CONSTRUCTION OF BUNDS FOR OIL STORAGE TANKS

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Project Supervisor: Assoc. Prof. Dr Nasiman Sapari

PROJECT FINAL REPORT

Submitted to the Civil Engineering Department
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Civil Engineering)

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CERTIFICATION OF APPROVAL

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Omer Awad Elbasha Mohamed Ahmed

ABSTRACT

There is increasing pressure on oil industry to provide containment systems that will substantially reduce the risk of incidents occurring which could cause environmental pollution. Approximately 25% of all water and environment pollution incidents involve oil and a significant proportion of those incidents involve oil storage tanks with inadequate or non-existent bund. The main purpose of providing bunds in many oil storage tanks is to give provision for containing leakage. It is clear that standards of design and construction for bunds vary widely and in some cases defects or poor quality would render them ineffective as secondary containers.

This project is aiming to investigate the current practice of bunds construction for oil storage tanks and provide the most adequate design can be used taking in consideration different criteria and construction aspects. Through this research Analytical hierarchy process were used to analyze the data collected from the current practice in oil and gas industry. In ideal situation constructing earth bund lined with High Density Poly Ethylene will be the best path to take. This research also explains and provides a certain steps that should be followed when building bund for oil storage tank by taking one tank as case study and design bund for it.

ACKNOWLEDGEMENTS

Firstly, my utmost gratitude to ALLAH the All-Mighty for his uncountable graces upon me and for the successful completion of this project in due course of time.

My enormous thanks to my family members for their priceless support and continuous encouragement. Special gratitude to my Parents for their continuous and unlimited support that kept me going. There is no words can fulfill their effort.

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INTRODUCTION

1.1 Background of Study

Oil is responsible for about 25% of all pollution incidents. Pollution, whether accidental or deliberate, is a criminal offence and can kill birds, fish and other wildlife. Oil spreads rapidly over the surface of a body of water, killing fish and invertebrates by cutting off oxygen. Only a small amount of oil is necessary to create pollution – a gallon of oil can cover an acre of water [21]. The risk of pollution arising from an oil storage installation may be reduced by:

- ✓ Providing secondary containment.
- ✓ Providing high specification or high quality primary containment.
- ✓ Providing alarms and/or fail-safe devices.
- ✓ Ensuring that suitable management systems are in place.
- ✓ Protecting from accidental damage and vandalism.
- ✓ Ensuring that operators are adequately trained.
- ✓ Sitting the facility away from sensitive environmental receptors.

A bund is an embankment or wall of brick, stone, concrete or other impervious material, which may form part or the entire perimeter of a compound and provides a barrier to retain liquid. Since the bund is the main part of a spill containment system, the whole system (or bunded area) is colloquially referred to within industry as the 'bund'. The bund is designed to contain spillages and leaks from liquids used, stored or processed above ground, and to facilitate clean-up operations [3]. As well as being used to prevent pollution of the receiving environment, bunds are also used for fire protection, product recovery and process isolation.

Bunds are secondary containments. It is frequently used to describe liquid containment facilities that prevent leaks and spillage from tanks and pipes. The liquids in tanks and pipes are normally toxic, but bund is used to prevent the liquid from causing damage. If a large tank has a catastrophic failure, the liquid alone can cause extensive damage. If built properly, bund is large enough and strong enough to contain the contents of an entire tank, though regulations may require it to be up to a third larger. When multiple tanks share a bund, the capacity is based on the largest tank.

1.2 Problem Statement

The storage of oil is carried out on thousands of industrial and commercial sites. Every year there are hundreds of incidents arising from inadequate storage, poor practice, vandalism and theft. Many of these result in pollution of water courses, drains, sewers or the land. The absence of good standards and guidelines for bund construction increases these risks possibilities. Constructing a well designed bund will result in providing containment for any loss of oil from the storage tank. That will reduce the danger of pollution to the surrounding environment.

1.3 Objective and Scope of Study

The Objectives of the project are:

- To investigate the current practice and the bund construction methods used for oil storage tanks.
- Design the most adequate and suitable bund for oil storage tank.
- Provide engineered guidelines for construction of bunds.

The scope of the study starts with investigating the history of oil pollution and the use of bunds to prevent that. Then doing research on the existing bunds used in the oil industry. Finally the outcome design will be introduced towards the end of the project.

Chapter 2

LITERATURE REVIEW

2.1 Oil Pollution

Human technological and scientific advances have caused environmental changes that are impossible to evaluate and fully comprehend. Our ability to change the environment has increased faster than the ability to predict the effect of that change. Pollution of the environment is one of the major effects of human technological advancement. Pollution results when a change in the environment harmfully affects the quality of human life including effects on animals, microorganisms and plants. Hence Odewunmi (1987) defined pollution as the presence in significant amounts of an extraneous material, which may be solid, liquid, or gas in a particular location. The contamination of the environment (mainly terrestrial and aquatic) by crude oil is therefore referred to as oil pollution and it is estimated that 80% of oil pollution is as a result of spillage (Odu, 1977).

Crude oil, refined petroleum products, as well as polycyclic aromatic hydrocarbons are ubiquitous in various environmental compartments. They can bioaccumulate in food chains where they disrupt biochemical or physiological activities of many organisms, thus causing carcinogenesis of some organs, mutagenesis in the genetic material, impairment in reproductive capacity and / or causing hemorrhage in exposed population. The cause / effect of oil pollutant are usually quantified by using biological end point parameters referred to as biomarkers. Contamination of soil arising from spills is one of the most limiting factors to soil fertility and hence crop productivity. These deleterious effects make it mandatory to have a counter measure for the petroleum hydrocarbon pollutant in the environment [16].

Spilled petroleum hydrocarbons in the environment are usually drawn into the soil due to gravity until an impervious horizon is met, for example bedrock, watertight clay or an aquifer. Poor miscibility of crude oil accounts for accumulation of free oil on the surface of ground water and this may migrate laterally over a wide distance to pollute other zones very far away from the point of pollution. Industrial and municipal discharges as well as urban run-offs, atmospheric deposition and natural seeps also account for petroleum hydrocarbon pollution of the environment [17]. It is worthy of note that groundwater is one of the many media by which human beings, plants and animals come into contact with petroleum hydrocarbon pollution.

In United Kingdom only spills of oil to inland water account for about quarter of all substantiated water pollution incidents. Information on the number, type and severity of pollution incidents is published annually by the environment agency. In 1994 there were 25,415 substantiated incidents of pollution reported of which oil pollution amounted up to 17% of the major environment pollution incidents [3]. Please refer to figure (2.1) and (2.2).

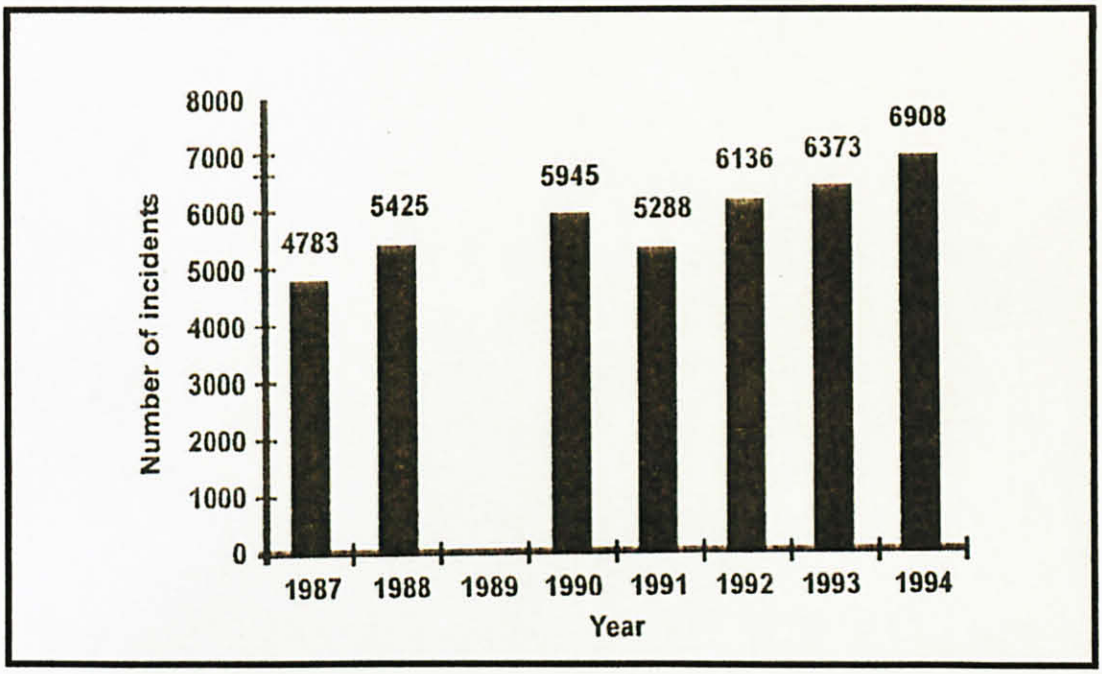


Figure (2.1): Total Number of pollution incidents recorded in UK 1987 to 1994.

