AN EVALUATION OF AIRFIELD PAVEMENTS IN BANGLADESH

Hasib Mohammed Ahsan*[1] and Md. Emrul Hasan[2]

[1]*Professor, Department of Civil Engineering, BUET, Dhaka, Bangladesh, e-mail: hmahsan@ce.buet.ac.bd*
[2]*Lecturer, Department of Civil Engineering,WUB, Dhaka, Bangladesh, e-mail: h.emrul_006@yahoo.com*

ABSTRACT

In 2013, worldwide air traffic crosses 6 billion marks with an annual growth rate of 4.6%. The air travel demand in Bangladesh has also increased even more rapidly. In the last 5 years the average growths of air passenger and cargo movements were 9.7% and 7.05% respectively. To meet the air travel demand in Bangladesh, at present all aviation activities are carried out from three international and six domestic airports and five STOL's. The three international airports are Hazrat Shahjalal International Airport (HSIA), Dhaka; Shah Amanat International Airport (SAIA), Chittagong and Osmani International Airport (OIA), Sylhet. Airfield pavement is the most striking features of an airport. Airport pavement evaluations are necessary to assess the ability of an existing pavement to support different types, weights, or volumes of aircraft traffic. ICAO develops (AC 150/5335-5C) a single international method of reporting pavement strengths. ICAO adopted the Aircraft Classification Number - Pavement Classification Number (ACN-PCN) method. Using this method, it is possible to express the effect of an individual aircraft on different pavements with a single unique number that varies according to aircraft weight and configuration (e.g. tire pressure, gear geometry, etc.), pavement type, and subgrade strength. Depending on different pavement layer characteristics and air traffic configurations COMFAA 3 was used to determine ACN-PCN for HSIA, SAIA and OIA, which are 89-127, 89-46, and 107-41 respectively.

Keywords: *airport, airfield pavement, ICAO, ACN, PCN*

1. INTRODUCTION

Bangladesh is situated at the head of the Bay of Bengal and stretches over 640 km to the north and is some 490 km in width. The country is traversed by several very large river systems; the Ganges, Padma, Jamuna, Brahmaputra and Meghna. These rivers are of such size as to present major barriers to cross and represent discontinuities in the land surface transport systems- road and rail.

Air transport plays an important role in linking and integrating all Divisions of the country and will be significant in promoting improved socio-economic conditions as the economy of Bangladesh undergoes development and structural change towards increased industrialization and national growth. In last few years air travel demand has increased rapidly because of highly congested and time-consuming roadway, waterway and emerging business and tourism in Bangladesh (Hasan, 2015). In last 5 years the growth of air passenger and cargo movement was 9.7% and 7.1% respectively. In 2012-2013, The Biman Bangladesh carried a total number of 15,72,708 passengers and 33,434 tons of cargos (MOCAT, 2013). Further, airports in Bangladesh have greater importance because of their geographical locations. Hazrat Shahjalal International Airport has been considered for potential refuelling hub of the South Asia region for foreign airlines using the Bangladesh skylines (Alam, 1998). In Bangladesh, there are 15 airports, aerodromes and landing strips, including three airports for international services - Hazrat Shahjalal International Airport (HSIA), Dhaka; Shah Amanat International Airport (SAIA), Chittagong and Osmani International Airport (OIA), Sylhet.

With the rapid and sustained growth of air traffic the runway pavement of the international airports are being deteriorated fast. The life cycle of previous asphalt overlay work has been exhausted and the pavement surface shows significant signs of serious distresses. The deteriorating condition of the runway continues to become harmful day by day for the safe operation of the aircrafts on the runway. In order to ensure safe movement of wide bodied Aircrafts, it is necessary to assess the runway pavements and prescribe treatment options.

