INVESTIGATION INTO THE VARIATION IN AIRFIELD PAVEMENT STRENGTH RATING CALCULATION

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ABSTRACT

The Pavement Classification Number (PCN) was an international method developed by the International Civil Aviation Organization (ICAO) to report runway, taxiway as well as apron pavement strength. In the past, the great variation in calculated PCN values obtained through available internationally recognised methods for PCN calculation, allowed pavement engineers to target a specific PCN to the potential detriment of the airfield pavement and its safe operation. Recently, in June 2020, the ACN-PCN system was replaced by the new ACR-PCR (Aircraft Classification Rating – Pavement Classification Rating) system. During this study a series of PCN calculations were performed for a range of typical airport pavement structures with different internationally recognised PCN calculation approaches. The process was repeated using the new PCR approach with the currently available calculation approaches. The variation in PCN was compared to the variation in PCR to confirm if the new rating system results in reduced variation. The analysis confirmed a reduced variation in calculated ratings for flexible pavements, but not for rigid pavements.

1. BACKGROUND

Since the 1980s, ICAO has published an internationally recognised system, the ACN-PCN system, for airport pavement strength rating (ICAO, 1983). All airports that serve commercial airline operations were obliged by ICAO to publish its PCN in their Aeronautical Information Publication (AIP). Similarly, all aircraft manufacturers were required to provide an Aircraft Classification Number (ACN) for each type of aircraft they manufacture. The ACN is a number that expresses the aircraft loading on the airfield pavement for specified standard subgrade strengths (ICAO, 1983).

If the PCN value of an airport pavement is greater than the ACN value of the aircraft, then the pavement should be able to carry the weight of the aircraft and the extreme pavement failures like those shown in Figure 1 should be prevented.

The ACN-PCN system does not dictate a specific design method for strength rating but allows local civilian airport authorities to determine a technical rating as an extension of their existing national pavement design and evaluation technologies (Stet and Verbeek, 2005). The main reason for not specifying a specific method was the reluctance of the member states to agree on a common method. In most developing countries, where the advancement of local pavement design and evaluation technologies has been limited and local civil aviation authorities are less prescriptive, pavement engineers have adopted different well-established international evaluation techniques, including those from America (FAA and Corps of Engineers), Europe (North Atlantic Treaty Organization), France, the

Netherlands, Australia and South Africa. Accordingly, technical ratings can vary significantly depending on the evaluation method used (CROW, 2004).

Figure 1: Extreme airfield pavement failures due to overloading (Amerika Pilot Akademisi, 2019 and Whitfield, 2019)

Although differences in calculated PCN values have been reported (CROW, 2004) and (Stet and Verbeek, 2005), limited information on its variation is available in the literature. At the time of this study, the calculation approach to PCR was available only in draft format and the author was unaware of any studies on potential variation in the calculated PCR values.

2. OBJECTIVES AND SCOPE OF THIS STUDY

It is anticipated that the new ACR-PCR pavement strength rating system will reduce the potential variation in the calculation of the strength rating of airfield pavements, compared to the old ACN-PCN system. The objective of this study was to investigate the variation in PCN values by performing a series of PCN calculations for a range of typical airport pavement structures with different internationally recognised PCN calculation approaches. The process was then repeated using the new PCR approach with the currently available calculation techniques. The variation in PCN was then compared to the variation in PCR to determine if the new rating system results in reduced variation.

The scope of the investigation included three typical flexible and three typical rigid airfield pavement structures. Only one subgrade class was investigated. Variations in the pavement structures were limited to the thickness of the asphalt layer for the flexible pavement and the concrete layer for the rigid pavement. In terms of the loading of the pavements, the following were considered:

- Only one aircraft in the aircraft fleet was used.
- The number of load cycles selected was inclusive of traffic wander so that any variation in strength rating would not be due to different approaches in handling traffic wander.
- The standard fatigue transfer functions of different software packages were used.

