NEW ALPHA CURVES FOR CBR THICKNESS DESIGN WHICH ARE COMPATIBLE WITH THE NEW ICAO ACN CRITERIA

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ABSTRACT

A new set of Alpha Factor curves is derived for use in the CBR methodology for designing flexible airport pavements. The new Alpha Factor curves are compatible with the new Alpha Factors at 10,000 Coverages for 4- and 6-wheel gears proposed by ICAO for calculating the ACN of airplanes operating on flexible pavements. The standard set of Alpha Factors at 10,000 Coverages for 1, 2, 4, 6, 8, 12, 18, and 24 wheels, as defined in the ICAO Pavement Design Manual, have the values: 0.995, 0.900, 0.825, 0.788, 0.755, 0.722, 0.700, and 0.689. These are replaced by a new set of values: 0.995, 0.900, 0.800, 0.720, 0.690, 0.660, 0.640, and 0.630. The new values for more than six wheels were derived based on maintaining a consistent ranking of damaging effect. Analytic curves are defined so that Alpha Factors can be computed at any number of coverages and for any number of wheels up to twenty four. Alpha factors computed with the analytic curves are compatible with the new ICAO values at 10,000 coverages and with existing full-scale test data. The new analytic curves are implemented in the computer program COMFAA, which may be used to compute ACN for any arbitrary gear configuration.

1. INTRODUCTION

The International Civil Aviation Organization (ICAO) has proposed that the Alpha Factors for 4- and 6-wheel gears at 10,000 Coverages be redefined for use in calculating the Aircraft Classification Number (ACN) of airplanes operating on flexible pavements. The proposed Alpha Factors are 0.800 and 0.720 and the existing values are 0.825 and 0.788, with the new values being based on an analysis of a recently expanded set of full-scale test data for four- and six-wheel traffic. With these changes, Alpha Factors at other numbers of wheels, and over the full range of coverages for design, also require redefinition to maintain consistency in the CBR (California Bearing Ratio) procedure for flexible pavement thickness design as required for ACN calculations, even though additional full-scale test data is not available for other than 4- and 6-wheel gears.

A new set of Alpha Factors at 10,000 Coverages is defined first based on recommendations contained in ICAO AOSWG/4 Discussion Paper No. 21. A new set of functions is then defined to allow the calculation of Alpha Factor over the full range of Coverages expected in flexible pavement thickness design for commercial airplane operations. The new set of functions defining Alpha Factor versus Coverages is compatible with the new set of Alpha Factors at 10,000 Coverages. The functions are also compatible, to the extent possible, with existing definitions of Alpha Factor versus Coverages.

2. ALPHA FACTOR AT 10,000 COVERAGES VERSUS NUMBER OF WHEELS

The Alpha Factors embedded in ICAO Computer Program No. 2 for calculating flexible pavement ACN values for 1, 2, 4, 6, 8, 12, 18, and 24 wheels [1] are listed in table 1 and shown graphically in figure 1.

Table 1 - Alpha factors embedded in ICAO Computer Program No. 2.

Number of Wheels	Alpha Factor from ICAO Computer Program No. 2
1	0.995
2	0.900
4	0.825
6	0.788
8	0.755
12	0.722
18	0.700
24	0.689

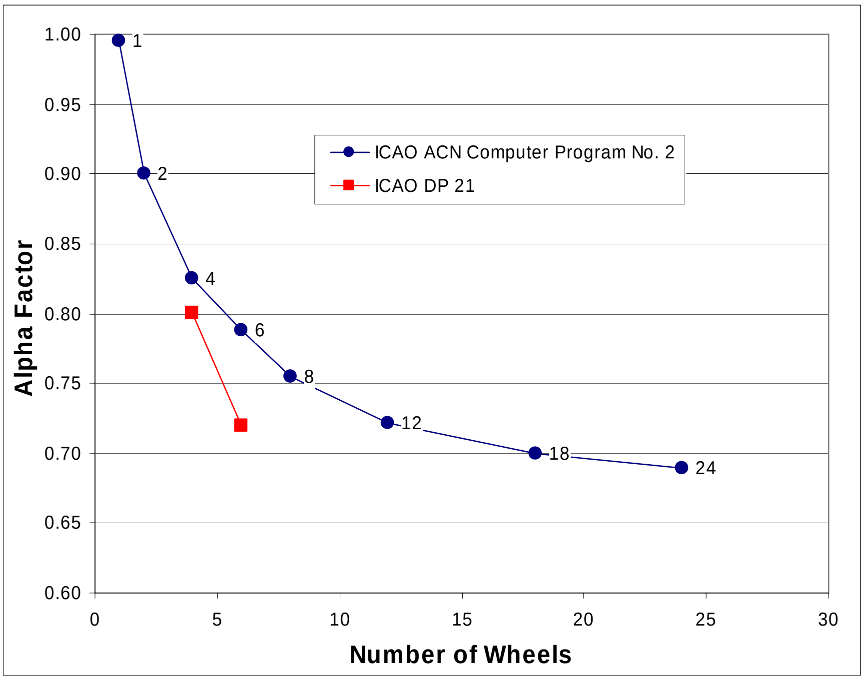

Figure 1 - Alpha factors embedded in ICAO Computer Program No. 2, Flexible Pavement ACN, with proposed changes for 4- and 6-wheel airplanes.

ICAO AOSWG/4 Discussion Paper No. 21 (DP21) recommends that the following change be made to the Alpha Factors for the computation of ACN values:

> "Change the Alpha Factors for all 4-wheel and 6-wheel aircraft (0.80 and ~~0.71~~/0.72), and alter the Alpha Factors for other wheel numbers so that the ranking of damaging effect is consistent. ACNs for all aircraft would change, and the Alpha Factors would be technically correct."

Figure 1 also shows the new Alpha Factors for 4- and 6-wheel airplanes as well as the original Alpha Factors.

The Alpha Factors in table 1 were originally derived from curves of Alpha Factor versus Coverages published in [2] and [3] for gears with 1, 2, 4, 6, 8, 12 18, and 24 wheels. Reference [2] published the 1-, 4-, and 12-wheel curves based on full-scale test data for single, dual tandem, and two C-5 six-wheel gears in tandem (for the 12-wheel gear curve). Reference [3] added the additional curves by interpolation (for 2-, 6-, and 8-wheel gears) and extrapolation (for 18- and 24-wheel gears). Extrapolation outside the range of the existing full-scale test data was necessary because the CBR design procedure as defined in [4] requires that pavement thickness be computed for all combinations of wheels in the main landing gear, and that the largest of these thicknesses be used for design. Quoting the relevant passage from pages 70 and 71 of [4]:

> "The α_i curves have been developed using the load on one landing gear assembly of an aircraft. In actual practice, designs are to be based upon the load on all main tires. Therefore, the α_i versus passes curves (figure 82) show the total number of aircraft main gear tires represented by the gear type. Use of the criteria, therefore, is accomplished by determining the ESWL and the α_i for all main gear tires, which generally results in maximum thickness requirements for a specific aircraft. However, where it is shown that some combination or grouping of tires other than all main gear tires will produce a greater thickness requirement, then the other combination or group will be used."

