Field evaluation of pavement load-carrying capacity on clay subgrade during construction



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ABSTRACT

Flexible pavement design is generally guided by the subgrade strength, traffic and construction techniques employed to reduce subgrade deflections (stresses) to a desired level. A total of 375 Benkelman beam deflection tests were performed prior to and after subgrade stabilization and each of compacted material layers during several local roadway constructions. The analysis is based on i) linear relationship between prior and after deflections of each of material layers placed, ii) Department of Transport design theory derived empirically from substantial volumes of plate bearing data. Multiple regressions were performed to develop design models using SPSSx statistical package at University of Alberta.

RÉSUMÉ

La conception d'une chaussée flexible est généralement liée à la solidité du niveau inférieur, à la circulation et aux techniques de construction employées pour réduire les déflexions (contraintes) de la couche inférieure à un degré voulu. Un total de 375 tests de déflexion par la poutre Benkelman ont été effectués avant et après la stabilisation du niveau inferieur et sur chacune des couches compactées durant la construction de plusieurs routes locales.

L'analyse est basée sur i) la relation linéaire entre les déflexions antérieures et postérieures de chaque couche de matériel. ii) la théorie de conception du Département des Transports, dérivée de manière empirique des volumes substantiels des données de chargement à la plaque. De multiples régressions utilisant les statistiques SPSSx ont été effectuées pour développer des modèles de conception à l'Universite d'Alberta.

1 INTRODUCTION

The conventional Beam Deflection is probably one of the most widely used field tests for pavement structural design and evaluation. The method is basically a field load test which measures the pavement surface deflection under a standard static axle load of 80 kN (18,000 lbs). The magnitude of a pavement deflection may be considered as an indicator of the load carrying capacity for a pavement structure. Although general design models have been developed by several agencies in North America, these models may not be accurate for local pavement design and often considerable experience is needed to judge the results derived from general models.

The Beam Test has been employed for pavement design in Alberta for a long time, but this method has not been used extensively by the City until recent years. During the 1980s the City's research group had routinely used this approach to evaluate pavement structural adequacy for research projects. Since 1987 a preliminary deflection data base was compiled taking advantage of data from several other studies in the City. It is felt that a local structural design model may be developed using this data to benefit the City's pavement designs. The flexible pavements were designed using asphalt concrete surface over 150 mm soil cement on 150 mm cement stabilized clay subgrade. The local clay is typically medium to high plasticity with a corresponding swelling potential. The objective of this study was to develop local structural design models for soil cement base pavements in Edmonton. This report documents the study results and provides recommendations for the use of these models.

2 FIELD STUDY

The standard Benkelman Beam tests undertaken during the 1987 construction season were generally conducted in the outside wheel path at approximately 40 metre intervals and conformed to the procedures recommended by the Asphalt Institute MS-17 (1983). A SOILTEST HT-300 Beam was employed with two features modified by the City's research group, i.e. a Mutitiyo Digi-Matic Indicator and an automatic safety lock at the handle. The aluminum probe beam has a ratio 4:1 and a conversion factor is required for field readings. The beam has a calculated constant of 3.96 in view of its geometric shape. The field readings and related information were recorded on a standard sheet and then reduced by a computer program. All readings were temperature corrected according to the Canadian Good Road Association (now TAC) method. The field results were compiled and analyzed using the SPSSX statistical package at the University of Alberta. Two criteria were considered for analysis of the study: 1) linear relationship between deflections before and after placement of a pavement layer and 2) Transport Canada pavement design theory (CGRA 1962, 1965).

3 FIELD RESULTS AND DISCUSSSION

Figures 1, 2 and 3 present the Edmonton design models for cement stabilized subgrade (CSS), soil cement layer (SC), and asphalt concrete layer (AC).

Figure 1 indicates the applied cement stabilization would reduce an original subgrade deflection from 10mm to 5mm, quite a significant improvement. Analysis results suggest that this layer would best perform for an original deflection ranging from 5mm to 10mm as indicated by (K) constant. This constant is an indicator of material effectiveness based on the before and after deflection ratio. It may be noted that the CSS layer would perform less effectively for an original subgrade deflection higher than 15mm because the required CSS thickness for a unit deflection improvement increases significantly.



Figure 1. Beam Deflection and Thickness Requirements (CSS Model)

Figure 2 indicates that a 150mm of soil cement layer would reduce the CSS surface deflection from 5mm to almost 1mm. it is evident that the SC layer would perform more effectively for the CSS surface deflection between 2mm and 5mm. Where the CSS surface deflection is less that 2mm, the SC layer appears to perform ineffectively, probably due to the degree of strength mobilization.



Figure 2. Beam Deflection and Thickness Requirements (SC Model)

Figure 3 shows that a 50mm of asphalt concrete layer would reduce the SC layer surface deflection from 2mm to 1.3mm. Evidence indicates that the AC layer would be more effective for SC surface deflections less than 2mm.