2. INCREASING AIR TRAFFIC DEMAND IN BANGLADESH

Bangladesh has a strategic position in Asia Pacific whereby businesses from Pakistan and India see great potential. With cheap labour and a fairly secure environment, Bangladesh has become a low-cost manufacturing hub and many businesses from neighbouring countries have even relocated to Bangladesh. India was the leading source market for arrivals in Bangladesh in 2012 and the primary reason for this are the trade links between the two countries (Euromonitor International 2013). According to official statistics about 8.5 million Bangladeshis are living and working abroad contributing to the growth of passenger movements. Again due to economic and business growth Bangladeshis are also travelling to international destinations in great numbers. At present the aggregate global growth in passenger movement is 4.4% and in Asia pacific region it is 8.7%. But for Bangladesh the growth rate is 9.9% which is almost doubled in comparison to global growth.

Same scenario is seen in the cargo movements also. The global annual growth for cargo movement is 0.9% and in Asia pacific region 2.1%. But for Bangladesh it is 7.4%. Accordingly the aircraft growth rate is 2.9% where the global aircraft growth is only 0.6%. It is also expected that within 2031 there will be more than 90 aviation megacities and Dhaka will be one of them. The average growth rate for aircraft movement, passenger movement and cargo movement for Bangladesh during last 5 years are shown in Figures 2, 3 and 4 respectively.

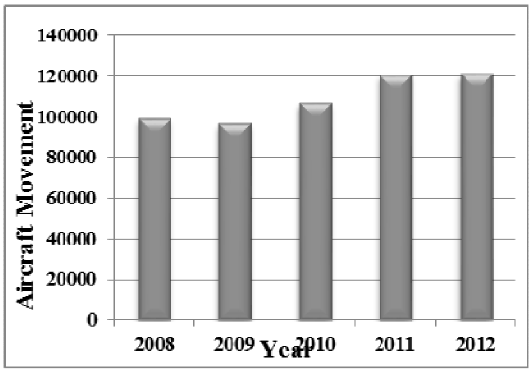

Figure 1: Annual Aircraft Growth Rate in Bangladesh

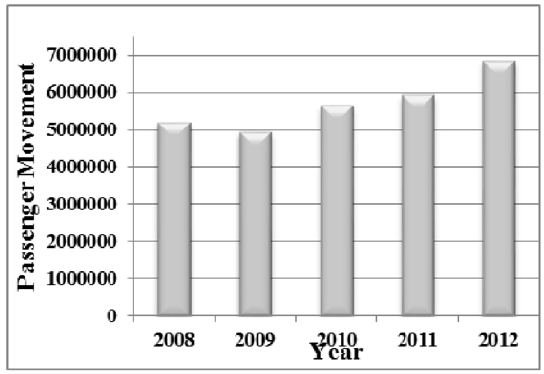

Figure 2: Annual Air Passenger Growth Rate in Bangladesh

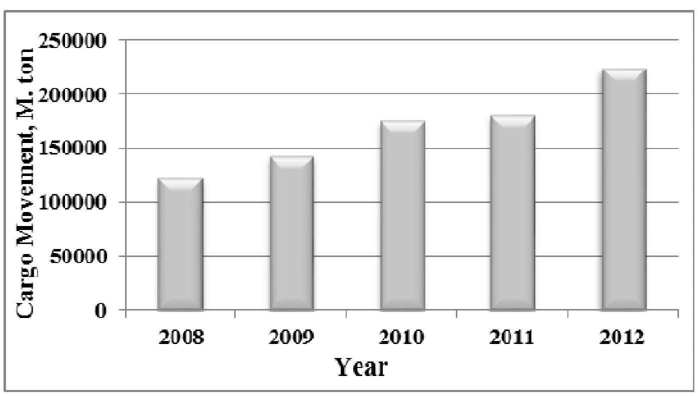

Figure 3: Annual Air Cargo Growth Rate in Bangladesh

3. AIRPORT RUNWAYS IN BANGLADESH

3.1 Status of airport runways

The air transportation network in Bangladesh is comprised of three international, six domestic, six STOL (short Take-off and Landing) ports and nine other unused airports. All airports of the country are, however, in the public sector, only a minor element of the ground facility is in the private sector (CAAB, 2014). The status of airfield runways and pavements are shown in Table 1.

