SAFEGUARDING RUNWAY PAVEMENTS AT SCHIPHOL WITH RESPECT TO THE ARRIVAL OF NGA BY MEANS OF PCN

By:

Marc Stet
VIA APERTA Pavement Consultants
Mina Krusemanlaan 90, NL 7421 LL Deventer, The Netherlands
Phone: +31(0)570 657 563 Fax: +31(0)570 657 783
stet@via-aperta.nl

Marien Voorwinde and Ronald van der Vegte
Amsterdam Airport Schiphol, Business Area Aviation, Infrastructure
P.O. Box 7501, NL 1118 ZG Luchthaven Schiphol, The Netherlands
voorwinde@schiphol.nl and vegte_r@schiphol.nl

Adrian van Leest
CROW Technology Platform for Transport, Infrastructure and Public Space
P.O. Box 37, NL 6710 BA Ede, The Netherlands
vanleest@crow.nl

PRESENTED FOR THE
2007 FAA WORLDWIDE AIRPORT TECHNOLOGY TRANSFER CONFERENCE
Atlantic City, New Jersey, USA

April 2007

INTRODUCTION

Amsterdam Airport Schiphol (AMS) is gearing up for the arrival of the “New Generation Aircraft” (NGA) such as the European A380 and Boeing’s B777 Long Range and Extended Range versions. The Airbus 380 is the largest commercial passenger aircraft ever built and carries around 550 passengers .It impacts on a number of parts of the airport system including, runway and taxiway strength, strength of aircraft bridges, airport hard stand width and length, terminal gate width and passenger processing. In preparation of the arrival of the NGA, Amsterdam Airport Schiphol has carried out an extensive program to ensure A380 compatibility. As part of this program airside tests on runways pavements were performed and the results were used to review & upgrade reported PCN’s. The ACN-PCN system of rating airport pavements is designated by the International Civil Aviation Organization (ICAO) as the only approved standardized method for reporting strength [1].

ICAO Member States have agreed to evaluate and publish the bearing strength of airport pavements using the ACN-PCN system. Although there is a great amount of material published on how to compute an ACN [2], ICAO has not specified regulatory guidance as how an airport authority is to arrive at a PCN, and has left it up to the airport operating authority under the approval of the regulating Civil Aviation Authority (CAA) as to how to perform this task. The system does not prescribe or dictate a specific design method for PCN assignment. For states or individual civilian airport authorities, technical PCN values are often determined as an extension of existing national pavement design and evaluation technologies. As a consequence, technical PCNs can vary depending on the evaluation method used [3].

To harmonize and arrive at comparable and reproducible PCNs, the CROW Coordinating Committee on Airport Pavements developed a ‘Guideline on PCN assignment’ that prescribes the structural evaluation of jointed rigid and flexible pavements [4]. The Guideline is to be used to assign a PCN by means of technical evaluation for civil airport pavements on a national level. The guideline contains procedures for the calculation of a technical PCN in full detail. The basis for the PCN-determination is the use of Layered Elastic Analysis and calibrated failure criteria derived from material testing and/or full-scale pavement tests. Several States have implemented mechanistic design/evaluation systems with criteria that appear to be yielding reasonable results. Many of these procedures are based on linear, elastic theory coupled with empirical relationships for relating computed stress/strain to allowable aircraft load. This approach is well understood and well documented. Uniform sets of pavement transfer functions (performance models) and material characterization (mechanical properties) are described and procedures to access these properties are given. It should be noted that the transfer functions presented in this guideline are typical for Dutch construction materials and subgrades. However, the elastic layer mechanistic-empirical methods are adaptable to new criteria. For example, it is not very difficult to add/remove/modify the criteria (fatigue relationships or transfer functions). This makes the guideline attractive for other ICAO Member States since own transfer functions can be adopted and the results from continuing research and development can be incorporated as necessary.

The guideline has been used to evaluate the bearing capacity of the main runway system of Amsterdam Schiphol Airport. The bearing strength is not only based on the strength of the subgrade, but moreover on the strength and performance of all constructed pavement layers. Historical and future runway usage including NGA have been taken into account. Based on the

PCN-evaluation, Amsterdam Schiphol Airport can make the appropriate revisions to the PCN codes reported in the AIP manual.

