THE EFFECTIVENESS OF USING STEEL REINFORCE CONCRETE IN COMPARISON WITH FILEXIBLE BITUMEN WITH POLYMER MODIFIED BINDER AND HOW IT WILL AFFECT THE PROJECT TIME AND COST: A CASE STUDY AT KUALA LUMPUR INTERNATIONAL AIRPORT (KLIA)

MOHAMMAD HAZIQ BIN ZAMRI

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UNIVERSITI MALAYSIA PAHANG

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ABSTRACT

The structure of the runway must me good enough to make sure that the extreme pressure made by the aircraft when it is going to land, taxi, take-off, and the blast produce by the jet engine did not harm the runway. Steel reinforce concrete and flexible bitumen with polymer modified binder are among the materials that normally used in runway construction. Both of these materials have its own unique characteristics in term of effectiveness, maintenance record, and life span. Therefore, this study is aim to determine the effectiveness and life span of steel reinforce concrete and flexible bitumen with polymer modified binder in runway construction. The study was conducted at KLIA as it is the main airport in Malaysia and thousands of aircraft passes through the two main runways every year. KLIA uses flexible bitumen with polymer modified binder as the structure of the runway. The effectiveness and life span of the runway at KLIA are important in order to make sure that the operation at the airport become smooth and no interference will occur. Two engineers at the KLIA engineering department were the respondents that answering the close-ended questionnaire designed for this study. The questionnaire consists of certain elements on how steel reinforce concrete and flexible bitumen with polymer modified binder runway structure react on term of the materials behavior, maintenance frequency, cost and time consumes to build and maintaining the runway, and the life span of the runway. At the end of this study, the result concludes that the effectiveness and life span of both materials are bias towards the flexible bitumen with polymer modified binder rather that steel reinforce concrete because of its characteristics that is better and suit the runway construction and specification of KLIA. Hence, various types of runway structure materials and opinion from other engineer from different airport are recommended as it can evaluate more on the runway construction technology and may become beneficial for future reference in runway construction.

ABSTRAK

Struktur landasan mestilah dalam keadaan yang baik supaya dapat menahan tekanan extrim yang dihasilkan oleh kapal terbang apabila ia mahu mendarat, bersedia untuk berlepas, terbang dan tujahan yang dihasilkan oleh enjin jet agar tidak merosakkan landasan. 'Steel reinforce concrete' dan 'flexible bitumen with polymer modified binder' adalah diantara bahan yang biasa digunakan dalam penbinaan landasan. Kedua-dua bahan ini mempunyai karakteristik yang unik dari segi keberkesanan bahan, rekod penyelenggaraan dan jangka hayat. Oleh itu, kajian ini dilaksanakan untuk mengenal pasti keberkesanan bahan dan jangka hayat 'steel reinforce concrete' dan 'flexible bitumen with polymer modified binder' dalam pembinaan landasan. Kajian ini telah dilakukan di KLIA kerana KLIA merupakan lapangan terbang utama di Malaysia dan menerima ribuan laluan kapal terbang di kedua-dua landasan utama setiap tahun. Keberkesanan dan jangka hayat landasan di KLIA adalah sangat penting dalam memastikan operasi di lapangan terbang berjalan dengan lancar dan tiada gangguan berlaku. Dua orang jurutera di bahagian kejuruteraan KLIA adalah responden sasaran yang membantu manjawab soalan tertutup kaji selidik direka untuk kajian ini. Soalan kaji selidik akan menyentuh beberapa elemen dalam struktur landasan yang menggunakan 'steel reinforce concrete' dan 'flexible bitumen with polymer modified binder' dan bagaimana bahan ini bertindak balas dari segi sifat bahan, kekerapan penyelenggaraan, kos dan masa diambil untuk menbina dan menyelenggara landasan, dan jangka hayat landasan. Di pengakhiran kajian ini, keputusan kajian bedasarkan keberkesanan bahan dan jangka hayat kedua-dua bahan telah memilih 'flexible bitumen with polymer modified binder' berbanding 'steel reinforce concrete' kerana karakteristik bahan tersebut sesuai dengan pembinaan landasan dan spesifikasi yang diperlukan di KLIA. Pelbagai jenis struktur bahan landasan dan pendapat dari jurutera daripada lapagan terbang yang lain adalah disyorkan agar mendapat lebih penghuraian dalam teknologi pembinaan landasan dan boleh menjadi rujukan untuk pembinaan landasan pada masa hadapan.