Table 1: Status of International and Domestic Airport Runways in Bangladesh

Name of the Airports	Runway Orientation	Runway Length, m	Runway Width, m	Pavement Type
Hazrat Shahjalal International Airport (HSIA)	14/32	3201	61	Asphalt Concrete
Shah Amanat International Airport (SAIA)	05/23	2940	45	Asphalt Concrete
Osmani International Airport (OIA)	11/29	3125	46	Asphalt Concrete
Saidpur Airport	16/34	1829	30	Asphalt Concrete
Shah Makhdum Airport, Rajshahi	17/35	1829	30	Asphalt Concrete
Jessore Airport	16/34	2438	45	Asphalt Concrete
Barisal Airport	17/35	1829	30	Asphalt Concrete
Cox's Bazar Airport	17/35	2042	38	Asphalt Concrete
Tejgaon Airport	17/35	2439	46	Asphalt Concrete

3.2 Runway pavement layers of international airports

3.2.1 Pavement layers of HSIA runway

The runway of the HSIA was opened for routine service in 1980. The subgrade of the runway pavement was constructed by placing local soils from adjoining areas. The thickness of the compacted fill varied from 0.9 to 4.2 m (CAAB and BRTC, 1993). A 150 mm lean mix concrete with 1:3:6 (cement: sand: aggregate) was used as subbase material to support the Portland cement concrete slabs. The thickness of the original cement concrete runway-taxiway pavement slab varied from 250 mm to 330 mm. The condition of the runway deteriorated significantly by early 1990s, and after a detailed study, a flexible overlay of thickness 200mm was placed on top of the original pavement in 1994-95. This pavement was given a 2nd asphaltic overlay of 190 mm in 2012-2013. In order to improve drainage, slope of overlay surface of 1.5 percent for the runway and 2 percent for the shoulder were kept. Figure 5 shows that the existing runway pavement. At present the PCN of HSIA runway is 107/F/B/X/T in 14 and 23 both ends (BUET, 2014).

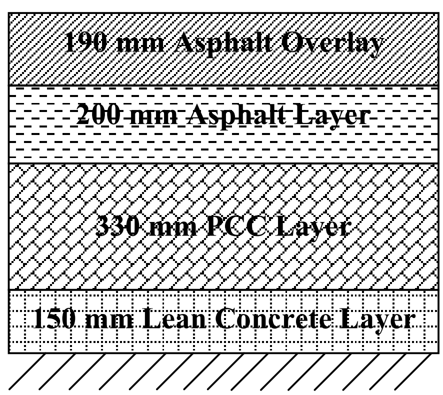

Figure 4: Existing HSIA Runway Pavement Layers

3.2.2 Pavement layers of SAIA runway

Considering the distinctive layer system of the existing runway structure along the runway, the layer profiles are shown in Figure 3.9 for the following five sections separately (BUET 2014-2015):

C1 : from No. 10 to No. 17+60
C2 : from No. 17+60 to No. 22+20
C3 : from No. 22+20 to No. 31+20
C4 : from No. 31+20 to No. 34+20
C5 : from No. 34+20 to No. 36+90