3. METHODOLOGY

3.1 Introduction

The methodology that was followed involved a simulation exercise. A single aircraft fleet was selected based on the standard aircraft available in the software packages used and their loading characteristics. The loading cycles were adjusted to roughly ensure that a low, medium and high spread in pavement strength rating could be targeted. Traffic cycles were considered as inclusive of traffic wander. Once the baseline pavement structures were evaluated, the thickness of the surfacing layer (asphalt for flexible and concrete for rigid) was varied to test the sensitivity of the strength rating calculation on variations of the pavement structure.

For the initial PCN calculation, the loading characteristics of the aircraft in the different software packages were amended to ensure similar loading conditions. The range of PCN values calculated provided a baseline of expected variation for the old PCN rating system.

A PCR calculation was then performed using the same settings as for the PCN calculation, and the range of strength rating values used to compare the overall variation in the two strength rating systems.

Throughout this study, the variation is defined as the maximum difference between the calculated rating values, expressed as a percentage of the lower value as defined in equation (1).

$$\text{Variation (\%)} = \frac{(\text{Maximum value} - \text{Minimum value})}{\text{Minimum value}} \quad (1)$$

3.2 Flexible Pavement Structures

Three typical flexible pavement structures were selected for the investigation, as indicated in Table 1. All the structures have asphalt surfacings. Both the medium and the light pavement structure have a crushed stone base layer with a natural gravel subbase, while the heavy pavement structure has a cemented base. A standard subgrade support was selected for all the pavements structures with a CBR strength of 15% and stiffness of 120MPa. A standard Poisson ratio of 0.35 was assumed for all the pavement materials.

3.3 Rigid Pavement Structures

Three typical rigid pavement structures were also selected for the investigation also shown Table 1. All the structures have a cemented gravel subbase. A concrete poison ratio of 0.2 was assumed, while a 0.35 ratio was used for the subbase and subgrade materials. As with the flexible pavement structures a standard subgrade support with a 15% CBR (stiffness 120 MPa) was used.

Table 1: Flexible and rigid pavement structures investigated during the study

	Flexible			Rigid		
	Layer	**Thickness (mm)**	**Stiffness (MPa)**	**Layer**	**Thickness (mm)**	**Stiffness (MPa)**
Light	Asphalt	40–80	1,300	Concrete	180–220	40,000
	Crushed stone	150	220	Stabilised gravel base	150	1,000
	Gravel subbase	250	200			
Medium	Asphalt	100–140	1,300	Concrete	180–260	40,000
	Crushed stone	200	220	Stabilised gravel base	150	1,000
	Gravel subbase	250	200			
Heavy	Asphalt	150–190	1,300	Concrete	300–380	40,000
	Stabilised base	300	1,500	Stabilised gravel base	150	1,000
	Gravel subbase	250	200			

3.4 Selected Aircraft

The selection of the aircraft used for loading was limited by the aircraft available in the Pavers demo version software package. Accordingly, the following aircraft was used:

- Light pavement structures – Fokker 100.
- Medium pavement structure – Boeing B737-200.
- Heavy pavement structures – Lockheed L-1011-1.

The basic loading characteristics of the aircraft are summarised in Table 2.

Table 2: Basic loading characteristics of the aircraft used in the study

Parameter		**Unit**	**Fokker 100**	**B737-200**	**L-1011-1**
Passes (coverages)	Flexible	no.	10,000	50,000	50,000
	Rigid	no.	10,000	10,000	50,000
Wheels in main gear		no.	2	2	4
Main gear offset		mm	2,535	2,615	5,485
Wheel track		mm	550	770	1,320
Wheel base		mm	n.a.	n.a.	1,780
Tyre pressure		kPa	980	950	1,330
% weight on main gears		%	95.6	91.9	94.8
Loads	MTOW	kN	447	457	1,913
	OME		244	259	1,070

MTOW = Maximum take-off weight
OME = Operating mass empty

3.5 PCN/PCR Calculation Software

The software packages used to calculate PCN include the following:

- PCASE 2.09.06 Desktop (US Army Engineering Research Laboratory, 2019).
- Pavers Demo Version 2.5 (Stet, et al., 2001).
- COMFAA Version 3.0 (FAA, 2014).