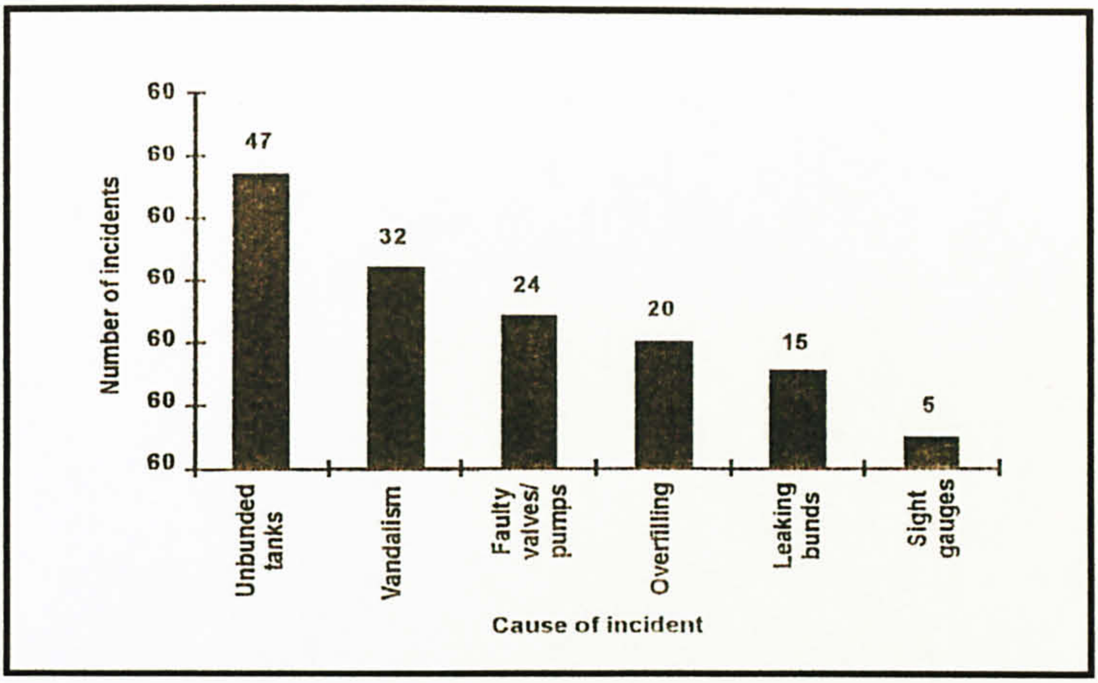


Figure (2.2): Factors contributing to oil pollution incidents

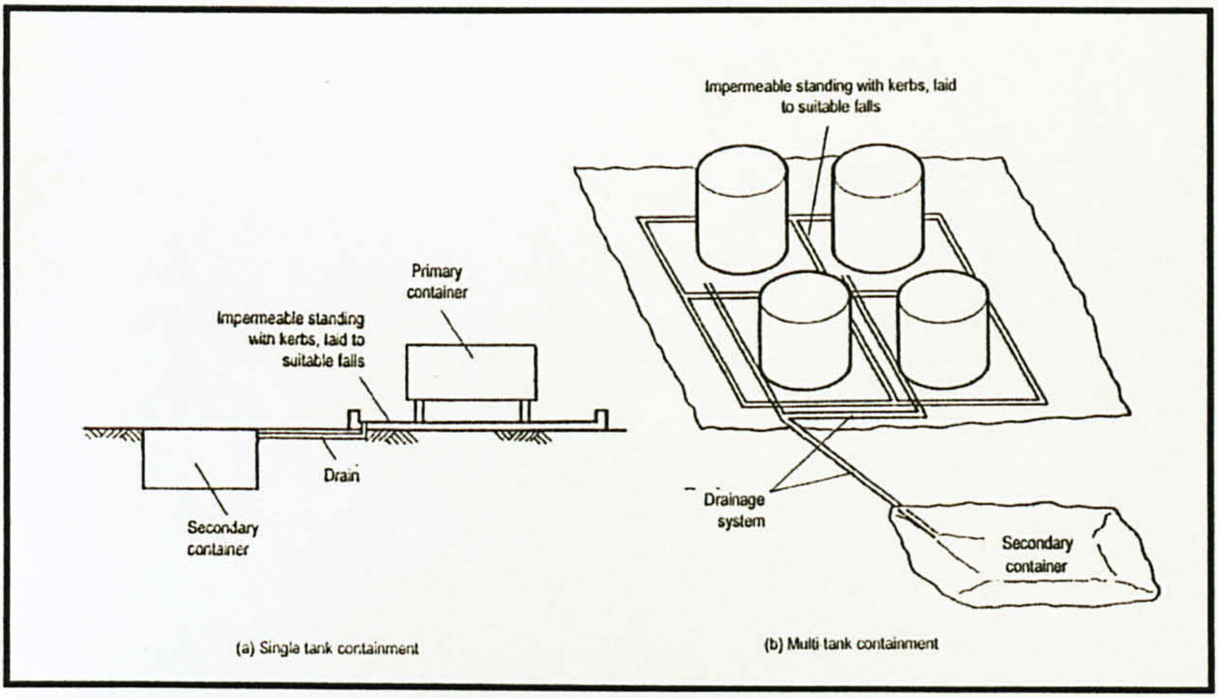
It is evident, therefore, that oil is significant source of pollution and that the provision of effective bunds around oil storage facilities would play an important part in minimizing the problem.

2.2 Bunds for Oil Storage Tanks

Bund is secondary containment system which capable of preventing the escape of material to the aquatic environment in the event of the failure of the primary storage or containment (oil storage tank). There are two types of secondary containment for oil storage tanks:

- Remote secondary containment is where provision is made to prevent pollution by channeling any escape of stored material to another suitable container where it may be stored pending safe disposal. (Refer to figure (2.3))

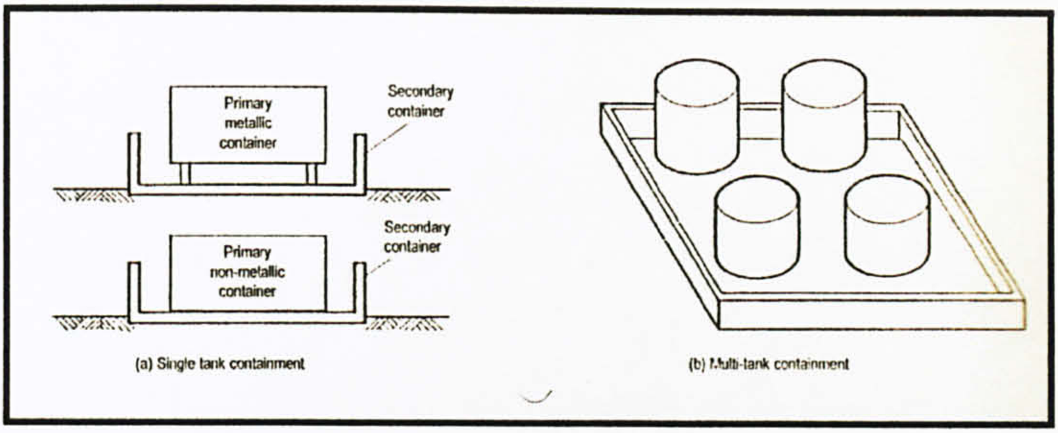
- Local secondary containment is where provision is made to contain any escape of stored material by building a further containment system around the primary containment. The bund may be constructed around an individual primary storage tank or group of tanks. Bunds belong to this type of secondary containment. (Refer to figure (2.4))



(a) Single tank containment

(b) Multi tank containment

Figure (2.3): Remote Secondary containment



(a) Single tank containment

(b) Multi-tank containment

Figure (2.4): Local Secondary containment

Bunds should consist of a base and surrounding walls which must be constructed of, or lined with, a material impermeable to the oil stored (Refer to figure (2.5)). Ideally, pipe work should not pass through the bund wall. However, if this is unavoidable, the material used for sealing around the pipe must be resistant to attack by the oil stored and the overall integrity of the bund should not be compromised.

Figure (2.5) Bund for oil storage tank

2.2.1 Legislation

Bunds are a legal requirement in many countries particularly around tanks, storage vessels and other plant that contain liquids which may be dangerous or hazardous to the environment. Particular examples which receive specific attention in the UK, the rest of Europe and the USA are oil and fuel storage tanks. In Malaysia it is covered under the Environmental Quality Act 1974 while in the United Kingdom is covered under the Water Resources Act 1991, Environment Act 1995 and Control of Industrial Major Accident Hazards Regulations 1984.

These Acts and Regulations lay general responsibilities on plant operators and others to take appropriate steps to control pollution. It is important to point out that the legislation does not prescribe the physical measures to b taken in order to meet those responsibilities. Although, for example, a plant operator may decide to bund an oil storage tank to reduce the pollution risk and thereby satisfy the legislation, only few legislations specify how the bund should be designed.

Environmental legislation gives the courts powers to impose fines and in extreme cases to imprison directors and managers of companies if pollution is proved to have resulted from their negligence. In addition to prosecution for criminal acts there is an increasing trend towards civil proceedings to recover the costs incurred in clean-up following pollution incidents. These costs can be considerable, particularly where the clean-up of groundwater or contaminated land is involved. It is difficult to predict the full extent of the consequences of pollution incidents, and it may be difficult, therefore, to obtain insurance cover for all the potential liabilities. One option is for insurance companies to require that plant operators either provide properly designed and constructed bunds or face higher premiums.

2.2.2 Current Practice

It is common practice for bunds surrounding small or medium-size tank installation to be built by local contractors who are guided by previous experience rather than engineered plans. As a result the quality of construction is variable and may compare unfavourably with associated with major schemes or with building contracts which are covered by the building regulations and which rely heavily therefore on the recommendations given in the British Standards and Eurocodes dealing with construction [21].

Bunds may be provided to protect a single tank or several tanks grouped together. Size, in relation to the amount of oil stored is variable, with some bunds having a capacity of only a fraction of the tank, or tanks, they are intended to protect. Further information about the bund holding capacity will be discussed later.

Unintended discharges from the pumps and pipework associated with oil tanks are responsible for a significant number of pollution incidents, but this mode of failure of the primary containment is frequently overlooked in the design of bunds. There are many examples of bunds which have been built in such way that they would intercept oil discharges or leaks only if they came from the bottom, or near the bottom, of the storage tank.

Most bunds built in situ are constructed using concrete or masonry. It is unusual to find reinforced concrete or masonry, except in larger bunds with relatively high walls, and shrinkage cracking is consequently a common problem. In addition, unreinforced masonry bunds are particularly susceptible to impact damage. Joints in concrete and masonry, especially those provided between the bund walls and the base, are often insufficiently or incorrectly detailed to give a reliable impermeable seal [3].

2.2.3 Holding Capacity

Almost all regulations require a holding capacity of 110% of the capacity of the maximum capacity of the biggest tank within the bund or 25% of the total capacity of all the tanks within the bund whichever is the greatest. In addition further guidelines in some countries (e.g. the UK) recommend additional measures such as providing sufficient "freeboard" or height of wall above the maximum holding capacity to accommodate dynamic factors such as surge in situations of major tank failure or storm driven waves in larger bunds [3].

Although the existing recommendations on bund capacity are not underpinned by any clearly defined rationale, they do have the benefit of being well established and therefore well know and understood by industry and regulators. There are no known cases where bund failure has been attributed solely to inadequate capacity calculations.

The existing 110% recommendation for single tanks and hydraulically linked multi-tank installation implies a safety margin of 10%. The recommendation for other multi-tank installations –the 25% rule- is based on the assumption that it is unlikely that more than one tank will fail at any one time. Although this may be a reasonable assumption in circumstances where oil escapes from a primary tank as result of , for example, tank corrosion or operator error, which is likely to affect only one tank at a time, it is difficult to defend when considering the potential effects of vandalism which could affect simultaneously all of the tanks within a bunded area. The risk of more than one tank failing is highly site-dependent. The 10% safety margin is interpreted by the industry to cover a range of factors including the following:

- Prevention of over-topping in the event of a surge of liquid following the sudden failure of promary tank.
- Prevention of over-topping which may be caused by wind-induced wave action during the time that the bund is full following failure of primary tank.
- An allowance for fire-fighting agents, including a foam blanket on the surface or fire-fighting water.
- Protection against overfilling.
- An allowance for rain that might collect in the bund and reduce it is net capacity, or for rain that might fall coincident with, or immediately following, the failure of the primary containment.

There is an alternative approach for assessing the required capacity and height of a bund. It is a more rigorous approach and may be more appropriate for sensitive sites. The method is based on the principle that a bund should be capable of containing:

1) The total volume of oil could be released from the bunded tank (or tanks).
2) The maximum rainfall that is likely to accumulate either before or after an escape of oil into bund.
3) Fire-fighting agents (water and/or foam)

and should have sufficient freeboard to minimize the risk of oil escaping as a result of dynamic factors such as surge and wave action.

For many sites a bund capacity calculated on the basis of current practice may be satisfactory, however in deciding which of these methods to use the designer in consultation with the regulator should consider the following:

- The sensitivity of the site and the seriousness of the environmental consequences that would result from escape of oil from the bund.
- Whether freeboard to contain fire-fighting agents is required, if it is, will the 110% rule provide the minimum of 100mm required.
- Whether the 110% rule is likely to give sufficient freeboard to cater for possible rainwater accumulation.
- Relative costs in the relation to environmental benefits.

2.2.4 Bund Shape

The plan shape of a bund is determined by the footprint of the tank, or group of tanks, to be protected and the space available. The latter may be affected by adjacent facilities and site boundaries. The plan shape will affect construction and maintenance costs [21].

It is important that, where practicable, pumps, valves, couplings, delivery nozzles and other items associated with the operation of a tank are located inside the bund. The vent from the storage tank should operate in such a way that any discharge resulting from the storage tank being overfilled would be contained within the bund. It is strongly recommended that all pipework leading to or from primary tanks within a bund are routed over the top of the bund in order to avoid the need to pierce the walls.