Reference [3] (page 27) contains a similar statement:

> "The number of tires used to compute the ESWL is that combination of tires which gives the greatest ESWL …"

These two statements are not necessarily consistent, but the intent is clear. In particular, the pavement thickness design charts for the Boeing 747 airplane published in Federal Aviation Administration (FAA) AC 150/5320-6C and -6D are based on equivalent single wheel loads (ESWLs) computed using 16 wheels and Alpha Factor curves for 16 wheels.

Looking at figure 1, it is clear that, in order to integrate the new Alpha Factors (0.8 and 0.72) into the Aircraft Classification Number–Pavement Classification Number (ACN–PCN) system, adjustments need to be made to the Alpha Factors for wheel numbers other than 4 and 6. The 1-wheel Alpha Factor is based on a reasonably large set of full-scale tests (see [2]) and there does not appear to be a compelling reason to change it. The 2-wheel Alpha Factor was based on interpolation between the 1-wheel and 4-wheel Alpha Factor curves and it seems reasonable to also not change its value, although a reduction in its value proportionate to the reduction of the 4-wheel value from 0.825 to 0.80 would also be reasonable. That is, a new Alpha Factor for 2 wheels which has the same proportions relative to the new 1- and 4-wheel Alpha Factors as the old 2-wheel Alpha Factor has to the old 1- and 4-wheel Alpha Factors could be defined by:

$$\begin{aligned}\alpha_{2new} &= 0.995 - \frac{(0.995-0.900)\times(0.995-0.800)}{(0.995-0.825)} \\ &= 0.886\end{aligned} \qquad (1)$$

The remaining Alpha Factors, for 8 wheels and above, have no basis in full-scale test data except that the C5 test data had originally been treated as being from a 12-wheel gear.

This formed the basis for the old 12-wheel Alpha Factor with the old 6-wheel Alpha Factor being an interpolation between the 4- and 12-wheel values. But after test data had been collected with a triple-dual-tandem (3D) gear at higher coverage levels than for the C5 tests, the C5 was re-categorized as two 6-wheel gears in tandem so that the two data sets could be combined (see [5] for more details). As stated above, ICAO AOSWG/4 DP 21 recommends that undefined new Alpha Factors be altered "so that the ranking of damaging effect is consistent." The Alpha Factors for 8 wheels and above have therefore been adjusted so that the ratio of ACN relative to the ACN for a 6-wheel gear is, to a very good approximation, the same in the new system as in the old. The equation used to calculate the new Alpha Factors is:

$$\alpha_{Inew} \approx \left(\frac{\alpha_{Iold}}{\alpha_{6old}} \right) \times \alpha_{6new} \qquad (2)$$

where:

α_{Iold} = old Alpha Factor for *I* number of wheels as listed in table 1 for *I* = 8, 12, 18, and 24
α_{6old} = old Alpha Factor for 6 wheels = 0.788 as listed in table 1
α_{6new} = new Alpha Factor for 6 wheels = 0.72

Equation 2 is derived in [6].

Table 2 shows the new alpha factors as defined by full-scale test data (1, 2, 4, and 6 wheels) and from equation 2 (8, 12, 18, and 24 wheels).

Table 2 - New Alpha factors at 10,000 Coverages.

Number of Wheels	New Alpha Factor
1	0.995
2	0.900
4	0.800
6	0.720
8	0.690
12	0.660
18	0.640
24	0.630

In order to determine values of Alpha Factor for numbers of wheels other than those in table 2, a curve fitting or interpolation scheme is needed. A non linear correlation curve fitting computer program was used to evaluate different modeling functions describing the relationship between Alpha Factor at 10,000 Coverages versus number of wheels, but none of the curve fits tried were satisfactory over the full range of the data and for both old and new Alpha Factors. Figure 2 shows the old and new Alpha Factors with the best of the curve fits also displayed. The curve fit for the old Alpha Factors is very good, but that for the new Alpha Factors is poor, particularly over the critical range of 2 to 12 wheels. This curve fit cannot be used to compute Alpha Factor without either giving inaccurate values at the defined points (when the defined points are computed with the curve fit equation) or giving inaccurate relative values between undefined and defined points (when the undefined points are computed with the curve fit equation and the defined values are used at the defined points). Other modeling functions than those displayed in the figure sometimes gave better correlation coefficients, but none satisfactorily solved the problem described in the previous sentence. A simple linear interpolation was therefore selected for computing the Alpha Factor values for numbers of wheels between those defined in table 2.

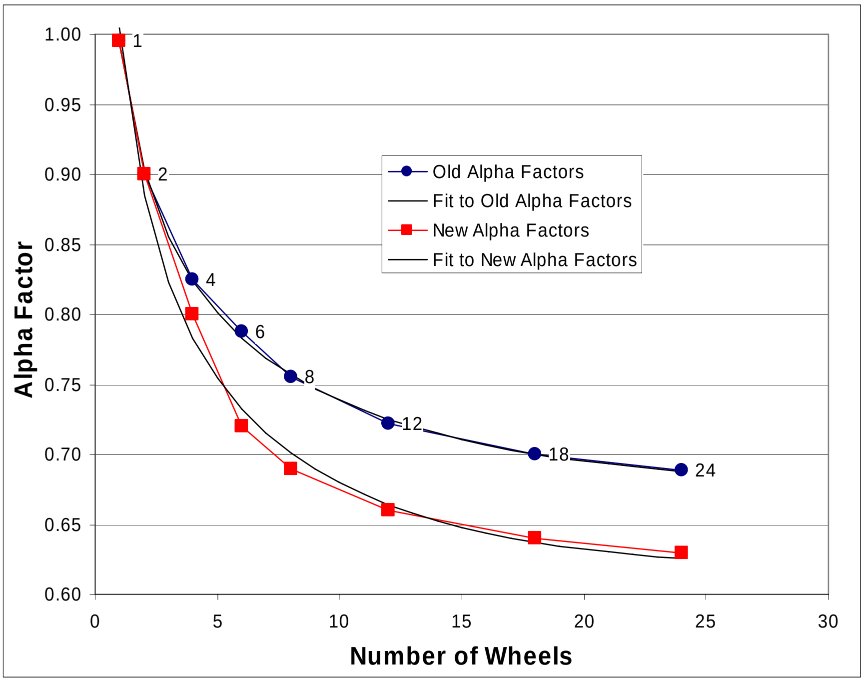

Figure 2 - Old and new Alpha Factors with curve fits.