The PCR approach has been rolled out only provisionally since June 2020. Accordingly, only two software packages are available with a PCR calculation module, namely:

- FAARFIELD (FAA, 2020).
- Alize-LCPC (IFSTTAR and STAC, 2016).

However, because the PCR procedure is based on a linear elastic analysis approach, it is possible to calculate a PCR using a linear elastic stress analysis software package.

4. RESULTS

4.1 Strength Rating System Calculations

This section provides the results of the PCN and PCR calculations for the flexible and rigid pavements.

4.1.1 Flexible Pavements

For each of the light, medium and heavy flexible pavement structures, the asphalt thickness was varied and the PCN value calculated using Pavers, PCASE (CBR cover curve approach) and COMFAA, while the PCR was calculated using Pavers, Alize-LCPC and FAARFIELD. The results are presented in Figure 2 to Figure 4.

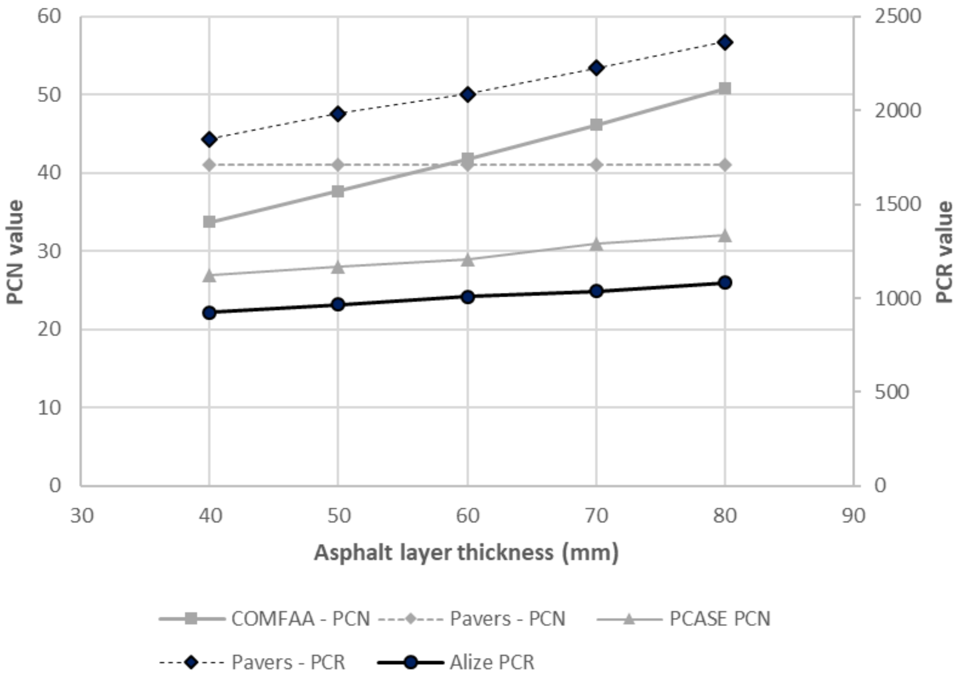

Figure 2: PCN and PCR with varied asphalt layer thickness for light flexible pavement structure

