The Evaluation of Structural Performance of New Benazir Bhutto International Airport Islamabad, Pakistan

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Abstract: Sub grade strength, bitumen content of different structural layers and riding quality of wearing surface are the most important factors that affect the overall performance of pavement so it is necessary to evaluate the structural behavior and surface characteristics of pavement. The study reveals that runway of new Benazir Bhutto International Airport Islamabad will behave under the heavy loading of aircrafts as per design requirements. This paper documents the Sub grade CBR tests, field density test, different layer's soil classification, profilograph tests and skid resistance tests were performed to find out structural performance of main runway, secondary runway and taxiway and then compared with internationally design standards. From this research, it was concluded that new BBIAP is properly designed according to specifications. IRI values of main, secondary and taxiway are 1.54, 1.99 and 2.96 respectively which are well within internationally accepted values. Optimum asphalt content of bitumen wearing and bitumen base courses are 5.10% and 4.50% respectively when tested on different samples by extraction tests. Loss of stability in Bitumen wearing course and Bitumen Base course are 18% and 9% respectively. It was also concluded that the best Soil used in sub grade of any pavement is A-2-4 with 95% compaction achieved. Because A-2-4 soil can bear maximum load with respect to other groups soil, it is considered to be very effective while preparing sub grade in any runway pavement. From this research, it was also concluded that the factor of percentage of bitumen is dominating factor in the behavior of resilient modulus at a certain limit , as we increase the percentage of bitumen resilient modulus increases and vice versa. After a certain limit resilient modulus decreases by increasing bitumen content.

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1. Introduction

Pakistan is a developing country and spent a lot of money on different transportation projects. New Benazir Bhutto International Airport Islamabad is an important example of one of these projects. Benazir Bhutto International airport (previously named as Islamabad International airport) is located in Islamabad serving approximately 2,885,700 passengers per year since a long time ago. An average of 23,400 flights per year has been entertained on the runway of BBIAP. Due to increase in congestion problems in previous BBIAP located in Islamabad, it becomes necessary to construct a new wide airport which replaces the previous one. The New Islamabad International Airport is located in Fatah Jang Tehsil of Attock District some 30 km southwest of the Federal Capital, is expected to be completed and operational by June 2014. This airport will eventually replace the overloaded Islamabad International Airport at Chaklala. The plan to construct a new airport for Islamabad was conceived in the late 1980s to deal with the with the problem of increased passenger load at the Benazir Bhutto International Airport (then known as the Islamabad International Airport). The current annual turnover of passengers at the current airport is about 3.5 million. It was estimated that the number of passengers at the airport is growing by 14 per cent annually compared to national air passenger growth rate of less than four per cent, making it one of the busiest airports in the country. Therefore a site near Fateh jang, Attock District Pakistan was selected as the site for its construction. Finally the plan to construct a new airport was announced on January 7, 2005 by Civil Aviation Authority (CAA). New Benazir Bhutto International Airport Islamabad contains two runways. One is primary runway and 2nd is secondary/emergency runway. Secondary runway has the same length as primary runway but difference is design criteria. Figure 1 describes the cross-section of main runway. It also describes the lengths and widths of main runway. Main runway has a length 3657.60m (3.6Km), width 60m and consists of shoulder running along the main runway. The width of shoulder is 7.50m. So the area devoted by main runway is 219,456.00 m^2.

2. Objectives

i. Evaluation of Structural and Functional performance of Runway of New Benazir Bhutto International Airport Islamabad.
ii. To investigate the effect of test pulse conditions on the resilient modulus of runway pavement of BBIAP.
iii. To investigate the variation of International Roughness Index (IRI) in runway, secondary runway and taxiway.
iv. To find Skid resistance value of main runway, secondary runway, taxiway and especially at that place when runway meets taxiway.
v. Behavior of aggregates under the upcoming heavy loads.
vi. Ability of Asphalt concrete to resist two important failures i.e. cracking and rutting

3. Experimental Program

3.1: Testing with Profilograph:

A device for measuring pavement surface deviations by the vertical movement between a center mounted measuring wheel to the reference plane created by a 25 foot wheel truss system. This test is performed to find out roughness of pavement, because high roughness in any pavement will affect the overall performance of pavement. There are nine numbers of lanes in main runway. Most left and right corner lanes were not tested by Profilograph while remaining all seven lanes were tested. Among all seven lanes, three lanes were tested in the direction where aircrafts takes off while other four lanes in the direction where the aircrafts landsIRI of any pavement can be calculated from profile index and the reading of profile index is directly obtained from Profilograph testing. The formula for calculating Profile Index is as follows:

1. Profile Index = $\frac{1\text{mile}}{\text{length of section in miles}}$ x total count in inches.
2. IRI (International Roughness Index) = (2.19*Total Profile Index) + 0.22

3.2: Testing With Skid Resistance:

Skidding is loss of adhesion between a vehicle's tires and the road surface, occurs in many road accidents whether or not it is the actual cause of the accident. To measure texture depth and skid resistance of a road surface, BS Pendulum Skid Resistance Tester is used. The purpose of performing this test is to find skid resistance value. Actually it is the friction between vehicle tires and pavement wearing surface. There must be some proper frictional value, so when the brakes of a vehicle apply pavement grips the tires and vehicle stop at a certain distance. There are nine numbers of lanes in main runway. All lanes were tested by skid resistance. Runway meeting taxiway plays an important role because it is the place where an aircraft applies brakes and turns (shearing force is applied). Skid resistance value of taxiway and the place where runway meets taxiway were determined.

3.3: Testing in UTM-5P:

The purpose of performing this test is to find Resilient modulus of different layers of runway of BBIAP. Universal Testing Machine (UTM) is the advance computer based Machine which is capable of determining Resilient Modulus (Mr) and Permanent Deformation (Rutting) characteristics of asphalt concrete. Mr is generally affected by the temperature and time of loading. Different Cores were tested in UTM-5P under varying pulse width because in runway pavements applied loading width plays an enormous role. Repeated load Uniaxial strain test using UTM-5P was performed on the cores of all the layers according to the test conditions. Three samples of cores were obtained at each layer of runway. All the samples of the cores were tested at temperature variation of 25ºC, 40ºC and 55ºC respectively. Pulse width varies from 150, 300 and 450ms and test loading stress ranges from 100kpa to 500kpa. Pulse period has a constant value of 2000ms.

Table1. Description of Parameters

Description	Value
Temperature	25ºC , 40ºC
Pulse period	2000 ms
Pulse width	150,300, 450 (ms)
Test loading stress	500kpa

4. Results and Discussion

Structural Layers of main runway:

There are four structural layers of runway of new BBIAP excluding sub grade. The properties of these layers are given below;

1. Sub grade:

Sub grade of main runway is divided into three different zones depending upon compaction achieved and classification of soil.

- **Zone C:**

Zone C is the most bottom layer of sub grade which is compacted almost 90% minimum. It is compacted in different layers depending upon level of earth. A-6 soil is used in zone C. It is approximately 15cm thick.

- **Zone B:**

Zone B is placed above zone C and it consists in two numbers of structural layers placed above one another. Its thickness is same as zone B. A-2-4 soil is used in zone B. It is compacted up to 93% minimum.

- **Zone A (Main Sub grade):**

A-2-4 soil is used in sub grade of runways of new BBIAP which is considered to be most load bearing soil. It include various granular materials containing 35 percent or less passing the 75-µm (No. 200) sieve, and with that portion passing 425-µm (No. 40) sieve having the characteristics of the A-4 and A-5 groups. These groups include materials such as gravel and coarse sand with silt contents. Different proctor test were performed on sub grade soil and average Maximum Dry Density and Optimum Moisture Content (OMC) were observed as 2.12g/cc and 8.4% respectively. Design CBR value of sub grade is 60%. The value of CBR calculated from laboratory was 61%.