2.1. Numerical Examples

Two numerical examples are worked through to establish how well the new Alpha Factors for 8, 12, 18, and 24 wheels maintain the same relative ACN ratios as in the old system. The first example compares two C5 airplane gear configurations. The first configuration consists of one 6-wheel gear and the second configuration consists of two 6-wheel gears in tandem. The two-gear configuration is treated as a 12-wheel gear for ACN computation. The second example compares a triple-dual-tandem (3D) 6-wheel configuration with a 5D 10-wheel configuration. The 3D and 5D configurations have the same dual and tandem wheel spacing. The 3D configuration is close to B777-300 gear geometry and wheel loading. These two examples represent two extremes of wheel configuration and wheel loading for the same numbers of wheels.

2.1.1. *Example 1 – C5 Landing Gear*

Figures 3 and 4 show the wheel configurations for the 6- and 12-wheel cases. Gear geometry is standard and wheel loads are 30,000 lbs (133 kN). A computer program called COMFAA, available for download at http://www.airporttech.tc.faa.gov, was used to calculate ACNs with both the old and the new Alpha Factors. Tables 3 and 4 list the results for 3 CBR and 15 CBR, together with pavement thicknesses and equivalent single-wheel loads (ESWLs). The ACN ratios for old and new Alpha Factors are summarized in table 5.

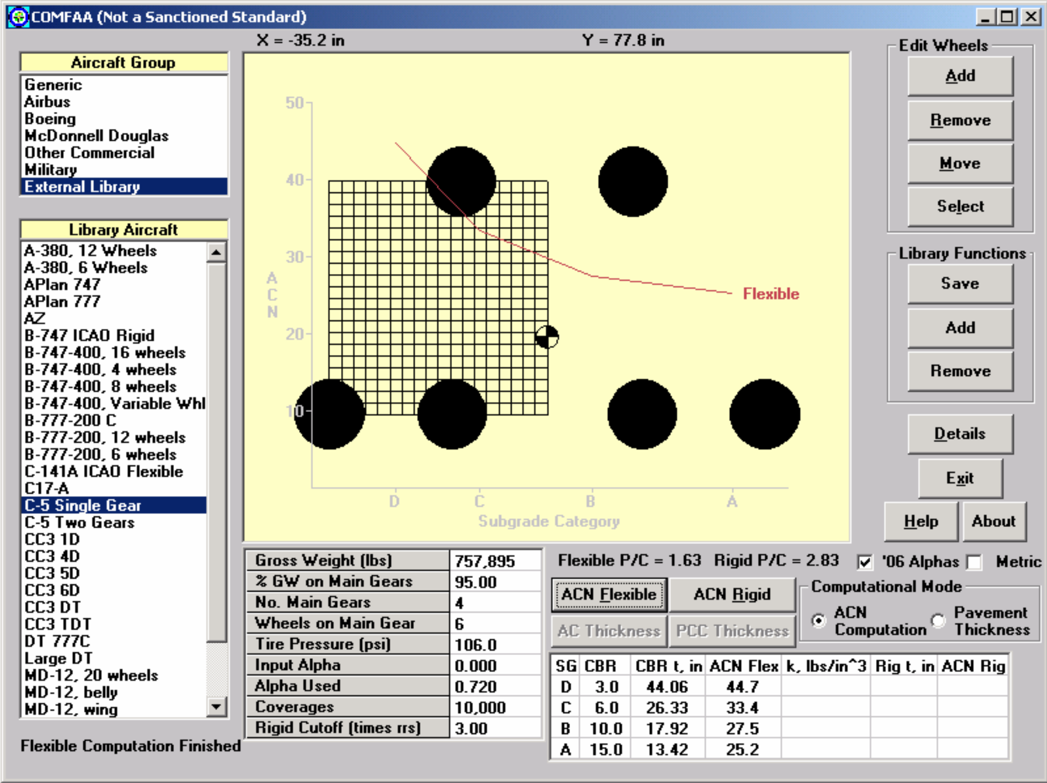

Figure 3 - COMFAA screen shot showing C5 single-gear six-wheel configuration.

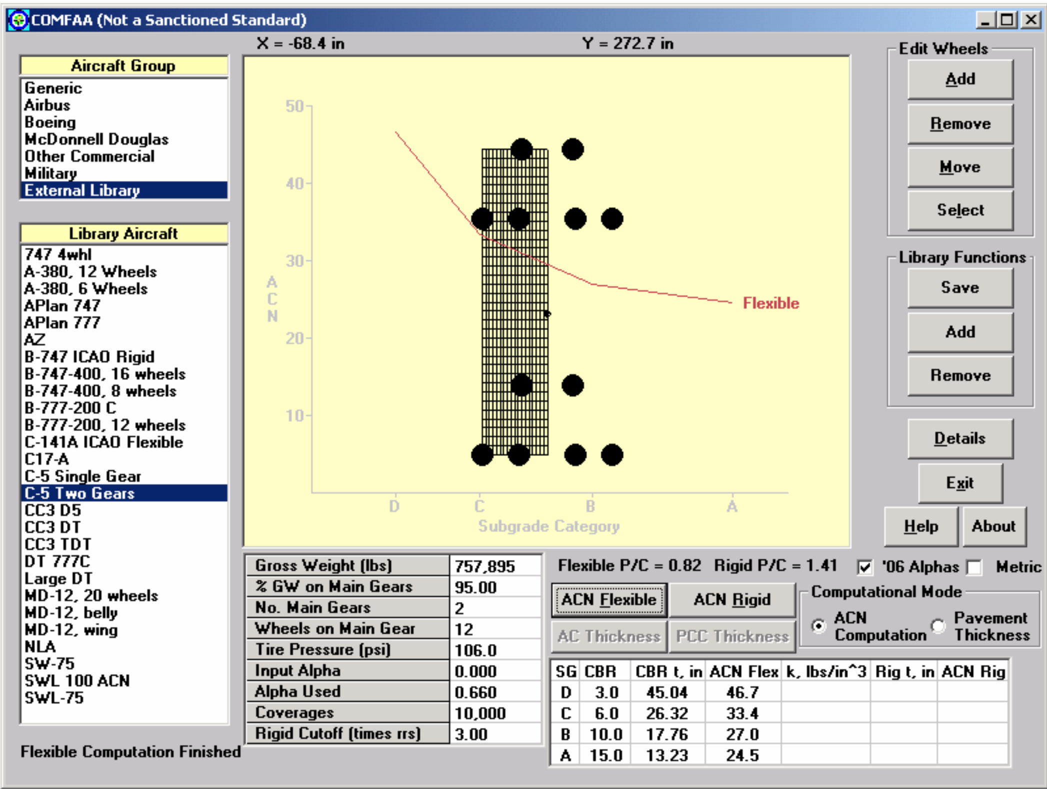

Figure 4 - COMFAA screen shot showing C5 double-gear twelve-wheel configuration.