It is recommended for health and safety requirements hat bund walls should not exceed 1.5 m in height in order :

1) Not to hinder fire-fighting operations.
2) To ensure relatively easy egress from a bunded area in the event of an emergency.
3) To encourage natural ventilation of the bunded area.

2.2.5 Materials used for bunding

The bund floor and wall must be built of materials impervious to the contents of any tank or container within the bund. It should be of sufficient strength and structural integrity to ensure that it is unlikely to burst or leak in ordinary use, and should not have a damp course. The materials that can be used to construct bund walls are:

- **Concrete:**

  Concrete is effectively an artificial stone or rock. Its primary properties are that it is workable before hardening, strong in compression and stays strong for extremely long timescales. Concrete is a strong hard building material composed of sand and gravel and cement and water. The water/cement ratio (w/c) of the mixture has the most control over the final properties of the concrete. The water/cement ratio is the relative weight of the water to the cement in the mixture. The water/cement ratio is a design criterion for the engineer. Selection of a w/c ratio gives the engineer control over two opposing, yet desirable properties: strength and workability. A mixture with a high w/c will be more workable than a mixture with a low w/c: it will flow easier. But the less workable the mixture, the stronger the concrete will be. The engineer must decide what ratio will give the best result for the given situation. This is not an entirely free choice because the water/cement ratio needs to be about 0.25 to complete the hydration reaction. Typical values of w/c are between 0.35 and 0.40 because they give a good amount of workability without sacrificing a lot of strength. Refer to Table (2.1) [10].

Table (2.1): Concrete properties

Density	*2240 - 2400 kg/m*^{3} *(140 - 150 lb/ft*^{3}*)*
Compressive strength	*20 - 40 MPa (3000 - 6000 psi)*
Flexural strength	*3 - 5 MPa (400 - 700 psi)*
Tensile strength	*2 - 5 MPa (300 - 700 psi)*
Modulus of elasticity	*14000 - 41000 MPa (2 - 6 x 10*^{6} *psi)*
Permeability	*1 x 10*$^{-10}$ *cm/sec*
Coefficient of thermal expansion	$10^{-5}\,{}^{o}C^{-1}$ $(5.5 \times 10^{-6}\,{}^{o}F^{-1})$
Drying shrinkage	*4 - 8 x 10*$^{-4}$
Drying shrinkage of reinforced concrete	*2 - 3 x 10*$^{-4}$
Shear strain	*6000 - 17000 MPa (1 - 3 x 10*^{6} *psi)*
Specific heat capacity	*0.75 kJ/kg K (0.18 Btu/lb*$_m$ *°F (kcal/kg°C))*

- **Asphalt Concrete:**

Asphalt is a petroleum residue left over from the distillation of crude oil. Asphalt is one of the two principal constituents of Hot Mix Asphalt. Asphalt functions as an inexpensive, waterproof, thermoplastic, visco-elastic adhesive, in other words, it acts as the glue that holds the road together. According to ASTMD 8 asphalt is a dark brown to black cementitious material in which the predominating constituents are bituments, which occur in nature or are obtained in petroleum processing. While the asphalt cement is A fluxed or unfluxed asphalt specially prepared as to quality and consistency for direct use in the manufacture of bituminous pavements, and having a penetration at 25^0 C (77^0F) of between 5 and 300, under a load of 100 grams applied for 5 seconds [13].

Asphalt concrete, normally known simply as asphalt or AC (in North America), is a composite material commonly used for construction of pavement, highways and parking lots. It consists of asphalt binder and mineral aggregate mixed together then laid down in layers and compacted.

- **Earth bund lined with HDPE :**

High-Density Poly Ethylene (HDPE) is a polyethylene thermoplastic made from petroleum product. HDPE is prepared from ethylene by a catalytic process. The absence of branching results in a more closely packed structure with a higher density and somewhat higher chemical resistance than LDPE. High Density Polyethylene is also somewhat harder and more opaque and it can withstand rather higher temperatures (120° Celsius for short periods, 110° Celsius continuously). High density polyethylene lends itself particularly well to blow molding [6].

HDPE is used for cell liners in subtitle D sanitary landfills, wherein large sheets of HDPE are either extrusion or wedge welded to form a homogeneous chemical-resistant barrier, with the intention of preventing the pollution of soil and groundwater by the liquid constituents of solid waste. Refer to appendix (1) for HDPE physical and chemical properties.

2.3 Importance of Bunds

Presence of bunds surrounding oil storage tanks is very important. Good example of that is the incident happen at oil storage terminal which belongs to a large oil company. The oil storage terminal contains 7 storage tanks in one large bund made with earth dikes. Between the tanks there are lower inner dikes. (Refer to figure (2.6))

- 4 crude oil storage tanks with a content of 40 000 m3 each: D1, D2, D3 and D4;
- 2 storage tanks for the multifunctional storage of crude oil or rainwater contaminated with crude oil, slop oil, with a content of 24 000 m3 each: D10 and D11;
- 1 small tank D26, with a content of 730 m3 which is out of service.

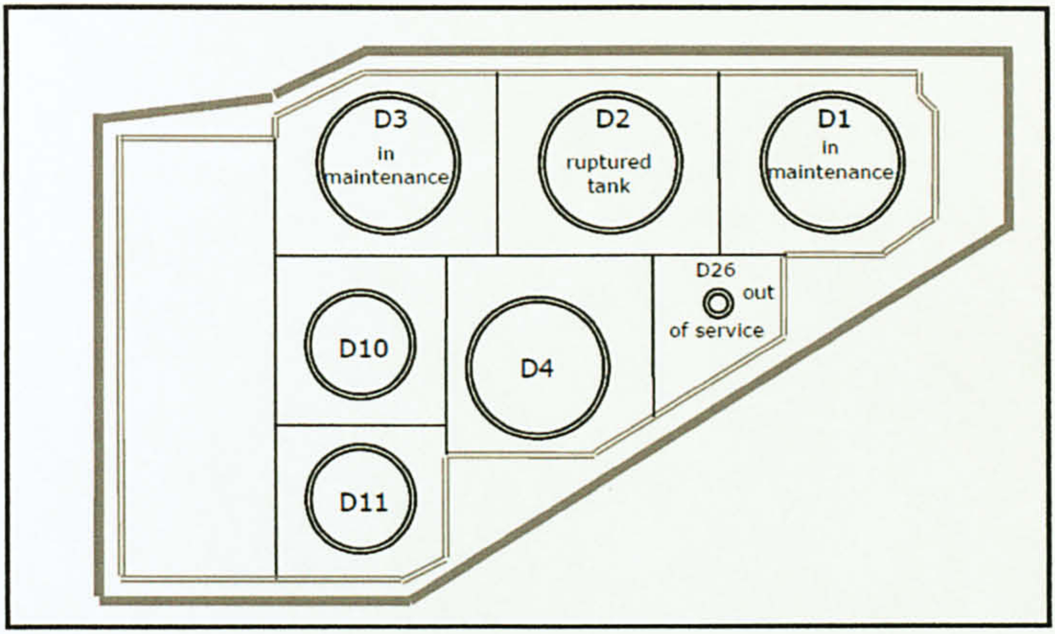


Figure (2.6): Lay-out of the oil storage terminal

On October 25, 2005 around 18.15h a major leak at tank D2 was detected. The operators in the control room of the refinery were alerted by a low level alarm for tank D2. Storage tank D2 contained almost 37 000 m3 crude oil before the release. The level history in the control system situated in the control room of the refinery indicates that after a short period of increasing leakage almost the full inventory of storage tank D2 was released within 15 minutes. After the release the storage tank was leaning forward and a part of the foundation of the storage tank had disappeared [7].

Because the content of the storage tank was released in such a short time, an enormous wave was created. This wave moved in the direction of the several meters high earth dike. Due to the height of the dike only a small amount of crude oil (approximately 3 m^3) was ejected out of the bund. The released crude oil filled the whole bund (40 000 m^2 large) with crude up to a height of 1 m (Refer to figure (2.7)). After the major accident all the crude oil stored at the terminal was immediately pumped to the refinery and the contents of the bund was pumped to the storage tanks D10, D11 and D4 by using the existing drain water pump system.

Figure (2.7): Picture of the situation in the bund the morning after the major accident

2.4 Common problems observed with bunds

All bunds should be routinely inspected to ensure maintenance of their integrity. A routine inspection and maintenance program must be tailored to suit the specific installation; common problems that have been observed are listed below [11] :

1. Chemical resistant lining on bunds have been damaged.
2. Storm water has been allowed to accumulate in bunds thereby reducing the effective volume.
3. Spills of material stored within the bund have been allowed to accumulate in bund thus reducing the effective volume.
4. Spills of acidic material stored in concrete bunds have been allowed to accumulate resulting in chemical attach leading to loss of bund integrity.
5. The flexible joints between concreted sections have shrunk resulting in gaps in the bund.
6. Concreted sections have been poured without any jointing material between them resulting in gaps in the bund.
7. Concrete bunds have cracked due to movement or damage from mobile plant.

8. Besser blocks have been used to build a bund (the porosity of besser blocks and the large number of mortar joints result in a low integrity bund).
9. Pipe work has been installed through bund walls or floors without any specific design provision to isolate the bund from pipe work movement.
10. The bund has been installed with storm water drainage holes (or valves) in the walls.
11. An earthing system has been installed through the bund walls.
12. Material such as pallets or drums has been stored in the bund.
13. Bunds have been used as a rubbish dump.
14. A bund has been used as a process vessel.
15. Pipes, pipe fittings such as valves or flanges, or hoses have been installed on top of or outside bund walls.

Chapter 3

METHODOLOGY

The following flow chart explains the methodology in executing the project:

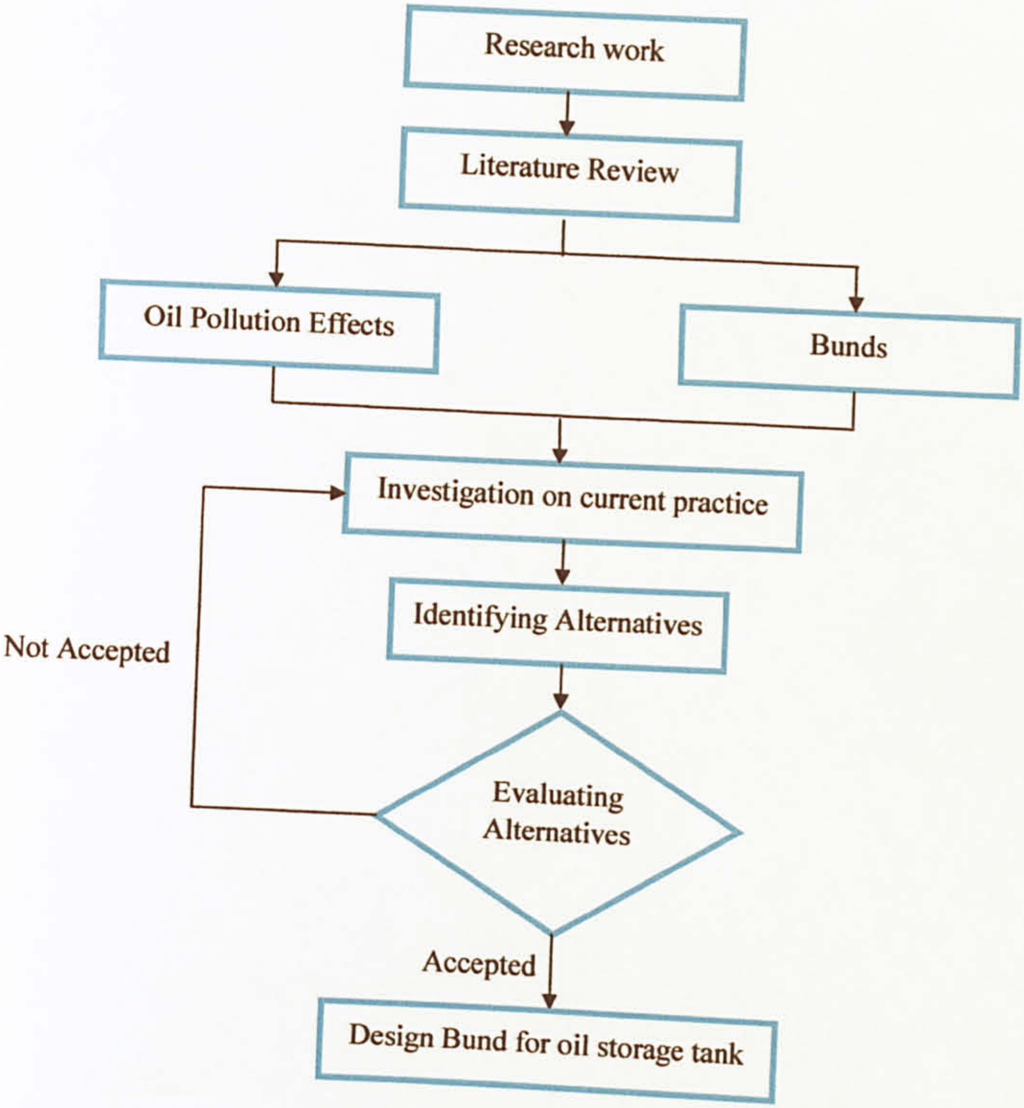


Figure (3.1): Methodology flow chart FYP I

- Refer to appendix (2) for FYP I gant chart.

Chapter 3

METHODOLOGY

The following flow chart explains the methodology in executing the project:

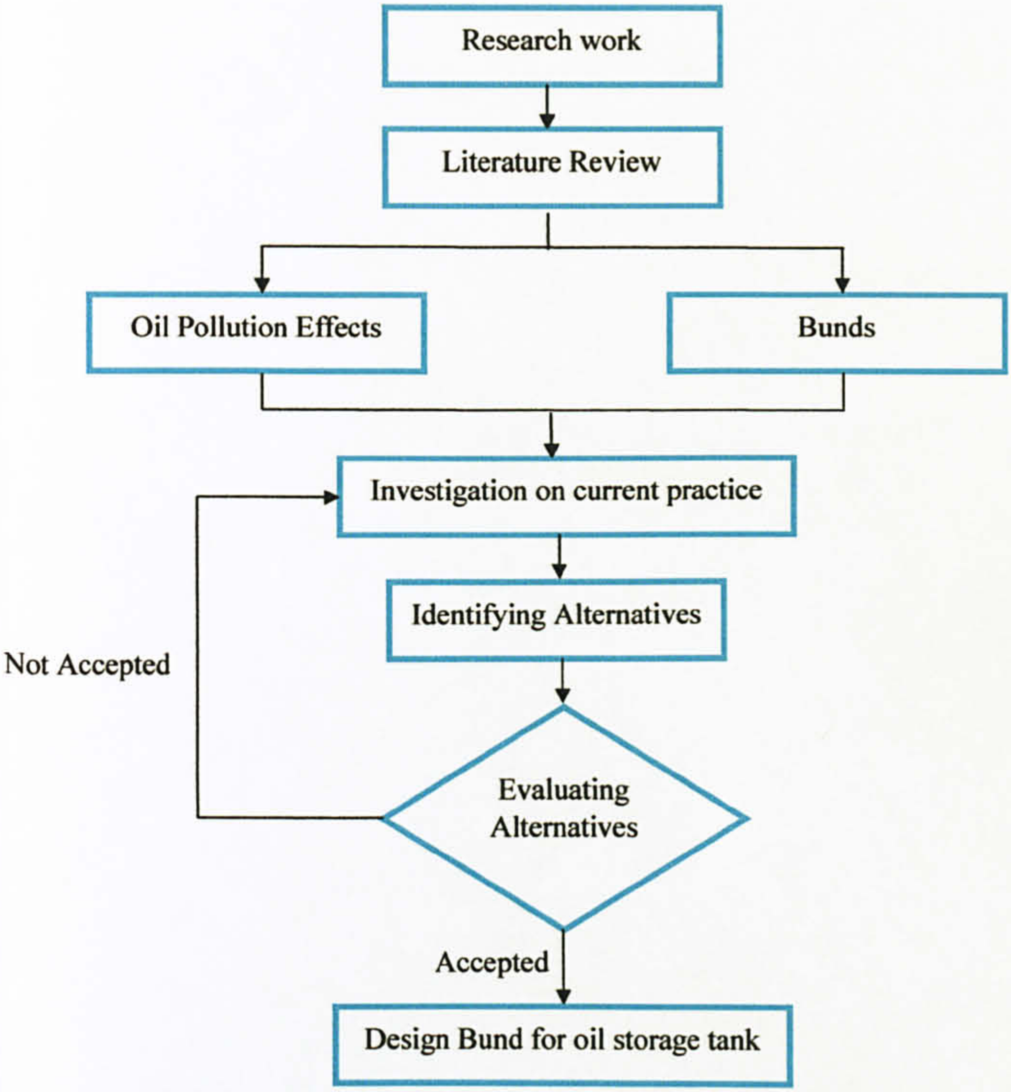


Figure (3.1): Methodology flow chart FYP I

- Refer to appendix (2) for FYP I gant chart.

3.1 Project work Part (1):

The first part of the project is basically about collection of data regarding the construction of bunds for oil storage tanks. Specify different reference and building a strong literature background to support the project idea. Highlight clear objectives and scope of work to start working on a full plan for the whole project. Look into the history of bunds construction in oil industry, guidelines and the rules and regulations governing it. Find out all the types and materials used in bunds construction for oil storage tanks.

After finishing all the data collection and research work analysis and evaluation work will be carried out to come out with final decision on which of all these types is best to constructed as the most adequate bund for oil storage tank (Refer to appendix (2)). The evaluation will be done on two stages as discussed in the following points:

- **Commercial evaluation:** The types of bunds will be judged basically on the cost wise and the economic analysis. It will also be evaluated according to the execution time need to get the job done. Availability of material and equipments will also be considered as part of the commercial evaluation.
- **Technical evaluation:** Based on the information and the data collected the types of bunds will be judged according to it is technical specification especially those associated with permeability, fire resistance and durability. The ability to withstand the hydraulic load incase of primary tank failure and the chemical reaction with the stored crude oil will also be considered as part of the technical evaluation.

3.2 Analysis Method:

Analytical Hierarchy Process (AHP) is a multi-criteria technique that combines qualitative and quantitative factors suitable for application of problem evaluation, for example, in qualitative factors dominate. In Analytical Hierarchy Process (AHP), the priority of any alternative has on the overall goal of the problem by developing of interest. The top of the hierarchy is the overall goal or prime objective one is seeking to fulfill. While in the succeeding lower levels then represent the progressive decomposition of the problem. This mathematical method allows the decision-maker to assess and analyze the complex decision problems as well as the relative importance of multi-criteria in an intuitive manner (Saaty, 1995).

Figure (3.2) below shows four (4) essential steps in problem solving with the Analytical Hierarchy Process (AHP):

Figure (3.2): The Four (4) Essential Steps in Analytical Hierarchy Process (AHP)

Based on the figure (3.2), the following described the details o the AHP methodology accordingly:

1. Develop the hierarchical representation of the problem. At the top of the hierarchy are the overall objective and the decision alternatives are at the bottom. Between the top and bottom levels are the relevant attributes of the decision problem, such as selection criteria and the various "actors" (individuals, agencies and organizations), if appropriate, that provides significant input on the decision process. The number of the problem and the analyst / decision maker's model of the problem hierarchy.
2. Generate relational data for comparing the alternatives. This requires the analyst (decision-maker) to make pairwise comparisons of elements at each level relative to each activity at the next higher level in the hierarchy. In the system example the importance of each criterion relative to system acceptance needs to be established.

In AHP a relational scale of real numbers from 1 to 9 is used to systematically assign preferences. When comparing two attributes (or alternatives) A and B, with respect to an attribute U, in a higher level, the following numerical relational scale is used:

Table (3.1): Scale for Pairwise Comparison

Preferences expressed in numeric variables	Preferences expressed in linguistic variables
1	A has the same importance as B with respect to U
3	A has slightly more importance than B with respect to U
5	A has more importance than B with respect to U.
7	A has a lot more importance than B with respect to U.
9	A totally dominates B with respect to U
1/3	B has slightly more importance than A with respect to U
1/5	B has more importance than A with respect to U.
1/7	B has a lot more importance than A with respect to U.
1/9	B totally dominates A with respect to U
Intermediate numbers are used for finer resolution	

3. Utilizing the pairwise comparisons of step 2 an eigenvalue method is used to determine the relative priority of each attribute to each attribute one level up in the hierarchy. In addition, a "consistency ratio" is calculated and displayed. According to Saaty, small "consistency ratios" (less than 0.1 is the suggested rule-of-thumb) don drastically affect the ratings. The used has the option of redoing the comparisons matrix if desired.

4. In this step, the priorities (or weights) of the lowest level alternatives relative to the top most objective are determined and displayed.