To conclude, the CSS layer would not only improve the soft subgrade to a workable condition but also contribute a lot to the pavement structural strength. The SC layer would perform structurally effectively and economically as a main structural element. It appears to be more economical to use the AC layer for surface course for the soil cement base pavement construction. Structural effectiveness depends on not only the strength of material but also the depth of the structural layer and original deflection.



Figure 3. Beam Deflection and Asphalt Thickness Requirements (AC Model)

4 APPLICATION

Example 1: Given critical Benkelman Beam rebound = 1.11mm, design ESAL = 5,000,000, design rebound = 0.64mm (0.025 in), design an overlay for the pavement using Edmonton, Asphalt Institute and CGRA methods.

- 1) Edmonton AC Model yields 50 mm (2 in) of asphalt overlay.
- 2) Asphalt Institute model yields 100mm (4 in) overlay.
- 3) CGRA Model yields 127mm (5.0 in)

Thus the Edmonton Model gives the most economical design.

Example 2: Design a new collector pavement for a 20 year design life, maximum design rebound 1.27mm (0.05 in). If original subgrade summer rebound (x + 2x) = 8mm, find the structural requirements for the soil cement base pavement using Edmonton's new design models.

- The estimated peak rebound would be 8 x 1.3 = 10.4mm. The CSS model suggests a 150mm (6 in) of cement stabilized layer would reduce the estimated peak rebound from 8mm to 5.5mm.
- 2) The SC model suggests an additional 150mm (6 in) of soil cement layer would further reduce the deflection from 5.5mm to 0.9mm which is less than the design rebound of 1.27mm taking into consideration of fatigue.
- Although the pavement does not require additional structural layers, a minimum of 50mm (2 in) asphalt concrete surface course is required for all practical purposes. The AC model suggests that the top 50mm of asphalt concrete

layer would slightly benefit the structure, reducing the rebound from 0.9mm to 0.5mm. Thus the pavement is considered to be structurally adequate with 150mm cement stabilized subgrade, 150mm soil cement, and 50mm asphalt concrete surface course.

Where it is often that the original subgrade deflection data is not available, Benkelman Beam test may be undertaken on the cement stabilized subgrade surface to obtain the initial deflection data before subsequent upper layers are placed.

Example 3: Develop a rational pavement design for widening 23^{rd} Avenue between 111^{th} Street and 119^{th} Street using local design models. The existing south half of the roadway pavement structure consists of 150mm soil cement layer, 280mm asphalt concrete layer, condition rating = 8 at 6 years of age, design rebound = 0.51 mm (0.02 in), summer Benkelman Beam rebound = 1.53mm, CBR = 4.

- 1) Local experience predicts the existing pavement would have a 17 year expected life at acceptable condition rating of 5 (Chai, 1989).
- 2) Remaining life for the exiting pavement would be 17 6 = 11 years. A material deduction factor = 11/17 = 0.65.
- Effective thickness adjustment by remaining life:

Soil Cement Layer: 150 x 0.6 x 0.65 = 59mm

Asphalt Concrete Layer 280 x 1.0 x 0.65 = 182mm

Remaining Total Effective Asphalt Thickness = 241mm.

- 4) For CBR = 4, design ESAL = 10,000,000, the required total pavement thickness is 370mm asphalt concrete.
- 5) If late spring Benkelman Beam rebound is 1.56mm, the critical spring rebound would be 1.56 x 1.1 = 1.7mm. For a design rebound of 0.51mm (0.2 in), Edmonton AC model yields an overlay requirement of 130mm (5 in). For comparison, the Asphalt Institute Model yields 150mm (6 in) overlay and Canadian Good Road Association (CGRA) Model yields 203mm (8 in) overlay.
- 6) The total structural thickness:
 - Edmonton Model t = 241 + 130 = 371 mm (14.5 in) AC.

For comparison:

Asphalt Institute

t = 241 + 150 = 391mm (15.5 in) AC. CGRA Model

t = 241 + 203 = 544mm (21.5 in) AC. CBR Method

t = 241 + 129 = 370mm (14.5 in) AC.

5 SUMMARY

- These design models were developed based on local field deflection data obtained from several construction projects. The models meet general statistical criteria and are considered to be useful for local pavement design applications. The models are recommended for the soil cement base pavement within the following deflection limitations: CSS (5 -15 mm), SC (2 - 5 mm) and AC (<2 mm).
- The Edmonton design models provide the most economical approach for local pavement design in comparison with other popular models.
- 3) From a design point of view, the behavior of a pavement structural layer changes depending on material strength, depth of layer, level of deflection and mobilized strength. It is suggested that other local models be developed for pavements such as the granular base pavements in order to obtain more effective design for local use.
- It is our opinion that a field pavement performance evaluation program of selected pavements should be warranted to further verify the design models.

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