Table 3 - C5 ACN results for old Alpha Factors.

Gear Configuration	CBR	ACN	Pavement Thickness, in	Pavement Thickness Squared, in^2	ESWL, lbs
12-Wheel	3	61.7	51.75	2,678	127,111
6-Wheel	3	58.7	50.47	2,547	101,903
Ratio 12Whl:6Whl		1.051	1.025	1.051	1.247
12-Wheel	15	30.9	14.84	220.2	61,702
6-Wheel	15	31.3	14.96	223.8	54,280
Ratio 12Whl:6Whl		0.987	0.992	0.984	1.137

Table 4 - C5 ACN results for new Alpha Factors.

Gear Configuration	CBR	ACN	Pavement Thickness, in	Pavement Thickness Squared, in^2	ESWL, lbs
12-Wheel	3	46.7	45.04	2,029	115,349
6-Wheel	3	44.7	44.06	1,941	93,257
Ratio 12Whl:6Whl		1.045	1.022	1.045	1.237
12-Wheel	15	24.5	13.23	175.0	59,126
6-Wheel	15	25.2	13.42	180.1	52,403
Ratio 12Whl:6Whl		0.972	0.986	0.972	1.128

Table 5 - ACN and ESWL ratios (12Whl:6Whl) for C5 gears (from tables 3 and 4).

CBR	ACN Ratio with Old Alpha Factors	ACN Ratio with New Alpha Factors	Percent Difference	$\sqrt{\frac{P_{Iold}}{P_{6old}}\frac{P_{6new}}{P_{Inew}}}$
3	1.051	1.045	0.6	1.0042
15	0.987	0.972	1.5	1.0037

2.1.2. *Example 2 – 3D and 5D Landing Gear*

Figures 5 and 6 show the wheel configurations for the 6- and 10-wheel 3D and 5D gears. Gear geometry is 54 inches (1,372 mm) dual spacing and 57 inches (1,448 mm) tandem spacing. Wheel loads are 55,000 lbs (245 kN). Tables 6 and 7 list the results for 3 CBR and 15 CBR, together with pavement thicknesses and ESWLs. The ACN ratios for old and new Alpha Factors are summarized in table 8.

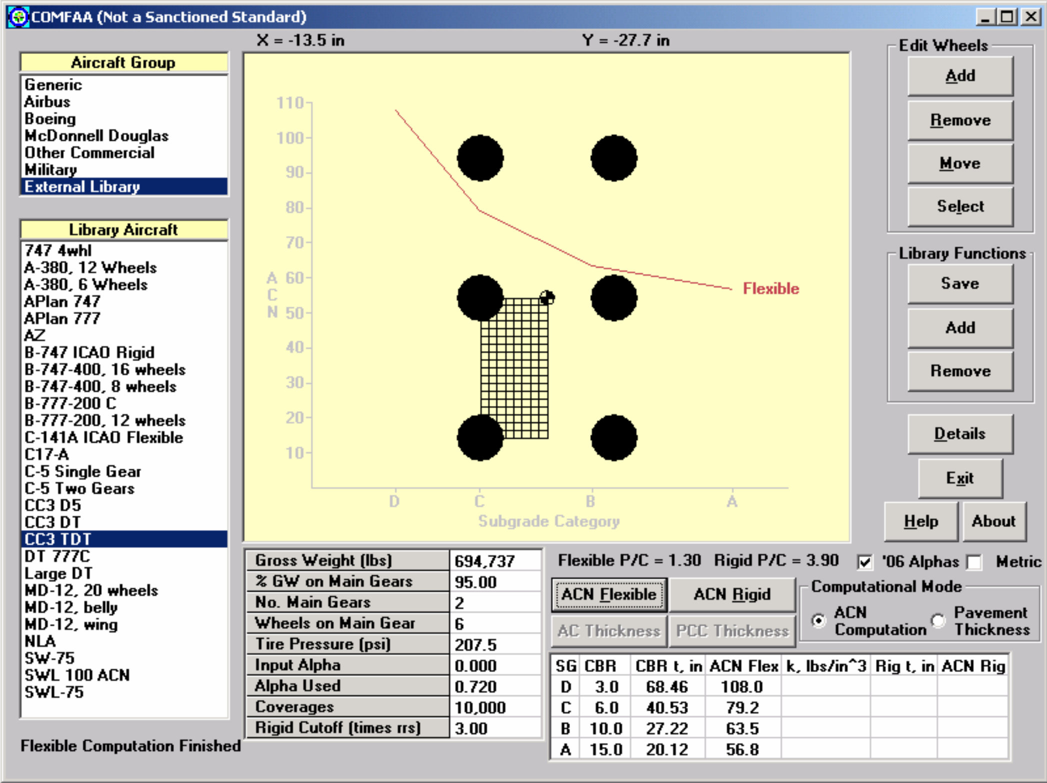

Figure 5 - COMFAA screen shot showing 3D six-wheel gear.