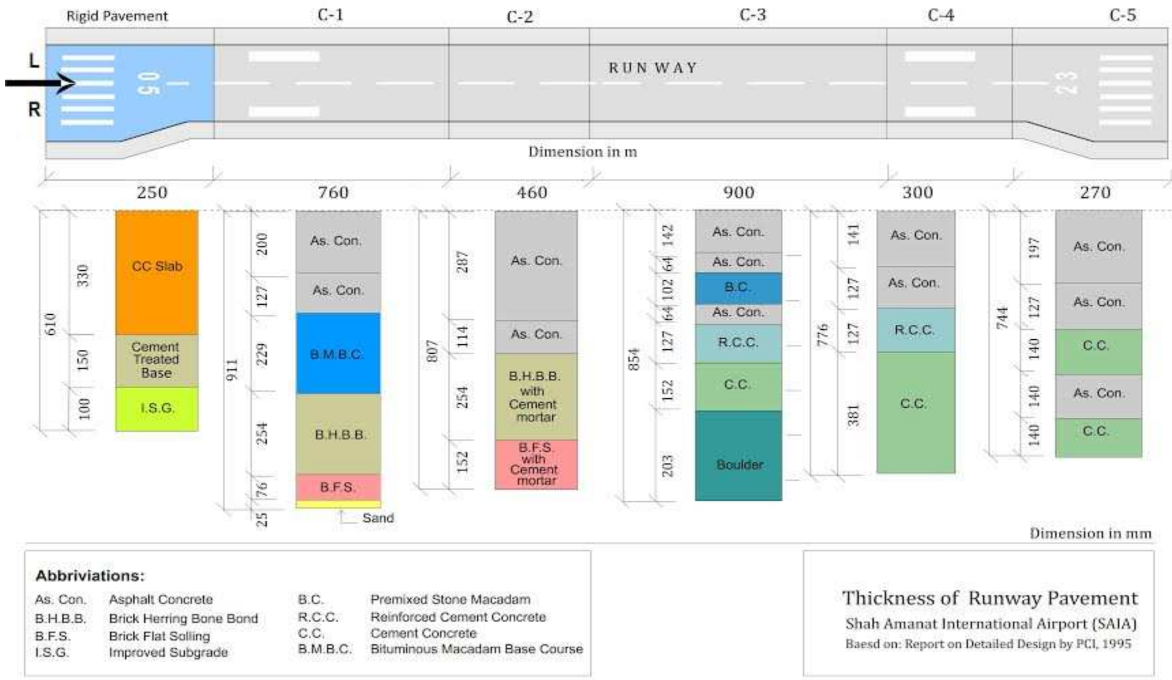

Figure 5: Existing Layers of SAIA Runway Pavement at Different Sections

3.2.3 Pavement layers of OIA runway

Considering the distinctive layer system of the existing runway structure along the runway, the layer profiles are shown in Figure 7 for the following five sections separately (BUET 2015):

SEC C1: 1840m (Org. runway, incl. 60m over run at 29-End) Ch. 0+60 to 1+900
SEC C2: 300m (1st Extension) Ch. 1+900 to 2+200
SEC C3: 460m (2nd Extension) Ch. 2+200 to 2+660
SEC C4: 140m (3rd Extension) Ch. 2+660 to 2+800
SEC C5: 154m (Over runway) Ch. 2+800 to 2+954
SEC C6: 233m (Last Extension, incl. turning pad) Ch. 2+954 to 3+187