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ACN	Aircraft classification number
FAA	Federal Aviation Administration
KLIA	Kuala Lumpur International Airport
MAB	Malaysia Airport Berhad
PCN	Pavement classification number

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In this chapter, seven sections will be evaluated and discussed to explain in detail about the study. Those sections are background of study, problem statement, research objective, research question, scope and limitation of the study, significance of study and expected result. The study will clarify briefly from the aim of the study until the expected result that might be get at the end of the study.

1.2 BACKGROUND OF STUDY

Kuala Lumpur International Airport (KLIA) is one of the largest airports in the world that was designed to handle 25 million passengers and one million tons of cargo per annum. The airport is located 50 kilometers away from the capital of Malaysia, Kuala Lumpur, but several express highways and trains are built so that people can go to the airport with ease. There are two main buildings which are, satellite building and terminal building that will be used for all passengers to embark and disembark the airplane for domestic and international flight. The design of KLIA has its own specialty to handle Malaysia tropical weather.

More than 4,000 meters of runway were built for this airport in order for modern and big aircraft to take-off and landing. Kuala Lumpur Air Cargo Terminal and Low Cost KLIA 2 were built near KLIA in order to make that area the hub for aircraft from around the world to enter Malaysia using air travel. Two runways were built on the left and on the right sides of KLIA, Runway 1 (14L/32R) and Runway 2 (14R/32L). Since KLIA can hold millions number of passengers, the runway structure of KLIA must be able to withstand the roughness and extreme force of aircraft tire rubbing and squealing towards the surface of the runway in every minute.

It is important for engineers to construct runways for KLIA that can hold so much energy transfer from the tire of the aircraft to the surface of the runway. The selection of proper material is an important parts in designing the best structure to be used in runway construction. For more than ten years, development and findings by the researcher have shown that the technology in choosing the best runway material has become the important part of constructing a better runway for the future. Materials like steel reinforce concrete and flexible bitumen with polymer modified binder are the technology that have been upgraded from conventional concrete and asphalt pavements. Concrete pavements have been used for constructing highways, airports, streets and other type of infrastructure. Material enhancement in concrete pavement makes the structure more durable and provide many decade of service with little or no maintenance (Hoel and Short, 2006). Modification of asphalt was also become attractive because the price of bitumen had increased and the modification shows better structure behavior compare to conventional asphalt pavement (Kandhal, no date).

Steel reinforce concrete had been selected as a material to be used in runway construction for years after several research in concrete technology. Advantages from restructuring conventional concrete pavement had shown that, runway safety issues, runway structure behavior and project cost and time in choosing steel reinforce concrete as a pavement present an impact in runways engineering. Steel reinforced concrete pavement offers a potential economic advantage over conventional unreinforced concrete pavements and help in enhancing its structural behavior (Ahmed, et al, 1998). Reinforced concrete are widely used in both transportation engineering, to construct highway and airport pavements and bridge decks due to their mechanical strength, good surface finish, durability and economy (Guissini and Mola, 2012). This new conception was proven to be very effective as the introduction of an adequate amount of steel reinforcement allows to maintain the crack within the desired limits (Guissini and Mola, 2012). On the other hand, steel reinforce concrete had promote and show that issue that always arises when conventional concrete pavements is used had been solve and better life span of the runway structure was improved.

Flexible bitumen with polymer modified binder is the prove that engineering technology had been improved from the conventional asphalt pavement that usually being use for old runway. KLIA for instance use this type of material to build their runway when it is done couple of years ago. Past research had shown that polymer modified binder gives so many advantages, improve the overall structure and cut cost in making such material. Fatigue structure improvements, workability to work in all temperature and increased structure durability had been the evidence that show how well this material performs (Kandhal, no date). Many publications have indicated that the use of a polymer modified binder contribute to a beneficial effect with regard to resistance in several tough condition (Lu, Isacsson and Ekbald, no date). The reason why many airport around the world use this type of material is answered in several past research that show how well this material perform when it is dealing with the force delivered by the aircraft.