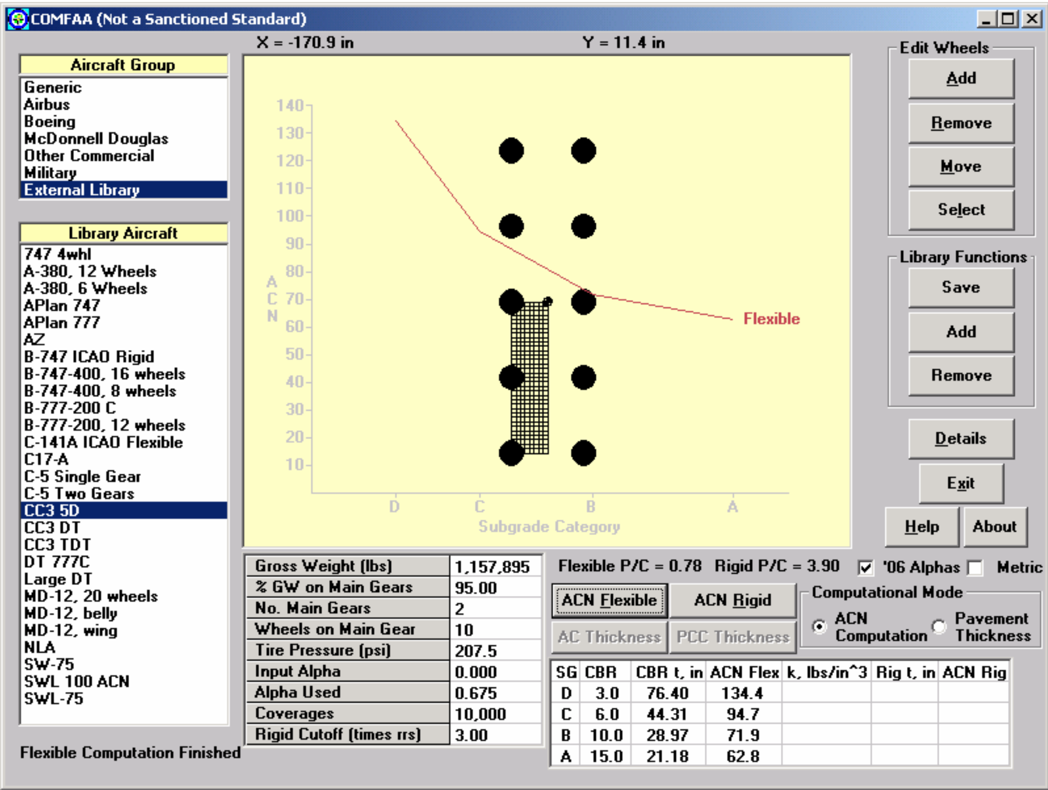

Figure 6 - COMFAA screen shot showing 5D ten-wheel gear.

Table 6 - 3D and 5D ACN results for old Alpha Factors.

Gear Configuration	CBR	ACN	Pavement Thickness, in	Pavement Thickness Squared, in^2	ESWL, lbs
10-Wheel	3	174.1	86.92	7,555	338,278
6-Wheel	3	137.8	77.35	5,983	235,986
Ratio 10Whl:6Whl		1.263	1.124	1.263	1.433
10-Wheel	15	81.1	24.06	578.9	139,310
6-Wheel	15	72.5	22.75	517.6	111,887
Ratio 10Whl:6Whl		1.119	1.0576	1.118	1.245

Table 7 - 3D and 5D ACN results for new Alpha Factors.

Gear Configuration	CBR	ACN	Pavement Thickness, in	Pavement Thickness Squared, in^2	ESWL, lbs
10-Wheel	3	134.4	76.40	5,837	313,265
6-Wheel	3	108.0	68.46	4,687	221,748
Ratio 10Whl:6Whl		1.244	1.116	1.245	1.413
10-Wheel	15	62.8	21.18	448.6	129,780
6-Wheel	15	56.8	20.12	404.8	105,625
Ratio 10Whl:6Whl		1.106	1.0527	1.108	1.229

Table 8 - ACN and ESWL ratios for 3D and 5D Gears (from tables 6 and 7).

CBR	ACN Ratio with Old Alpha Factors	ACN Ratio with New Alpha Factors	Percent Difference	$\sqrt{\frac{P_{Iold}}{P_{6old}}\frac{P_{6new}}{P_{Inew}}}$
3	1.263	1.244	1.5	1.0073
15	1.119	1.106	1.2	1.0067

In both examples, the ACN ratios for the new Alpha Factors are consistently higher than those for the old Alpha Factors, but by less than 2 percent. The discrepancies are presumably due to the approximations made in deriving equation 2 and, for the second example, the linear interpolation between 8- and 12-wheel values. To determine the order of magnitude of the errors in the new Alpha Factors, the new Alpha Factor for 12 wheels in example 1 was adjusted until the ACN ratio for the new Alpha Factors at 3 CBR was the same as the ACN ratio for the old Alpha Factors at 3 CBR. This resulted in a corrected 12-wheel Alpha Factor value of 0.661 instead of the value of 0.660 from table 2. Performing the same process in example 2 resulted in a corrected 10-wheel Alpha Factor value of 0.678 instead of the value of 0.675 found by interpolating between the 8- and 12-wheel Alpha Factors in table 2. These differences are negligible and it is recommended that the values in table 2 be used for the new Alpha Factors at the indicated number of wheels and that intermediate values continue to be found by linear interpolation.

Also of note is that the 6-wheel gear has a lower ACN than the gear with more than 6 wheels in example 1 at 3 CBR and in example 2 at both 3 and 15 CBR. But the ACN of the 6-wheel gear is higher than the ACN of the 12-wheel gear in example 1. A major difference in the examples is that the 12-wheel C5 configuration has two 6-wheel groups spaced a considerable distance apart whereas the wheels in the 10-wheel gear of example 2 all have the same tandem spacing as the wheels in the 6-wheel gear, which leads to the noted discrepancy (see [6] for more details). Further examination of this discrepancy also leads to the recommendation [6] that, when applying the CBR design procedure to the computation of ACN values using the new Alpha Factor system, the wheel configurations used to compute ESWLs should be as close to the wheel configurations from which the Alpha Factors were derived in full-scale tests. This means that the wheel configuration used to compute the ACN for any particular airplane should be selected on the basis of the wheels forming a recognizable group, with the spacing between adjacent wheels being about the same for all wheels in the group. With the exception of one or two unusual and low-damage airplanes, this is the scheme which has been followed by ICAO for computing ACNs of multiple-gear airplanes, in particular the Boeing 747 where a single group of 4 wheels on the same strut is used to calculate ACN. It is recommended that the same scheme be followed when computing ACNs for other large multiple-gear airplanes such as the Airbus A380.

