESIGN CONCEPT OF THE SUNGAI KINTA DAM (SKD), PERAK

By

DAYANG NOREHAN BINTI ABANG ABDULLAH

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ABSTRACT

This case study is based on Sungai Kinta Dam and situated in Kinta, Perak. This dam was designed using the Roller-Compacted Concrete (RCC) method. This case study is focused on Roller-Compacted Concrete design concept of Sungai Kinta Dam (SKD). The study was done to evaluate the advantages of using Roller-Compacted Concrete with respect to the cost, the time of construction, the materials and the selected location. The risk of Sungai Kinta Dam project to environmental impact was also done. The literature review and questionnaire were used to get data for Sungai Kinta Dam project. The analysis shows that the SKD give advantages due to cost effectiveness, short in time of construction, quality in materials, suitable to the location, economic and low impact to environment. But the major threat to Sungai Kinta Dam is soil erosion.

ABSTRAK

Kajian kes yang dibuat berdasarkan kepada Empangan Sungai Kinta yang terletak di Sungai Kinta, Perak. Empangan ini menggunakan kaedah konkrit tergelek mampat (RCC). Kajian kes ini juga fokus kepada konsep rekabentuk untuk konkrit tergelek mampat (RCC) bagi Empangan Sungai Kinta. Kajian dibuat untuk menilai kebaikan penggunaan konkrit tergelek mampat dari segi kos, tempoh pembinaan, bahan-bahan yang digunakan dan pemilihan lokasi. Risiko kepada Empangan Sungai Kinta terhadap kesan persekitaran turut dibuat. Kajian literatur dan soal selidik digunakan untuk mendapatkan data. Analisa menunjukkan bahawa Empangan Sungai Kinta memberi kebaikan dari segi keberkesanan kos, lokasi yang sesuai, ekonomi dan memberi kesan yang rendah kepada persekitaran. Namun begitu, hakisan tanah merupakan masalah utama kepada Empangan Sungai Kinta.

CHAPTER 1

INTRODUCTION

1.1 Background

Sg Kinta Dam (SKD), Perak is a Roller-Compacted Concrete (RCC) dam project. The purpose of this dam is to supply water to the surrounding Kinta Valley. The date of possession of this project is on 27 January 2003 and the date of completion is on 27 November 2005. The client for this project is Lembaga Air Perak (LAP), the project manager is Metropolitan Utilities Corporation Sdn Bhd while Seribong-Konbina-Hazama Consortium as contractor and the consultants are Angkasa Consulting Services Sdn Bhd and GFH Pty. Ltd.

The use of Roller-Compacted Concrete (RCC) for dams was first mooted in the early 1960s. The original concept was to combine the advantages of the concrete dam, which is relatively a small volume of erosion-resistant material, together with the advantages of the fill dam, which is the very efficient plant-intensive method of construction. It was apparent that the future of the traditional concrete gravity dam looked uneconomic at due to the rather inefficient method of construction. In 1970s, the development of RCC for dams was started and by the end of the 1980's, RCC dams was an accepted method of construction. The number of initial concerns regarding the performance of this form of dam were overcome and the properties sought after which were at least as good as that of traditional concrete gravity dams had been completed (M.R.H Dunstan, 1992).

1.2 Aim and Objectives

The aim of the case study is to evaluate the RCC dam design concept for the Sungai Kinta Dam (SKD), Perak. To achieve the aim stated above, the objectives of the case study are:

- To conduct analysis about RCC dam design approach
- To determine whether the sitting of the dam is suitable and appropriate

1.3 Scope of Research

The scope of the research is limited at Sungai Kinta Dam project only. The data will be gathered through literature review, questionnaire and formal and informal interview with client and consultant. From the literature review, it is to gather information about the RCC dam design concept/methods while the questionnaire/interview is to gather the respondent's view to different aspects of the SKD design. This approach is to compare between design method and the respondents view through their experience.