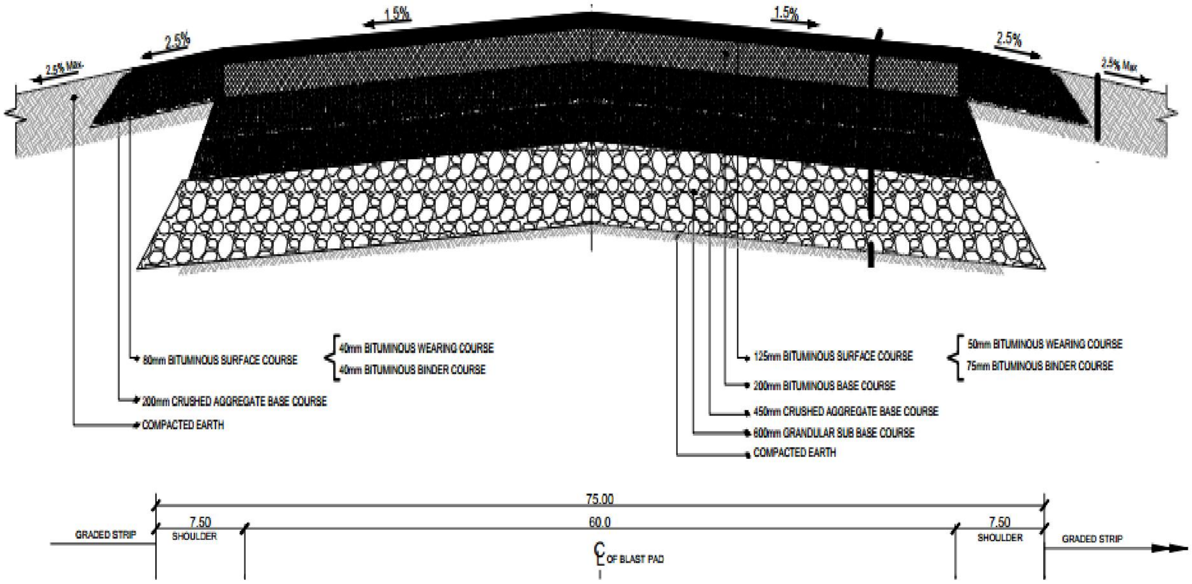

Fig1. Cross-Section of Main Runway

2. Sub base:

A-1-b soil is used in sub base of runway on new BBIAP. Its thickness is also 15cm and the number of layers which were compacted is four. So overall thickness of sub base is 60cm. Design CBR value lies within the range of 75-90% and when performed CBR test in laboratory, the result of this test lies within the range when calculated. Compaction to be achieved for this layer is 100% min but when performed test its value is obtained within permissible limits.

3. Aggregate Base Course (A.B.C):

450mm crushed aggregate base course is provided above 600mm granular sub base. A-1-b soil is used in this layer. CBR value of aggregate base course lies in the range of 80-90% in the design and the examined value when performed CBR test in the laboratory is 83%. Compaction required for this layer is 100% (min) and compaction achieved is 100.2%. It contains four number of layer depending upon compaction and the thickness of each layer is 15cm.

4. Bitumen Base Course (B.B.C):

200mm bitumen base course is provided over aggregate base course. Optimum Asphalt content of this layer is 4.50%, the specified values for this layer lies within the range of 4.50% (min). Stability and flow for this layer are 1580kg and 2.7mm respectively which are within the limits of design values.

5. Bitumen Wearing Course (B.W.C):

125mm bitumen wearing course is provided on top of the runway pavement. Optimum Asphalt content of this layer is 5.10%, the specified values for this layer lies within the range of 4.5-7% (min). Stability and flow for this layer are 1130kg and 2.7mm respectively which are within the limits of design values. Bitumen grade used in this layer is 60-70. This layer is compacted up to 96%.

Table2. Summary of Mix Design of Bitumen Wearing Course

	Bitumen Wearing Course	
Description	Achieved Values	Specified Values
Optimum Asphalt at medium Air Voids	5.10%	4.5-7.0%
Stability	1130Kg	1000Kg(Min)
Flow	2.7mm	2-4mm
Air Voids	4.00%	3-5%
Voids filled with Asphalt	76%	70-80%
Voids in Mineral Aggregates	14.0%	
Loss of Stability	18%	25%(Max)