Aircraft engines, especially the big aircraft normally produce high heating temperature through its exhaust. When the pilot revs the aircraft engine, thrust produce by the engine is enough to blown away a family sedan. Boeing 747 aircraft that weighted during the take-off is 447,969 kg and the amount of thrust produce is 66,500 lb. So, the toughness and the shear properties of the runway structure are really being tested at the time the aircraft take-off and landing on the runway. Considering the material and the ingredients of both steel reinforce concrete and polymer modified binder, the amount of pounding force towards the runway are be able to be hold by the material that used to build the runway.

Time and cost are the very vital element in a project. In project time and cost management, input, tools and technique, and output are the process that need to be taken into considerations in order to make the project on time and within budget (Phillips, 2008). Runway construction needs to take time to be design and built, appropriate cost need to consider. This is because, proper deliverable is important so that the amount of work in maintaining, changing plan and redesign the runway can be taken as smartly as possible contemplating the time and cost for entire construction of the airport to finish.

As a conclusion, both of these materials have been smartly defined in order to have the ultimate solution for constructing the airport runway. All possible cause and defect have to be investigated and experimented; research and development need to be conduct so that no future issues arise.

1.3 PROBLEM STATEMENT

Steel reinforce concrete and flexible bitumen with polymer modified binder pavement structure that being used to construct runways for every airport around the world must withstand the load of the aircraft when it is going to land or take-off because in this situation, the pilot will throttle the engine of the aircraft to a certain limit of thrust in order for it to fly or to reduce the speed while landing. The weight of the aircraft when it is going to taxi, landing and take-off will also affect the runway in term of structural behavior such as bending, cracking, depression and rutting. High temperature of heat will be released by the engine exhaust in this circumstances and it might harm the runway structure. Steel reinforce concrete structure at some point might have a problem to handle such heavy and surprise situation that usually occur on the airport runway. Meanwhile, flexible bitumen with polymer modified binder at some point could no longer hold the engine blast and loads transmitted by the aircraft.

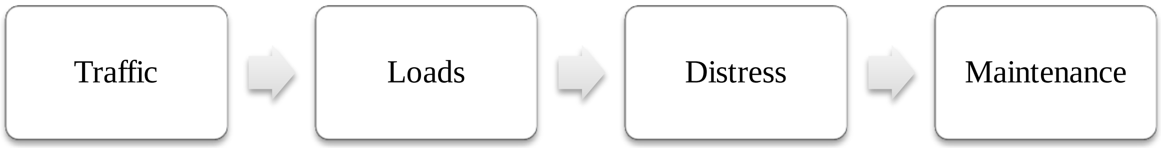

Figure 1.1: Normal behavior for runway structure

Past studies had shown that there are several weaknesses when using steel reinforce concrete. One of the issues that arise is that the cost of using this material is sometimes quite high for the usage in runway construction. Compare to the highway steel reinforce concrete pavement, the structure specification of the runway pavement must be higher and follow the Federal Aviation Administration (FAA) standards. Every year, the runway especially at the main airport will receive thousands of aircraft passes. The thickness and the amount of reinforce use for the runway pavement must be sufficient enough to hold the aircraft take-off and landing load (Delatte, 2008). The cost of using this material is also quite expensive but the frequency of maintaining the runway is low. Although the steel reinforce concrete runway maintenance will be quite rare to conduct, the cost of each maintenance is quite costly. If an accident happen on the runway that might shredded its surface, the cost of repairing the runway will be high because of the complex structure of the pavement. The time consumes are also longer considering the 28 days curing time for concrete.

There are also the drawbacks when choosing flexible bitumen with polymer modified binder as a runway material. Although this material was greatly used at the airport around the world because of its low in construction cost but the maintenance frequency of this material was quite high. Hence, the cost of repairing and maintaining this type of runway structure will need to be repeated in a matter of time. The usual behavior that occur for this type of structure are cracking, rutting and depression especially in runway pavement because of the loads, thrust and repetition of aircraft passes on the runway. The capability for this structure to hold aircraft load at the busy airport may always become the main concern for engineers because of its structure that is not as good as steel reinforce concrete. The way to produce the polymer modified binder was also said to be complex because of the chemical properties of bitumen and polymer that need special chemical procedure to produce (Kandhal, no date).

