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Design of geosynthetic reinforced flexible airfield pavement

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ABSTRACT: In this paper a method has been proposed for designing synthetic reinforced flexible airfield pavement by combining Barenberg method, which is a synthetic reinforced flexible highway pavement design method and Federal Aviation Administration (FAA) method, which is widely used for design of airfield pavements. Small modifications have been made in both the Barenberg and FAA method in order to make them applicable for the design of synthetic reinforced flexible airfield pavements. A computer program has been written to calculate aggregate thickness using the new method. The results were plotted in the form of design charts. The results show an appreciable decrease in pavement thickness due to use of geosynthetics.

1 NTRODUCTION

Most current procedures for flexible airport pavement design, in particular the Federal Aviation Administration (FAA) design method and International Civil Aviation Organization (ICAO) system for aircraft load classification, have their origin in the empirical California Bearing Ratio (C. B. R.) method originally developed for highways.

Many design methods were available for the geotextile reinforced flexible highway pavements like that given by Barenberg et al. (1975), Bakker (1977), Steward et al. (1977), Giroud and Noiray (1981), Sowers et al. (1982), Mazedjadeh et al. (1982), Raumann (1982), Barksdale et al. (1982), Milligan et al. (1989), Milligan et al. (1989a), Palmeira (1998), etc. However, till date no attempt has been made to produce a design method for geotextile reinforced flexible airfield pavements.

In this paper a method has been proposed for designing geotextile reinforced flexible airfield pavement by combining Barenberg method and FAA method. Small modifications have been made in both the Barenberg and FAA method in order to make them applicable for the design of geotextile reinforced flexible pavements.

2 BARENBERG DESIGN METHOD

In this method it was assumed that the allowable stress on subgrade is,

$$\sigma_z = Nc \times C_u \qquad (1)$$

where:

σ_z = allowable stress on the subgrade

C_u = undrained cohesion

Nc = bearing capacity factor
= 3.3, without geotextile
= 6.0, with geotextile

The stress on the subgrade due to the wheel load is calculated using Boussinesq's stress distribution beneath a circularly loaded area.

A modification is made in the design method in order to apply it for design of geotextile reinforced airfield pavement. It is assumed that 95 percent of the gross weight of aircraft is taken by the main landing gear assembly.

3 FEDERAL AVIATION ADMINISTRATION (FAA) DESIGN METHOD

The FAA design method is primarily based on the CBR design method. In this method, the thickness of different components of the pavement are determined based on the California Bearing Ratio (CBR) values, using the following equation,

$$t = \alpha \times \sqrt{A \times \left[\frac{17.9\ p_e}{CBR} - \frac{1}{\pi}\right]} \qquad (2)$$

where:
t = thickness of aggregate layer (cm)

A= contact area of one tire (cm^2)

CBR = California Bearing Ratio (percentage)

p_e = tire pressure of a single wheel load (SWL) or of equivalent single wheel load (ESWL)
= SWL / A or ESWL / A (MPa)

α = load repetition factor depending on number of load repetitions and carriage configuration.

Two modifications are made in the original design method, they are:

1. The original chart presented by the Corps of Engineers for the evaluation of load repetition factor, , is extrapolated to include upto 3 10^5 coverages as shown in Figure 1 (Chaudhury, 2001). This is done because of the fact that number of coverages corresponding to 25,000 annual departures of an aircraft using a pavement having 20-years design life exceed the maximum value of coverages viz., 1 x 10^5 available in the chart given in *Aerodrome Design Manual, Part 3, Pavements,* 1983.