1.4 Report Outline

This case study is presented in the following 4 Chapters. In Chapter 2, the literature will cover the background of dam design, the selection of dam, dams for water supply and RCC dam design.

The descriptions of methodology are presented in Chapter 3. It discussed how the case study approaches in this chapter. The design of the questionnaire and the sample selection of the sample population are described.

In Chapter 4, the results of the questionnaire are analyzed. The results are divided into three parts where Part A details about the background of the respondents whilst Part B details about the RCC Dam Analysis and Part C details about the Environment, Safety and Health. Then details discussions are given which is about the RCC dam analysis.

In Chapter 5 presented the conclusion of the study and it summarized the study and its outcomes.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A dam is defined a barrier that is built across a river in order to stop the water from flowing which is used especially to make a reservoir or to produce electricity (Oxford Advanced Learner's Dictionary, 2001). Wahlstorm (1974) noted that dams are barrier, either natural or artificially constructed that impounds or divert the flow of water, especially in a water course.

According to Novak and Moffat (1990), the construction of dams ranks as the earliest and most fundamental of civil engineering activities. All great civilizations have been identified with the construction of storage reservoirs appropriate to their needs, in the earliest instances to satisfy irrigation demands arising through the development and expansion of organized agriculture.

2.2 The Purpose of Dams

According to Wahlstorm (1974), dams are generally constructed for:

a) Flood control
b) Conservation means to save the surplus water during monsoon and to use it when the rivers are low. The purposed of conservation are for irrigation, generation of hydro-electric power, flood control, navigation, domestic and

municipal purposes, industrial use, recreation, wild life conservation, storage for stream flood regulation and reclamation of low lying lands.

2.3 Background of Dams

The first dam built by early man was low earth or rock structures designed to impound and divert water for agricultural use. Today, the face of the earth is dotted with small and large dams and reservoirs contributing in a variety of ways to the complex requirements of an expanding technologically advance civilization (Wahlstorm, 1974).

According to Novak and Moffat (1990), the history of dam building dates back to antiquity and is bound up with earlier civilizations of the Middle East and the Far East. Countless small dams, invariably simple embankment structures, were constructed for irrigation purposed in, for example in China, Japan, India and Sri Lanka.

The dam built at Sadd-el-Kafara, Egypt around 2600BC is generally accepted as the oldest known dam of real significance. Constructed with an earth fill central zoned flanked by rock shoulders and with rubble masonry face protection, Sadd-el-Kafara was completed to a height of 14m.

We can see that early dams were built for irrigation purposed. Beside there are only two types of dam which are the masonry dam and earth fill dam and these type of dams were built using the material that can found from surrounding.

2.3.1 Types of Dams

From Water Resource Technical Publication (1987), dams are divided into five types. Below are the types of dams:

1) Earth fill dam

Earth fill dams are the most common type of dam, principally because their construction involves the use of the materials from required excavations and the use of locally available natural materials requiring a minimum of processing. Moreover, the foundation and topographical requirements for earth fill dams are less stringent than those for other types. Unless the site is off stream, provision must be made for diverting the stream past the dam site through the conduit or around the dam site through a tunnel during construction.

2) Rock fill dam

Rock fill dams use rock of all sizes to provide stability and an impervious membrane to provide water tightness. The membrane may be an upstream facing of impervious soil, a concrete slab, asphaltic-concrete paving, steel plates, other impervious elements or an interior thin core of impervious soil. Rock fill dams require foundations that will not subjected to settlement large enough to rupture the watertight membrane. The only suitable foundations therefore are rock or compact sand and gravel. The rock fill dams are popular in tropical climates because their construction is suitable for long periods of high rainfall.

3) Concrete gravity dams

Concrete gravity dams are suitable for sites where there is a reasonable found rock foundation, although low structures may be founded on alluvial foundation if adequate cutoffs are provided. There are well suited for use as spillway crests and because of this advantage, an often used as spillways for earth fill or rock fills dams or as overflow sections of diversion dams. The curved dam may offer some advantage in both cost and safety.