THE ACN-PCN METHOD

The engineering system used for the control of aircraft loadings on airside surfaces is the ACN-PCN method. The International Civil Aviation Organization (ICAO) (DOC 9157-AN/901 and Amendment number 35 to Annex 14, [1]) devised the ACN/PCN method as an effective, simple, and readily comprehensible means for reporting aircraft weight-bearing capacity of airfields. The ACN-PCN is a reporting method for weight-bearing capacity introduced for world wide civil use in the mid-1980's. ICAO requires that the strength of pavements for aircraft with mass greater than 12,500 lb (5,700 kg) be made available using ACN-PCN method by reporting all of the following information: Pavement Classification Number, pavement type, subgrade strength category, maximum allowable tire pressure category or maximum allowable tire pressure value and evaluation method used.

The ACN-PCN system is simple to use. Each aircraft is assigned a number that expresses the structural effect on a pavement for a specified pavement type and a standard subgrade category. Under the ACN-PCN system, an aircraft has assigned an ACN that indicates design thickness requirements for the aircraft on a more expanded scale that ranges from an ACN of 5 for light aircraft to an ACN of 130 or more for heavy aircraft. Each airport operating authority reports site pavement strengths using the same numbering system. The PCN number indicates the suitability of a pavement area for unrestricted operations by any aircraft that has an ACN and tire pressure not exceeding the limits reported in PCN format of stated pavement type and subgrade strength category. The pavement is capable of accommodating unrestricted operations provided the aircraft load number is less than or equal to the pavement strength number. Maximum tire pressure limitations may also be applied to some pavements which may further restrict certain aircraft operations. The ACN is based on the static application of aircraft loads to the pavement surface making them somewhat conservative in nature. The national CAA publishes weight bearing limits in terms of ACN/PCN in a Flight Information Publication for civil and international use. The intent is to provide planning information for individual flights or multi-flight missions which avoid either overloading of pavement facilities or refused landing permission. The ACN and PCN are defined as follows:

- ACN is a number that expresses the relative structural effect of an aircraft on different pavement types for specified standard subgrade strengths in terms of a standard single-wheel load. The ACN has been developed for two types of pavements, flexible and rigid, and for four levels of subgrade strength.

- ACN values will normally be provided by the aircraft manufacturers at maximum and minimum operational gross weight.

- PCN is a number that expresses the relative load-carrying capacity of a pavement in terms of a standard single-wheel load.

- The system is structured so that a pavement with a particular PCN value can support, without weight restrictions, an aircraft that has an ACN value equal to or less than the pavement's PCN value.

- The PCN value is for reporting pavement strength only. The PCN value expresses the results of pavement evaluation in relative terms and cannot be used for pavement design or as a substitute for evaluation.

The ACN-PCN system is not intended for the design nor for the evaluation of pavements, nor does it dictate the use of a specific method for the design or evaluation of pavements. To archieve this, the system shifts emphasis from the evaluation of the pavement to the evaluation of aircraft loads. The concept of a single-wheel load has been employed as a means to define the landing gear assembly-pavement interaction without specifying pavement thickness as an ACN parameter. This is done by equating a fictitious pavement thickness, given by a mathematical model for an aircraft gear assembly, to the pavement thickness for a single wheel at a standard tire pressure of 1.25 MPa (181 psi).

The PCN number indicates the suitability of a pavement area for unrestricted operations by any aircraft that has an ACN *and* tire pressure not exceeding the limits reported in PCN format of stated pavement type and subgrade strength category. The method of PCN pavement evaluation is left up to the airport, under the approval of the regulating CAA. Some guidance to the selection of an appropriate PCN is provided in Chapter 3, ‘Evaluation of pavements’ of the Aerodrome design manual [2]. Although ICAO does not give specified regulatory guidance on how to determine a PCN, it states that the PCN must represent a relation between allowable load i.e. the ACN of the critical i.e. most damaging aircraft and the structural pavement life. In the most fundamental terms, the determination of a rating in terms of PCN is a process of deciding on the maximum allowable gross weight of a selected critical airplane for a pavement knowing its ACN at that weight, reporting it as PCN. This process can be as simple as knowing the operational gross weight of each aircraft that is currently using the pavement and looking up its ACN (referred to as the *Using* aircraft method). This method can be applied with limited knowledge of the existing aircraft and pavement characteristics. The *Using* aircraft method should be considered as, at best, a close approximation. This method was introduced in the ACN-PCN method for general world-wide acceptance of the method. The second method is more complex and referred to as *Technical* evaluation, and requires knowledge of the pavement and its traffic, as well as a basic understanding of engineering methods that are used in pavement design. The *Technical* evaluation method of determining PCN should be used when there is reliable knowledge of the existing traffic and pavement characteristics. The PCN numerical value for a particular pavement is determined from the allowable load- carrying capacity of the pavement. Once the allowable load is established, the determination of the PCN value is a process of converting that load to a standard relative value. The allowable load to use is the maximum allowab1e load of the most critical aircraft that can use the pavement for the number of equivalent passes expected to be applied for the remaining life.