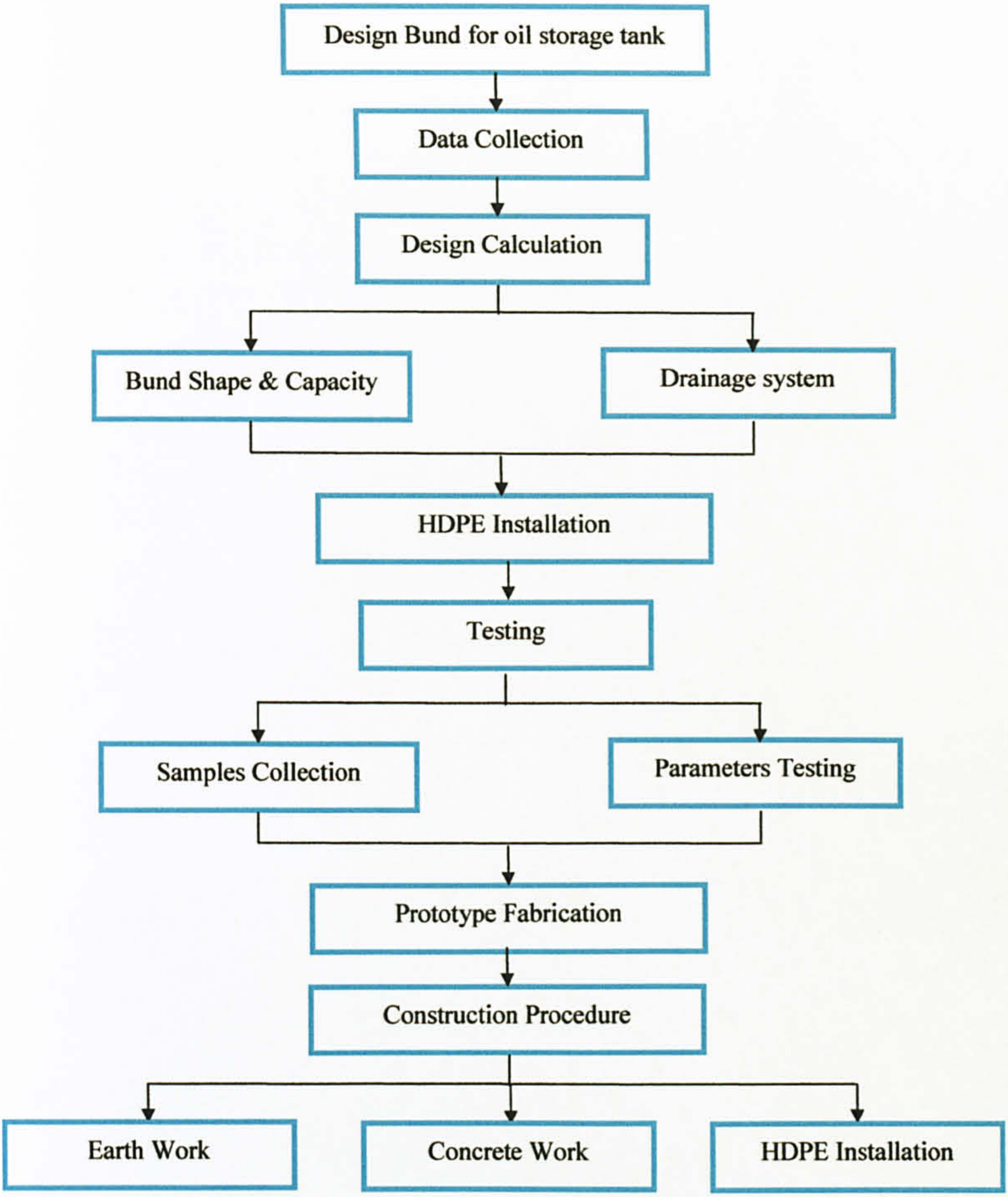


Figure (3.3): Methodology flow chart FYP II

- Refer to appendix (2) for FYP II gant chart.

3.3 Project work Part (2):

The second part of the project is concentrating on designing an earth bund lined with HDPE for a chosen oil storage tank there for the process is done as following:

1. ***Data Collection:*** collect information about the tank properties, dimensions, location, oil stored properties and any other data will help through the designing phase. This is done through site visit, the tank specification manual and some other research methods. By the end of this stage all the data needed to start the bund design.

2. ***Design Calculation:*** This part actually is divided into two section for ease of design process they are :
    a. Earth work : this basically concern about the design of bund shape , the holding capacity of the bund, the bund wall cross-section and bund ground adjustments
    b. Concrete work: this section focus on the design of the drainage system including the trenches, collection sumps and the weir gates. The engineering concepts used are reinforced concrete design and open flow channel design.

3. ***High Density Poly Ethylene Installation:*** in this part the installation plan is introduced and the procedures to finish this installation successfully are discussed.

4. ***Parameters testing:*** Strength and permeability tests were done on 4 different earth samples collected from sites around Universiti Teknologi Petronas. Permeability test was done using cooking oil and for 24 hours to simulate the situation in case of tank failure.

5. ***Prototype Fabrication:*** a small scaled model of earth bund for oil storage tank is fabricated for exhibition purposes and to ease the understanding of the bund use and main aims.

6. ***Construction Procedures:*** The final stage is to provide steps to be followed when constructing a similar earth bund for oil storage tank.

Chapter 4

RESULTS AND DISCUSSION

4.1 Commercial Evaluation:

The criteria used for the commercial evaluation are:

- Cost, execution time and availability of materials and equipments.

The evaluated bund types are:

- Bund using masonry concrete walls
- Bund using asphaltic concrete (Asphalt)
- Bund using clay lined with HDPE

4.1.1 Applying AHP

- **Criteria:**

$$\begin{array}{cccc} & \text{Cost} & \text{Execution} & \text{Availability} \\ \text{Cost} & 1/1 & 3/1 & 5/1 \\ \text{Execution} & 1/3 & 1/1 & 2/1 \\ \text{Availability} & 1/5 & 1/2 & 1/1 \end{array} \qquad \begin{array}{c} \text{eigenvector} \\ \begin{bmatrix} 0.6483 \\ 0.2297 \\ 0.1220 \end{bmatrix} \end{array}$$

- **Bund types in terms of cost (cheaper):**

$$\begin{array}{cccc} & \text{Concrete} & \text{Asphalt} & \text{HDPE} \\ \text{Concrete} & 1/1 & 2/1 & 1/3 \\ \text{Asphalt} & 1/2 & 1/1 & 1/5 \\ \text{HDPE} & 3/1 & 5/1 & 1/1 \end{array} \qquad \begin{array}{c} \text{eigenvector} \\ \begin{bmatrix} 0.2297 \\ 0.1220 \\ 0.6483 \end{bmatrix} \end{array}$$

- **Bund types in terms of execution time :**

$$\begin{array}{c} \\ \text{Concrete} \\ \text{Asphalt} \\ \text{HDPE} \end{array} \begin{array}{c} \begin{array}{ccc} \text{Concrete} & \text{Asphalt} & \text{HDPE} \end{array} \\ \begin{bmatrix} 1/1 & 1/2 & 1/3 \\ 2/1 & 1/1 & 1/2 \\ 3/1 & 2/1 & 1/1 \end{bmatrix} \end{array} \qquad \begin{array}{c} \text{eigenvector} \\ \begin{bmatrix} 0.1634 \\ 0.2970 \\ 0.5396 \end{bmatrix} \end{array}$$

- **Bund types in terms of availability of materials and equipments:**

$$\begin{array}{c} \\ \text{Concrete} \\ \text{Asphalt} \\ \text{HDPE} \end{array} \begin{array}{c} \begin{array}{ccc} \text{Concrete} & \text{Asphalt} & \text{HDPE} \end{array} \\ \begin{bmatrix} 1/1 & 2/1 & 3/1 \\ 1/2 & 1/1 & 1/2 \\ 1/3 & 2/1 & 1/1 \end{bmatrix} \end{array} \qquad \begin{array}{c} \text{eigenvector} \\ \begin{bmatrix} 0.5468 \\ 0.1899 \\ 0.2633 \end{bmatrix} \end{array}$$

- **The Solution:**

$$\begin{array}{c} \\ \text{Concrete} \\ \text{Asphalt} \\ \text{HDPE} \end{array} \begin{array}{c} \begin{array}{ccc} \text{Cost} & \text{Execution} & \text{Availability} \end{array} \\ \begin{bmatrix} 0.2297 & 0.1634 & 0.5468 \\ 0.1220 & 0.2970 & 0.1899 \\ 0.6483 & 0.5396 & 0.2633 \end{bmatrix} \end{array} * \begin{array}{c} \text{Criteria Ranking} \\ \begin{bmatrix} 0.6483 \\ 0.2297 \\ 0.1220 \end{bmatrix} \end{array} = \begin{array}{c} \text{Final Ranking} \\ \begin{bmatrix} 0.2532 \\ 0.1705 \\ 0.5764 \end{bmatrix} \end{array}$$

4.1.2 Results of Commercial Evaluation:

After conducting the Analytical Hierarchy Process the final ranking is as following:

1. Bund using clay lined with HDPE (0.5764)
2. Bund using masonry concrete walls (0.2532)
3. Bund using asphaltic concrete (Asphalt) (0.1705)

4.2 Technical Evaluation:

The criteria used for the technical evaluation are:

- Permeability, fire resistance and durability.

The evaluated bund types are:

- Bund using masonry concrete walls
- Bund using asphaltic concrete (Asphalt)
- Bund using clay lined with HDPE

4.2.1 Applying AHP

- **Criteria:**

$$\begin{array}{ccc} & \begin{array}{ccc}\text{Permeability} & \text{Fire} & \text{Durability}\end{array} & \text{eigenvector} \\ \begin{array}{c}\text{Permeability}\\ \text{Fire}\\ \text{Durability}\end{array} & \begin{bmatrix}1/1 & 2/1 & 3/1\\ 1/2 & 1/1 & 1/2\\ 1/3 & 2/1 & 1/1\end{bmatrix} & \begin{bmatrix}0.5556\\ 0.1852\\ 0.2593\end{bmatrix}\end{array}$$

- **Bund types in terms of Permeability :**

$$\begin{array}{ccc} & \begin{array}{ccc}\text{Concrete} & \text{Asphalt} & \text{HDPE}\end{array} & \text{eigenvector} \\ \begin{array}{c}\text{Concrete}\\ \text{Asphalt}\\ \text{HDPE}\end{array} & \begin{bmatrix}1/1 & 3/1 & 1/2\\ 1/3 & 1/1 & 1/3\\ 2/1 & 3/1 & 1/1\end{bmatrix} & \begin{bmatrix}0.3325\\ 0.1397\\ 0.5278\end{bmatrix}\end{array}$$

- **Bund types in terms of fire resistance :**

$$\begin{array}{ccc} & \begin{array}{ccc}\text{Concrete} & \text{Asphalt} & \text{HDPE}\end{array} & \text{eigenvector} \\ \begin{array}{c}\text{Concrete}\\ \text{Asphalt}\\ \text{HDPE}\end{array} & \begin{bmatrix}1/1 & 1/2 & 3/1\\ 2/1 & 1/1 & 5/1\\ 1/3 & 1/5 & 1/1\end{bmatrix} & \begin{bmatrix}0.3090\\ 0.5816\\ 0.1095\end{bmatrix}\end{array}$$

- **Bund types in terms of durability:**

$$\begin{array}{cc} \begin{array}{c|ccc|} & \text{Concrete} & \text{Asphalt} & \text{HDPE} \\ \text{Concrete} & 1/1 & 2/1 & 3/1 \\ \text{Asphalt} & 1/2 & 1/1 & 2/1 \\ \text{HDPE} & 1/3 & 1/2 & 1/1 \end{array} & \qquad \begin{array}{c} \text{eigenvector} \\ \begin{bmatrix} 0.5396 \\ 0.2970 \\ 0.1634 \end{bmatrix} \end{array} \end{array}$$

- **The Solution:**

$$\begin{array}{c|ccc|} & \text{Permeability} & \text{Fire} & \text{Durability} \\ \text{Concrete} & 0.3325 & 0.3090 & 0.5396 \\ \text{Asphalt} & 0.1397 & 0.5816 & 0.2970 \\ \text{HDPE} & 0.5278 & 0.1095 & 0.1634 \end{array} * \begin{array}{c} \text{Criteria Ranking} \\ \begin{bmatrix} 0.5556 \\ 0.1852 \\ 0.2593 \end{bmatrix} \end{array} = \begin{array}{c} \text{Final Ranking} \\ \begin{bmatrix} 0.3819 \\ 0.2623 \\ 0.3559 \end{bmatrix} \end{array}$$

4.2.2 Results of Technical Evaluation:

After conducting the Analytical Hierarchy Process the final ranking is as following:

1. Bund using masonry concrete walls (0.3819)
2. Bund using clay lined with HDPE (0.3559)
3. Bund using asphaltic concrete (Asphalt) (0.2623)

4.3 Evaluation outcomes:

The commercial evaluation result is bund using clay lined with HDPE while the technical evaluation result is bund using masonry concrete walls. After comparison between the two evaluation final results it is obvious that bund using clay lined with HDPE will be the best choice. Therefore the outcome of this analysis is that designing a well constructed bund using earth lined with HDPE will be a good choice commercially and technically.