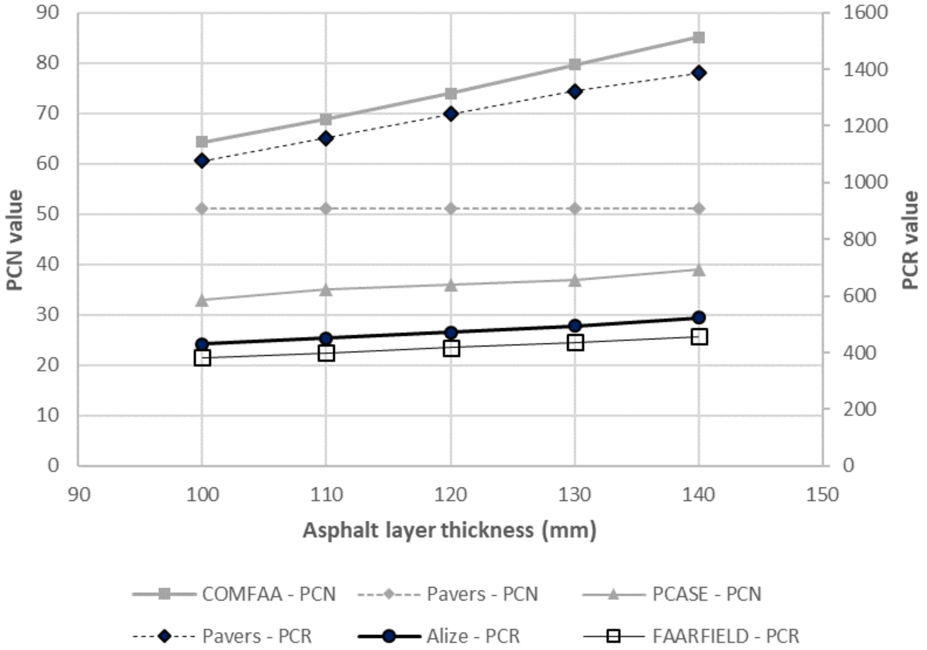

Figure 3: PCN and PCR with varied asphalt layer thickness for medium flexible pavement structure

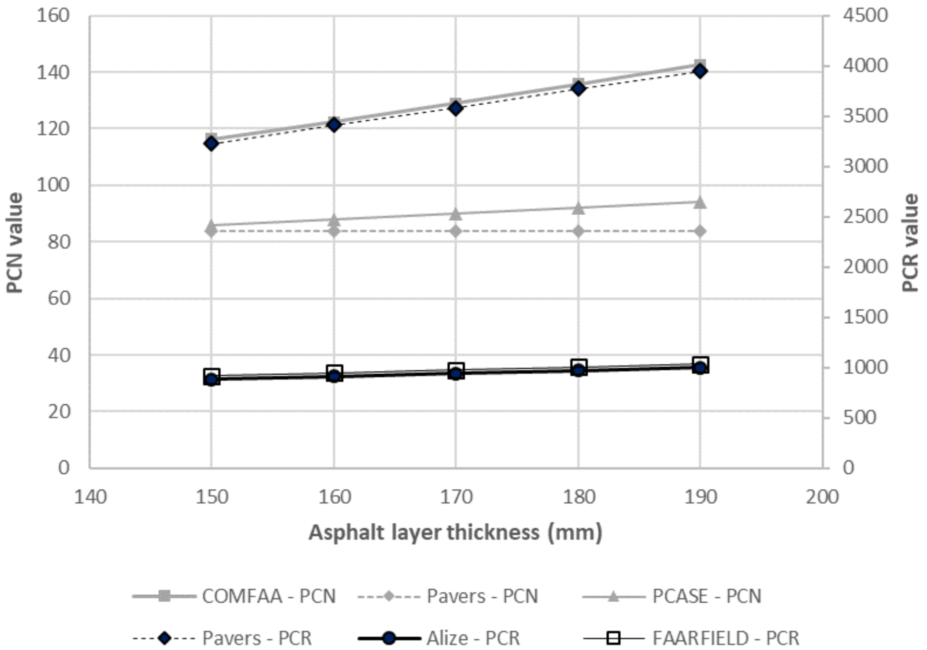

Figure 4: PCN and PCR with varied asphalt layer thickness for heavy flexible pavement structure

The variation in the strength rating was calculated as a percentage between the maximum and minimum calculated values. A summary is provided in Figure 5 and Figure 6. In Figure 5, the Pavers PCR data is included. In Figure 6, the Pavers PCR data is excluded. This was done because FAARFIELD and Alize-LCPC are the only two recognised PCR software packages currently available, while Pavers provides for an indirect calculation. Note that a variation could not be determined for the Light PCR option due to restrictions in the FAARFIELD package on minimum asphalt layer thicknesses. A variation of up to 120% was calculated for the PCN and one of up to 294% for PCR when the Pavers data is considered. If the Pavers data is omitted, the variation is significantly reduced to 15%.