CROW GUIDELINE ON PCN ASSIGNMENT

Generally, pavement strength evaluation involves making a comparison of the structural loading effect of an aircraft on a pavement to the structural ability of the pavement to support the imposed load. Inverse pavement design is the basis for the PCN assessment in the Guideline. This concept is generally used for the structural design of pavement systems in the Netherlands (and Europe). The requirement to understand pavement performance has resulted in a demand for accurate site testing systems that will allow accurate prediction of pavement performance. However, information on how to evaluate an in-service airport pavement and to assess a pavement model is not discussed in this document, but can be found elsewhere [see 5 and 6]. In order to appreciate the procedure presented and its pavement models used, a brief introduction regarding design concepts is thought necessary. The Addendum to the Guideline [7] contains both test methods and worked examples of PCN assignments of flexible and rigid pavement.

STRENGTH EVALUATION EQUIPMENT AND METHODS. The Guideline uses an established and industry recognized engineering method appropriate to the pavement construction type to determine the structural capability of a pavement to support proposed aircraft loads and traffic levels. The strength determination method should rely on the results of in-situ pavement strength tests combined with a knowledge of the thickness' and strength properties of the various material layers comprising the pavement structure. Linear elastic analysis is the basis to compare the structural loading effect to the structural ability to support the imposed loads.

DESIGN CONCEPTS. It is widely recognized that the US Corps of Engineers' CBR method cannot adequately compute or predict pavement damage caused by new large aircraft. Layered elastic design was first introduced in the late 1960's and is quite common in Europe nowadays. It is because of the complexities of structural behaviour and material properties that empirical procedures have endured for so long in pavement engineering. However, with the knowledge now available from research, mechanistic-empirical procedures based on layered elastic design can be applied to asphalt and rigid pavements. Following the load input into the model, the stresses and strains are calculated at the design positions. For flexible pavements these are at the bottom of the bituminous layer (fatigue cracking), the top of the subgrade (rutting) and in a cement bound base at the bottom of this layer (reflective cracking). For concrete pavements the edge-loading position is critical. Stresses and strains are calculated at the edge position using Westergaard incorporating temperature induced stresses and the measured load transfer. By means of fatigue relationships or transfer functions the (residual) allowable number of standard axles and thus the residual pavement lives are calculated. Accumulation of the damaging effects of the number of load repetitions is made on the basis of Miner's damage hypothesis for all pavement materials, i.e. concrete, flexible layers, foundation sub-base layers and subgrade.

SOFTWARE. Implementation of calibrated design criteria into modern software tools allow the designer to access the full advantages of the layered elastic method, including treatment of wander, and quickly produce designs for complex aircraft mixes and layered structures that are consistent with the original design concept.

The Dutch Guideline requires the use of specific software capable of linear elastic analysis (LEA) using flexible multi layer and rigid multi-layer design theories. CROW does not endorse the use of certain software products, however, based on a review of only APSDS and PAVERS® these programs are suitable to use for the PCN assignment as is presented in the Guideline. For asphalt pavements only APSDS and PAVERS® qualify, since they use a layered elastic Burmister model as the programs engine. For rigid pavements, only Pavers® has implemented a multi-layered rigid pavement model. The latter is a necessity when assessing PCN for pavements with a stabilized base. FAA recommends the use of cemented bases when aircraft with an operating mass over 45 tons use the pavement.

APSDS (Airport Pavement Structural Design System) is a proprietary computer program based on layered elastic analysis [8]. One of its unique features is that it rationally takes account of aircraft wander. This is the statistical variation of the paths taken by successive aircraft relative to runway or taxiway centerlines, or to the lead-in lines to parking positions. Increased wander reduces pavement damage by different amounts that depend upon pavement thickness. This treatment of aircraft wander is more realistic than methods that are based on the simplified 'coverage' concept. Its method for dealing with aircraft wander meant that the 'pass-to-cover ratio' was no longer required. The user can define his fatigue transfer functions in the design of flexible pavement. APSDS is not suitable for concrete pavement design, nor is fit for FWD-based flexible or concrete pavement evaluations.