4.4 Data collection:

This bund is designed for oil storage tank with the following details:

- The oil Storage tank belongs to White Nile Petroleum Operating Company – Sudan.
- The tank is located in the southern west part of Sudan in Heglig oil field around 750 Km from the capital Khartoum with the Coordinates: 10°0'56"N 29°24'27"E
- Table (4.1) show the main geometry characteristics of the tank :

Table (4.1): Tank Dimension

Tank Capacity	23,850 m^3
Tank Diameter	48 m
Tank Area	1809.6 m^2
Tank Height	16 m
Crude oil Height	14 m

- Rainfall intensity average is ranging from 200 – 300 mm.
- Crude oil density is 862 kg/m^3
- For the sake of this project we assume the ideal conditions at site but normally it is not like that and we have to take consideration of all the aspects at site which will affect the construction work.
- The Design was done for a total failure of the tank.

4.5 Bund capacity:

From the literature review most of the designs used the bund capacity as 110% of the oil storage tank capacity. The bund wall height should not exceed 1.5 m for many reasons as explained in Chapter 2. Table (4.2) shows the calculations for the bund capacity.

Table (4.2): Bund Capacity

Bund Capacity	26,235 m^3
Bund wall height	1.5 m
Bund ground area	17,490 m^2
Net gross area	19,299.6 m^2
Liquid Static Pressure	118.3 kPa

4.6 Bund Shape:

The bund can take any shape here I present three types which is the most convenient shapes possible to be constructed. The following points explain in details the three chosen shapes:

- Circular shape:

Diameter	157 m
Height	1.5 m
Perimeter	494 m
Dynamic pressure on the wall	3.5 kPa

- Square shape:

Width & Length	139 m
Height	1.5 m
Perimeter	556 m
Dynamic pressure on the wall	4.2 kPa

- Rectangular shape:

Width	130 m
Length	148 m
Height	1.5 m
Perimeter	556 m
Dynamic pressure on the wall	4.6 kPa

Figure (4.1) shows the bund shapes all the dimensions in meter.

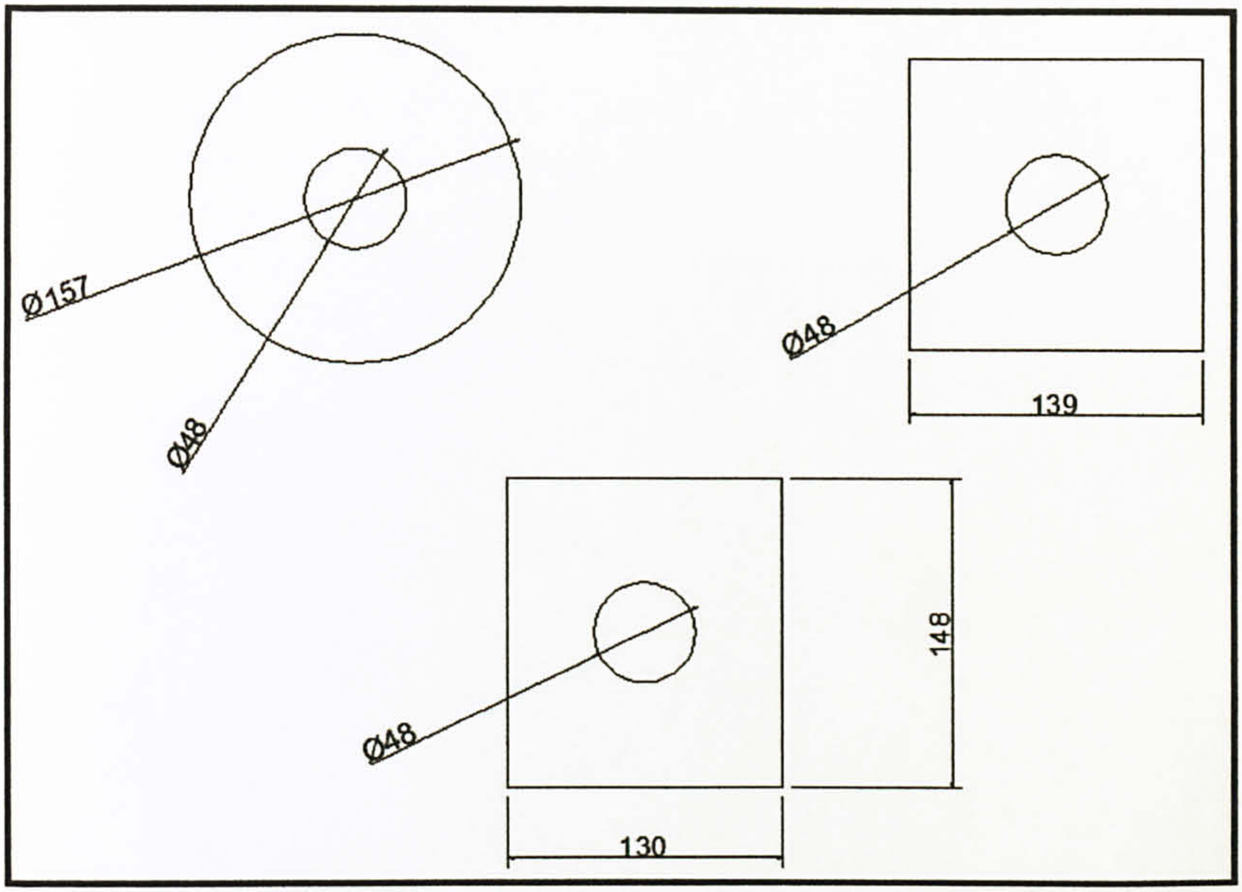


Figure (4.1): bund shapes

4.7 Bund Wall:

Considering the pressure exerted on the wall from the sudden relief of crude oil due to failure of the oil storage tank and the installation procedures for HDPE. The following drawing shows the cross section of the bund wall.

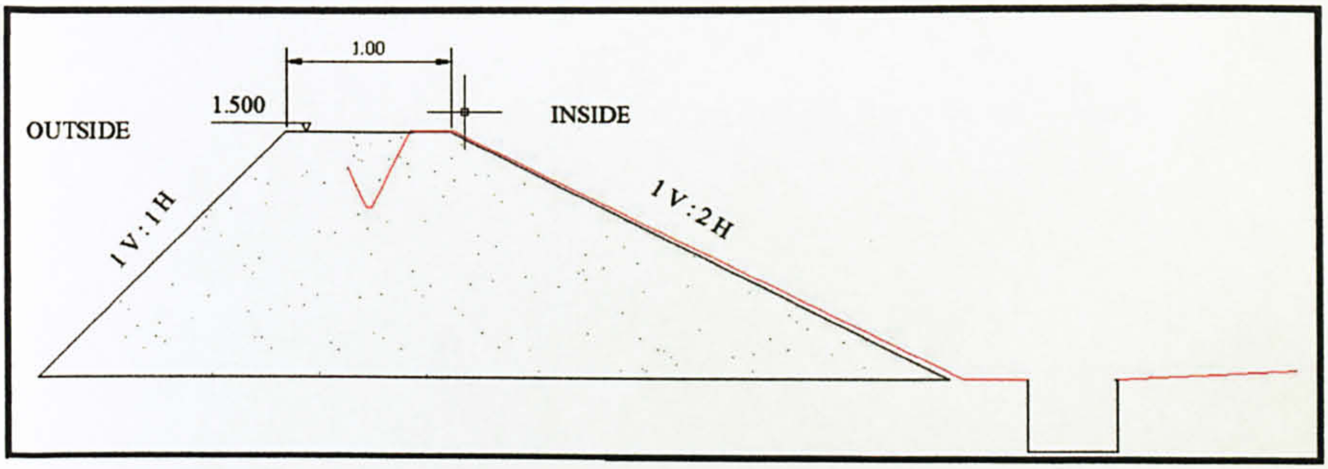


Figure (4.2): Bund wall cross section

4.8 Rain water drainage system:

Considering the soil properties at the selected site and the Rainfall intensity in that area and following the open flow channel procedure to construct a reinforced concrete rainwater drainage system. The following drawing represents the proposed rainwater trench surrounding the bund ground. All the drainage slopes are directed to two collection sumps and then leaded outside the bund area through weir gates as shown in figure (4.4).

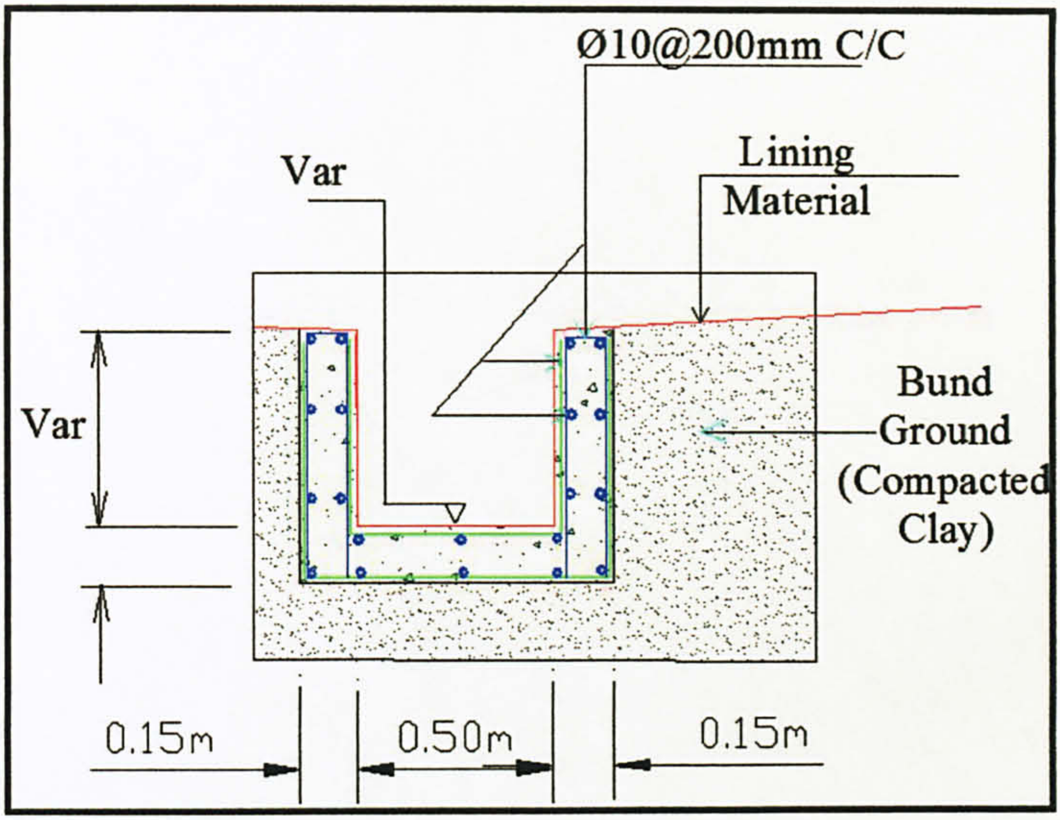


Figure (4.3): Rainwater drainage

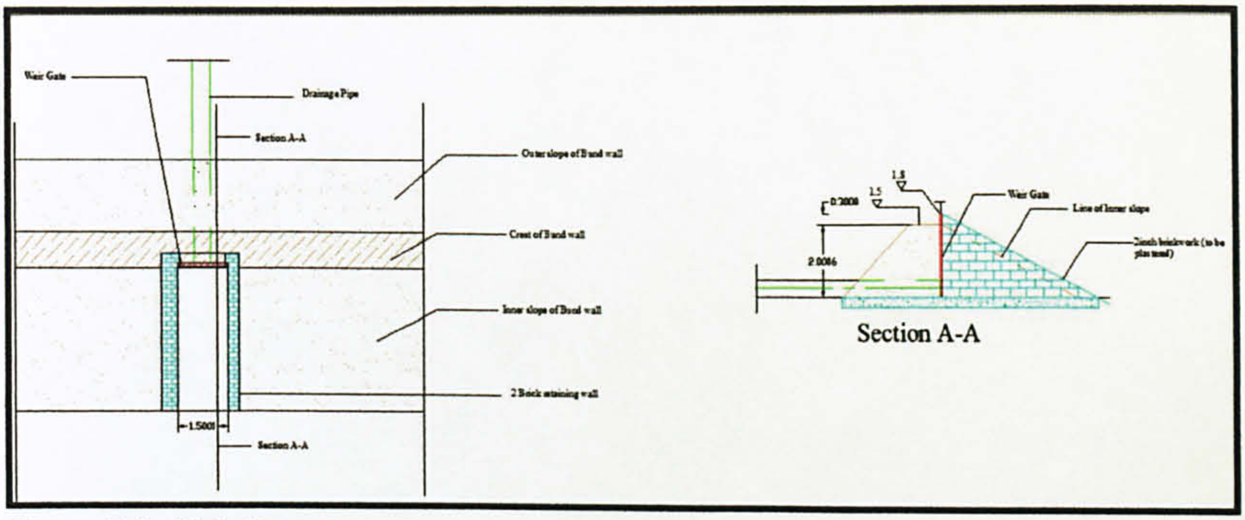


Figure (4.4): Weir Gate

4.9 HDPE Installation:

- The membrane liner installation will be carried out in accordance with the installation plan. This plan will show the location of each membrane section-Field revisions to the installation plan may be required to liner installation.