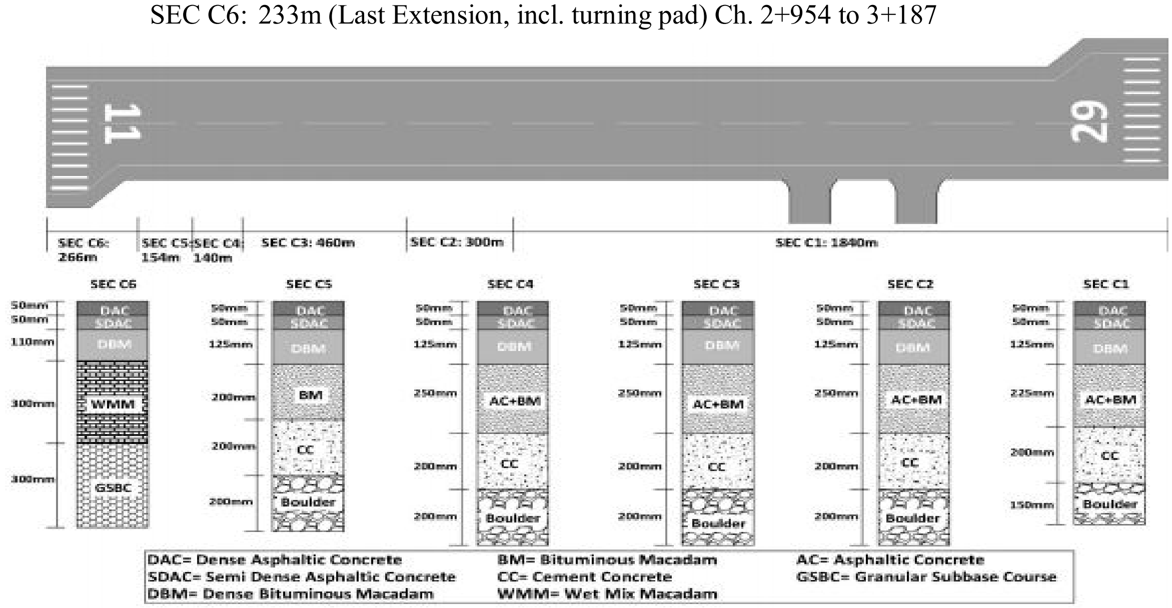

Figure 6: Existing Layers of OIA Runway Pavement at Different Sections

3.3 Evaluation of Structural Condition of the Existing Runway Pavements of the international airports of Bangladesh

Pavement evaluation process is the reverse of the design procedure. The pavement evaluation is made by reviewing data/information/report available with the Civil Aviation Authority of Bangladesh (CAAB) and calculating the ACN/PCN values for international airport pavements.

3.3.1 Definition of ACN and PCN

ICAO develops (AC 150/5335-5C, 2014) a single international method of reporting pavement strengths. ICAO adopted, the Aircraft Classification Number - Pavement Classification Number (ACN-PCN) method. Using this method, it is possible to express the effect of an individual aircraft on different pavements with a single unique number that varies according to aircraft weight and configuration (e.g. tire pressure, gear geometry, etc.), pavement type, and subgrade strength. This number is the Aircraft Classification Number (ACN). Conversely, the load-carrying capacity of a pavement can be expressed by a single unique number, without specifying a particular aircraft or detailed information about the pavement structure. This number is the Pavement Classification Number (PCN).

3.3.2 Determination of ACN and PCN

To facilitate the use of the ACN-PCN system, FAA developed a software application that calculates ACN values using the procedures and conditions specified by ICAO called COMFAA. The COMFAA 3.0 software is a general purpose program that operates in two computational modes: ACN Computation Mode and Pavement Thickness Mode.

The strength of a pavement section is difficult to summarize in a precise manner and will vary depending upon the unique combination of airplane loading conditions, frequency of operation, and pavement support conditions. The technical evaluation method attempts to address these and other site-specific variables to determine reasonable pavement strength. In general terms, for a given pavement structure and given airplane, the allowable number of operations (traffic) will decrease as the intensity of pavement loading increases (increase in airplane weight). It is entirely possible that two pavement structures with different cross-sections will report similar strength. However, the permissible airplane operations will be considerably different. This discrepancy must be acknowledged by the airport operator and may require operational limitations administered outside of the ACN-PCN system. All of the factors involved in determining a pavement rating are important, and it is for this reason that pavement ratings should not be viewed in absolute terms, but rather as estimations of a representative value. A successful pavement evaluation is one that assigns a pavement strength rating that considers the effects of all variables on the pavement. The variables are subgrade characteristics, aircraft characteristics, equivalent Pavement Thickness.

3.3.2.1 Subgrade characteristics

The ACN-PCN method adopts four standard levels of subgrade strength for rigid pavements and four levels of subgrade strength for flexible pavements. These standard support conditions are used to represent a range of subgrade conditions as shown in Table 2 and Table 3.

Table 2: Standard Subgrade Support Conditions for Flexible Pavement ACN Calculation
(Source: AC 150/5335-5C)

Subgrade Strength Category	Subgrade Support CBR-Value	Represents	Code Designation
High	15	CBR ≥ 13	A
Medium	10	8<CBR<13	B
Low	6	4<CBR≤8	C
Ultra Low	3	CBR≤4	D

Table 3: Standard Subgrade Support Conditions for Rigid Pavement ACN Calculation
(Source: AC 150/5335-5C)

Subgrade Strength Category	Subgrade Support k-Value pci (MN/m3)	Represents pci (MN/m3)	Code Designation
High	552.6 (150)	k ≥ 442 (≥120)	A
Medium	294.7 (80)	221<k<442 (60<k<120)	B
Low	147.4 (40)	92<k≤221 (25<k≤60)	C
Ultra Low	73.7 (20)	k≤92 (≤25)	D