As a conclusion, both of these materials have their own weakness point and not entirely perfect. Initial cost, long term issue and the structural behavior of steel reinforce concrete and polymer modified binder must be consider in order to get better development in runway construction.

1.4 RESEARCH OBJECTIVES

There are two objectives in accordance towards the study and the objectives are:

1. To compare the effectiveness of the runway structure when using steel reinforce concrete and flexible bitumen pavement with polymer modified binder.

2. To determine the life span of steel reinforce concrete and flexible bitumen with polymer modified binder.

1.5 RESEARCH QUESTIONS

This study will raise several questions to evaluate in details about the study objectives. The questions are:

1. How good the structure of steel reinforce concrete in comparison with flexible bitumen pavement with polymer modified binder when it is consider to be used in runway construction?

2. Can both steel reinforce concrete in comparison with flexible bitumen pavement with of polymer modified binder structure hold the extreme condition on the runway (load, landing and take-off force of an aircraft)?

3. How steel reinforce concrete in comparison with flexible bitumen pavement with of polymer modified binder effect the project time and cost considering the beginning of construction, short-term and long-term aspect of the project?

1.6 SCOPE AND LIMITATION OF THE STUDY

The study will be conducted at Kuala Lumpur International Airport (KLIA) located at Sepang, Selangor. The location of KLIA is near to Kuala Lumpur Air Cargo Terminal and Low Cost Airport KLIA 2. These airports share the same runways which are Runway 1 (14L/32R) and Runway 2 (14R/32L). These runways can be used by small aircraft and super-jumbo aircraft ever invented. At KLIA, the department that manages the runway will be visited in order to collect the data. The people who are responsible for the runway such as the person in charge for the runway pavement or the runway engineer will be given a questionnaire to get the data needed. The runway maintenance, runway development and services, reports and all the data about the runway such as its structure and plan are entirely manage by this department.

However, there are some limitations associated with the study. First, are the limitations on the materials that will be used to analyze in order to get the result of its effectiveness and life span in runway construction. There are only two materials that are studied which are steel reinforce concrete and flexible bitumen with polymer modified binder. Secondly, the scope of this study is limited to only one airport in Malaysia. The study will only be conducted at Malaysia main airport, KLIA.

1.7 SIGNIFICANCE OF STUDY

The significance of this study is to show how steel reinforce concrete and flexible bitumen pavement with polymer modified binder can influence the construction of a runway by considering the effectiveness and life span of both materials. This study may provide the knowledge for project manager, engineer and contractor later to choose appropriate material to develop a runway especially in Malaysia after looking into some important statements that highlighted on both of the materials in term of its effectiveness and life span. General public such as Malaysian citizen can also learn and be expose to the specification of local airports runway and how good the technology that have been used and will be used for KLIA runway development.

1.8 EXPECTED RESULT

The expected result of this study is to be successfully determining the effectiveness when using steel reinforce concrete and flexible bitumen pavement with polymer modified binder. Advantages and disadvantages of these two materials will be taken into account to check the performance of the materials in today's runway construction. Structure performance, drawbacks and specification will be analyzed lightly in order to answer the research objective and research questions but no detail engineering specifications will be written out in the overall result of the study. Life span and maintenance issue of both materials can also be determine in order to get better perspective of using these material n runway construction.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, journals, articles, books and past research related to the study will be discussed, evaluated and summarized. This section will be divided into four main topics. The first topic will discussed about runway in general view. The second topic is the introduction of the runway at KLIA. The third and fourth topic will be about the same except the material that will be evaluated in constructing the runway are steel reinforce concrete and flexible bitumen pavement with wearing course of polymer modified binder.

2.2 RUNWAY IN GENERAL VIEW

In most of the major airport, the runway was developed to cope with any type of aircraft like the civilian and military aircraft. Most of today’s aircraft were design to operate according to a wide range of available runway lengths and design (FAA, 2005). The critical factor in designing available runway lengths at the airport is that the runway must be construct above a certain sea level for an environment purposes and the temperature at the airport need to be at the certain suitable level so that it can cope with the runway material and structure. Moreover wind velocity, airplane operating weights while takeoff and landing and a flap setting are important for such airplane to maneuver on the runway surface setting. The planning period for designing runway according Federal Aviation Administration 2005 was at least five years.