3. ALPHA FACTOR VERSUS COVERAGES FOR THICKNESS DESIGN

The computation of ACN values requires only that Alpha Factors be defined at 10,000 Coverages. However, to determine the airplane for which ACN is to be found typically requires that pavement thickness designs be made in order to determine the “design” airplane for a specified mix operating on the pavement of interest (see [1] and [7]). This requires the definition of Alpha Factors over the full range of Coverages expected at an airport. The computer program F806FAA, published by the FAA in 1989 for flexible pavement thickness design by the CBR method [8], contains curve fits of Alpha Factor as a function of number of wheels and $\log_{10}$(Coverages) for 1, 2, 4, 6, 8, 12, 16, and 24 wheels. Each curve of Alpha Factor versus Coverages is divided into three separate functions which are continuous at the changeover points (10 and 10,000 Coverages). Figure 7 shows the curves plotted in the range 1 to 1,000,000 Coverages. The curve marked “Base” is the linear equation, $\alpha = 0.23 \times$ Coverages + 0.15, in use before the introduction of Alpha Factors [4].

The same equations were implemented in the computer program COMFAA when it was first written except that the curve for 8 wheels was not included because it does not have the same trend as the other curves and does not fit uniformly between the 6- and 12-wheel curves. To find the Alpha Factor for a number of wheels other than those in the F806FAA set, COMFAA does a cubic spline fit through the defined Alpha Factor curve values at the $\log_{10}$(Coverages) of interest and then interpolates at the desired number of wheels. COMFAA is therefore compatible with the previous FAA methods for flexible pavement design by the CBR method but is applicable in a consistent manner for pavement design with any number of wheels up to a maximum of twenty four. Now that the defined Alpha Factors at 10,000 Coverages have changed for ACN computation (table 2), the thickness design portion of COMFAA has to be modified to be compatible with the ACN portion.

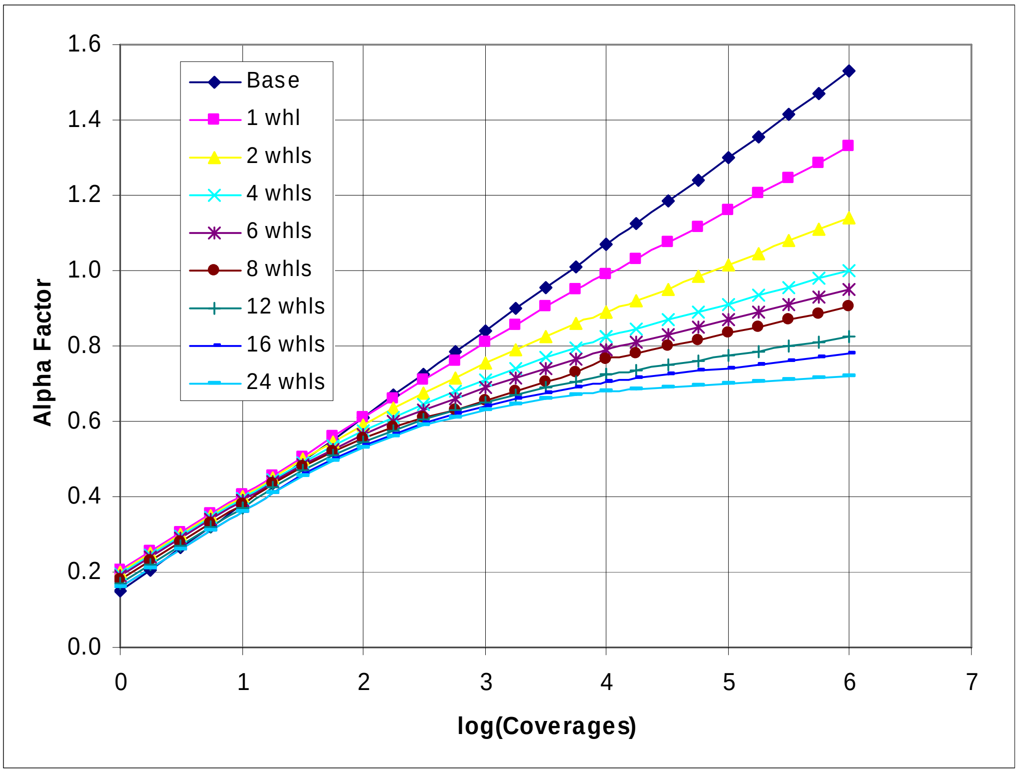

Figure 7 - ACN versus $\log_{10}$(Coverages) as implemented in Computer Program F806FAA.

As described in [5] and [9], and from ICAO panel deliberations, the new Alpha Factors at 10,000 Coverages for 4- and 6-wheel gears were derived from quadratic curve fits to the full-scale test data. These curve fits are only valid within the range of the test data and an alternative procedure has been developed to extrapolate outside the range of the test data in a simple and consistent manner.

To enable reliable extrapolation outside the range of the test data, a non linear correlation curve fitting computer program was used to select the best fitting function in terms of goodness of fit to the test data and applicability to representing Alpha Factor as a function of $\log_{10}$(Coverages) for pavement design. The function selected is called Exponential Association (3) in the curve fitting program (see [6] for details of the selection) and is defined by equation 3.

$$\alpha = a\left(b - e^{-c.\log(\text{Coverages})}\right) \tag{3}$$

The 4- and 6-wheel full-scale test data from [4] and [9] used to determine the quadratic Alpha Factor curves for an assumed thickness equivalency of 1.4 between standard quality base and subbase materials (data for SQS = 1.4 × CA in [9]) are shown in figure 8. Also shown in figure 8 are the base curve from figure 7, the two quadratic curves, and the corresponding exponential association curves. It can be seen that the exponential association curves agree very well with the quadratic curves over the range of the full-scale test data (about 10 to 15,000 Coverages, or 1 to 4.2 $\log_{10}$(Coverages)). But outside the range of the test data the quadratic and exponential curves diverge significantly. Coverage levels below 10 are of relatively little interest, particularly for commercial operations. Coverage levels from 15,000 to 100,000, and higher, are, however, well within normal commercial operations at large airports and figure 8 demonstrates clearly that the quadratic curves are not suitable for extrapolation outside the range of the test data. The design program F806FAA extrapolates outside the range of the test data with linear functions of $\log_{10}$(Coverages) and it is considered that this is a reasonable strategy at low coverage levels. But at high coverage levels it seems more reasonable to continue the curved characteristic evident within the range of the test data, as long as the slope does not become negative as can happen with the quadratic curves. The two exponential association curve fits in figure 8 have a very simple and well defined characteristic at all coverage levels beyond 10,000. On this basis, and considering that it appears to be a physically reasonable continuation of the existing test data, the exponential association curve was selected for extrapolation at high coverage levels.

