Premature failure of road network

Bahria town ltd started its development works in 1996 as a joint partner with Bahria foundation initially British Columbia were the consultants on the project. The extraordinary progress rate and high quality consultancy work of British Columbia (pvt) ltd was thought to be a big hurdle in the progress rate, eventually the agreement with the consultants terminated and Bahria Town (pvt) Ltd formed its own consultant wing. Unfortunately the consultancy wing failed to develop because of incompetent individuals who can really invest their heart and souls to address core issues . Site management and technical / top supervision issues were ignored . Today Bahria Town is facing problem of premature failure in its road network.

Most of the road network has not been under projected traffic for which it has been designed; even then road failures are prominent . Most common failures depictive are settlement of road, flexural cracking, weathering of the road network. The mechanism of road failure is quite complex and it is tedious to identify the root cause of failure.

The approach adopted was to analyze road network truly depictive of premature pavement failures, the representative sections were selected from the road network under study . Various field and laboratory test were performed on each section to determine the cause of premature pavement failures.

The investigation revealed that mix produced from asphalt plant fails to meet specifications. The compaction of HMA and subsequent road layers is not adequate. The source gradation for aggregate base is improper . The Plasticity of fines is not in tolerance range. Pavement structural design

depths were not executed on site besides poor workmanship and improper patching procedures.

Keywords: Premature Failure, Flexural Cracking, Weathering, Source gradation.

Undertaking

I certify that research work titled " To investigate the causes of Premature Failure of Road Network of Bahria Town & to propose its Remedial Measures" is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

Tehseen Ellahi

2k9-MSc-Trans-05

Acknowledgements

This research work is obviously a result of the initial encouragement and support in admission to the MS Transportation (Taxila) by Ehsan ul Haq, the Director General Planning and Design, Bahria Town (pvt) Ltd. Extraordinary help and support form Rana Zulfikar Ahmed Khan , Site Manager Bahria Town (pvt) Ltd. Continuous encouragement, and valuable input from Dr. M. A. Kamal, Director Taxila Institute of Transportation Engineering (TITE) and Dean, Faculty of Civil and Environmental Engineering, University of Engineering and Technology (UET) Taxila. There guidance, comments and suggestions from time to time, are gratefully acknowledged.

1. 2. 2 Rigid Pavements

In rigid pavements the stress is transmitted to the sub-grade through beam/slab effect. Rigid pavements contain sufficient beam strength to be able to bridge over the localized sub-grade failures and areas of inadequate support.

Factors effecting Pavement Performance

There are numerous factors influencing the performance of a pavement, the following five are considered the most influential (Transportation research board, England; April 1985)

1. 3. 1 Traffic

Traffic is the most important factor affecting pavement performance. The performance of pavements is mostly affected by the loading scale, arrangement and the number of load repetitions. The damage caused per pass to a pavement by an axle is defined relative to the damage per pass of a standard axle load, which is defined as a 80 kN single axle load (E80). Thus a pavement is designed to withstand a certain number of standard axle load repetitions that will result in a certain terminal condition of deterioration. (Kamal M. A. et al., 2009)

1. 3. 2 Moisture

Moisture significantly reduces the supporting ability of gravel materials, especially the sub grade. Moisture enters the pavement structure through capillary action. The resulting action is the wet surface of particles, excessive movement of particles and dislodgment which ultimately results in pavement failures. (Terrel 1990)

1. 3. 3 Sub grade

The sub grade is the lower layer of soil that supports the wheel loads. If the sub grade is not strong enough the pavement will show flexibility and finally the pavement will fail. Pavement will fail to perform ideally if the variation in particles behavior is not catered for in the design.

1. 3. 4 Construction quality

Pavement performance is affected by poor quality construction, inaccurate pavement thicknesses, and adverse moisture conditions. These conditions stress the need for skilled staff and the importance of good inspection and quality control procedures during construction.

Pavement performance is dependent on where, when and how maintenance is applied. No matter how good the pavement is built, it will deteriorate with time based upon the mentioned factors. The timing of maintenance is very important, if a pavement is allowed to deteriorate to a very poor condition, as illustrated by point B, then the added life compared with point A, is typically about 2 to 3 years. This added life is about 10 percent of the total life. The cost of repairing the road at B is four times of the cost required at A. The delay of maintenance hold implications, in that for the cost of repairing one poorly weathered road (Point B), four roads at point A would have to be postponed, which would mean that in a few years the rehabilitation cost could be 16 times as much. Thus, differing maintenance because of budget constraints will result in a significant financial penalty within a few years. (www. nra. co. za/live/content. php)

History

Bahria town is a modern township planned on an inspiration drawn from the home of American Society of civil engineers i. e the city of Reston, Virginia. The designing of its town ship is based on the most modern and strict criterion.

