TIA Runway Overlay Project Failure:
A Case Study from Nepal

By Shailesh Nepal

History of Tribhuvan International Airport:

As per Wikipedia, Tribhuvan International Airport (IATA: KTM, ICAO: VNKT) is an international airport in Kathmandu, Nepal. It is the sole international airport in Nepal and has one domestic and one international terminal. At present, about 30 international airlines connect Nepal to destinations in Asia, Europe and the Middle East. The airport is about six kilometres from the city centre, in the Kathmandu valley.

The airport began as Gauchar Airport, named after the area of Kathmandu where it was situated. The formal beginning of aviation in Nepal occurred in 1949 with the landing of a lone, four-seater, Beechcraft Bonanza aircraft, carrying the Indian ambassador. The first charter flight took place between Gaucher and Calcutta, in a Himalayan Aviation Dakota on 20 February 1950.

In 1955, the airport was inaugurated by Ex-King Mahendra and renamed Tribhuvan Airport in memory of the king's father. The airport was again renamed Tribhuvan International Airport (TIA) in 1964. The first jet aircraft to land at TIA was a Lufthansa Boeing 707, which touched down on the 2,000 m runway in 1967. Nepal Airlines Corporation commenced jet operations at the airport in 1972 with Boeing 727 aircraft.

Chronological Development of TIA Runway

Initially, there was 1,140m long grass runway. The original grass runway was re-laid in concrete in 1957 and extended from 1,140 m, to 2,000 m in 1967. The runway was again extended from 2,000 m to 3,000 m in 1975. In 1985, the overlay of Runway 02/20 was done and in 1987 Taxiway overlay was completed both with Hot Mixed Asphalt Concrete (HMAC). Though the need for Runway Overlay was experienced since early 2000, the last overlay was done during 2009-2011 with HMAC.

Design Issues during 2009-2011 Runway and Taxiway Overlay with HMAC

One of the objectives of the Hot Mixed Asphalt Concrete (HMAC) design is to prevent rutting on the surface during hot summer days. The rutting on the surface is caused by the high impact load exerted by the aircrafts on the Runway Pavement during hot summer days when the ambient temperature rises above 30°C. The proper choice of Bitumen Grade in HMAC Pavement depends on the several factors; however; the effect of temperature and the load the pavement has to bear are considered major factors to prevent rutting.

Department of Hydrology and Meteorology (DHM) estimated from 1977 and 1994, the mean annual temperature to have increased by 0.06°C, and is projected to increase by another 1.2°C by 2030. Furthermore, summer days with maximum temperatures above 30°C are also increasing. U.K. Met Office recorded that average temperature of
Kathmandu was 23.4°C and 25.3°C in July in year 1976 and 2010 respectively.

During 1970s, only small aircrafts were operational. The Boeing 707 and 727 that first landed in TIA were no more than 100 MT in weight. Presently, AIRBUS 340 lands on TIA Runway whose landing weights is more than 350 MT.

In light of the above facts; both temperature and landing weights of aircrafts; designed Grade 80-100 Bitumen used in 2009-2011 HMAC Overlay should be considered as a major driving force for the rutting on the pavement. This article is intended to explore the current problems in the runway and propose remedial measures for the same.

Problems Encountered after 2009 - 2011 Runway Overlay

The problems on the newly overlaid surface of runway and taxiway was seen in June 2011 first time, the problem reoccurred in 2012 and 2013 as well. The impact of the runway problem in 2013 was more severe as many national and international flights were either delayed, cancelled or diverted to another airport on a number of occasions. In 19 August 2013, Civil Aviation Authority of Nepal (CAAN) confirmed that it has requested all international airlines to find alternatives to their wide-body aircrafts flying into the Tribhuvan International Airport (TIA) in Kathmandu, due to safety concerns. The announcement was made after potholes started to appear on the TIA runway, which has caused a number of international flights to be delayed, diverted or cancelled few weeks ago. Then this issue was published in some international newspaper, which not only conveyed the negative message to the foreign countries but also affected the Nepalese Tourism Business. Furthermore, this issue may affect adversely during future ICAO audits.

The following illustrates stepwise analysis of the problem with short description of each activity:

**High Impact Load:** The heaviest aircraft that land into TIA Runway is AIRBUS 340 whose maximum landing weight is more than 350 MT. With such a huge aircraft weight and high velocity at landing especially in touchdown area (the area where the aircraft first touches the runway during landing), there is very high impact loads concentrated in the wheel path.