- The plan is developed with three principle objectives:
    - Maximizing the installation speed
    - Minimizing the welding joints
    - Minimizing the waste of membrane

- The membrane sections are unrolled with approximately 13 cm overlap to adjacent membrane and are temporarily held down against the wind unrolling of the liner is usually carried out with available construction equipment, mechanical accessories or sometimes simply by hand and finally welded together.

4.9.1 HDPE requirements/specifications

- Be manufactured from plasticized polymers **(high density polyethylene)**
- None existence of any pinholes and excellent resistance to Ultra Violet (UV) radiation and is suitable for exposed applications.
- Outstanding chemical resistance, mechanical properties, environmental stress, crack resistance, dimension stability, and thermal aging characteristics.
- Not react with organic and non-organic chemicals as well as causes of bacteria and fungi and prevent them from growing on their surface.
- High resistance to hydrocarbons (crude oil at contained temparature 110 °C).
- Not allow plant roots and biting insects to penetrate their surface.
- Resistant to puncturing.
- Rot proof.
- Have long life cycle of at least 50 years.
- Minimum thickness of 0.75 mm

4.10 Parameters Testing:

Strength and permeability tests were done on 4 different earth samples collected from sites around Universiti Teknologi Petronas. Permeability test was done using cooking oil and for 24 hours to simulate the situation in case of tank failure table (4.3) show the tests results.

Table (4.3): Parameters Testing Results

	Permeability (cm/sec)	Unit weight (KN/m^3)	Cohesion (KN/m^2)
Batu Gajah	$13.9 X 10^{-6}$	15	20
UTP	$9.3 X 10^{-6}$	14.4	30
Bandar U	$138.9 X 10^{-6}$	15.3	10
clay	0	14	40

CHAPTER 5

CONSTRUCTION PROCEDURES

The first thing to do in a project that involves earth work is to do the survey work to know the ground level and the slopes. This data is very crucial for the design phase. After that construction of earth bund lined with HDPE can go through the following steps:

5.1 Earth work:

Earth work in this project can be divided into two sections where can the work go on concurrently:

1. Bund Ground: The survey data will play a big role here since some adjustment should be introduced to the ground surrounding the oil storage tank inside the bund area towards the drainage system that surrounds the bund area as shown in drawings. The most important thing is to make sure that the compaction is up to 95% and the surface is smooth to ease the HDPE installation.
2. Bund Wall: The construction of the earth walls should be done in layers of 30 cm and the compaction must be 95% and the surface smooth just like the bund ground. For the wall cross-section is must be according to the design drawings provided. Table (4.4) show the earth material needed for each proposed shape.

Table (5.1) Earth material needed for bund wall

Shape	Material needed (m^3)
Circular	2,470
Square	2,780
Rectangular	2,780

5.2 Concrete work:

The concrete work in this project is mainly focus on the drainage system which is done through three stages discussed as follow:

1. Rain water trenches: Construct reinforcement concrete drains as per the specification and requirements mentioned in the drawings. The concrete mix used is C25 (1:1.5:3). The drain depth varies according to the slope. The most important concern that should be taking care of is the sharp edges of the trenches to ease the HDPE installation.

2. Collection Sumps: Two collection sumps located at the corners of the bund area in case of rectangular and square bund and one collection sump in case of circular bund constructed of reinforced concrete according to the design drawings. The main purpose of it is to collect the rain water or oil (in case of failure) and then leaded through the weir gate to the outside drainage system for rain water and for oil it is pumped out to a spare storage.

3. Weir gate: Constructing of two (square & rectangular) or one (circular) single weir gates two in each site. Connected to 0.5 m pipe for outside drainage. For brick work bricks should be immersed in water prior to laying. In the mortar mix, cement sand ratio should be 1:8 or 1:6.

5.3 HDPE Installation:

Typical installation sequences for membrane lining are:

1. The embankment surrounding of the basin is inspected and covered with the membrane liner. This protects against erosion of embankments and shifting of sand or earth around the perimeter.
2. The top edge of the membrane liner is temporarily secured in the anchor trench with small amounts of backfill.
3. After the perimeter slopes are covered and welded, the bottom of the basin is covered and welder
4. After the entire basin has been lined and inspected, the top edge of the membrane liner is permanently secured in the anchor trenches around the perimeter.

The welding process consists of the following steps :

1. Assurance that the surfaces to be joined are clean. The liner surface is wieldable as manufactured, but may require cleaning after deployment over some sub grades.
2. Adjust the overlap to accommodate the welding machine used. This is generally about 13 cm.
3. Adjust the welding machine for speed, temperature and membrane thickness on scrap liner prior to starting the weld.
4. Complete the weld.
5. Complete quality inspection and documentation.

CONCLUSION

In order to reduce the risk of oil pollution to the oil storage tanks surrounding environment proper provision leakage containment must be provided. Bunds – if designed properly - can provide good secondary containment in case of primary containment (oil storage tank) failure. Comparing to other alternatives bunds are more preferable due different reasons such as cost, execution time and reliability. It is not only a suitable oil pollution control method but it can also eliminate the danger of crude oil loss. Depending on the site conditions different types of bunds can be designed and constructed.

According to the data collected and the information provided and after conducting all the analytical procedure the best type of bund to be designed is Earth Bund lined with HDPE. For the second part of this project a detailed design for earth bund lined with HDPE will be provided.

The designed earth bund has a holding capacity of 26,235 m^3 with walls that can withstand a dynamic pressure up to 14 KN/m^3. The material needed and the time of construction is depending on the shape chosen for the bund. Technically the best shape to be chosen is circular.

ECONOMIC BENEFITS

Economic benefit analysis is a term that refers both to:

- Helping to appraise, or assess, the case for a project or proposal, which itself is a process known as project appraisal; and
- An informal approach to making economic decisions of any kind.

Under both definitions the process involves, whether explicitly or implicitly, weighing the total expected costs against the total expected benefits of one or more actions in order to choose the best or most profitable option. Benefits and costs are often expressed in money terms, and are adjusted for the time value of money, so that all flows of benefits and flows of project costs over time (which tend to occur at different points in time) are expressed on a common basis in terms of their "present value." Closely related, but slightly different, formal techniques include cost-effectiveness analysis, economic impact analysis, fiscal impact analysis and Social Return on Investment (SROI) analysis. The latter builds upon the logic of cost-benefit analysis, but differs in that it is explicitly designed to inform the practical decision-making of enterprise managers and investors focused on optimizing their social and environmental impacts.

Since this a research based project the project cost wasn't so high. The project expenses were around 150 RM they were spent on communication, transportation and experiments. The benefits gained from this project are so many comparing to the cost of it. The economic validity of the project was a deciding factor when investigating the current practice used for construction of bunds for oil storage tank.

Items	Expenses (RM)
Experiments	60
Transportation	40
Communication	10
Documentation	40

REFERENCES

1. Buduh, M. (2007). *Soil Mechanichs and Foundations (2nd ed.)*. United states of America: John Wiley & sons, Inc.
2. Beer, P. F., Johnston, R. E., Dewolf, T. J. (2006). *Mechanics of Materials (4th ed.)*. Singapore: The McGraw.Hill companies.
3. Chakravarty, Sukhamoy (1987). cost-benefit analysis, The New Palgrave: A Dictionary of Economics, v. 1, pp. 687-90.
4. CIRIA (Construction Industry Research and InformationAssociation). (1997). *Construction of bunds for oil storage tanks.* London: Author.
5. Das, B. M. (2007). *Principles of Geotechnical Engineering (5th ed.)*. United states of America: The Wadsworth Group.
6. Dunnet, G., Crisp, D., Conan, G., Bourne, W. (1982) "Oil Pollution and Seabird Populations [and Discussion]" Philosophical Transactions of the Royal Society of London.
7. Dynalab Corporation. (2001).*Plastic Properties of High-Density Poly Ethylene (HDPE).* Retrieved July 9, 2009, from

   http://www.dynalabcorp.com/technical_info_hd_polyethylene.asp
8. Fedral Public Service Employment, Labour and social Dialouge , Chemical Risks Division. (November 2006). *Safety Alert : Rupture of an Crude Oil Storage Tank.* Bilguem: Author.
9. JOHN SHADELY. 1973. *Acoustical analysis of the New Jersey Turnpike widening project between Raritan and East Brunswick*, Bolt Beranek and Newman.
10. J.R. Century. *Tar Sands: Key geologic risks and opportunities. The Leading Edge*, Vol. 27, No. 9, Pg. 1202-1204. September 2008.
11. Kosmatka, S.H.; Panarese, W.C. (1988). *Design and Control of Concrete Mixtures*. Skokie, IL, USA: Portland Cement Association. pp. 17, 42, 70, 184.
12. Mabro, Robert; Organization of Petroleum Exporting Countries (2006). *Oil in the 21st century: issues, challenges and opportunities*. Oxford Press

13. Mckenzie, W. M. C. (2004). *Design of Structural Elements* . China: Palgrave macmillan.

14. Michael Hogan. September 1973. *Analysis of Highway Noise,* Journal of Soil, Air and Water Pollution, Springer Verlag Publishing, Netherlands, Vol. 2, Number 3

15. Mosley, W. H., Bungey, H. J., Hulse, R. (1999). *Reinforced Concrete Design (5th ed.).* Great Britain: Palgrave.

16. NOAA (2002). Environmental Sensitivity Index Guidelines, version 3.0. NOAA Technical Memorandum NOS OR&R 11. Seattle: Hazardous Response and Assessment Division, National Oceanic and Atmospheric Administration, 129p.

17. Odewumi, A.: 1987, 'Oil Pollution in Nigeria', *A Report on Environmental Pollution Shell Pet. Dev. Co.* Warri, (In-House Report).

18. Odu, C. T. I.: 1977, *'Microbiology of soils contaminated with petroleum hydrocarbons 'Natural rehabilitation and reclamation of soil affected'* ', Inst. Petroleum Technol. Publ. 1, 77–105.