It is located between the GT road and Islamabad Bahria town borders Safari Park on the northern side and is bounded to the south and west by Soan river and the Korang respectively.

Town planning for Bahria Town has been done taking full advantage of the layout of the natural ground. Roads have been designed according to the traffic intensity rush hours. They have been standardized as 30, 40, 50, 60, 80 and Main Boulevards with the configuration of Pavement sidewalks and green areas.(www. bahriatown. com/index. php)

Problem Statement

Bahria Town (pvt) Ltd development represents a unique mark of distinction for Pakistan. Over a period of decade Bahria Town has emerged as Asia’s largest private property developers.

The dilemma is that the capital involved is huge and to meet market demands common Engineering practices & quality assurances are being ignored on account of time savings.

One of the major problem , that Bahria Town that face today is related to premature failure of road network.

Objectives

The main objective of the study was to highlight the causes of pavement failures and to propose the remedial measures.

Methodology

Reconnaissance survey in study area to identify problems.

Selection of test sections based upon road classification and distresses for deep testing analysis.

Extraction of samples from the test sections for various laboratory testing.

Comparison of various parameters between damaged and undamaged portions of test sections.

Recommendations on the basis of investigation.

Chapter 3

Chapter 3

Introduction to Study Area

Pavement Evaluation Process

Pavement evaluation is the first step in the development of pavement rehabilitation alternatives for the project . It is the process of learning the existing pavement system to understand the extent and the cause of problems prior to developing a rehabilitation plan.(www. pavementinteractive. org)

Evaluation at Road Network Level

Monitoring of the network is carried out at on a network level to define the status of an entire pavement network as part of the pavement management system . To achieve the said objective the road network of Bahria Town was divided in different zones . Preliminary reconnaissance survey was carried out to access the pavement condition of road network . The object was to confine the study and help prioritize and select the evaluation at the project levels. The road network under study is Safari valley. (Design report on Bahria Town, ESS. I. AAR Consultants)

The justification behind selecting this study zone is that this zone is fully developed and in the possession of the residents therefore it is more realistic to study the road network performance of this zone.

History

The idea of Safari Valley was conceptualized in 2000 confirming to planning parameters of the cities of Ruston, Virginia, USA. Ruston being the American society of civil engineers has been planned in the most beautiful manner, the next year Safari Valley lunched another housing project. One of the aims of lunching this scheme was to provide a modern housing scheme with all the amenities for the general public at an affordable cost. Any middle class person desirous of buying a plot in Islamabad/Rawalpindi could not do so as the price in Islamabad/Rawalpindi is beyond the reach of the common man.. This scheme is planned and designed for the low-income people of the country to provide them affordable housing.(www. bahriatown. com/index. php)

Location

The Safari Valley is located in Southern part of Rawalpindi City, adjacent to Takht Pari forest on Japan Road. This site falls in Mauza Gali. The main access to this scheme is through Japan Road from G. T. Road, 3 Km from High Court towards Lahore. 120′ wide newly constructed Bahria Expressway along River Soan is another access to this project which is completed a year ago.(www. bahriatown. com/index. php)

Untitled

Figure 3: Study area Location in road network

Road Network

The proposed colony has been planned according to the contemporary principles of planning and design criteria of Tehsil Municipal Administration (TMA) for private housing schemes. Following three types of roads has been proposed.

Primary Roads 120 Feet wide& 80 Feet wide

Collector Roads 65 Feet wide

Streets 40 Feet wide

The safari valley has 37. 880 km of 40′ wide roads, 6. 083km of 65′ wide roads, 1. 23 km of 80′ wide roads and 4. 0 km of 120′ wide roads.

General Considerations

It is desired by the consultant to provide the sub grade strength of the area in general for the construction of the internal roads. The purpose of the

structural design is to limit the stresses induced in the sub grade by the traffic to a safe level at which the sub grade deformation is insignificant whilst at the same time ensuring that the road pavement layers themselves do not fail in any way within a specified period of time . In most design methods it is assumed that the routine and periodic maintenance is carried out during the design period of the road and that at the end of the design period , relatively low level of detoriation has occurred.(Structural design of Pavement at Safari valley, SS Soil explore Consultants)

For the design of the flexible pavement the following factors should be kept in mind for guidance

Economic Considerations

Effect of climate

Variability in the material Properties

Construction Control

Uncertainty in traffic forecasting

Variability in material properties and construction control is generally much greater than desired by the engineer and must be taken into account explicitly in the design process. In practice only it is actually the variability of the sub grade strength that is considered and all other factors are controlled by setting out minimum acceptable values for the key properties by means of the specifications.