Even if there is mild velocity while turning in turning pad or taxing, the pressure exerted by the aircraft will be considerably high due to turning maneuver and application of brakes. This may cause either premature deformation just after the newly laid HMAC Overlay or rutting on the Pavement surface during service Period.
Premature Deformation: As TIA has only one runway, the overlay works was carried out during NOTAM Hours i.e. 12:30 to 6:00 AM. As Marshall Design has been carried out to determine the Mix Properties at 60 degree centigrade, the pavement surface should be less than or equal to this temperature before opening to the air traffic. The cooling time varies depending on the weather, the more in summer and less in winter. Premature deformation of the Asphalt Pavement is obviously possible during hot summer days where the pavement surface remains hot (temperature more than 60 degree centigrades) even during the landing of aircraft.

Rutting: Rutting is the surface depression in the wheel path due to repeated loading in hot summer days. Pavement uplift (shearing) may occur along the sides of the rut. Ruts are particularly evident after a rain when they are filled with water. There are two types of rutting, Mix Rut and Subgrade rut. In case of TIA runway, the rut is a result of bitumen mix as the rut is evident only in top 30 mm of the surface while underlying surface is still intact. The Penetration grade 80-100 bitumen in the asphalt is a major driving force to rutting as it becomes very soft in summer.

Effect of Monsoon Rain: Whether it is premature deformation or rutting, monsoon rain makes the situation worse. In Nepal, monsoon starts just after the summer season. Hence, water starts accumulating on the rutted surface. It is also possible that water infiltrates to the Pavement as there is obviously cracks developed on the surface due to rutting. Water is identified as the main cause of Pavement distress as it accelerates de-bonding of the aggregates and bitumen. As the aircrafts intend to follow the same wheel path during landing, these water filled areas develop into potholes.

Patchworks as Emergency Maintenance: To resume air traffic, it is essential that all the developed potholes be filled with the asphalt as soon as possible. From structural point of view these patches exhibit less strength. Generally, patchwork is carried out during night. However, due to emergency of the situation, sometimes it has to be done in daytime, which causes disturbance to the air traffic and the aircrafts should either be delayed, diverted or cancelled depending upon the time required for patchworks.
Types of Bitumen and its Effect in Rutting

In Nepal the most widely used Bitumen is Penetration grade 80/100 and all types of Bitumen are generally imported from India. As per the Hindustan Petroleum Hand Book, the following types of Penetration Grade Bitumen are available in India:

Bitumen 80/100: The characteristics of this grade confirm to that of S 90 grade of IS-73-1992. This is the softest of all grades available in India. This is suitable for low volume roads and is still widely used in the country.

Bitumen 60/70: This grade is harder than 80/100 and can withstand higher traffic loads. The characteristics of this grade confirm to that of S 65 grade of IS-73-1992. It is presently used mainly in construction of National Highways & State Highways.

Bitumen 30/40: This is the hardest of all the grades and can withstand very heavy traffic loads. The characteristics of this grade confirm to that of S 35 grade of IS-73-1992. Bitumen 30/40 is used in specialized applications like airport runways and also in very heavy traffic volume roads in coastal cities in India.

Thus the lower penetration grade bitumen is less susceptible to rutting and has high strength to cater for the heavy traffic.

Research on Bitumen across the Globe to Prevent Rutting on the Asphalt Pavement

Several researches have been carried out during last two decades on the properties of bitumen in general and its resistance to rutting in particular as the problem of rutting became a major issue across the globe. In the USA, the Strategic Highway Research Program (SHRP) conducted a $ 50 million research effort from October 1987 through March 1993 to develop performance based test methods of Bitumen. One of the objectives of the research was to identify factor responsible for rutting in the Asphalt Pavements. The outcome of the research identified the invention of new type of Bitumen called Superpave. Superpave performance grading is reported using two numbers – the first being the average seven-day maximum pavement temperature (°C) and the second being the minimum pavement design temperature likely to be experienced (°C). Thus, a PG 58-16 is intended for use where the average seven-day maximum pavement temperature is 58°C and the expected minimum pavement temperature is -16°C.
The research also found out that Complex Modulus of the Bitumen (expressed as G*) is responsible for rutting. As per the test carried out on Dynamic Shear Rheometer as per AASHTO T 315 specification, G* value should be greater than 1000 MPa to prevent rutting and greater than 2,200 MPa (after RTFOT) to prevent fatigue cracking. However, in case of Kathmandu, only criterion for rutting is considered as the lowest temperature of TIA usually does not fall below -3°C and hence eliminating the possibility of Fatigue Cracking.