2. In the original FAA design method it was assumed that 95 percent of the gross weight of the aircraft is taken by the main landing gear. But in the present study it is assumed that 100-135 percent of the gross weight of aircraft is taken by the main landing gear for various types of aircraft. For single wheel gear

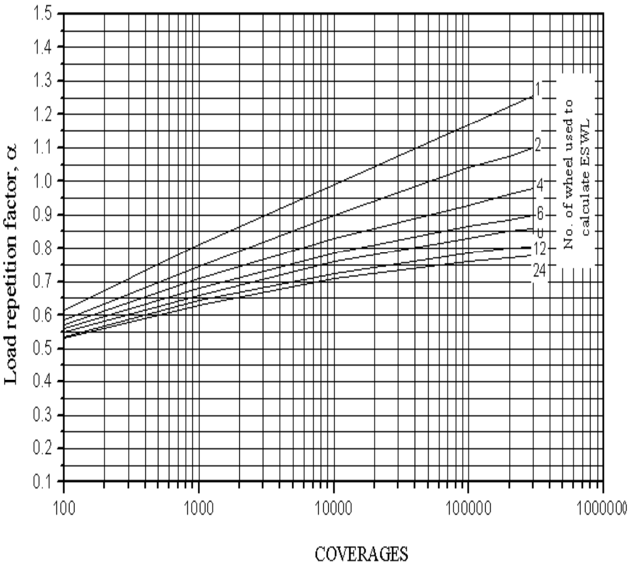

Figure 1. Modified load repetition factor versus coverages.aircraft no such special assumption is needed.

These values are arrived at by trial and error, in order to match the thickness of the unreinforced pavement given by FAA method. Table 1 lists the percentage of gross weight of various aircrafts, assumed to be taken by main landing gear assembly of the respective aircrafts.

Type of aircraft	Assumed percent of gross weight carried by main landing gear
Dual wheel gear	100
Dual tandem wheel gear	105
DC10-10, 10CF	105
A300-B2, B4	105
B747-100, SR, 200B, C,F	135
B 747 SP	135

Table 1. Percentage of gross weight of aircraft taken by main landing gear of various aircraft (as assumed in the modified method)

A computer program has been written to calculate the aggregate thickness for various values of CBR, using equation 2 and considering all the modifications. Design charts showing aggregate thickness versus CBR value have been prepared for annual departure of 1,200 to 25,000 and various gross weights of aircrafts (Chaudhury, 2001).

The aggregate thickness values obtained from the design charts for various aircraft are slightly on the lower side as compared to the values given in the ICAO manual for design of aircraft pavements

4 COMBINATION OF MODIFIED BARENBERG AND MODIFIED FAA (CBF) METHOD

In this method, for various CBR values the thickness of aggregate layer is determined using the CBR design equation 2, considering all the modifications. The CBR values are then converted into the corresponding undrained cohesion values by using,

$$C_u = 30 \times CBR \quad (3)$$

where:

C_u= undrained cohesion (kPa)

The undrained cohesion values so obtained are then multiplied by the appropriate values of bearing capacity factor, Nc, for the reinforced and unreinforced case (as used in equation 1, to get cNc values.

A computer program has been written to calculate the aggregate thickness for various values of bearing capacity (indicated by cNc for cohesive soil under undrained condition). Design charts showing aggregate thickness versus bearing capacity values have been prepared using the above method for various gross weights of all the types of aircraft mentioned in Table 1. However, for the sake of brevity only the design charts for single wheel gear aircraft of gross weight 13,600 kg. (Figure, 2), dual wheel gear of gross weight 22,700 kg (Figure 3) and dual tandem wheel gear aircraft of gross weight 45,360 kg (Figure 4) are presented in this paper.