4) Concrete arch dam

Concrete arch dam are suitable for sites where the ratio of the width between abutments to the height is not great and the foundation at abutments is solid rock capable of resisting arch thrust. Structural and economic aspects prohibit the design of an arch design of arch dams founded stiff, graves or cobblestones. Concrete arch dam are divided into two types, single arch dam and multiple arch dam. A single arch dam spans a canyon as one structure and is usually limited to a maximum crest length to height ratio of 10:1. a multiple arch dam may be one of two distinct designs. It may have either a uniformly thick cylindrical barrel shape spanning 50 ft or less between buttresses or it may consist of several single arch dams supported on massive buttresses spaced several hundred feet or centers.

5) Concrete buttress dam

Buttress dam are comprised of flat deck and multiple arch structure. They required 60% less concrete than solid gravity dams but the increased formwork and reinforcement steel required.

2.4 Selection of Dams

The selections of dams are classified according to use, classified by hydraulic design and classified by materials, (Water Resource Technical Publication, 1987). The classifications have been partially divided to make sure the designer easier to choose the suitable types of dam.

2.4.1 Classification According To Use

Dams may be classified according to the broad function they serve, such as storage, diversion or detention. Storage dams are constructed to impound water during periods of surplus supply for use during periods of deficient supply (seasonal/annual/longer). Storage dams may be further classified according to the purpose of the storage such as water supply, recreation, fish and wildlife, hydroelectric power generation etc. The specific purpose or purposes to be served by a storage dam often influence the design of the structure and may establish criteria such as the amount of reservoir seepage permitted.

Diversion dam are ordinarily constructed to provide head for carrying water into ditches, canals or other conveyance systems. They are use for invigation developments, for diversion from a live stream to an off-channel location storage reservoir. Detention dams are constructed to retard flood runoff and minimize the effect of sudden floods.

2.4.2 Classification by Hydraulic Design

Dams may also be classified as overflow or non-overflow dams. Overflow dams are designed to carry discharge over their crests or through spillways along the crest. Concrete is the most commonly material used for this type of dam. Non overflow dams are those designed not to be overtopped. This type of design extends the choice of materials to include earth fill and rock fill dams.

2.4.3 Classification by Materials

The most common classification used for the discussion of design procedures is based upon the materials used to build the structure. This classification also usually recognizes the basic type of design, example “concrete gravity” dam or “concrete arch” dam. The materials are categorized into two categories. There are masonry dams and concrete dams (R.S Varshney, 1978).

2.4.4 Classification According To Design

This classification is referring to R.S Varshney (1978).

a) Solid gravity dam

This type of dam is the most rigid and requires the least maintenance. It is adaptable to all localities, but height is governed by the strength of the foundations. This type of dam resists overturning moment of water pressure by its weight alone.

b) Hollow gravity concrete dam

Most hollow dams have been constructed of reinforced concrete of the buttress type. Turbine and apparatus have often been placed within hollow dams, thereby effecting a saving in the cost of necessary housing for such appliances.

c) Cored gravity dam

It resembles hollow gravity dam in principle, except that hollows are provided along contraction joints and not in the middle of he section.

d) Buttress dam

If the flanges of hollow gravity or cored gravity are omitted on the downstream side, we get buttress type dams. These can be deck type with reinforced cement concrete slab spanning between adjacent buttresses or multiple arch types with concrete arch support on buttress.

e) Arch dam

These dams are curved in plan and resist the water pressure partly by their weight with vertical elements acting as cantilever and partly by arch section with horizontal elements acting as arches, spanning from abutment to abutment and thus transferring a part of water thrust to the abutments.

2.5 Dams for Water Supply

One of the ability of dam is to provide a water supply to people for their purposes. Properly planned, designed and constructed and maintained dams contribute significantly toward fulfilling our water supply requirements. The primary source of fresh water supply is from precipitation.