Another study conducted by African and Australian researches in various Asphalt Pavements in Australia and Africa derived a relation between G and Penetration grade of bitumen. As per the research, G* value came out to be 630 MPa and 400 MPa for Pen. 80 and Pen. 100 respectively. Therefore, it is noted that G* value decreases as the penetration increases and Bitumen Grade 80-100 is not able to prevent rutting as per AASHTO specification. They also developed a regression equation to correlate the relationship between Penetration and G value, which is as follows:

\[ \log (\text{Pen.}) = 2.971 - 0.381 \log (G^*) \] (i) (Log to the base 10)

These two researches can be analyzed and combined to derive the grade of Bitumen suitable for the better performance of the Asphalt Pavement in Kathmandu and specifically to prevent rutting during hot summer days. As per the data of the Weather Underground, an American based company, the seven days average maximum temperature for Tribhuvan International Airport is 31.7°C (June 2010) based on 2010 Annual Data. The empirical random tests suggest that the temperature of the Pavement could be as high as 26°C than air temperature. Hence, the maximum seven days average temperature of the Asphalt Pavement would be 57.7°C. Assuming the temperature to be 58 °C catering for the possible future rise in temperature due to the effect of Global Warming, the Performance grade PG 58-16 can be used as a standard for the purpose of calculating rutting during hot season; though PG Bitumen are not available in Nepal.

Minimum value of G* to prevent rutting (for PG 58-16 Bitumen) = 1000 MPa

Solving the equation (i) for G*=1000, the value of Pen. comes out to be approximately 67. Hence it can be derived that minimum grade of bitumen required in Asphalt Pavement in Kathmandu valley is Pen. 60-70. However, this derivation is for Highways and not for the Airfields.

Indian researchers have also modified penetration grade classification of Bitumen as a result of the research conducted by European researchers which found temperature as primary driver for viscosity of bitumen which, in turn, is the cause of the asphalt pavement rutting under the field condition. As a result of the research, Viscosity Grade Bitumen is commonly used in India nowadays rather than conventional Penetration one.
The following table suggests the appropriate bitumen Grade for HMAC Pavements in different temperature zones of Nepal

<table>
<thead>
<tr>
<th>S N</th>
<th>Max. 7 Days Average Temp. (°C)</th>
<th>Type of Bitumen (BS EN 12591)</th>
<th>Viscosity Grade (IS-73-2006)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&gt;35</td>
<td>Pen Grade 40-50*</td>
<td>VG-40</td>
<td>Terai Region</td>
</tr>
<tr>
<td>2</td>
<td>25-35</td>
<td>Pen grade 60-70</td>
<td>VG-30</td>
<td>Valleys such as Kathmandu,</td>
</tr>
<tr>
<td>3</td>
<td>&lt;25</td>
<td>Pen Grade 80-100</td>
<td>VG-10</td>
<td>Mountainous and Hilly Regions</td>
</tr>
</tbody>
</table>

*Subject to Availability

What Type of Bitumen to be used for Runway Pavements to Prevent Rutting?

There is no single and simple answer to this question as it depends on several factors including but not limited to existing runway surface, weather and temperature of the place, type of aircraft and its loading and so on.

It is often found in practice that airfield HMAC is designed the same as for a road HMAC and that often leads to deformation problems due to the subtle differences in aspects such as resistance to rutting. Part of the reason is the fact that the larger HMAC market is the roads sector and these design standards and norms tend to be used more and more frequently for airfield works with scant recognition of the actual differences.

Runways carry less traffic than a typical highway, but typically much higher loads. The hot-mix asphalt requirements for runways are therefore different from those of roads, and include more focus on rut resistance and durability. The Marshall method is still the dominant design method for airfield hot-mix asphalt although the latest generation wide body aircraft such as the Airbus A340 and Boeing 777 are showing up the limitations of using Marshall design, and require additional consideration of permanent deformation resistance. Laboratory hot-mix asphalt rut test devices are increasingly used, and scale device like the MMLS have given good results. The Superpave Repeated Simple Shear Test at Constant Height has also been used with success.