3.3.2.2 Concept of equivalent traffic

The ACN-PCN method is based upon design procedures that establish one airplane as the critical or most demanding on the pavement structure. Calculations necessary to determine the PCN can only be performed for one airplane at a time. The ACN-PCN method does not directly address how to represent a traffic mixture as a single airplane. To address this limitation, FAA uses the equivalent airplane concept to consolidate entire traffic mixtures into one representative airplane. In order to complete the equivalent traffic calculations for converting one of the aircraft in the mix to another, a procedure based on cumulative damage factor (CDF) is used.

3.3.2.3 Equivalent pavement thickness

The thickness of the pavement section under consideration must be converted to an equivalent pavement thickness based on a standard reference pavement section for evaluation purposes. The equivalent pavement thickness is the total thickness requirement calculated by the COMFAA program assuming minimum layer thickness for the asphalt surface, minimum base layer thickness of material with a CBR 80 or higher, and a variable subbase layer with a CBR 20 or greater. If the pavement has excess material or improved materials, the total pavement thickness may be increased according to the FAA CBR method as detailed in Appendix B of AC 150/5335-5C.

The pavement is considered to have excess asphalt, which can be converted to extra crushed aggregate equivalent thickness, when the asphalt thickness is greater than the minimum thickness of asphalt surfaced. The recommended reference section for this traffic mix is an asphalt surface course thickness of 5 inches (130mm). The pavement may also be considered to have excess crushed aggregate base thickness when the cross-section has a high quality crushed aggregate base thickness greater than 8 inches (203mm) or when other improved materials such as asphalt stabilization or cement treated materials, are present. Likewise, additional subbase thickness or improved subbase materials may also be converted to additional total pavement thickness. The support program facilitates converting existing pavement structures to the requisite standard equivalent structure used in COMFAA.

The assumed conversion factor for converting existing pavement layers to P209 base and P154 subbase layer are presented in the Table 4. The conversion factors are conservatively estimated from AC No: 150/5335-5C suggested value ranges based on current field and laboratory investigation results. Following Table 4 shows the details of equivalent pavement thickness calculation for COMFAA 3.0 input.

Table 4: Layer Conversion Factor for Evaluation Thickness Calculation

Existing pavement layer	Factor for converting to P209	Factor for converting to P154
Asphalt concrete	1.4	1.7
Premixed stone macadam	1	-
Bituminous macadam base course	-	1.7
Cement concrete	-	1.6
Reinforced cement concrete	1.4	1.6
Brick Herring bone bond	-	1
Brick flat soling	-	1

Source: Table B-1. FAA Flexible Pavement Layer Equivalency Factor Range, AC No: 150/5335-5C

3.3.3 ACN and PCN of HSIA runway

Technical Evaluation Method in the COMFAA 3 software was used to determine the residual Pavement Classification Number (PCN) of the existing runway. The input parameters to the COMFAA program are as follows:

- Critical Airplane: B777-300ER
- Maximum gross weight of B777-300ER: 347.452 tonnes
- Subgrade CBR: 7.0 (Code C)
- Tire Pressure: 218 psi (Code X)
- Percent weight on the main gear: 95%
- Equivalent Evaluation Thickness: 1182 mm

Using these conditions the COMFFA 3.0 program calculates the ACN and PCN of the existing runway. The Detailed results of analysis are shown in Figure 8.

This file name = PCN Results Flexible 1-23-2016 15;36;31.txt
Library file name = C:\Program Files (x86)\COMFAA 30\HSIA-2014.Ext
Units = Metric

Evaluation pavement type is flexible and design procedure is CBR.
Alpha Values are those approved by the ICAO in 2007.

CBR = 7.00 (Subgrade Category is C(6))
Evaluation pavement thickness = 1,182.0 mm
Pass to Traffic Cycle (PtoTC) Ratio = 1.00
Maximum number of wheels per gear = 6
Maximum number of gears per aircraft = 4

At least one aircraft has 4 or more wheels per gear. The FAA recommends a reference section assuming 127 mm of HMA and 203 mm of crushed aggregate for equivalent thickness calculations.