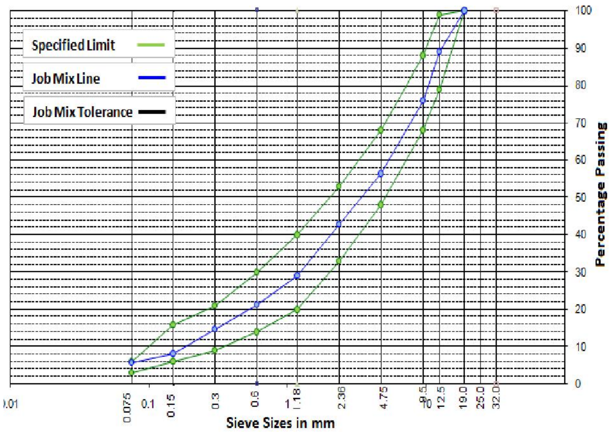

Fig2. Sieve Analysis of Bitumen Wearing Course

Table3. Summary of Mix Design of Bitumen Base Course

Description	Bitumen Base Course	
	Achieved Values	Specified Values
Optimum Asphalt at medium Air Voids	4.50%	4.50%(Min)
Stability	1580Kg	1000Kg(Min)
Flow	2.7mm	2-5mm
Air Voids	4.00%	3-6%
Voids filled with Asphalt	72%	60-75%
Voids in Mineral Aggregates	14.4%	
Loss of Stability	9%	25%(Max)

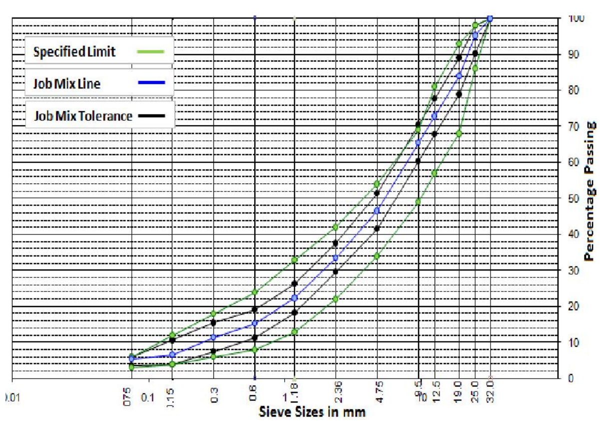

Fig3. Sieve Analysis of Bitumen Base Course

Resilient Modulus of Different Layers of Pavement:

The diameter of the asphalt cores is either 4" or 6". The cores are obtained by the Lab Supervisor Mr. Mumtaz Ahmed under the observation of my self. I computed and marked the locations to be cored using random numbers to determine station and offset from the edge of the pavement. Then removed and transported the cores to the laboratory for density testing and Resilient Modulus and conducted Core density testing and Resilient Modulus tests according to specifications in UTM-5P.

We were tested three types of Layer's cores;

1. Bitumen Wearing Course
2. Bitumen Base Course
3. Aggregate Base course

We varied the pulse width of loading and examined the behavior of Pavement under a constant maximum loading.

Table4. Comparison of Resilient Modulus of Bitumen Wearing Course(B.W.C), Bitumen Base Course (B.W.C)and Aggregate Base course(A.B.C) from UTM-5P

Test pulse period (ms)	Peak loading force (N)	Pulse Width (ms)	Resilient Modulus of B.W.C (MPa)	Resilient Modulus of B.B.C (MPa)	Resilient Modulus of B.W.C (MPa)
2000	500	150	5132	3807	3548
2000	500	300	4676	3540	2414
2000	500	450	4304	3060	1997

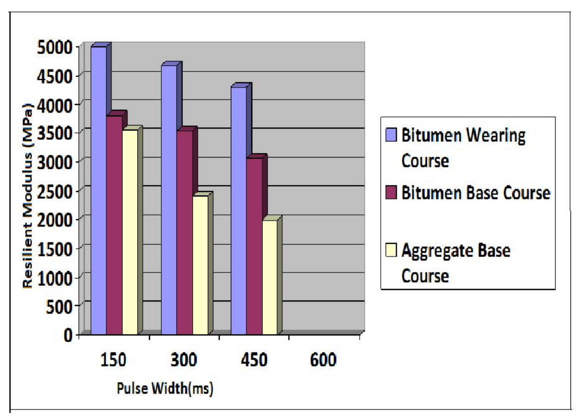

Fig 4. Graphical Representation of Comparison of Resilient Modulus

Skid Resistance Results:

Main Runway contains Nine Number of layers. Most Left and Right corners were not tested. Remaining Seven Lanes are tested. After getting all the values of every lane with the help of skid resistance, the value of overall skid resistance of main runway is 33 and that of secondary runway is 40 which is applicable according to specifications. The factor of Skid Resistance becomes very important where runway meets taxiway. Because on that path the speed of aircraft will be slow and a curvature is built on the pavement which provides centripetal force to aircraft. The average value of skid resistance where runway meets taxiway is 51 and 60 at taxiway. The comparison of skid resistance values of main runway, secondary runway, taxiway and portion where runway meets taxiway are as given;

Table 5. Skid Resistance values of Runway and Taxiway

Type of Pavement	Skid Resistance
Main Runway	33
Secondary Runway	40
Taxiway	60
Runway meeting Taxiway	51

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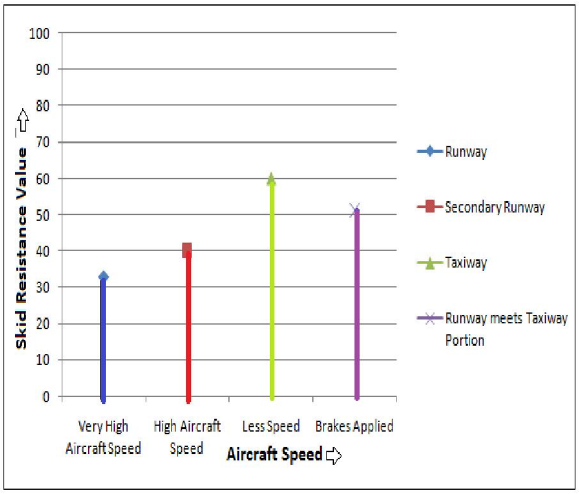

Fig.5 Graphical Representation of Comparison of Skid Resistance values in varying speed zones

Profilograph Results:

The average profile Index and IRI on main runway are 579.77(mm/km) and 1.54 respectively, secondary runway 811.03(mm/km) and 1.99 and that of taxiway are 1244.37(mm/km) and 2.96 respectively. All the values lie within internationally accepted values.

Table6. IRI values of Runway and Taxiway

Nature of Pavement	Average Profile Index (mm/km)	IRI(International Roughness Index) value
Main Runway	579.77	1.54
Secondary Runway	811.03	1.99
Taxiway	1244.37	2.96

The Pavement will be considered a better Pavement if value of IRI is less than 4. All the Pavements of Main Runway, Secondary Runway and Taxiway have IRI value lies in the range of 1.50 to 3.

5. Conclusion

Following conclusions have been drawn from this study:

- It is concluded that runway of new BBIAP is properly constructed according to design and specifications after all the tests which were being performed in Transportation Laboratory of UET Taxila.

- As pulse width increase from 150ms to 450ms, modulus of Resilience decreases accordingly in all layers of runway pavement. These layers are
  - Binder Course
  - Bitumen Base course
  - Aggregate Base Course

- From the study it was concluded that the percentage of Bitumen is dominating factor in the behavior of resilient modulus. Percentage of Bitumen is directly proportional to the Resilient modulus.

- The Sub grade of Runway of new BBIAP has a CBR value of 60% and compaction achieved is 95% of modified AASHTO. The material used in Sub grade is A-2-4 which contains Gravels and Sand.

- Bitumen Wearing Course has an Asphalt content of 5.10% where as Base Course has Asphalt content of 4.50%, which are well with the range of designed values.

- Skid Resistance value of main Runway lies in the range of 30-40 and that of Secondary Runway from 35-45, which are well within the acceptable limits.

- Skid Resistance Values at the junction of taxiway and runway lies in the range of 50-60.

6. Recommendations:

1. UTM-5P can be referred as simple performance test for the determination of Resilient Modulus of various asphalt mixes.
2. For the Structural Design latest available codes and specifications should be used considering load conditions, environmental conditions and material properties.
3. IRI is the most important factor to be considered in evaluation of functional performance of any pavement and its value should be less than 4.

4. A-2-4 is an excellent soil having high bearing capacity and is suitable for sub grade of all kinds of pavements.
5. It is also recommended to conduct a comprehensive study, in collaboration with \industry and academia, on all provincial and Civil of Pakistan Aviation Authority to find out the causes of pavement failure of Runway of Airports of Pakistan

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