For both the PCN and the PCR ratings, the variation seems to be dependent on the aircraft load and the pavement composition. The medium pavement and loading setup produced higher variations for the PCN rating and the PCR rating (excluding the Pavers data). For the PCR rating, which included the Pavers data, a trend of higher variation with higher loading and increased pavement thickness was observed.

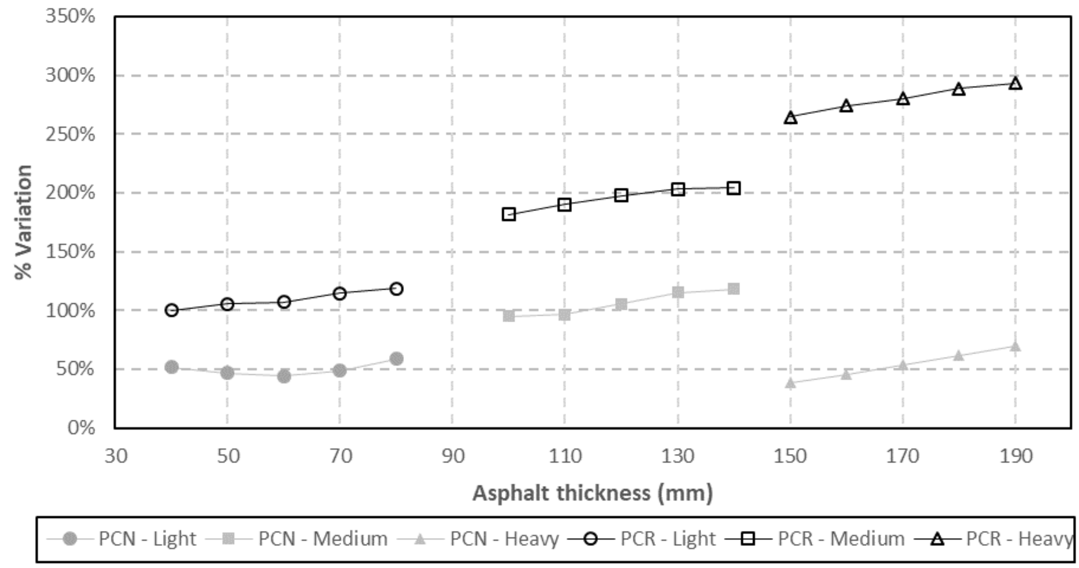

Figure 5: Variation in PCN and PCR with asphalt thickness (Pavers data included)