Results Table 1. Input Traffic Data

No.	Aircraft Name	Gross Weight	Percent Gross Wt	Tire Press	Annual Deps	20-yr Coverages	6D Thick
1	C-130	70.307	95.00	724	300	2,595	543.1
2	C-141	156.489	95.00	1,310	600	7,108	819.2
3	Fokker 50 HTP	20.820	95.60	590	10,000	49,843	389.4
4	DC10-30/40	264.444	75.04	1,220	1,500	16,601	873.9
5	B777-300 ER	352.441	92.44	1,524	6,500	99,613	1,048.8
6	B767-300 ER	187.334	92.40	1,379	200	2,190	745.8
7	B747-400ER	414.130	93.60	1,586	1,200	13,121	919.8
8	A340-300 std	275.895	79.58	1,420	300	3,191	816.7
9	A330-200 std	230.900	94.80	1,420	1,550	16,466	899.5
10	A300-B4 STD	165.900	94.00	1,490	1,550	17,005	841.2
11	A300-B2 STD	142.900	94.00	1,280	1,300	14,281	743.1

Results Table 2. PCN Values

No.	Aircraft Name	Critical Aircraft Total Equiv. Covs.	Thickness for Total Equiv. Covs.	Maximum Allowable Gross Weight	ACN Thick at Max. Allowable Gross Weight	CDF	PCN on C(6)
1	C-130	>5,000,000	965.5	97.077	795.25	0.0000	47.3
2	C-141	>5,000,000	1,157.1	161.489	958.81	0.0000	68.7
3	Fokker 50 HTP	>5,000,000	588.0	73.925	836.22	0.0000	52.3
4	DC10-30/40	>5,000,000	1,124.0	281.674	1001.02	0.0000	74.9
5	B777-300 ER	>5,000,000	1,158.3	361.578	1115.55	0.0000	93.1
6	B767-300 ER	>5,000,000	1,177.9	188.206	941.31	0.0000	66.3
7	B747-400ER	13,231	920.3	575.282	1303.24	0.0002	127.0
8	A340-300 std	1,828,005	1,063.9	316.633	1085.22	0.0000	88.0
9	A330-200 std	2,800,149	1,071.6	262.468	1075.13	0.0000	86.4
10	A300-B4 STD	>5,000,000	1,136.9	175.089	953.08	0.0000	67.9
11	A300-B2 STD	>5,000,000	1,018.0	175.602	953.69	0.0000	68.0
					Total CDF =	0.0002	

Results Table 3. Flexible ACN at Indicated Gross Weight and Strength

No.	Aircraft Name	Gross Weight	% GW on Main Gear	Tire Pressure	ACN Thick	ACN on C(6)
1	C-130	70.307	95.00	724	658.0	32.3
2	C-141	156.489	95.00	1,310	937.3	65.7
3	Fokker 50 HTP	20.820	95.60	590	393.1	11.5
4	DC10-30/40	264.444	75.04	1,220	953.9	68.0
5	B777-300 ER	352.441	92.44	1,524	1,092.9	89.3
6	B767-300 ER	187.334	92.40	1,379	937.9	65.8
7	B747-400ER	414.130	93.60	1,586	1,020.2	77.8
8	A340-300 std	275.895	79.58	1,420	980.8	71.9
9	A330-200 std	230.900	94.80	1,420	978.6	71.6
10	A300-B4 STD	165.900	94.00	1,490	916.3	62.8
11	A300-B2 STD	142.900	94.00	1,280	819.2	50.2

Figure 7: ACN and PCN output from COMFAA 3

3.3.4 ACN and PCN of SAIA runway

Technical Evaluation Method in the COMFAA 3 software was used to determine the residual Pavement Classification Number (PCN) of the existing runway. The input and output parameters to the COMFAA 3 program are shown in Table 5.