The differences in traffic loading between roads and airfields imply that there will be some areas on an airfield which may not experience distress in the form of fatigue or deformation. Such areas would definitely experience more environmentally related types of distress such as age related cracking, raveling and stripping. This dictates different design and rehabilitation goals for the different areas on a runway and clearly also different from the design goals for a road situation.

A recent study on the Toronto International Airport in Canada revealed that PG Bitumen alone could not be sufficient to cater for the rutting problem and since 2006 Polymers are being added to PG Bitumen to prevent rutting on the Runway Surface.

To address these issues specific to Runway Pavement, Polymer Modified Bitumen (PMB) has widely been used as it has low penetration, increased viscosity and improved performance to rutting problem. Although PMB has sometimes been criticized to need high temperature for production and compaction due to its high...
viscosity and owing to its stiffness, yet it has widely been used in many new Runways and non-operational runways.

However, in an operational Airport having a single runway where the air traffic has to be opened immediately after the HMAC overlay Works, the overlaid surface may get premature deformation due to the loading of the air traffic as the pavement temperature will still greater than 60°C.

An online simulation output generated by MULTICOOL 3.0, widely used in USA, suggest that a typical HMAC layer compacted at 120°C will take approximately 10 hours in summer and 3 hours in winter to reach to the prescribed temperature of 60°C. This fact is also confirmed by the Japanese researchers based on their onsite measurement at Fukuoka Airport that for 80mm thickness of HMAC surface course, the required cooling time to drop down to 60°C is 12 hrs. in summer and 4 hrs. in winter. As per the Weather Underground History Report both Fukouka Airport and TIA has similar weather condition with seven days average maximum temperature of 32°C in summer and minimum temperature of -2°C in winter. Thus the same conditions can also be assumed in case of TIA. Therefore, if we have to open traffic immediately after Overlay, the new type of Asphalt called Warm Mix Asphalt can be easily used by the addition of temperature reducing agent, such as Sasobit, which can lower the mixing and laying temperature by as much as 30°C. Hence, traffic could be opened in just 1 hour after the overlay works.

SASOBIT is completely soluble in bitumen at temperatures in excess of 115°C. It forms a homogeneous solution with base bitumen on stirring and produces a marked reduction in the bitumen's viscosity. This enables mixing and handling temperatures of the asphalt to be reduced by 30°C. Temperature reductions of up to 50°C can be reached by process optimization between the mixing plant and paving. The WMAC will have increased resistance to rutting as shown in the figure below.

Reduction of Rutting Depth by the addition of Sasobit in HMAC
The following is some of the examples of operational runway overlay with PMB and 3-5% of Sasobit:

<table>
<thead>
<tr>
<th>SN</th>
<th>Project</th>
<th>Completed Year</th>
<th>Size (sq.m.)</th>
<th>Reason for using Sasobit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Runway of Belgrade Airport, Serbia</td>
<td>2005</td>
<td>20 000</td>
<td>Improved deformation resistance and earlier opening to traffic</td>
</tr>
<tr>
<td>2</td>
<td>Runway of Linz-Harsching Airport, Austria</td>
<td>2005</td>
<td>50 000</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Apron and Taxiway of Johannesburg Airport, South Africa</td>
<td>2006</td>
<td>80 000</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Runway of Frankfurt Airport, Germany</td>
<td>2005</td>
<td>250 000</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Apron and runway of Sturoman Airport, Sweden</td>
<td>2003</td>
<td>110 000</td>
<td></td>
</tr>
</tbody>
</table>

The following case study also suggests the problem of Runway overlay and its rational solution using Sasobit in Fukuoka Runway which was also an operational Airport with a single Runway.

**Sample Case Study: Fukuoka Airport Runway Rehabilitation (Japan)**

Fukuoka Airport, which presently has one runway of 60m wide and 2,800m long, was constructed as a small airbase in the beginning. An asphalt overlay has been placed over the existing cement concrete pavement three times since 1974 in addition to the expansion of the facilities, due to an increase of air demands. When the third overlay was designed, multilayer elastic theory was used to determine the appropriate thickness. The detailed design conditions were as follows: a design traffic volume of 40,000 ESWL (equivalent single wheel loads) with the Boeing 747 as the standard design aircraft and a coefficient of foundation reaction of 24 MN/m³. The overlay thickness was determined as 14 cm and 15 cm for the middle section and the two end sections, respectively. This overlay was constructed beginning in 2000 according to these specifications, with the work completely finished in 2002. However, some distresses such as rutting, blistering, distortion by grooving and moisture damage were observed shortly after some of the rehabilitated areas opened to traffic.