Nevertheless, it is the task of the designer to estimate the likely variations in layer thickness and material strengths so that the realistic target values and tolerances can be set in the specifications to ensure the satisfactory road performances can be guaranteed as far as possible.

Design basis

The purpose of the structural design is to limit the stresses induced in the sub grade by the traffic. Estimating the amount of traffic and the cumulative number of equivalent standard axles that will use the road over the selected design life assessing the strength of the sub grade soil over which the road is built by selecting the most economical combination of the pavement materials and layer thickness that will provide the satisfactory service over the design life of the pavement when appropriate maintenance is carried out.

In following paragraphs the component layers of a flexible pavement are referred in these terms:

Surfacing

This is the upper most layer of the pavement and will normally consist of bituminous surface dressing or a premixed bituminous material . When premixed materials are laid in two layers these are known as wearing course and base course (or binder course)

Road Base

This is the main load spreading layer of the pavement . It will normally consist of crushed stone or gravel , or a gravelly soil , decomposed rocks, sand and sandy clays stabilized with cement , lime or bitumen.

Sub Base

This is the secondary load spreading layer underlying the road base . It will normally consist of material of lower quality than that used in the road base such as un processed natural gravels , gravel-sand or gravel-sand-clay. This layer also serves as a spreading layer preventing contamination of the road base by the sub grade material

Capping Layer

Where very weak soils are encountered capping layer is sometimes necessary. This may consist of better quality sub grade material imported from elsewhere or existing sub grade material improved by mechanical and lime stabilization.

Sub Grade

This is the upper layer of the natural soil, which may be undisturbed local materials or may be soil excavated elsewhere and placed as fill. In either case it is compacted during the construction to give it adequate stability.

Traffic

In the present case no definite traffic pattern can be estimated as the construction period extends to a longer span . During the construction stage, the maximum traffic even over loaded trucks carrying mostly the construction material would apply. After the construction phase . the internal roads of the proposed project are subjected only to the light car traffic, which have very little destructive effect.

The Sub grade Condition

Following is the recommendations for the structural design of the bituminous surfaced roads for the proposed project. The existing sub grade at the site comprises of A – 4 soil with PI range of 5 to 8. Determining the sub grade strength is necessary for the road construction and required by the design engineer for the internal light traffic roads, which are required to carry up to (assumed traffic) 0. 5 million cumulative equivalent standard axles in one direction for the design life of 10 Years.

Field investigation and Sampling

All the field tests necessary for the design of the flexible pavements have been carried out . Test pit locations were selected so that overall picture of the sub surface can be examined . To do this samples from the different locations collected for the classification and California bearing ratio (CBR) . Following field and laboratory tests have been carried out in the detail

Field density and moisture content

Gradation analysis

Sieve analysis

Hydrometric analysis

Hydrometric analysis

AASHTO Soil Classification

Laboratory compaction test

Laboratory CBR on soaked conditions

Appreciation of the sub grade condition

The strength of the sub grade is commonly assessed in the form of California bearing ratio of the sub grade soil and is dependent on the type of the soil, its density and its moisture content

The likely in situ strength of the sub grade is difficult to assess directly but its value can be obtained from the relationship between CBR, density and moisture content which must be measured in the laboratory for the soil in question, and form the knowledge of in situ density and equilibrium moisture content of the soil under the road. The density of the sub grade soil can be controlled under the road within limits by compaction at suitable moisture content at the time of the construction. The equilibrium moisture content of the sub grade soil is governed by the local climate and the depth of the water table below the road surfaces.

For designing the thickness of the road pavement, the strength of the sub grade should be taken as that of the sub grade soil at the moisture content equal to the wettest moisture condition likely to occur in the sub grade after the road is opened to traffic.

In the present case, field as well as the laboratory testing of different locations was carried out for gradation index and strength parameters and soaked CBR etc. The result of these tests are attached at the end of the report

The CBR test shows the value of 3. 5% having the representative design value of 90% and 95% modified by the AASHTO density . CBR value is considered to be unsatisfactory for the design of the flexible pavement . Therefore it is strongly recommended to provide capping layer over the existing sub grade soil to provide structural support and improve drainage conditions at the site. The thickness comes out to be 8 inches.