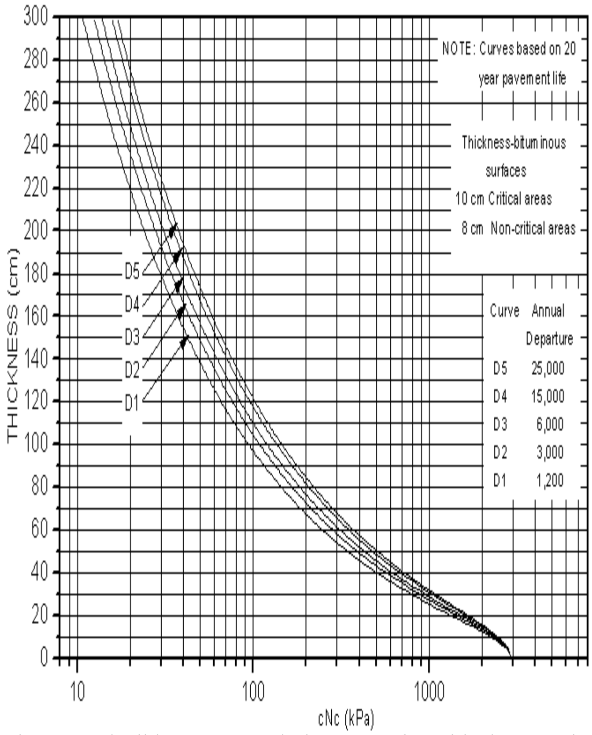

Figure 2. Flexible pavement design curve for critical areas, single wheel gear aircraft of gross weight 13,600 kg., without and with geosynthetic.

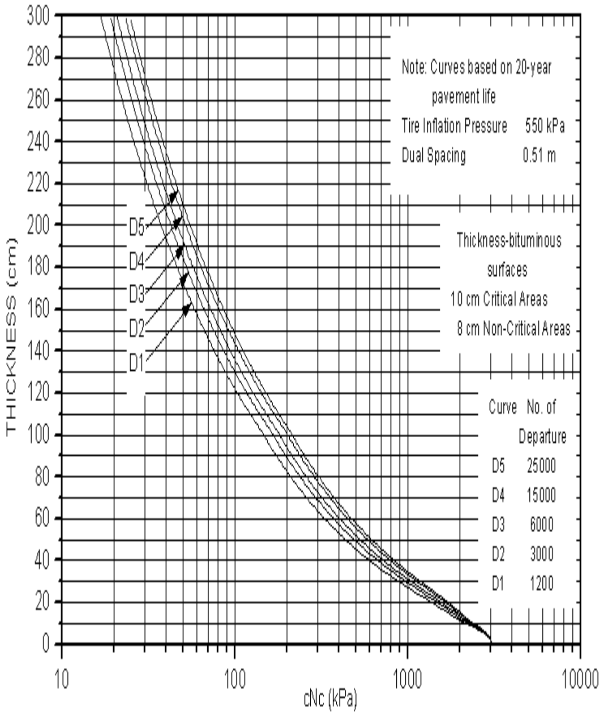

Figure 3. Flexible pavement design curves for critical areas, dual wheel gear aircraft of gross weight 22,770 kg., without and with geosynthetics.

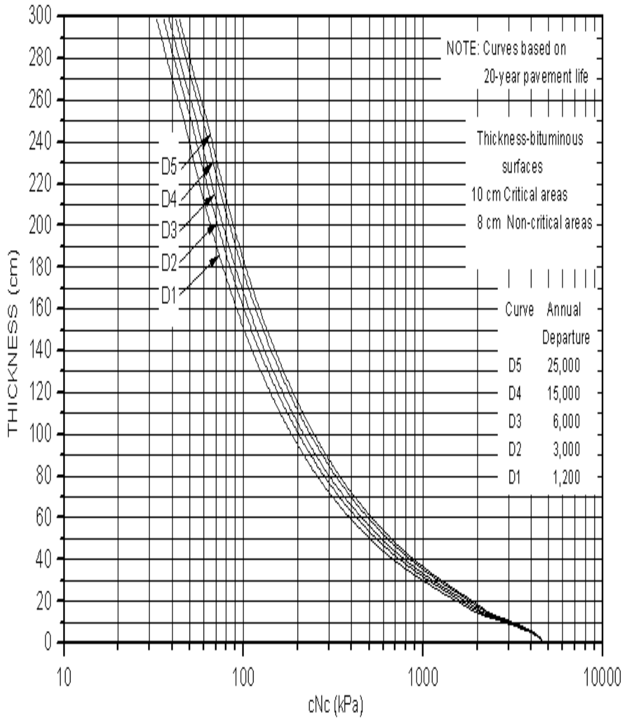

Figure 4. Flexible pavement design curves for critical areas, dual tandem wheel gear aircraft of gross weight 45,360 kg., without and with geosynthetics.