PAVERS® [9] was initially developed as part of the airport pavement evaluation methodology of the Dutch Ministry of Defense. The developers, Dr. F. Van Cauwelaert, H.P.M. Thewessen and M.J.A. Stet teamed up, improved and extended several models [10], built a tool-kit and implemented them in the latest versions of PAVERS®. The program and its models are property of its developers. The tool was created to give pavement specialists a definite tool for the structural design and evaluation of road, airport and industrial rigid and flexible pavements. The tool does not dictate a certain design methodology, but allows the pavement engineer to define or use *calibrated* failure criteria for all pavement materials. If fatigue relationships exist of these materials, then this information can be entered quite smoothly into one of the program’s subroutines. Hence, the effect of different pavement materials, strengths, loads or complex load mixes can quickly be explored. The program is capable to support the Dutch Guidelines for PCN assignment. The program contains a linear elastic multi layered model, which allows for the assessment and design of flexible pavement. The layers are isotropic except for the bottom layer where anisotropy is addressed by different moduli in the horizontal and vertical direction. The interface between two adjacent layers can be varied between full friction to full slip using the BISAR or Van Cauwelaert’s WESLAY definition. Pavers® uses closed form integral solutions to model a concrete multi slab-on-grade as a classical Westergaard slab on a Pasternak foundation. This model overcomes the classical discrepancy between the Westergaard-Winkler (joints) model and the layered elastic Burmister model (no joints). By using closed formed solutions, it is possible to calculate the response of multiple loads placed at random positions on a slab, thus overcoming the ESWL concept for rigid pavements.

Both Pavers® and APSDS rationally take into account variable lateral aircraft wander for flexible pavements, which is believed to be more realistic than the pass-to-coverage (p/c)ratio for flexible pavements or the pass-to-load repletion (p/lr) ratio for rigid pavements. The unique rigid model code of Pavers® allows to deal with aircraft wander for rigid pavement, eliminating the pass-to-load repetition concept.

PAVEMENT CHARACTERIZATION. The rigid pavement is to be modeled as a slab on-grade system. The Pasternak foundation was chosen as an attractive alternative to the classical Winkler foundation. The introduction of a horizontal linkage, Pasternak's shear constant, in Winkler's model is a remedy for the discrepancies between Westergaard's theory and the multilayer theory, while the great advantages of Westergaard's model (edge and corner loading) are maintained (for G=0, one obtains a classical Winkler foundation). Multiple loads can be placed anywhere on the slab. The closed form mathematical solving technique allows the use of n-number of loads, overcoming the ESWL concept which can be considered as one of the major drawbacks of the Westergaard model.

The multi-layer model to use is a classical linear elastic Burmister multi-layered structure. The layers are isotropic except for the bottom layer where anisotropy is addressed by different moduli in the horizontal and vertical direction. The interface between two adjacent layers can be varied between full friction to full slip using the BISAR or WESLAY definition.

MATERIAL CHARACTERIZATION. To tie the life of a pavement to the computed stress or strain response, mechanistic-empirical data are required to predict the load-carrying capacity. Like other structural materials, pavement materials are subject to the effects of fatigue. Fatigue failure induced by traffic load repetitions and temperature variations is one of the basic structural distresses which affect performance of pavements. Performance models are either derived from laboratory testing or are based on calibrated field data. It is important to use an appropriate transfer function so that the predicted distress can match with field applications. Mechanistic-empirical calibration can be done by using calibrated transfer functions which relate critical stresses and strains in a multi-layered pavement structure to an allowable number or load repetitions. The Guideline presents a number of test methods to assess in a *standardized* manner, the material and fatigue transfer functions *to be used for PCN-evaluation* in the Netherlands. This Guideline may also be used by others, provided that they use the characteristics of their road construction materials. The listed test methods presented in the Appendices comply with the European Standards published by the Comité Européen de Normalisation (CEN). European Standards have been prepared by Technical Bodies of CEN. Concrete and related products have been the subject of Technical Committee 104. European Standards on ‘Road Materials’ have been prepared by the Technical Committee CEN/TC 227 and its ad-hoc committee on ‘Airport Pavements’. An European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement at the latest by June 2004. Conflicting national standards shall be withdrawn. Several Standards have been ratified and published, others are under development. An updated list of European Standards and the current status of projects can be found at www.cenorm.be [11].

REPORTING PCN AND SUBMISSION TO CAA. The assigned PCN depends on the structural strength and fatigue life of the pavement. The assigned PCN is in fact the allowable ACN load representing the actual traffic mix that consumes the pavement life in a defined number of years. In this perspective, the pavement design life is also a parameter influencing the PCN. Pavements with the same bearing strength can be assigned a large PCN with respective small design life, but can also be assigned a small PCN with consequently a higher design life.