Throughout the world, the hydrologic cycle varies and is not predictable. Of the total precipitation, only 1/3 remains for runoff to our rivers, the rest is lost to infiltration and evaporation. Only about 36% of this runoff is available for the rest is lost to infiltration and evaporation (www.icold-cigb.org/article-barrages-an.html).

To accommodate the variations in the hydrologic cycle, dams and reservoirs are needed to store water and then provide consistent yearly supply. Water stored in reservoirs is also used for industrial needs. This ranges from the direct use in chemical and refining processes to cooling for conventional and nuclear power production. Managed flows from reservoirs can be used to dilute discharged substances by augmenting low river flow to maintain water quality at safe limits.

2.6 RCC Dam Design

The first concrete dam using roller-compacted concrete (RCC) was at Willow Creek Dam at Heppner, Oregon in 1982 by the US Corps of Engineers. Since the complication of the Willow Creek dam, the Corps of Engineers was considered to build others dam using RCC method.

The RCC method not only evolved in concrete dam design but also in geotechnical such as earth and rock fill embankment. Many construction of dam usually earth dam construction are combined with RCC methods. This was less costly compare to conventional concrete dam.

2.6.1 The RCC Dam Method Construction

RCC dam design was evolving in three different directions during the 1970s (Hansen & Reinhardt, 1991). In the United States, a lean-concrete alternative based on soils technology was being developed by the Army Corps of Engineers and other investigators. British engineers were focusing in high paste alternative while the Japanese research team were developing the new approach method for RCC dam, what it called roller compacted concrete (RCD).

RCC dam design constructions are shown below:

1. The lean RCC dam

   A common condition with lean RCC dam is that they have extra mass, producing thick section. Most of the basic RCC placing methods for lean RCC are same as high paste RCC or RCD method. The main difference is that the lean mixes usually tend to be drier and have less paste. Lean mix dams do not require more equipment, time or personnel. Lean mixes should delivered, spread and compacted more rapidly than other types of RCC

2. High paste RCC dam

   Three criteria should have in high paste RCC dam:

   - Reduced the potential for cracking due to thermal movement
   - Should keep the method of construction as simple as possible.
   - The design of high paste content RCC dam must be considered as a whole such as cross section of the structure, the details such as spillways and galleries and the design of the mixture properties.

3. The RCD method

   Criteria for mixes designed for the RCD method:

   - Cement should be as low as possible while being consistent with strength requirements. Some fly ash should be used as an admixture to reduce heat hydration and mixing water requirements.
   - A sand/aggregate ratio higher than for conventional mass concrete should be used to reduce segregation and to facilitate compaction by a vibratory roller.

2.6.2 Advantages of RCC Dam

The advantages of RCC dam are:

i) Cost reduction

ii) Increased duration of equipment operation

iii) Good resistance to water erosion

Details of the advantages of RCC are described below.

i) Cost Reduction

RCC cost 20% - 30% less than conventional concrete and is used for both mass concrete and concrete pavement construction. For mass concrete, the zero slump material is placed using rock fill and earthmoving equipment while for pavement construction the concrete is moved using heavy-duty pavers with tamping and vibrating screeds made especially for RCC construction, (Young & Darwin, 2002).

Roller-compacted mass concrete have much lower cement contents than conventional concrete [50 - 190 kg/m^3 (80 - 320 lb/yd^3) are typical cement contents] while roller-compacted pavement concretes have cement content close to those used for conventionally placed concretes.

The used of RCC in dam construction placed by conventional earthwork techniques results in much lower unit cost per cubic yard of concrete placed compared to gravity dams constructed by conventional mass concrete placement techniques (V. Loggie, 1985).

Comparisons within RCC gravity dam and earthfill and rockfill embankment dam typical cross-section are shown in Figure 2-1. At the same height, it shown that the RCC dam volume much less compare to earthfill and rockfill embankment. Besides, the construction speeds for RCC dam are faster than embankment dam. Therefore, it gives an economic advantage in the time factor of cost.