Taking into account the causes of the distress and the limitations on construction work, while also referring to similar projects at Nagoya and New-Chitose Airports, the following strategy was put forward for the work:

1. For the slippage area constructed in 2000 and 2002, 150 mm overlay was removed and re-constructed. In the underlaid layers where water was stagnating, the upper layer (50mm) was removed and then re-constructed;

2. To prevent blistering, adequate breathability was required in the wearing course. Therefore, slightly higher air void ratio of 4.5% was adopted in the asphalt mixture. Correspondingly, polymer-modified bitumen (type II) was used to minimize the risk of deformation resulting from the higher air void ratio. Moreover, the thickness of the wearing course was increased to 80mm, exceeding the specification of 70 mm, to inhibit slippage between the wearing and binder courses. The rationale of increasing thickness was based on the fact...
that wearing course efficiently reduce the shear stress induced by horizontal aircraft loading;

(3) A 120 mm binder course was placed in one lift to reduce construction time;

(4) In order to improve the resistance of asphalt mixture to rutting, a large stone mix with a maximum aggregate size of 30 mm was used in the binder course, also adopting the same polymer-modified bitumen.

(5) To realize a quick turn over to traffic by decreasing a temperature in a compacting process of asphalt mixtures, temperature-reducing additives were added to bitumen to make it foamed; that is, used the so-called warm asphalt mixtures.

Conclusion

Tribhuvan International Airport is not only one Airport in the world in which rutting appeared on the runway surface after HMAC overlay. However, the problem became more serious as it is only one International Airport and there is no alternative runway. Had there been another alternative runway in TIA or any other International Airport in Nepal, where the traffic could be diverted in case of emergency; there would not as many problems as it is today. Therefore, it is very urgent to expedite the construction of New International Airport and expansion of Bhairabha Airport Runway to international Standard as alternative solutions.

Nepal is very poor in the area of research. The failure of TIA runway is due to lack of research and study to cater for the current development in Asphalt Pavement Technology. However, we can learn from the researches of the developed countries and try to apply the best practices of runway overlay to suit our requirements.

The current problem in TIA Runway is development of potholes due to rutting in hot summer days and formation of potholes. The potholes are being patched up on a regular basis but this is not a permanent solution. The Runway may stabilize due to ageing of the Bitumen; which decreases penetration and increase viscosity in a couple of years; but still this problem will persist again and again in the coming summer and similar problems could be experienced until the bitumen is aged. Furthermore, the infiltration of water through cracks in the pavement may further decrease its structural stability.

It seems that Construction of Second International Airport is a long way to go; immediate actions should, therefore, be taken by the government for expansion of runway in Bhairahaba Airport. However, it will be a better decision to commence the overlay of TIA runway as soon as possible with the use of lower grade/Polymerized Bitumen (PMB) and temperature reducing agents (such as sasobit) to obtain Warm Mixed Asphalt Concrete (rather than HMAC) which researches have shown to be the best alternative and practice for operational runways.
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Shailesh Nepal is an active member of IPMA, Immediate Past President of Young Crew Nepal, Fellow member of American Academy of Project Management (AAPM), MPM™ & CIPM™ certified from AAPM, member of International Construction Project Management Association (ICPMA), and a founder and Managing Director of the Institute of Project Management Nepal (IPMN) Pvt. Ltd. He has served as Project Manager in several construction companies in Nepal. His recent project is in the capacity of Deputy Contract Manager on behalf of China Railway Engineering Corporation, China and Tundi Construction Nepal, JV for Runway and Taxiway Overlay Works of Nepal’s only International Airport.

Shailesh has been recognized internationally and awarded the IPMA International Young Project Manager of the Year Award for 2010. His specialism and innovative ground breaking techniques of project management have helped organizations to prosper and succeed in the challenging construction jobs in Nepal. In addition, he is dedicated to updating, enhancing and uplifting of the PM Profession through training and development as a Managing Director of IPMN Pvt. Ltd. in Nepal. Shailesh obtained his Bachelor Degree in Civil Engineering from the Institute of Engineering, Central Campus, Pulchowk in 2001. Since then, he has been involved in the Project Management Profession in various construction companies for roads, highways and airport rehabilitation projects. He believes in Professionalism, Integrity and Respect for diversity and believes that success only comes with dedication and hard work in the field. He can be contacted at shailesh.work@gmail.com.

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