Since the assignment of PCN is largely a business decision, an airport authority should also report the pavement life to a regulating CAA. It is suggested to take a period of time of at least 10 years as a minimum period to (re)calculate a PCN. During this period of time the PCN is fixed. Should during this period significant changes in aircraft traffic (fleet mix and frequency) or aircraft load (new large aircraft) occur, it is recommended to re-calculate and to submit a revised PCN to the CAA. At the submission of the PCN to the regulating CAA, the airport must also provide the underlying structural pavement data and assumptions. Appendix 5 of the Guideline presents a data sheets to submit a PCN application. Amongst other the following items should accompany the submission:

- Designation of pavement;
- PCN-evaluation life;
- Pavement and material data, i.e. the structural pavement break-down, the material properties, fatigue transfer function, critical pavement layer, subgrade strength;
- Load data: ACN data of aircraft, Details of fleet mix (frequency and aircraft type), Critical aircraft;
- PCN value and code.

PAVEMENT STRENGTH REVIEW AND UPDATE. The bearing strength of a pavement should be reviewed and re-determined when the structural composition and/or properties of the pavement change as a result of new or restorative construction (such as an overlay or reconstruction), when new large aircraft enter the fleet mix or when significant change in the structural condition of the pavement occurs.

The reported PCN should be reviewed, re-affirmed or re-determined at least every ten (10) years. As part of the review process, consideration should be given to re-testing the strength of the pavement. If the review results indicate that pavement strength values have changed, the airport authority should make the appropriate revisions to the PCN code reported in the AIP manual.

PCN PROCEDURE FOR FLEXIBLE AND RIGID PAVEMENTS

Amsterdam Schiphol has used the CROW Guideline to assess the bearing capacity of their runway pavements. A summary list of the steps to follow in a PCN assignment of flexible pavement can be recognized in the worked example presented hereafter.

A flexible runway pavement with a width of 60 meters comprises of a 270 mm thick asphalt layer resting on a 350 mm thick cement treated base layer. The pavement is newly constructed. The fleet comprises of a total of eight narrow and wide bodied aircraft. The departure level is 15.400 per annum, resulting in total of 308.000 movements in a 20-year pavement course. The example explains the PCN calculation procedure in a step by step manner. The procedure is demonstrated using the summarized list of steps presented earlier. The evaluator's input is printed in *italic*.

Step 1. General: Select the PCN-life course to use up the structural capacity of the pavement: *20 years*

Table 1. Pavement structure derived from field testing and back-calculation

Material	*Stiffness (MPa)*	*Poisson's ratio (-)*	*Thickness (mm)*
Asphalt	*7,500*	*0.35*	*250*
Cement Treated Base	*10,000*	*0.25*	*350*
Subgrade	*80*	*0.35*	∞

Step 2. Pavement Structure: Assess the pavement structure in terms of constructed thickness', elastic moduli and Poisson ratio's. The material properties to use are listed the CROW Guideline.

Step 3. Paved Materials: Determine the pavement's layer fatigue properties, including those of the subgrade CBR and pavement thickness. Properties can be determined from material testing or literature. Pavers® has pre-defined performance functions which were taken from literature. In this example, we selected a Shell criterion for the asphalt layer, Starr Kohn's criterion for the cemented base layer [12] and Shell's subgrade criterion.

The asphalt is characterised with a F-78 fatigue behaviour. The average transfer function for asphalt is: $log(N_{asph}) = 27.676 - 7.327\,log(S_{mix}) + 0.769\,log^2(S_{mix}) - 5.351\,log(\varepsilon_r)$. *The cement treated base has a compressive strength of 10.0 MPa. The flexural strength is 2.00 MPa. The fatigue transfer function of CTB has a reliability level of 85%.* $log(N_{bt}) = 11.782 - 12.120\left(\frac{\sigma_{bt}}{f_{bt}}\right)$.
The fatigue transfer function selected for the subgrade is the well known Shell-relation: $log(N_s) = 17.289 - 4.00\,log(\varepsilon_z)$. *The CBR is derived from the stiffness of the subgrade using the rule of thumb: CBR = Stiffness x 0.10 = 8%. A CBR of 8 % indicates a medium subgrade strength i.e. subgrade category 'B'.*

Step 4. Aircraft traffic:

- Determine the traffic volume in terms of type of aircraft, and number of future operations of each aircraft that the pavement will experience over its PCN pavement life course;
- Look up or calculate the ACNs of the aircraft at its operating empty (OEW) and maximum weight and at maximum takeoff weight (MTOW);
- The ACNs at OEW and MTOW of the critical aircraft are to be used in the PCN evaluation.
- Determine the degree of lateral wander for the pavement.