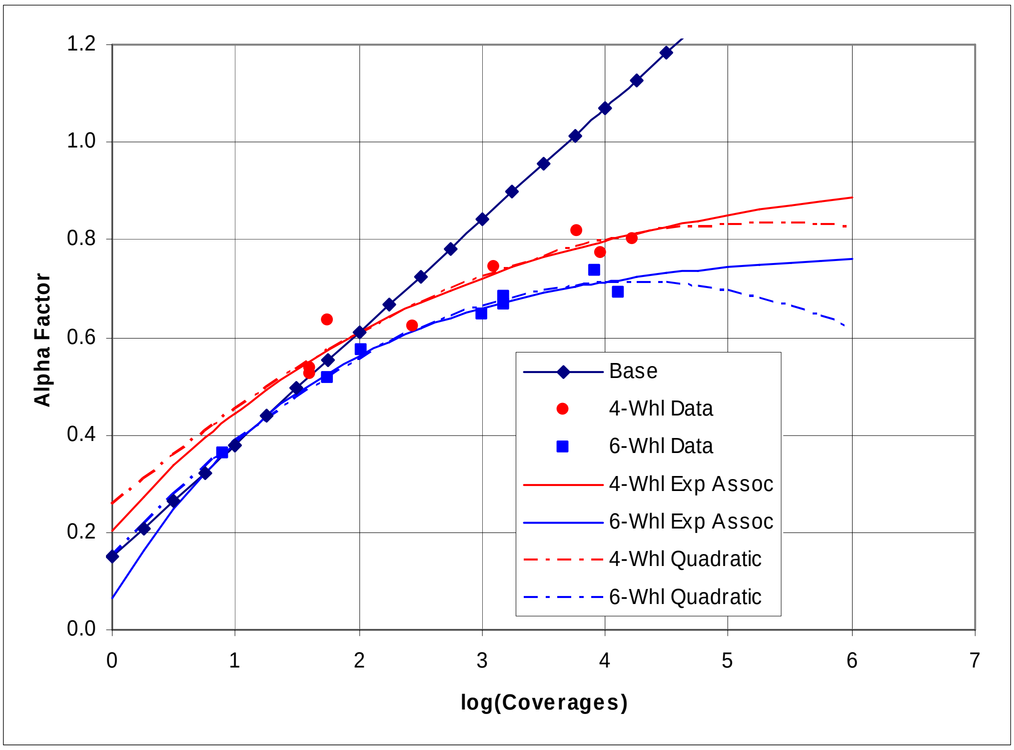

Figure 8 - Four- and six-wheel Alpha Factor versus $\log_{10}$(Coverages) showing raw data and quadratic and exponential association (3) curves.

In order to make the COMFAA thickness designs compatible with the Alpha Factor values at 10,000 Coverages of table 2, the exponential association curve for any number of wheels is constrained to pass through the point defined by the Alpha Factor value in table 2 (or linearly interpolated from the values in the table) and $\log_{10}$(Coverages) = 4.0. At the low end, the curves for all numbers of wheels are constrained to pass through two additional points: $\log_{10}$(Coverages) = 0.0, Alpha Factor = 0.1, and $\log_{10}$(Coverages) = 1.0, Alpha Factor = 0.38.

Constraint equations for calculating the coefficients (a, b, and c) in equation 3 are derived in [6] and a Visual Basic subroutine is provided in the same reference for finding the numerical values of the coefficients for any given number of wheels. Once numerical values of the coefficients have been found, the Alpha Factor for that number of wheels can be found at any given number of coverages from equation 3.

Figure 9 shows the new Alpha Factor curves versus $\log_{10}$(Coverages) for 4-, and 6-wheel gears when constrained at the three points. The raw data for the single-wheel test data from table 5 of [2] has also been included in the figure and extrapolation below $\log_{10}$(Coverages) = 1.0 is along the Base curve. In comparison with the best fit curves of figure 8, the 6-wheel curve in figure 9 is almost identical with that of figure 8. The 4-wheel curves in figures 8 and 9 correspond closely above 1,000 Coverages, but diverge below that value. The 4-wheel curve in figure 9 could be made to match better with that in figure 8 below 1,000 Coverages by making α_1 a function of the number of wheels to provide a spread in the curves similar to that shown in figure 7. However, this would probably be an unnecessary complication. Quoting again from [4], page 71: "The unique limiting curve shown [in figure 82] from 1 to 100 passes represents a composite of the single, twin-tandem, and 12-wheel curves shown in figure 80. Actually, the composite curve for the very low operational level is used for convenience because there is such a small difference in repetitions effect and because it is difficult to differentiate failure at a low operational level." The wide scatter of the single-wheel raw data seen in figure 15 at low Coverages supports these comments.

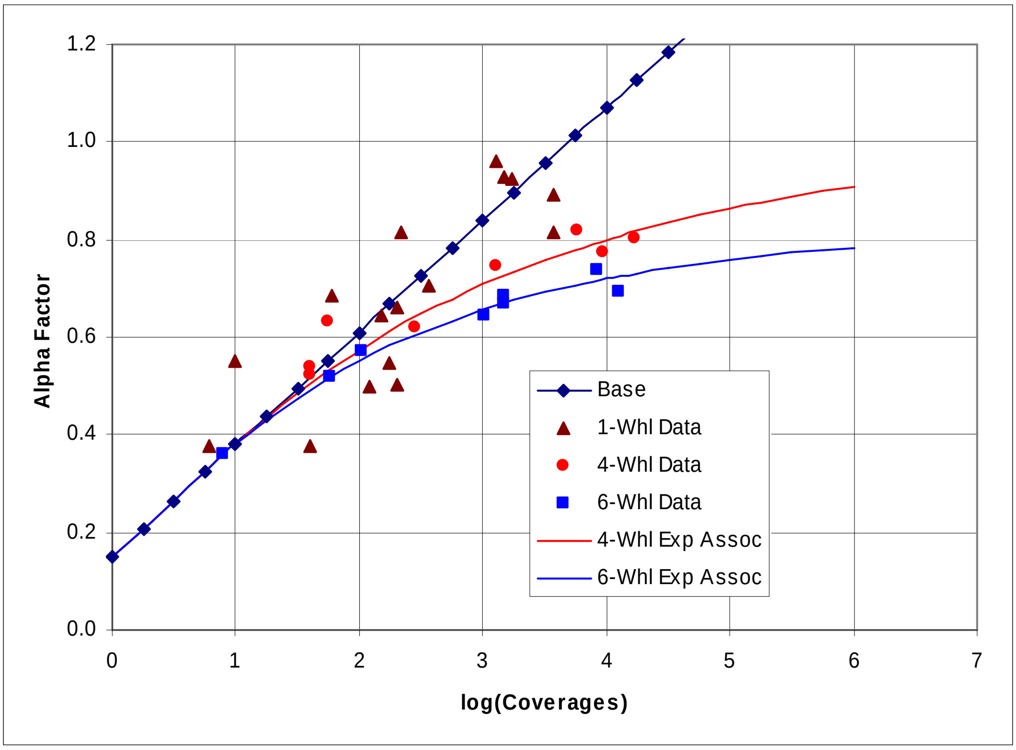

Figure 9 - Four- and six-wheel Alpha Factor versus $\log_{10}$(Coverages) showing raw data and constrained exponential association (3) curves.