5 DESIGN PROCEDURE

For obtaining the aggregate thickness required for various CBR values for a particular aircraft, from the design charts, the CBR value is first converted to C_u using equation 3. For obtaining the cNc values the C_u values are multiplied by 3.3, for the unreinforced case and by 6, for the reinforced case. The required aggregate thickness is then obtained from the appropriate design chart for the cNc values calculated in the previous step**.**

6 DISCUSSIONS

Reinforced and unreinforced aggregate thickness values, h_r and h_u, respectively, obtained from Figure 2 for single wheel, Figure 3 for dual wheel and Figure 4 for dual-tandem wheel gear aircraft is presented in the tabular form for a CBR value of 1 and annual departure of 1,200 for both the Modified FAA method and CBF method (Tables 2, 3 and 4).

Table 2. Thickness of aggregate layer obtained by using different design methods for single wheel gear aircrafts at 1 CBR for a departure of 1200.

Weight of aircraft (kg)	Modified FAA method, h_u (cm)	CBF method		
		h_u (cm)	h_r (cm)	% savings
13,600	98	98	69	30
20,400	119	119	85	29
27,200	138	138	99	28
34,000	154	154	115	25

Table 3. Thickness of aggregate layer obtained by using different design methods for dual wheel gear aircrafts at 1 CBR for a annual departure of 1200.

Weight of aircraft (kg)	Modified FAA method, h_u (cm)	CBF method		
		h_u (cm)	h_r (cm)	% savings
22,700	123	123	87	29
34,000	150	150	110	27
45,400	174	174	125	28
68,000	212	212	154	27
90,700	245	245	177	28

Table 4. Thickness of aggregate layer obtained by using different design methods for dual-tandem wheel gear aircrafts at 1 CBR for a departure of 1200.

Weight of aircraft (kg)	Modified FAA method, h_u(cm)	CBF method		
		h_u (cm)	h_r cm)	% savings
45,400	150	150	100	33
68,000	198	198	130	34
90,700	238	238	155	35
136,100	295	295	195	34
181,400	*	*	226	-

* values exceeded 300 cm.

From the Figures 2 to 4 and Tables 2 to 4, it is clear that there is an appreciable decrease in pavement thickness due to the inclusion of the geotextile. The saving in aggregate is in the range of 28 to 40 percent for various aircrafts.

For a particular type of aircraft (such as single wheel gear or dual wheel gear aircraft), as gross weight increases, there is a marginal decease in the percentage of aggregate saving. However, for a particular aircraft as the CBR value increases, there is almost no difference in percentage of aggregate saving as shown in Table 5. Due to space constraint only the table for dual wheel gear aircraft for an annual departure of 1200 is presented here.

Table 5. Percentage saving in aggregate thickness for various dual wheel gear aircrafts for an annual departure of 1200

Gross weight of aircraft (kg)	C. B. R.		
	1	2	3
	% savings	% savings	% savings
22,700	29	33	33
34,000	27	32	33
45,400	28	30	32
68,000	27	31	32
90,700	28	31	33

7 CONCLUSIONS

From the above discussion we can conclude that,

1. The unreinforced thickness values obtained from the CBF method are same as that for Modified FAA method.
2. In CBF method, using geosynthetic reinforcement the percentage reduction in aggregate thickness is in the range of 28 to 40, which is quite appreciable.
3. For a particular type of aircraft (such as single wheel gear or dual wheel gear aircraft), as gross weight increases, there is a marginal decease in the percentage of aggregate saving.
4. For a particular aircraft as the CBR value increases, there is almost no difference in percentage of aggregate saving.

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