Table 2 Technical evaluation critical airplane determination

Airplane	*Annual Departures*	*Operating weight (kg)*		*ACN Flexible Subgrade category B*		*Tire pressure (MPa)*
		MTOW	*OEW*	*MTOW*	*OEW*	
B727-200 Adv	*400*	*86,636*	*44,347*	*50 FB*	*22 FB*	*1.06*
B737-300	*6,000*	*61,462*	*32,904*	*33 FB*	*16 FB*	*1.34*
A319-100AT	*1,200*	*64,000*	*40,100*	*36 FB*	*19 FB*	*1.31*
B747-400	*4,500*	*395,987*	*178,459*	*64 FB*	*22 FB*	*1.41*
B767-300ER	*2,000*	*172,819*	*87,926*	*53 FB*	*22 FB*	*1.31*
DC8-63/73	*800*	*162,386*	*72,002*	*59 FB*	*19 FB*	*1.34*
MD11	*1,500*	*274,650*	*127,000*	*70 FB*	*26 FB*	*1.41*
B777-200	*300*	*288,031*	*138,346*	*54 FB*	*20 FB*	*1.51*

The critical aircraft is the MD-11, having ACNs of 70 and 26.

According to HoSang the lateral wander of the Take-Off mode is more critical than the landing mode. Therefore, the lateral wander for the runway pavement is 2,400 mm [13].

- Determine the critical pavement layer i.e. the constructed layer with the lowest bearing capacity or highest damage factor.

The critical pavement layer is the Cement Treated Base. Including a lateral wander of 2400 mm, the Miner sum after 20 years will be 0.74 or 74 % (see Figure 1).

It can also be depicted that the asphalt layer and the subgrade hardly suffer from strain related fatigue damage.

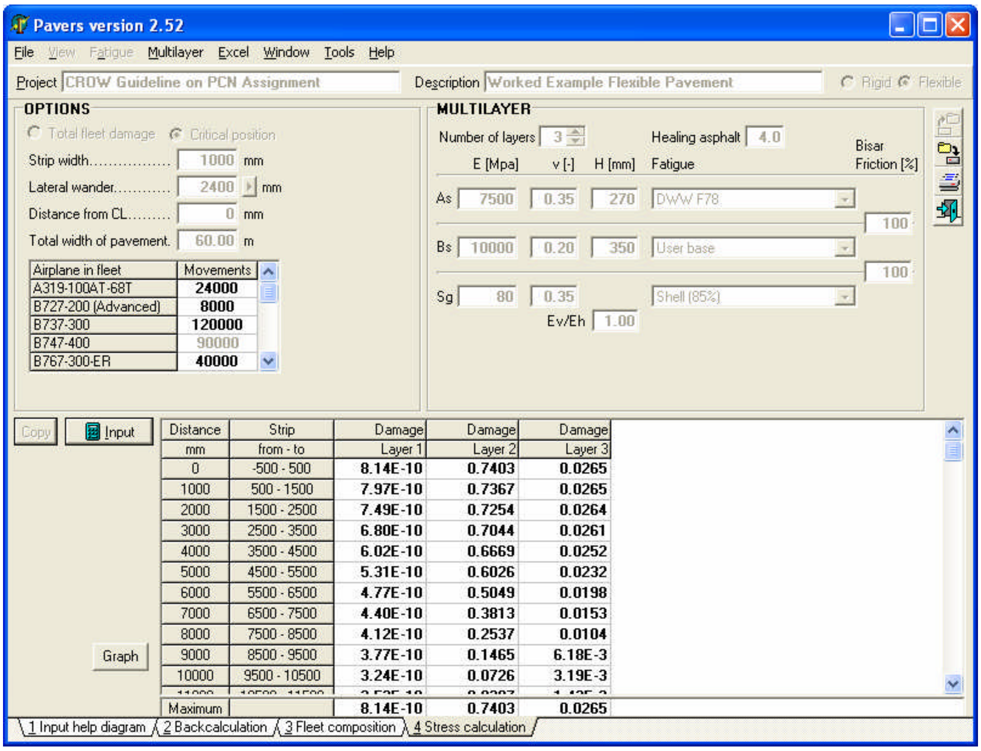

Figure 1. Calculating the structural pavement life to discern the critical pavement layer.

<u>Step 5. PCN Assessment: pavement life and PCN calculation:</u>
Convert the fleet mix into a number of movements of the critical aircraft resulting in the same Miner damage. Use this number to calculate the PCN of the pavement.