The majority of the airports provide a single primary runway. But for major airport like in Sepang, Malaysia that have three different terminals such as KLIA 1, KLIA 2 and cargo terminal, two main operating runways are most notably appropriate. According to FAA 2005, airport authorities, in certain cases, require two or more primary runways as a means of achieving specific airport operational objectives. The most common operational objectives are to:

1. Better manage the existing traffic if the volume exceeds the capacity capabilities of the existing primary runway.

2. To cope with forecasted growth that will exceed the current capabilities of the existing primary runway.

In the cases of the airport that must have two primary runways like KLIA, both of these runways must have the same main characteristics such as length, specification and accommodation for any unprecedented circumstances.

For all kind of airport runways around the world, safety concern contributes to a major part in designing the runway. Skid resistance on runway for example, is a critical safety concern that affects stopping distance and directional control of aircraft when it is about to takeoff or land (Mauro, et al, 2012). The smoothness of the runway may also affect the accident that let the aircraft to skid out of control. Runway roughness may cause the on-board vibrations, which prevent pilots from reading the accurate aircraft instruments during takeoff and landing. Tire to pavement contact may also reduce which will eventually affect the aircraft braking system and degrade aircraft stopping performance (Mauro, et al, 2012). Roughness has therefore need to be measured and/or evaluated during airport pavement construction and compare with the standards that had been specify when corrective actions have to be undertaken to restore surface smoothness. Safe operations and structural integrity of aircraft in airport pavement surface smoothness will also affect the safety of aircraft operations and comfort of passengers.

On the other hand, the increasing of airport traffic as can be seen nowadays is making the planning and the execution of runway pavement design to be cope with the current intervention that demand for a better runway structure (Kanazawa, et al, 2009). As a result, the key element for managing and designing airport pavements is to capture accurately and to forecast the performance of the latest and future demand of the runway.