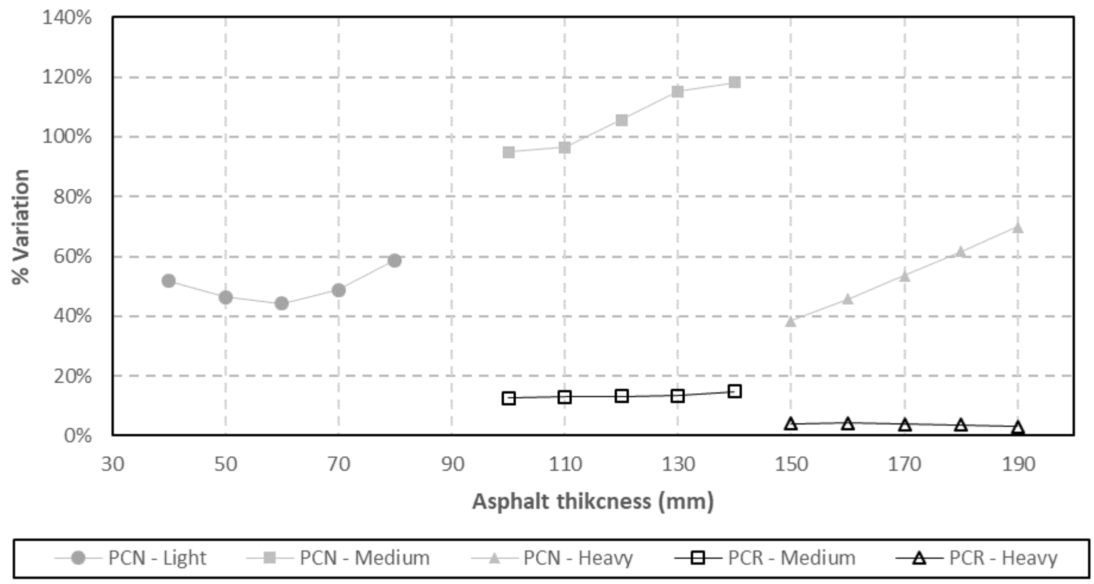

Figure 6: Variation in PCN and PCR with asphalt thickness (Pavers data excluded)

4.1.2 Rigid Pavements

For each of the light, medium and heavy rigid pavement structures, the concrete thickness was varied and the PCN value calculated using Pavers, PCASE (Westergaard model) and COMFAA, while the PCR value was calculated using Pavers and FAARFIELD. The results are presented in Figure 7 to Figure 9.

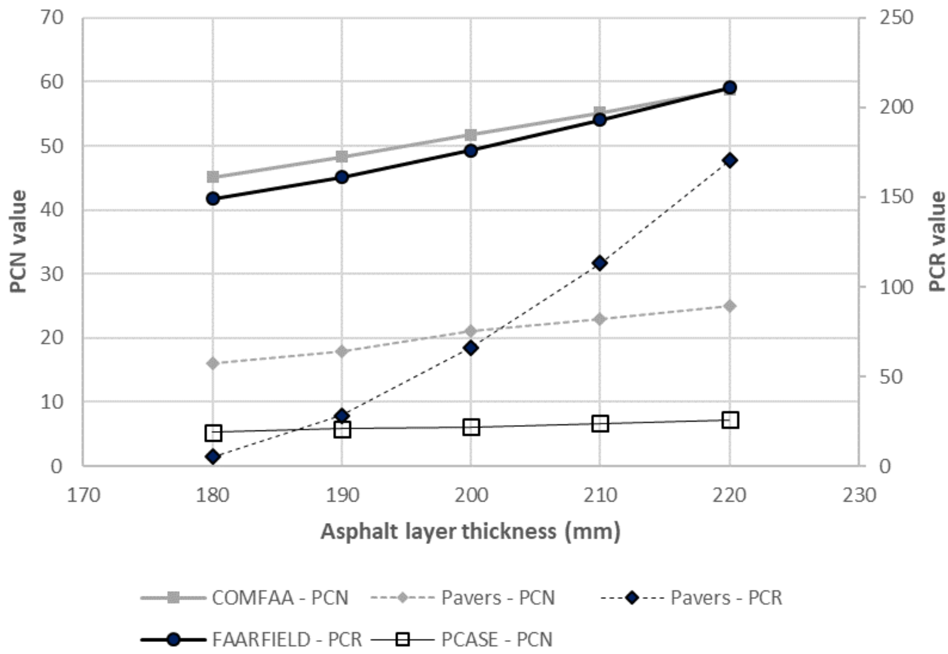

Figure 7: PCN and PCR with varied concrete thickness for light rigid pavement structure