Finally, figure 10 shows the complete family of new Alpha Factor constrained exponential association curves corresponding to the old F806FAA curves shown in figure 7. Curves for any other number of wheels can be found by linear interpolation between the values of Alpha Factor given in table 2 and the application of equation 3 as described above. All of the curves are collapsed onto the linear base curve at less than 10 Coverages. The new curves have been incorporated in COMFAA and are identified in the program interface as "'06 Alphas."

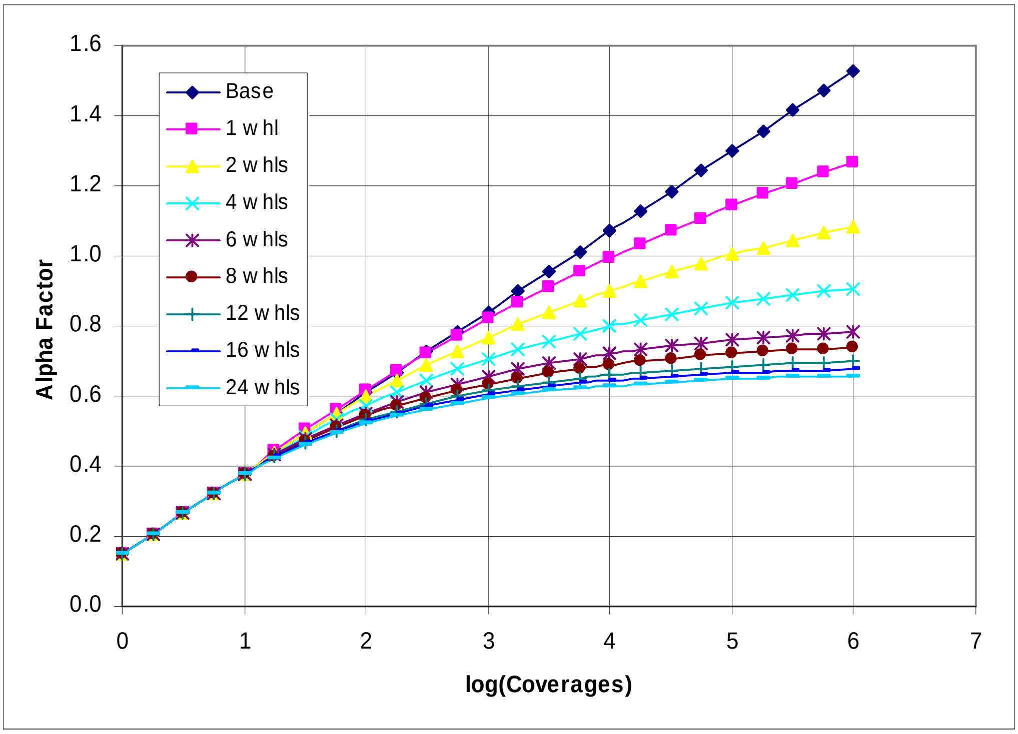

Figure 10 - Family of constrained exponential association Alpha Factor versus $\log_{10}$(Coverages) curves for use in COMFAA.

In correspondence with previous comments, it is recommended that the thickness design of flexible pavements using the new Alpha Factor functions shown in figure 10 be based on that number of wheels which gives the thickest pavement out of all combinations of wheels from the complete main landing gear group. This will maintain compatibility with the CBR flexible pavement thickness design procedure as specified in [4] and with the FAA design charts published in AC 150/5320-6D.

4. SUMMARY

ICAO has proposed that the Alpha Factors for 4- and 6-wheel gears at 10,000 Coverages be redefined for use in calculating the ACN of airplanes operating on flexible pavements. The proposed Alpha Factors are 0.800 and 0.720 compared to the existing values of 0.825 and 0.788. The new values are based on an analysis of an expanded set of full-scale test data for 4- and 6-wheel traffic. With these changes, Alpha Factors at other numbers of wheels, and over the full range of coverages for design, required redefinition to maintain consistency in the CBR procedure for flexible pavement thickness design as required for ACN calculations, even though additional full-scale test data is not available for other than 4- and 6-wheel gears. In fact, full-scale test data is not available at all for gears with more than six wheels. The Alpha Factors have been redefined as follows.

1. The standard set of Alpha Factors at 10,000 Coverages for 1, 2, 4, 6, 8, 12, 18, and 24 wheels have the new values: 0.995, 0.900, 0.800, 0.720, 0.690, 0.660, 0.640, and 0.630. The values for one and two wheels are unchanged from the old set because the old values were based on existing full-scale test data. The values for more than six wheels were derived based on maintaining a consistent ranking of damaging effect, as recommended in ICAO AOSWG/4 Discussion Paper No. 21. This was done by making the ratio of ACN for the higher numbers of wheels to ACN for six wheels in the new set of values approximately the same as in the old set of values.

2. Alpha Factors at 10,000 Coverages for numbers of wheels other than those in the standard set (in item 1 above) should be found by linear interpolation between the two closest numbers of wheels in the standard set.
3. It is recommended that the wheel configuration used to compute the ACN for any particular airplane should be selected on the basis of the wheels used in the computation forming a recognizable group, with the spacing between adjacent wheels being about the same for all wheels in the group. This is compatible with current ICAO ACN calculations for multiple-gear airplanes.
4. A new set of functions has been established for describing the variation of Alpha Factor with Coverages over the full range of 1 to 24 wheels. The functions are defined by an exponential equation constrained to pass through the points:
    a. Alpha Factor as defined in items 1 and 2 above and Coverages = 10,000.
    b. Alpha Factor = 0.38 and Coverages = 10.
    c. Alpha Factor = 0.1 and Coverages = 0.
5. If the new set of functions is to be used for flexible pavement thickness design, it is recommended that the design be based on that number of wheels which gives the thickest pavement out of all combinations of wheels from the complete main landing gear group. This is compatible with the CBR flexible pavement thickness design procedure as recommended by the U.S. Army Corps of Engineers and as implemented by the FAA for multiple-gear airplanes.

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