2.3 INTRODUCTION OF RUNWAY AT KLIA

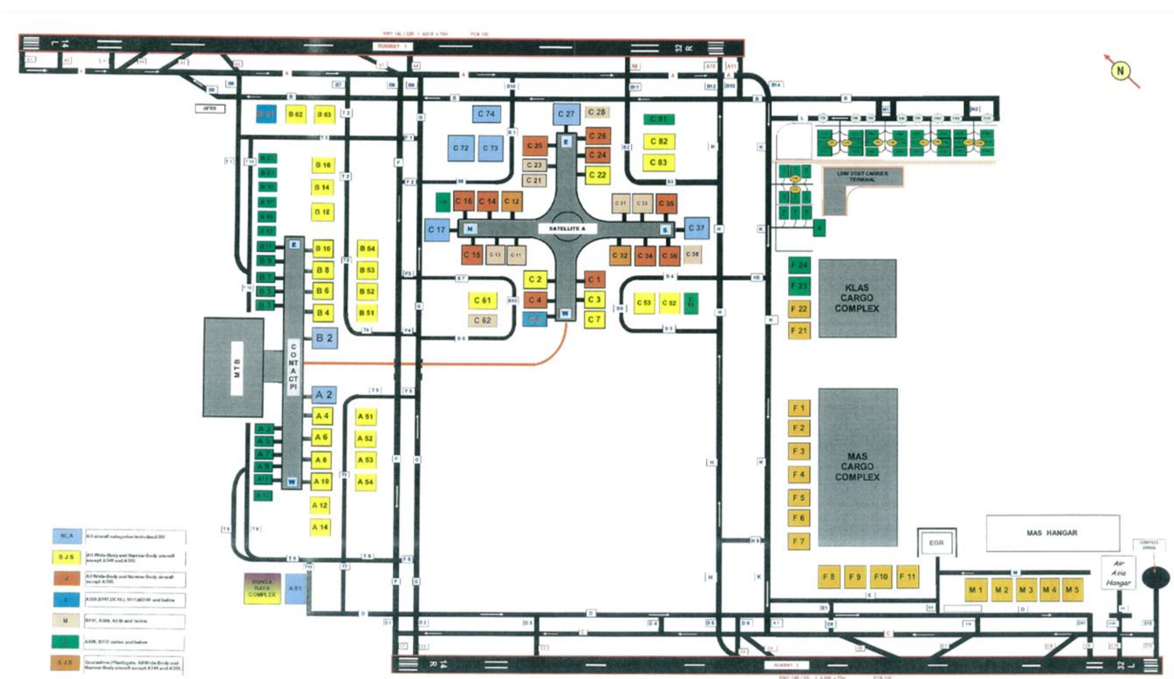

Figure 2.1: KLIA Plan

KLIA is the largest airport in Malaysia that consists of several terminals such as satellite terminal, domestic terminal, cargo terminal and low cost carrier terminal. More than 100 domestic and international flight inbound and outbound from KLIA every day. There are two main runways in KLIA which are Runway 1 (14L/32R) and Runway 2 (14R/32L). Both of these runways can handle as many types of commercial aircraft from the small Cessna plane until the biggest commercial plane ever made, the Airbus A380.

Engineers and people that involved in developing and building KLIA have taken into account any possibilities that benefit and harm the runways. The runways have fully equipped with proper lighting, runway markings, sign for pilot to identify the runway distance and runway safety area. All the standards to make the runway have fully obeyed the Federal Aviation Administration (FAA) standard. The runways are 2.5 km apart and the lengths of the runways are (each 4,000m by 60m). The usages between these two runways are also different in term of air traffic arrangement, one is for landings and the other one is use for take-off. Current material to made these runways are flexible pavement with wearing course of polymer modifies binder.

2.4 RUNWAY USING STEEL REINFORCE CONCRETE

It is logical that today's bigger and heavier airplanes require longer, sturdier runways for landing. Several research had been done by engineers and people who expert in runway construction to improve the structure of runway pavement. Demand for more heavy duty and tough material to build a runway are now being discussed worldwide by the groups of engineer and pilot. Safer, more reliable, state of the art engineering technology and able to withstand any potential pressure cause by the latest aircraft are the issue that hardly being talked and discuss in today's runway construction. Well-established design procedures have been extended to keep pace with the rapid growth in gross weight of an aircraft. In term of length issue, existing runway pavement need to be prolong in order to meet the landing criteria made by super big aircraft. A runway has to be long enough to allow the plane to become airborne and it must be thick enough to withstand the load (Randall, 1989).

Estimating future traffic is one of the most important factors in airport pavement design. Data on expected future operating and load conditions have to be gathered in order to forecast the future flow of air traffic in and airport. Data can be collected from several sources, such as commercial airline operation future schedule and airport operating officials (Packard, 1995). The important factor to gather up such data is to determine how much aircraft will be using the runway so that the planning on upgrading and enriching the runway pavement and maintenance can be develop. When runway in a certain airport id frequently being used, the pavement surface texture will be affected. Aircraft exhaust that produces high temperature and high velocity blast, high pressure tires on pavement during contact, and fuel spillage create problems for the runway pavement. However, the design of the latest aircraft that have been technologically improved such as attaching more pressure efficient multi gear indicate that some changes in design practices of the aircraft do improved the effectiveness that can mitigate the risk on damaging pavement.

Nowadays, plain and reinforced concrete are widely used in transportation engineering, to construct highway and airport pavements due to their mechanical strength, good surface finishing, durability and economy (Guissini and Mola 2012). The usage of steel reinforce concrete provide a better structural experience on constructing a runway because of its reliability and durability. Wide range of pavement design strengths using plain and reinforce concrete, such as thin pavements design to serve light commercial aircraft at small general aviation airports to thick pavements serving heavy military bombers have been shown for many years (Packard, 1995). For an example, according to Brown, 1996, airplanes that come in for a landing at the Dallas International Airport are able to glide smoothly onto a new concrete runway that meets demanding construction standards for smoothness. This example shows that the implementation of using concrete base material for runway pavement give so many advantages not just for the airport itself, but also the airline who become the customer for the airport.

