لا يعلمها ولا حجة في ظلامتها ولا رطب ولا تواب enzyme 2091

صدق الله العليم

سورة الانعام
Dedication

To the souls and memories of my parents, may God rest them in peace.

To my brother and sisters who shared the naughty childhood, the dreams and reality.

To my children who are my life fruits and the meaning of living.
Acknowledgments

Sincere thanks go to my supervisor Professor Dr. Galal A. Ali, for his invaluable advice, persuasion and guidance throughout the master courses and thesis study. His motivation to develop my interest in pavement industry is gratefully appreciated.

The thanks are dedicated to my dear husband Abdul Aziz without whom I would be lost, and whose gentle care, love and assistance made possible the successful completion of this study.

Thanks are also extended to Dr. Kamal Masoud for providing the research data.

Special thanks are also conveyed to Hadia and Awadallah, the engineers of the Ministry of Urban Planning and Infrastructure for providing the required related documents and reports that made possible the development of various designs.
Abstract

Flexible pavements are widely used despite some doubts regarding their economics under different conditions. Lack of research, less construction technology know-how and cement high rates compared with asphalt in the past are the main reasons for not implementing concrete pavement in Sudan.

The purpose of this study is to conduct comparison in total present cost between flexible pavement and jointed plain concrete pavement to locate a feasible long term good performance pavement type.

Two roads were selected to illustrate the case study, Elmonerra – Elsaffya road is considered as national highway (Road A), and Omdurman ring road representing the state road (Road B). The principles and cost comparison were applied for the two case study roads.

The two most important parameters that govern pavement design, namely sub-grade strength and traffic loading was determined in this study from Road A and Road B material laboratory tests reports and traffic surveying data. For flexible pavement design of both roads, the sub-grade resilient modulus $M_R$ was obtained from correlation with CBR. The design traffic in term of million ESAL was obtained from AASHTO equation for 20 year design life. The rigid pavement design used modified modulus of sub-grade reaction $k$ as measure of sub-grade strength, while design traffic was also million ESAL.

The AASHTO and PCA methods were applied for rigid pavement design in comparative manner with AASHTO and Asphalt Institute (AI) methods for flexible pavement design.
Typical standard pavement cross sections obtained by AASHTO design for flexible and jointed plain concrete pavements were adopted for life-cycle cost analysis (LCCA). The two components of LCCA, construction and maintenance costs were calculated for the entire roads using 2016 rates. The total present-worth of cost for each road pavement cost were used for comparison. It was found that the feasible long term pavement performance can be achieved by using jointed plain concrete pavement with saving of (28 %) for road A and (6 %) for road B.
تجريد

ان الرصف الأسفلتي لتعبيد الطرق يعتبر الأوسع استثماراً على الرغم من وجود بعض التحذيرات حول مدى جدوى ملامسته اقتصادياً في ظل ظروف مختلفة. كما وأن قلة أجراء البحوث العلمية ومعرفة التقنيات الحديثة للتشخيص والاستعراضات مقارنة بسعار الأسفلت في السابق من أهم مهارات استخدام الرصف الصلب في السودان.

الهدف الرئيسي لإجراء هذه الدراسة هو عقد مقارنة لتكاليف الكلية الخاصة بتشييد كل من الرصف المرن والرصف الصلب باستخدام البلاطات القصيرة الغير مسلحة لغرض الحصول على رصف ذو جدوى اقتصادية ويتمتع بداء جيد طويل المدى.

تم اختيار مشروع طريق المنيرة – الصفية والذي يمثل الطريق القومي (الطريق A) وقطاع من طريق ام درمان الدائري الذي يتم الطريق الولائي (الطريق B) كحالتين للدراسة وتم تطبيق المبادئ الرئيسية والمقارنة عليهم.

هناك عدة عوامل تتحكم في عملية التصميم لعل من أكثرها تأثيراً عامل مقاومة الطبقة التاسيسية وحركة الطرق المرور التصحيحية والذين تم حسابهما لانتشار البيانات الحقيقة السريع الحركي وتقارير اختبارات المواد. في حالة تصميم الرصف المرن تم قياس مقاومة الطبقة التاسيسية باستخدام معدل المرونة MR والذي يتم الحصول عليه معايرة بقيم معامل تحمل كاليفورنيا CBR، أما الحركة التصحيحية فتم حسابها بواسطة AASHTO معدلة ESAL باستخدام وحدة الحمل المحوري القياسي المكافئ، وذلك باستخدام فترة 20 عاماً عصر التصميم للمشروع الطريق. أما في حالة تصميم الرصف الصلب فتم قياس مقاومة الطبقة التاسيسية بواسطة معامل رد الفعل k والذي تم الحصول عليه باستخدام AASHTO. أما الحركة التصحيحية لهذا النوع من الرصف تم حسابها بوحدة الحمل المحوري القياسي المكافئ، كما تم في تصميم الرصف المرن.

AASHTO تم تطبيق طريقتين الجمعية الأمريكية لموظفي الطرق الولائية الاشنو وجمعية الاسمنت الاميركي PCA لموضوع الرصف الصلب مقارنة بطريقة الاشنو وطريقة معهد الاسفلت AI لتصميم الرصف المرن.