Design Recommendations

The pavement design of the internal roads of safari valley was calculated using the AASHTO Interim guide . Details of which are below:

Method # 01

Out of the different methods available for calculating the road design, which cater for the repetition of the standard axle loads during the design life of the various traffic configurations expected on the road . This method caters for the site conditions and type of traffic likely to use the roads after the construction. The pavement design has been worked out as per Overseas Road Note No 31 (Transport and road research Laboratory, TRRL; Road note 31)

The Local soil is moderately plastic for which average soaked CBR value was calculated to be 3. 5 % and the same has been incorporated in the design calculations . In case of borrow /selected fill material is to be used for the making of the roads . The Laboratory CBR for that soil should not be less than 3. 5 % against 96 hrs soaking.

Method # 02

The pavement design of the internal roads of different categories is calculated using the simplified method as given in civil engineering handbook by Leonard Church Urquhart of which is given below.

Design Procedure

Using the graph (annexure A) against the clayey silt conforming to A-4 Soil and CBR of 3. 5 % the total thickness of pavement above sub base is 15 inches. Keeping a minimum thickness of 8 inches for the base course and the wearing surface the sub base is required to be 7 inches.

Since method 1 gave higher values method 1 was adopted.

Flexible Pavement Distresses

Roads have become important in our lives as a sole mean of communication. Modern roads are smooth, so people can travel easily from one place to another. Maintenance of road network is very important to ensure its continued efficiency and reliability. Normally roads are damaged due to environment affects, vehicular loadings and moisture.(Asphalt Institute , MS 16)

Asphalt pavement distresses can generally be classified as one of the following type:

Cracking

Distortion

Disintegration

Skid hazard

Surface treatment distresses

Distresses caused can be related to:

Wheel loads

Environment

Poor drainage

Material deficiencies

Construction related deficiencies

External causes(Utilities)

Cracking

Cracking takes many forms . To make proper repairs, it is first necessary to determine the cause of cracking . Maintenance procedures generally depend upon the cause of distress, the crack width and the amount of cracking in the affected area.

Reflective cracks

These are cracks in asphalt overlays that reflect the crack pattern in the pavement structure underneath. The pattern may be longitudinal, transverse, diagonal or block. Reflective cracks are caused by vertical and horizontal movements in the pavement beneath the overlay, induced by expansion and contraction with temperature or moisture changes. They can

also be caused by traffic or earth movement or by loss of moisture in sub grade by high clay content.

Edge cracks

These are longitudinal cracks 30 cm or so . They are caused due to lack of lateral support, settlement or yielding of the material beneath the cracked area . This may be the result of poor drainage , frost heave or shrinkage from drying of the adjoining earth. They may be accelerated by concentration of heavy traffic near the edge of the pavement as well as heavy vegetation near the pavement edge.

Block Cracking

They are series of interconnected cracks forming the series of large blocks, 1 to 3 m. Frequently they are caused by volume change of the fine aggregate asphalt mix that have a high content of low penetration asphalt and adsorptive aggregate , daily temperature cycles and aged asphalt. Block cracking is not load related.

Alligator Cracking

They are cracks that constitute to form series of blocks . They can be caused by various reasons such as excess deflection, sub surface moisture conditions, thin asphalt surface, excessive overloading, in adequate pavement design. If the asphalt surface is thin alligator cracking can quickly develop into potholing.

Slippage Crack

They are crescent shaped cracks resulting from the horizontal forces induced by the traffic. They result from the lack of bond between the surface layer

and the courses beneath. The lack of bond may be due to dust, oil, rubber, dirt water or other non adhesive materials between the two courses. The Slippage cracks may result from the mixtures having a high sand content, as well as due to improper compaction.

Linear Cracking

This category includes categories such as joint cracks, construction joints, shoulder joint cracks and diagonal cracks. Transverse and diagonal cracks can result from low temperature contraction of the pavement or from the shrinkage of the cement bound base or sub grade soils . Longitudinal cracks in the wheel path may be fatigue related and eventually progress into alligator and a random occurring Longitudinal crack can be indicative of the sideways yielding sub grade or fill area. The cause of joint cracks (thermal and longitudinal) can be related to the thermal stresses or insufficient compaction. They can also be caused by a weak bond in the joint.

Distortion

Pavement distortion is the result of asphalt layer instability or granular base and sub base weakness. Distortion takes a number of forms: rutting, shoving, corrugation, depression and up heave.