Table 5: ACN and PCN determination of SAIA runway pavement

Pavement Layers	Subgrade CBR	Equivalent Pavement Thickness, mm	Aircraft Characteristics	ACN	PCN
C1 (10+00-17+60) : RWY 05 End	5.0 (Category C)	1118.6	o Critical Airplane: B777-300ER o Maximum gross weight of B777-300ER: 347.452 tonnes o Tire Pressure: 218 psi (Code X) o Percent weight on the main gear: 95%	89.3	63.7
C2 (17+60 -22+20)		947.2		89.3	46.9
C3 (22+20– 31+20)		1067		89.3	56.7
C4 (31+20 – 34+20)		1116		89.3	63.1
C5 (34+20 – 36+90) :RWY 23 End		1052		89.3	55.4

3.3.5 ACN and PCN of OIA runway

Technical Evaluation Method in the COMFAA 3 software was used to determine the residual Pavement Classification Number (PCN) of the existing runway. The input and output parameters of the COMFAA 3 program are shown in Table 6.

Table 6: ACN and PCN determination of OIA runway pavement

Pavement Layers	**Subgrade CBR**	**Equivalent Pavement Thickness, mm**	**Aircraft Characteristics**	**ACN**	**PCN**
Old Runway (00+60-19+00)	5.0 (Category C)	966.3	o Critical Airplane: B777-300ER o Maximum gross weight of B777-300ER: 347.452 tonnes o Tire Pressure: 218 psi (Code X) o Percent weight on the main gear: 95%	107.4	50.4
1st Extension (1+900~2+200 2nd Extension (2+200~2+660 3rd Extension (2+660~2+800		865.9		107.4	41.8
Over Runway (2+800~2+954					
Last Extension (2+954~3+220 New Taxiway New Turning Pad					

4. CONCLUSIONS

Air transportation is playing a significant role in the sustained growth of Bangladesh economy. The airports of Bangladesh are currently accommodating wide bodied aircrafts like Boeing 777, and it is expected that the operation of wide bodied aircrafts will increase significantly in future. With the sustained and increasing air travel demand the life cycle of existing Asphalt Overlay work has been exhausted and the pavement surface shows significant signs of serious distresses. In order to evaluate the strength of airport runway pavements, COMFAA 3.0 software was used. Analysis of results shows that the ACN value is greater than PCN for all the runways, which indicates an immediate need of overlay work for the runways.

REFERENCES

Hasan M. E. (2015). *Evaluation of Airport Configuration to Accommodate Increasing Air Traffic Demand in Bangladesh*, Department of Civil Engineering, BUET, Dhaka.

Alam, J.B. and Karim, D.M., (1998). Air travel Demand model for domestic Air Transportation in Bangladesh. *Journal of Civil Engineering*, IEB, Bangladesh, CE 26(1).

FAA AC No: 150/5335-5C (2014), Standardized Method of Reporting Airport Pavement Strength –PCN, August 14, 2014.

The Boeing Company (2012). Calculating PCN using the FAA Method.

Euromonitor International (2013). Travel and Tourism available at: http://www.euromonitor.com/travel-andtourism- in-bangladesh/report ,accessed on 20-11-2013 at 13.50.

CAAB (2014), Airports in Bangladesh, Civil Aviation Authority of Bangladesh, (6 November 2014), http://www.caab.gov.bd/ adinfo/airports.html.

CAAB and BRTC (1993). Soil Investigation Report for Zia International Airport Runway. Department of Civil Engineering, BUET, Dhaka-1000.

Department of Civil Engineering, BUET (2014). ACN-PCN Determination for HSIA Airport Runway. Department of Civil Engineering, BUET, Dhaka-1000.

Department of Civil Engineering, BUET (2014-15). *Investigation of Pavement Distresses and Structural Conditions of the Existing Runway, Estimation of Residual PCN of the SAIA Runway and the Existing AGL Layout*. Department of Civil Engineering, BUET, Dhaka-1000.

Department of Civil Engineering, BUET (2015). *Investigation Of Pavement Distresses And Structural Conditions Of The Existing Runway, Estimation Of Residual PCN Of The OIA Runway And The Existing AGL Layout*. Department of Civil Engineering, BUET, Dhaka-1000.