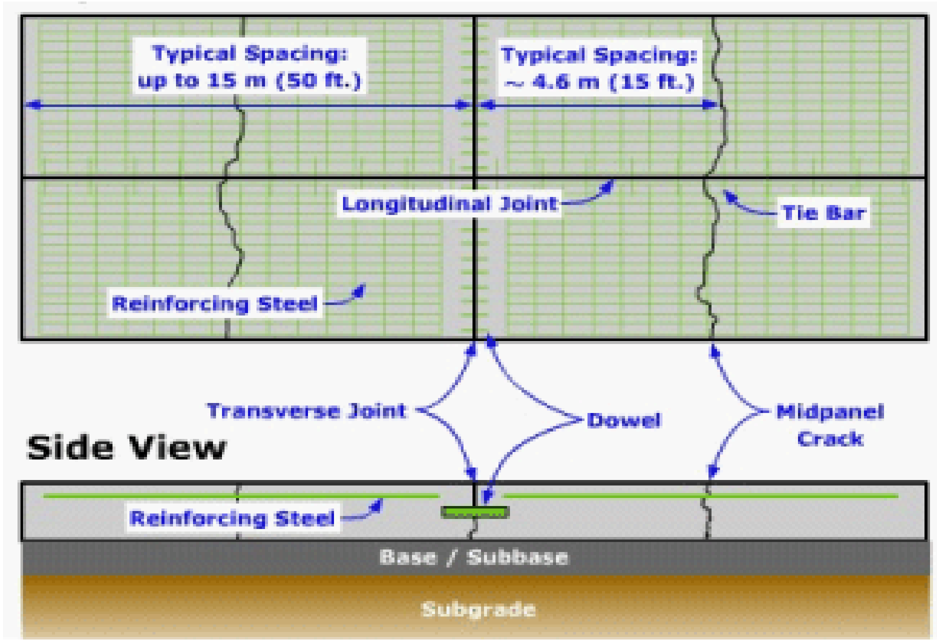

Figure 2.2: The structure of steel reinforce concrete

The structure of steel reinforce concrete consist of several parts. The main part of it are concrete, reinforcing steel, dowel and tie bar (refer Figure 2.2). The surface of steel reinforce concrete is usually granite because of the surface smoothness. The dowels parts are for load transfer across the longitudinal joints. Meanwhile, the tie bars at the middle of the steel reinforce concrete structure help to transfer load across the structure. The bars tie the lanes together so they won't creep apart with temperature and moisture changes. The tie bars actually help create a hinge at the longitudinal construction joints. Because of the rigidity of the steel reinforce concrete pavements, the loads that spread over the large areas of the subgrade produce a very low pressure on the subgrade. Recommended practices are given for the design reinforced and continuously reinforced pavements in several studies. The practices recommended in the study consist of joints and jointing arrangements, the use of tie bars and dowels and the treatment of subbases and subgrades (Packard, 1995). This element is a very important factor that needs to be taken into consideration when engineer wants to design and develop the pavement especially one that need to handle an extreme pressure and toughness.

Several major factors that involved in the structural design of concrete airport pavement are:

1. Properties of the concrete.

2. Type of aircraft and loads anticipated on the pavement and approximate frequency of operation.

3. Type of pavement being designed, such as runway.

Another type of steel reinforce concrete pavement is continuously reinforced concrete. This type of pavement is one with no transverse joints except where the pavement intersects (Packard, 1995). According to Packard, 1995, he design for this type of pavement must:

1. Provide adequate pavement thickness for the aircraft loads.

2. Provide enough longitudinal reinforcing steel so that transverse cracks are kept tightly closed and occur at the desired spacing.

The joint provide a smooth interfaces but does not have as high a load transfer capacity. Therefore, it is necessary to strengthen construction joints. This is done by installing additional deformed bars of the same size as the longitudinal reinforcement. The quantity of steel used can vary from 0.05 to 0.30 percent of the cross-sectional area of pavement, depending on joint spacing and several other factors (Packard, 1995).

Every airport runway in the world needs proper maintenance in order to keep the runway work well. For example, the runway pavement at India airport suffered widespread cracking that eventually need resurfacing (Ahmed, et al, 1998). This is because, proper maintenance are not being conducted. For most aircraft, the gear load can be estimated from the gross aircraft weight with the assumption that 93 to 95 percent of the weight is on the main gear (Packard, 1995). Bending of concrete pavement under wheel loads produces