أعمال القطاع العرضي النموذجي لنوعي الرصف المرن و البلاطات القصيرة IPCL، لكل طريق والمصممين على طريقة الاشنو وذلك لغرض عمل تحليل لدورة التكلفة خلال فترة عمر تصميم الطريق والتي تعتبر من أهم LCCA.
مكوناتها تكاليف التشييد وتكاليف الصيانة. هذه التكاليف تم حسابها للكامل طول الطرقين لكل نوع من الرصف باستخدام السعر الحالي للعام 2014. واخيرا تم ايجاد القيمة الحالية الكلية للتكليف وإجراء المقارنة التي أثبتت الجدوى الاقتصادية لاستخدام الرصف الصلب بواسطة البلاطات القصيرة لاداء جيد طويل المدى وذلك بتوفير في التكلفة الكلية تبلغ نسبة (6%) للطريق القومي ونسبة (6%) للطريق الولائي.
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## ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>AASHTO</td>
<td>American Association of State Highway officials</td>
</tr>
<tr>
<td>AC</td>
<td>asphalt concrete</td>
</tr>
<tr>
<td>ADT</td>
<td>average daily traffic</td>
</tr>
<tr>
<td>(ADT)_o</td>
<td>average daily traffic at start of design period</td>
</tr>
<tr>
<td>AI</td>
<td>Asphalt Institute</td>
</tr>
<tr>
<td>AS</td>
<td>area of steel</td>
</tr>
<tr>
<td>a_1, a_2, a_3</td>
<td>layer coefficients for asphalt surface, base, and subbase courses, respectively</td>
</tr>
<tr>
<td>CBR</td>
<td>California Bearing Ratio</td>
</tr>
<tr>
<td>CF</td>
<td>condition factor</td>
</tr>
<tr>
<td>CRCP</td>
<td>continuous reinforced concrete pavement</td>
</tr>
<tr>
<td>Cd</td>
<td>drainage factor for rigid pavements</td>
</tr>
<tr>
<td>C_W</td>
<td>allowable crack width</td>
</tr>
<tr>
<td>DTD</td>
<td>design temperature drop</td>
</tr>
<tr>
<td>D_SB</td>
<td>thickness of subbase under concrete slab</td>
</tr>
<tr>
<td>D_SG</td>
<td>thickness of subgrade above a rigid foundation</td>
</tr>
<tr>
<td>EALF</td>
<td>equivalent axle load factor</td>
</tr>
<tr>
<td>ESAL</td>
<td>equivalent single-axle load, which is the total number of repetitions of a standard 18-kip axle load during the design period</td>
</tr>
<tr>
<td>E_SB</td>
<td>resilient modulus of subbase for concrete pavement</td>
</tr>
<tr>
<td>E_C</td>
<td>elastic modulus of concrete</td>
</tr>
<tr>
<td>f'C</td>
<td>ultimate compressive strength of concrete</td>
</tr>
<tr>
<td>f_s</td>
<td>allowable stress in steel</td>
</tr>
<tr>
<td>ft</td>
<td>concrete indirect or splitting tensile strength</td>
</tr>
<tr>
<td>HMA</td>
<td>hot mix asphalt</td>
</tr>
<tr>
<td>.h</td>
<td>concrete slab thickness</td>
</tr>
<tr>
<td>JPCP</td>
<td>jointed plain concrete pavement</td>
</tr>
<tr>
<td>k</td>
<td>modulus of subgrade reaction</td>
</tr>
<tr>
<td>k_∞</td>
<td>modulus of subgrade reaction when D_SG is greater than 10 ft</td>
</tr>
<tr>
<td>LSF</td>
<td>load safety factor</td>
</tr>
<tr>
<td>M_R</td>
<td>resilient modulus; or effective roadbed soil resilient modulus</td>
</tr>
<tr>
<td>N_max</td>
<td>maximum number of steel bars per traffic lane</td>
</tr>
<tr>
<td>N_min</td>
<td>minimum number of steel bars per traffic lane</td>
</tr>
</tbody>
</table>
can number of passes of \( i_{th} \) axle load; or predicted number of load repetitions during \( i_{th} \) period; or predicted number of repetitions during \( i_{th} \) stage

- **PCC**: Portland cement concrete
- **PSI**: present serviceability index
- **\( P_{\text{max}} \)**: maximum percent steel
- **\( P_{\text{min}} \)**: minimum percent steel
- **SN**: structural number
- **\( S_C \)**: modulus of rupture of concrete
- **TH**: average daily high temperature during the month the pavement is Constructed
- **TL**: average daily low temperature during the coldest month of the year
- **Tf**: truck factor
- **t**: length of steel bar
- **\( W_{18} \)**: allowable 18-kip single-axle load applications for a given reliability
- **X**: crack spacing
- **Y**: design period in years
- **Z**: concrete shrinkage
- **\( Z_R \)**: normal deviate for a given reliability \( R \)
- **\( \alpha_c \)**: coefficient of thermal expansion for concrete
- **\( \alpha_s \)**: coefficient of thermal expansion for steel
- **\( \gamma_c \)**: unit weight of concrete
- **\( \Delta \text{PSI} \)**: serviceability loss
- **\( \sigma_w \)**: wheel load stress
- **\( \mu \)**: allowable bond stress for deformed bars