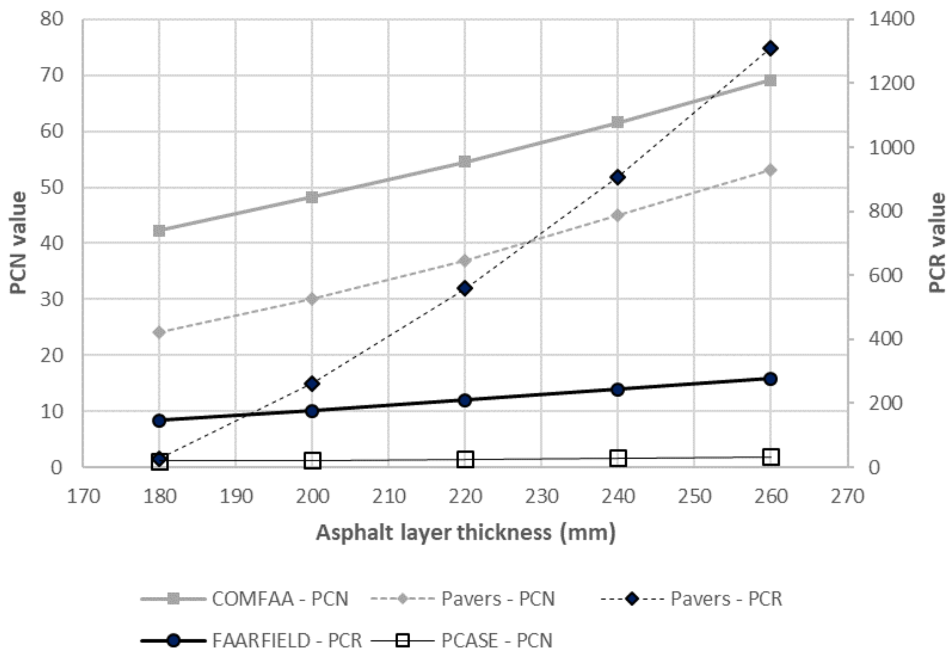

Figure 8: PCN and PCR with varied concrete thickness for medium rigid pavement structure

As with the flexible pavement options, the variation in the strength rating for the rigid pavement options was calculated as a percentage between the maximum and minimum calculated values. A summary is provided in Figure 10.

A variation of up to 200% was calculated for the PCN rating. The light and medium setup showed decreasing PNC variation with increasing concrete thickness. For the heavy PCN setup, the Pavers data reached a maximum above a concrete thickness of 330 mm and the graph shows a constant variation from that point onwards.

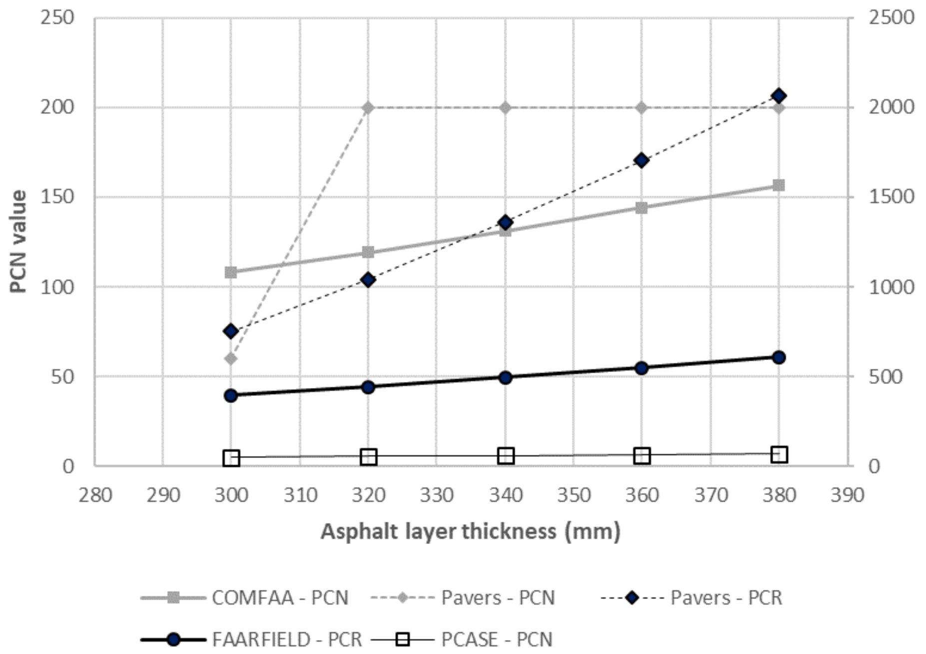

Figure 9: PCN and PCR with varied concrete thickness for heavy rigid pavement structure

Order of magnitude variation was calculated for the PCR on the light and medium pavement options. For the light pavement setup, the PCR variation decreased significantly with increasing concrete thickness. For the medium (except the data point at a thickness of 180 mm) and heavy setup, the PCR variation increased with increasing concrete thickness.