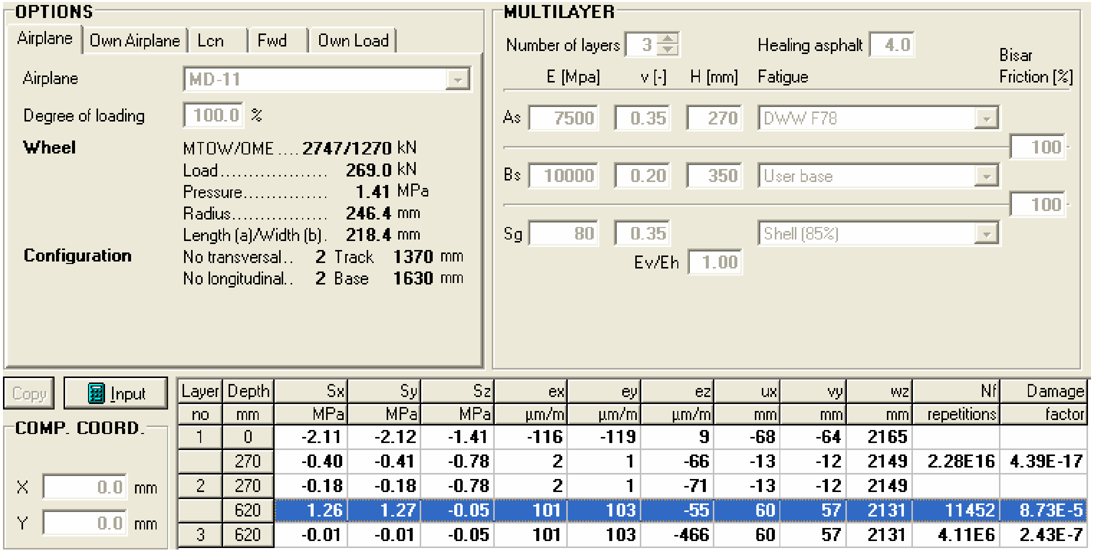

Figure 2. Calculating the allowable load repetitions of the critical aircraft (MD-11).

Calculate the allowable number of MD-11 movements resulting in a total Miner damage of 74.03%. As can be depicted from Figure 2, a total of 11,452 MD-11 movements are allowable for the pavement under consideration, consuming the total pavement structural life. However, during the 20 year pavement course, the accumulated Miner damage is 74.03%. Hence, the number of MD-11 movements is 0.7402 times 11,452 gives a total of 8,479 MD-11 movements.

- Calculate the allowable ACN-load of the critical aircraft by varying the gross weight of the aircraft until the same Miner damage is gained during the PCN life course;
- Calculate the corresponding ACN that refers to the allowable mass using the published ACN data of the critical aircraft.

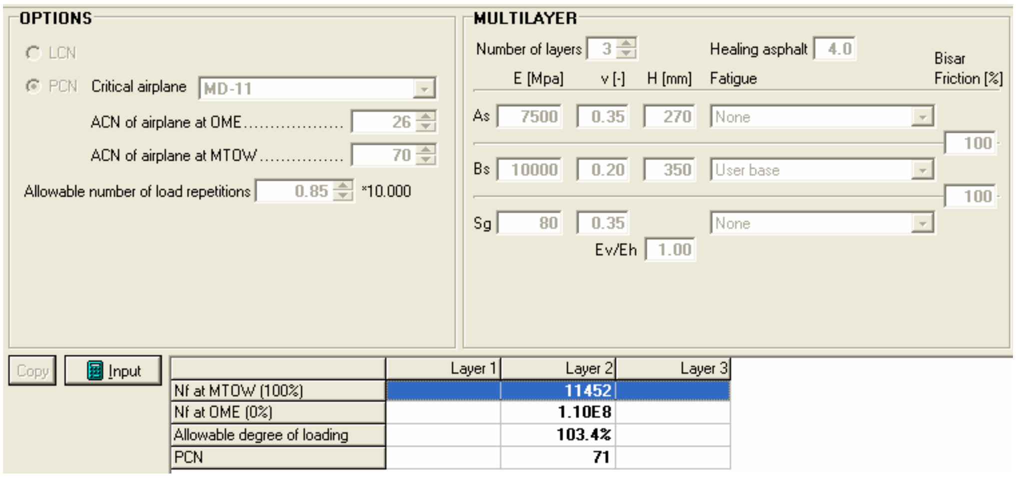

Figure 3. Calculating PCN.

The pavement can sustain an Allowable Gross Weight of 103.4 % compared to its MTOW, i.e. a weight of 283.988 kg. The ACN data of an MD-11 are 26 at an OEW of 1,270 kN and 70 at a MTOW of 2,747 kN. At an allowable load of 2,810 kN (103.4 times 2,747 kN), the ACN is 71.

Assign this ACN as being equal to the pavements PCN. Should the PCN be higher than the ACN of the critical aircraft, the PCN-life course can either be prolonged or limited to this ACN-value. Should the PCN be smaller than the required ACN of the critical aircraft, either a smaller PCN life course should be selected or the pavement must be strengthened in order to meet the requirements. The PCN reporting format is 71 F/B/W/T.