According to V. Loggie (1985), the appurtenant structure location or elimination and construction provided by RCC offer additional economic advantages. Specifically, spillway, energy dissipater and intake structure requirements can have adverse impact on overall embankment dam construction economics.

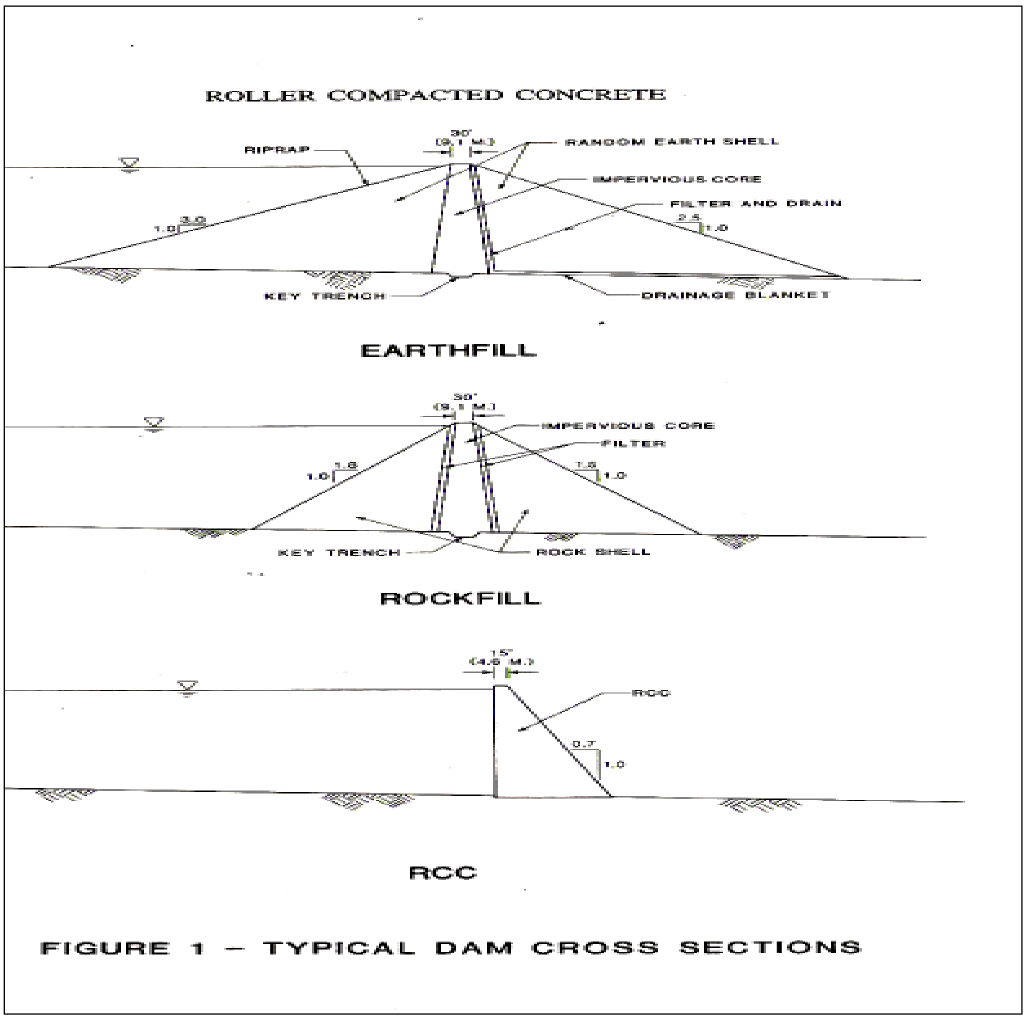

Fig 2-1 Typical Dam Cross-Section Comparison between RCC Dam, Earth Fill and Rock Fill Embankment Dam (Hansen, 1985)

ii) Increased Duration of Equipment Operation

According to Nagataki & Yanagida (1985), at Shimajigawa Dam, the daily average quantity of placement increased 24% and the daily maximum placement increased 90% as compared with the conventional method.