19. Ogboghodo, I. A., Iruaga, E. K., Osemwota, I. O., & Chokor, J. U. (July 2003). *An Assessment Of The Effects Of Crude Oil Pollution.* Netherlands: Kluwer Academic Publishers.

20. Onwurah, I. N. E., Ogugua, V. N., Onyike, N. B., Ochonogor, A. E.& Otitoju, O. F. *Crude Oil Spills in the Environment, Effects and Some Innovative Clean-up Biotechnologies.* International Journal of Environmental Research, Vol. 1, No. 4, 2007, pp.307-320.

21. Ray K., Linsley, Jr., Max A. Hohler. (1988). *Hydrology for Engineers.* Mc Graw Hill.

22. Scottish Environment Protection Agency Pollution Prevention Guidelines. (June 2007). *Bunding and spill management.* Scotland: Author.

23. Subramanya K. (1996). *Engineering Hydrology.* Tata McGraw-Hill.

24. Subramanya K., 1997, *Flow in Open Channel (2nd wd.),* Tata McGraw Hill.

25. Speight, James G. (1999). *The Chemistry and Technology of Petroleum.* Marcel Dekker

APPENDICES

Appendix
(1)

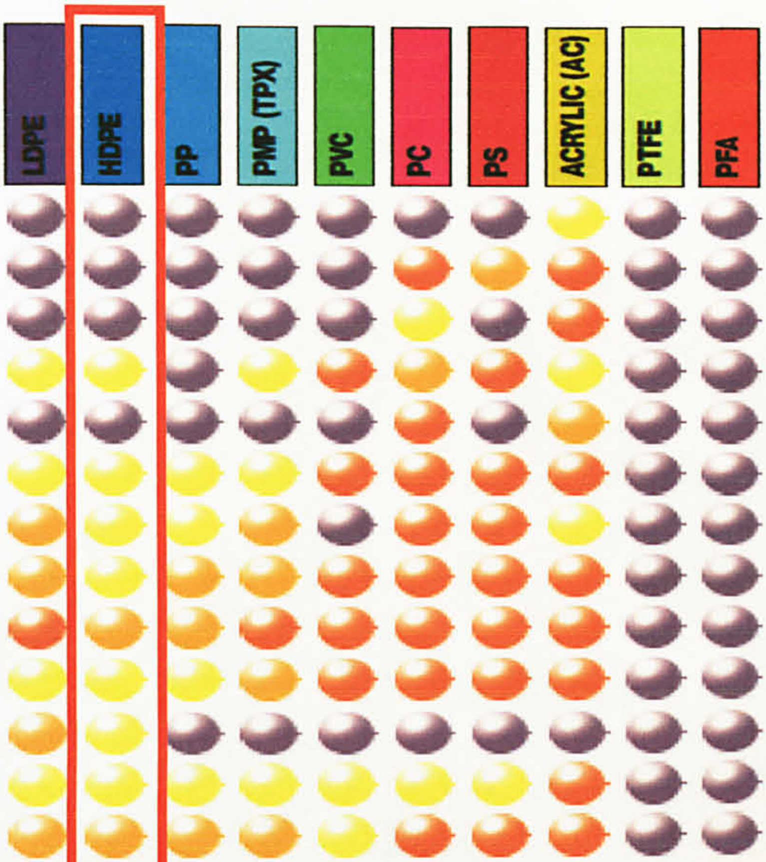
Physical Properties & Chemical Resistance of Polymers

🟣 Excellent resistance - can withstand use over a long period of time without change in physical, optical or chemical properties.

🟡 Good general resistance - minor attack may occur after long periods of storage.

🟠 Limited resistance - product can be used for brief mixing and measuring.

🔴 Poor resistance - product becomes unstable on contact with chemical.



	LDPE	HDPE	PP	PMP (TPX)	PVC	PC	PS	ACRYLIC (AC)	PTFE	PFA
Acids-Dilute	🟣	🟣	🟣	🟣	🟣	🟣	🟣	🟡	🟣	🟣
Acids-concentrated	🟣	🟣	🟣	🟣	🟣	🔴	🟠	🔴	🟣	🟣
Alcohols	🟣	🟣	🟣	🟣	🟣	🟡	🟣	🔴	🟣	🟣
Aldehydes	🟡	🟡	🟣	🟡	🔴	🟠	🔴	🟡	🟣	🟣
Bases	🟣	🟣	🟣	🟣	🟣	🔴	🟣	🟠	🟣	🟣
Esters	🟡	🟡	🟡	🟡	🔴	🔴	🔴	🔴	🟣	🟣
Hydrocarbons-aliphatic	🟠	🟡	🟡	🟠	🟣	🔴	🔴	🟡	🟣	🟣
Hydrocarbons-aromatic	🟠	🟡	🟠	🟠	🔴	🔴	🔴	🔴	🟣	🟣
Hydrocarbons-halogenated	🔴	🟠	🟠	🔴	🔴	🔴	🔴	🔴	🟣	🟣
Ketones	🟡	🟡	🟡	🟠	🔴	🔴	🔴	🔴	🟣	🟣
Oils, mineral	🟠	🟡	🟣	🟣	🟣	🟣	🟣	🟣	🟣	🟣
Oils, vegetable	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🔴	🟣	🟣
Oxidising agents	🟠	🟠	🟠	🟠	🟡	🔴	🔴	🔴	🟣	🟣

C	Clear	R	Rigid
O	Opaque	F	Flexible
TL	Translucent		

	LDPE	HDPE	PP	PMP (TPX)	PVC	PC	PS	ACRYLIC (AC)	PTFE	PFA
Max Temp °C	80	120[1]	135	180	70	130	70	90	300	270
Min Temp °C	-50	-100	-20*	-180	-25	-135	-40	-60	-200	-260
Autoclavable	NO	NO	YES	YES	NO	YES	NO	NO	YES	YES
Gas sterilisation	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Dry Heat sterilisation	NO	NO	NO	YES	NO	NO	NO	NO	YES	YES
Gamma irradiation sterilisation	YES	YES	NO	YES	NO	YES	NO	YES	YES	YES
Chemical Disinfectant sterilisation	YES	YES	YES	YES	YES	YES	YES	NO	NO	YES
Transparency	TL	TL	TL	C	C	C	C	C	O	TL
Flexibility	F	R	R	R	R	R	R	R	R	F
Gas Permeability N_2	20	3	4.4	65	0.4	3	3	-	-	-
Gas Permeability CO_2	280	45	92	-	10.2	85	75	-	-	-
Gas Permeability 0_2	60	10	28	270	1.2	20	15	-	-	-
Water Absorbtion %	<0.01	<0.01	<0.02	<0.01	0.06	0.35	0.05	0.3	0.3	<0.03
Resistivity Ohm CM²	$>10^{15}$	$>10^{15}$	$>10^{16}$	$>10^{16}$	$<10^{16}$	$2x10^{16}$	$>10^{16}$	$>10^{14}$	$>10^{18}$	10^{19}
Specific gravity	0.92	0.95	0.90	0.83	1.34	1.20	1.05	1.18	2.2	2.16

Gas Permeability: mm cm³/cm² sec (cm Hg) x 10^{10}

[1] *Please note that the polymer may become malleable at temperatures above 80°C if the product is under structural stress.*

Appendix
(2)

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Project Title: Construction of Bunds for Oil Storage Tanks

Final Year Project I Gant Chart

No.	Activities / Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Topic Selection	▨													
2	Literature Review :		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
2.1	➢ History Background		▨	▨											
2.2	➢ Oil pollution				▨	▨									
2.3	➢ Methods of pollution control					▨									
2.4	➢ Bunds (Definition, Types, Current practice)						▨	▨	▨						
3	Project Plan & Risk Analysis								▨						
4	Submission of preliminary & progress Reports								🟥						
5	Investigation on current practice									▨	▨	▨			
6	Data analysis and Decision making											▨	▨	▨	
7	Submission of interim report													🟥	
8	Oral presentation														🟥

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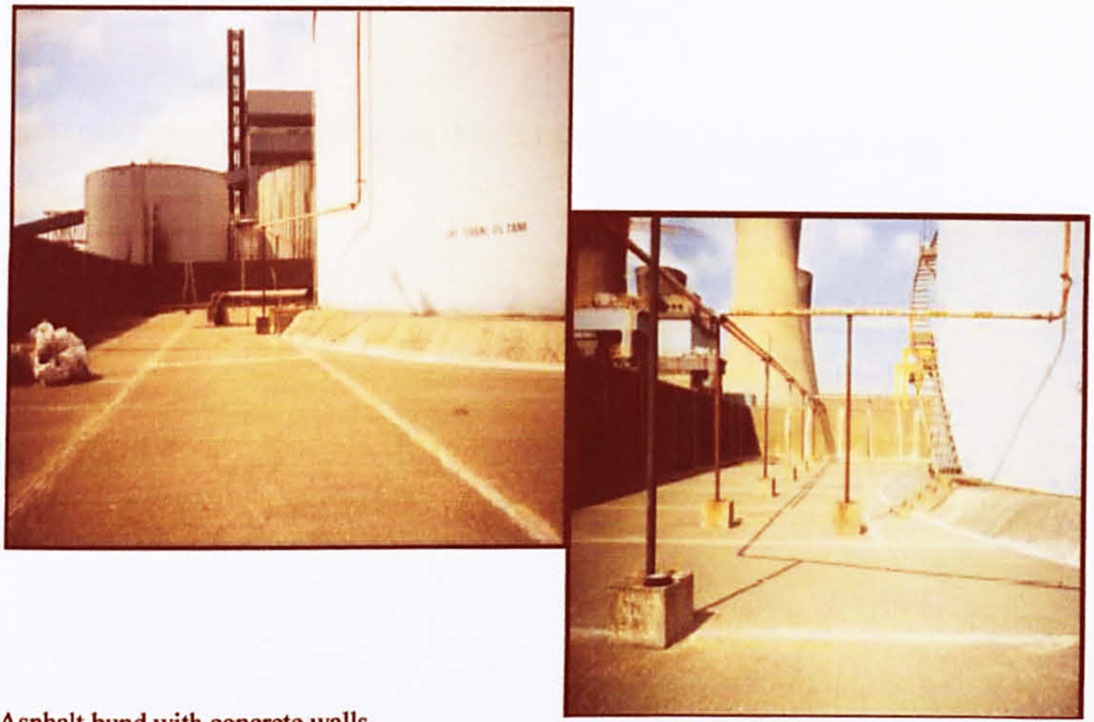
Project Title: Construction of Bunds for Oil Storage Tanks

Final Year Project II Gant Chart

No.	Activities / Weeks	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Project Planning and Data Collection	■							Mid –Semester Break							
2	Design Calculations :	■	■	■	■	■	■	■								
2.1	➢ Bund shape & capacity		■	■												
2.2	➢ Bund ground				■											
2.3	➢ Bund walls				■											
2.4	➢ Rain water drainage system					■	■									
2.5	➢ HDPE installation							■								
3	Parameters Testing :									■	■	■				
3.1	➢ Samples Collection									■						
3.2	➢ Penetration Testing										■					
3.3	➢ Strength Testing											■				
5	Prototype Fabrication												■			
4	Construction Procedures :													■	■	
4.1	➢ Earth Work													■		
4.2	➢ Concrete Work													■		
4.3	➢ HDPE installation														■	
8	Oral presentation															

Appendix
(3)



Asphalt bund with concrete walls

Earth bund lined with HDPE on surface

Earth bund lined with HDPE under surface

Earth bund lined with Concrete