CLOSURE

It is important to have an unambiguous, generally accepted methodology for computing pavement damage, to allow airport operators and pavement engineers to adequately design and evaluate pavements to accommodate new aircraft, and to allow airlines to anticipate airport pavement weight restrictions in planning their operations and in deciding which aircraft to purchase. An established and industry recognised engineering method appropriate to the pavement construction type should be used to determine the structural capability or PCN of a pavement to support proposed aircraft loads and traffic levels for the anticipated pavement life.

ICAO does not dictate a specific design method for PCN assignment. As a consequence PCNs can vary depending on the evaluation method used. This Dutch Guideline provides guidance for the assignment of the PCN of airport pavements. Several examples are given. The method does relate PCN to the structural pavement life and the volume of traffic to be encountered. Hence, the PCN can function as a pavement management tool, and its selection is largely a business decision by the airport authority. However, the airport authority must also submit the underlying structural pavement data to the responsible CAA according to a standardized format.

It should be borne in mind that, although this Guideline carefully describes layered elastic based PCN-procedures, pavement engineering skills are still required. This also implies that the bearing strength should be determined by a professional engineer or engineering consulting firm experienced in the analysis of the bearing strength of airfield pavements with a proper understanding of the (local) pavement materials used, in determining their ability to support airport loads, and in assessing the effect that aircraft loads are likely to have on the future performance and condition of the pavement.

The CROW Guideline is intended for usage on civil airports in the Netherlands only. The Guideline presents an uniform set of pavement transfer functions (performance models) and material characterization (mechanical properties) are described and procedures to assess these properties are given. The transfer functions presented herein are typical for Dutch construction materials and subgrades. The Guideline is primarily intended for use in the Netherlands, however, can very well be used by other Countries and/or NATO nations, provided that they use or test the characteristics of their own road construction materials. With the current emphasis and requirements for better design/evaluation methods, the use of the Guideline by ICAO State Members as a standard PCN assessment method is warmly recommended.

REFERENCES

1. International Civil Aviation Organization (ICAO). *International Standards and Recommended Practices, Aerodromes, Annex 14 to the Convention on International Civil Aviation, Volume 1 Aerodrome Design and Operations*, 3rd edition, International Civil Aviation Organization, 2004.
2. International Civil Aviation Organization (ICAO). *Aerodrome Design Manual. Part 3, Pavements*, Second edition, ICAO, 1983.
3. CROW, '*The PCN Runway Strength Rating and Load Control System*'. State of the art study 2003/2004. Edited by M.J.A. Stet. CROW-report 04-09. Ede, The Netherlands, 2004.
4. CROW, "*Guideline on PCN Assignment in the Netherlands. Guideline on Airport Pavement Strength Rating and Directive for Reporting*". Edited by M.J.A. Stet. CROW-report 05-06 downloadable at www.crow.nl.
5. CROW. *Deflection profile – not a pitfall anymore*. Edited by C.A.P.M. van Gurp. Record 17. Ede, The Netherlands, May 1998.
6. CROW. *Uniform Evaluation Method Concrete Airport pavements* (in Dutch). Edited by M.J.A. Stet. Ede, The Netherlands, March 1999.
7. CROW. '*Pavement evaluation and PCN-assignment*'. Addendum to CROW-report 05-06. 2006.
8. Rickards, I. *APSDS. A structural design system for airports and industrial pavements*. Ninth AAPA International Asphalt Conference, Surfers Paradise, Australia, 1994 www.mincad.com.au.
9. Stet, M.J.A., Thewessen. H.P.M. and Van Cauwelaert, F. *'PAVERS: Pavement Evaluation and Reporting Strength software*; *PCN Assessment using PAVERS software',* Pavers Pavement Team, www.pavers.nl, 2007.
10. Van Cauwelaert, F. '*Pavement design and evaluation. The required mathematics and applications'.* ISBN 2-96000430-0-6. Edited by M.J.A. Stet. Federation of the Belgian Cement Industry, Brussels Belgium, 2004.
11. Comité Européen de Normalisation. Homepage of CEN. www.cenorm.be, 2007.
12. Kohn, S.D. '*Development of Thickness Design Procedures for Stabilized Layers under Rigid Airfield Pavements*'. 4th Purdue Conference. West Lafayette, Indiana USA. 1989.
13. HoSang, V. et al. "*Field Survey and Analysis of Aircraft Distribution on Airport Pavements*". Research in Airport Pavements. Special Report 175, Transportation Research Board, Georgia, USA, 1978.