Concrete pavements are more sensitive to variations in the thickness of the surfacing layer due to the layer's significant contribution to the overall strength of the pavement. Small changes to the thickness of the concrete layer will result in greater changes in the stress situation in the concrete layer. In addition, stresses will also vary considerably depending on whether the loading is applied at the edge or in the centre of a concrete slab.

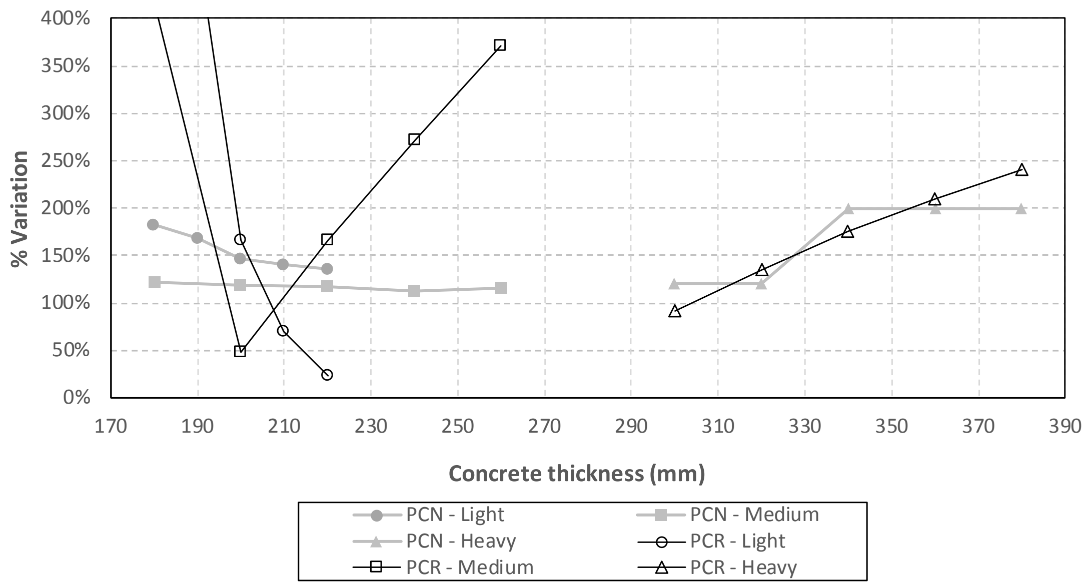

Figure 10: PCN and PCR variation with concrete layer thickness for rigid pavements

5. CONCLUSION

For a flexible pavement structure, the following conclusions can be drawn from the investigation:

- For the PCN rating system, variations of up to 120% are possible due to the calculation approaches of the different software packages used in the study. The variation can increase if a different approach to estimating the number of traffic passes is followed or if the default aircraft loading characteristics in the software are used.
- Considering only the Alize-LCPC and FAARFIELD software packages, the new PCR rating system produces less variation (up to 15%). This variation does not take into account differences in determining the number of loading cycles and the default aircraft loading characteristics. Heavier pavement structures produce less variation.

For a rigid pavement structure, the following conclusions can be drawn from the investigation:

- For the PCN rating system, variations of up to 200% are possible due to the calculation approaches of the different software packages used in the study. The variation could be greater if a different approach to estimating the number of traffic passes is followed or if the default aircraft loading characteristics in the software are used.
- The new PCR rating system may result in even larger variations than the old PCN rating system due to different concrete stress analysis approaches. A clear trend between concrete thickness and PCR variation was not evident, however.
- Thicker concrete pavements produce less variation due to different stress calculation approaches.

Based on the abovementioned analysis, it is argued that the hypothesis that the new ACR-PCR rating system will reduce variation in the calculated rating compared to the old ACN-PCN system is true for flexible pavement structures, but not for rigid pavement structures. The extent of the observed variations is such that an airfield pavement can potentially be overloaded while its strength rating is within the allowable limit.

6. REFERENCES

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