Rutting

Ruts are channelized depressions in the wheel tracks of the pavement surface. Rutting results from consolidation, lateral movement of the sub grade, aggregate base or asphalt layers under traffic load. Rutting may occur in the sub grade and sub base due to insufficient design thickness, lack of

compaction or weakness caused by moisture infiltration, down ward and lateral movement of the weak asphalt mixture under heavy wheel loads.

Corrugations and shoving

Corrugations and shoving are form of plastic movement typified by ripples across the asphalt pavement surface. They occur in the asphalt mixes that lack mix stability. It may also be caused due to excessive moisture in the granular base, contamination due to oil spillage or lack of aeration when placing mixes using emulsified and cut back asphalts.

Settlement or grade depression

Depressions are low areas of limited size that may be accompanied by cracking. They may be caused by traffic over loading or by consolidation, settlement or failure of the lower pavement layers.

Up heave or swell

Up heave is the localized upward displacement of the pavement due to the swelling of the sub grade. Up heave is most commonly caused by the expansion of ice in the lower courses of the pavement or sub grade. It may also be caused by the swelling effect of the moisture on the expansive soil.

Utility cut or patch failure

This is the failure of the utility installation or of a repaired area in the existing pavement. They usually are caused by lack of adequate compaction of the back fill, base or asphalt patch materials. Patch failures may also result from poor installation techniques, inferior materials or failure of the surrounding materials or under lying pavement.

Disintegration

Disintegration is the breaking up of the pavement into small, loose fragments. If the problem is not addressed the pavement disintegrates further until rehabilitation is required.

Raveling/Weathering

This is the progressive separation of the aggregate particles from the pavement surface downwards and from the surface inwards. Raveling usually occurs in wheel paths while weathering is found in non traffic zones and it extends over all surface.

Raveling is caused by lack of HMA compaction, construction of thin lift during the cold weather, dirty or disintegrating aggregates, too little asphalt in the mix or over heating of the asphalt mix. Raveling almost always requires the presence of both water and traffic to occur.

Potholes

Potholes are bowl shaped holes resulting from the localized disintegration. Most potholes occur in the pavements having thin asphalt concrete surface on an untreated aggregate base. Thin surfaces showing severe alligator cracking begin to lose the pieces of the asphalt out of the cracked area creating potholes.

Skid Hazards

One of the most common cause of the skid hazards in the asphalt pavement is a thin film of water on the pavement surface another is the thick film of water on the pavement surface that causes a high speed vehicle to hydro

plane. Slipperiness may also develop from the surface contamination such as from oil spillage or certain type of clay etc.

Bleeding or flushing

Bleeding or flushing is the upward movement in the asphalt pavement. This results in the formation of film of asphalt on the surface. Bleeding is identified by the pavement surface with a stick, glassy appearance that may be sticky to touch and usually occurs in hot weather . The most common cause of bleeding is excess asphalt in one or more of the pavement courses . Also traffic may cause the over compaction of the asphalt layers, forcing the binder to the surface.

Polished aggregate

These are the aggregate particles on the surface of the pavement that have been polished smooth. Some aggregates, particularly lime stone become polished rather quickly under traffic. Some type of gravel are naturally polished and if they are used in the pavement surface without crushing they will be a skid hazard. These polished aggregates are quite slippery when they are wet.

Surface Treatment Distresses

Because of the construction procedures being used, surface treatments may develop some defects that don’t occur in other type of pavement surfaces. These include loss of aggregate cover and streaking. Some of the asphalt pavement distresses such as corrugations, depressions, up heave, potholes and raveling occur most frequently in the pavement constructed with surface treatments.

Loss of cover aggregate

This distress is identified by the whipping off of aggregate by traffic from a surface treated pavement. Several things can cause loss of aggregate cover including weather too cool, fast traffic permitted on the new surface treatment too soon, a surface absorbing part of the asphalt, aggregates that are too dusty or too dry etc.

Longitudinal / Transverse Streaking

Longitudinal streaking is alternate lean and heavy lines of asphalt and/or aggregate running parallel to the center line of the road . Transverse streaking is the same phenomenon except that the direction is running transverse across the road way. Several things can cause longitudinal streaking including: improper height of the spray bar, incorrect asphalt pump speed, asphalt too cold, incorrect pump pressure etc. Transverse cracking is caused by spurts in the asphalt spray from the distributor spray bar. These spurs may be produced by improper pump speed, pulsation of the asphalt pump etc.