It shows that the duration of equipment operation is increased. It can reduce the construction time and another advantage of the RCC method is it can increase work efficiency which is the labor can use the equipment with properly.

iii) Good resistance to water erosion

Roller-compacted concrete has demonstrated extremely good resistance to water erosion and appears to provide excellent freeze-thaw durability except under very severe (saturated) exposure conditions.

2.6.3 Disadvantages of RCC

The disadvantages of RCC dams are:

i) Weather problem

ii) Scheduling conflict

iii) Comparison between RCC dam and others dam

which are described below:

i) Weather Problem

According to Young & Darwin (2002), as with conventional concrete, RCC must be cured and protected from the weather. Light rain will not cause a problem as long as vehicular traffic does not work moisture the surface or deposit mud from adjacent haul roads. Construction can continue as soon as the concrete surface returns to a saturated surface dry condition.

ii) Scheduling Conflict

Hauling RCC from the mixing plant to the dam can cause other complications. Raising the access road to keep up with the daily increase in the height of the dam becomes a cost and scheduling considerations. Also, for most RCC dams, gaining access from the upstream side can be difficult because of space and scheduling conflicts with work being done on the upstream face to control seepage, (Hansen & Reinhardt, 1991).

Good controls were required during construction. It means a good management during placing the concrete and hauling the concrete must considered to avoid the over estimated cost. Beside, it also to maintain the limit damage and prevent scheduling conflict.

iii) Comparison between RCC Dam and Others Dam

Wahlstorm (1974) noted that a particular advantage of an embankment dam as compared with a concrete dam is that the bearing strength requirements of the foundation are much less. Minor settlement of an embankment dam owing to load stresses during and after construction generally is not a serious matter because of the ability of the embankment to adjust to small dislocations without failure.

2.6.4 Risk Management in Dams

In managing the dams, risk involved are risks as applied to buildings where it can be defined as the possible occurrence of an uncertain event or outcome which should it occur will cause variations or consequences such as extra cost or delayed completion, (Shen, 1999). Gray & Larson (2000) also noted that project risks are those events that if they materialize, can delay or kill project. Risks are events that can affect project such as delayed or can cause an extra cost during construction.

2.6.4.1 Principle and Use of Risk Management

Managing risk demands a methodical approach and project risk management is a formalized discipline approach consisting of a set for decision-making (Baccarini, 2001).

The principle of risk management is widely used in the construction industry and applied at various stages during the procurement process. It has been shown that proper application of the risk management techniques can significantly improve performance of construction projects (Flanagan & Norman, 1993).

Risk management identifies as many risk events as possible, minimize the impact, manages responses to those events that do materialize(contingency plans) and provides contingency funds to cover risk events that actually materialize (Gray & Larson, 2000).

2.6.4.2 Risk in Dam Construction

According to Lecornu (1996), the overall risk for a dam is made up of the component risks arising from uncertainties, such as design flood, design earthquake, properties of its materials and foundation conditions.

Flanagan & Norman (1993) listed those risk factors which may affect construction projects include:

- Failure to obtain approvals from relevant authorities (government agencies, statutory bodies etc.) within the time allowed in the project program.
- Unforeseen adverse ground conditions (rock, sand, sub-surface)
- Inclement weather resulting in extension of time
- Unexpected price increase (labour, materials)
- Failure to let to a tenant on completion
- Accidents on site resulting in injury or death, causing delays and/or extra cost
- Latent defects due to poor workmanship, or supervision
- Force major (flood, earthquake, armed conflict)
- Disputes between project parties causing extra cost and/or delays

The NZSOLD Dam Safety Guidelines (2000) give guidance on the design, construction and commissioning of dams. Practices in dam design and management which contribute and treatment of risk include:

- Engaging suitable designers, peer reviewers etc.
- Selecting suitable contractors and applying quality assurance procedures for the constructed works.
- Assessing the flood hazard and providing adequate spillways and diversion facilities to manage this hazard
- Assessing the seismic hazard and providing adequate defense against earthquake effects.
- Adequate investigating the foundation
- Inclusion of appropriate filters and drainage details to prevent piping in an earth dam
- Appropriate monitoring and evaluation of dam safety data and regular visual observations
- Provision of an emergency action plan if fatalities are possible following a dam breach
- Regular safety reviews of the dam and associated gates and structures.

2.6.4.3 Types of Risk for Dam

According to Mansoor (2005), the types of risk for dam are divided into three groups and these are shown below.

a) Technical and design

i. Reservoir filling or impounding which is delay in commissioning

ii. Dam overtopping and failure that affect the loss of life, project stoppage and financial loss

iii. Dam foundation and geological requirement such as additional excavation and schedule delay and additional financial cost
iv. Thermal cracks in concrete

b) Construction risk

i. Hydrological risks (overtopping of upstream auxiliary cofferdam, overtopping of downstream coffer dam, dam failure during construction)
ii. Diversion culverts blocked
iii. Slope stabilization that have overburden soil and weathered rock which may be unstable.
iv. Poor construction management performance
v. Planning scope and sequencing of work and methodology not clearly defined
vi. Sedimentation of reservoir

c) Environment, safety, health and security risk

i. Deterioration of water quality downstream and in reservoir
ii. Flammable materials, hazardous chemical substance and storage of explosive materials
iii. Uncontrolled explosions such as damage to the works and loss of life
iv. Natural disaster (earthquake, storm fire)
v. Disease outbreak arising from floods, pollution.

2.7 Summary

Generally, the RCC is advantage in economic which is reduced cost and construction time. It can very costly in material especially for large dam and its construction is competitive with embankment dam construction. Beside it can increase the duration of equipment operation and will reduced the construction time.

The RCC dam are design in three design constructions which are lean RCC dam, high paste RCC dam and RCD method. These types of construction are based on soils technology was being developed by the US Army Corps of Engineers and other investigators.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology can defined as the way in which information is found or something is done. The methodology includes the methods, procedures, and techniques used to collect and analyze information. It is also known as to accomplish the objectives and aim of the project (http://www.epa.gov/evaluate/glossary/m-esd.htm).

The methodology is designed based on a case study of the RCC design concept and evaluation of the Sungai Ulu Kinta Dam (SKD), Perak. The goal of the methodology is to ensure the aim and objectives of this case study will be met as discussed in Chapter 2.

3.2 Data Gathering

To evaluate the design concept of the SKD the writer had selected to conduct a survey will be conducted through informal and formal interview, discussions, design survey and site visit. This approach is to gather the respondents view on different aspects of the SKD design through their own experience and opinion.

3.3 Selection of the Population Sample

The writer chose to question/interview those who had been active in the project organization. The respondents for this survey were selected based on their positions in the project organization. The selected participants include stakeholders who are permanent site personnel such as consultants, project manager and contractors including the client's representatives actively in the project. The proposed respondents include professionals from the Consulting Engineer Company and from the Client's Organisation. In total 10 respondents were selected to participate in the survey. Details and backgrounds of the respondents are in Table3-1 on page 30.

3.4 The questionnaire

The questionnaires comprise eighteen questions and are divided into3 parts:-

i) Part A : Background

   Question No.1 to No. 7 consisting of personal details including name, age, position, responsibilities and experiences. The questions are designed where the respondents are required to give the answers in their own words in which the writer can evaluate the role in the project, past experience and contribution to the project.

ii) Part B: RCC Dam Design Concept

   This section comprises 7 questions. For questions No 8 to No 13 the respondents are required to classify the RCC dam concept, temperature control and crack monitoring. For question No 15, the respondent required