THOMPSON, ROGER JOHN

THE DESIGN AND MANAGEMENT OF SURFACE MINE HAUL ROADS

PhD UP 1996

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

THE DESIGN AND MANAGEMENT OF SURFACE MINE HAUL ROADS

Roger John Thompson

A thesis submitted in partial fulfilment of the requirements for the degree of

PHILOSOPHIAE DOCTOR (ENGINEERING)

in the

FACULTY OF ENGINEERING
UNIVERSITY OF PRETORIA

December 1996

ABSTRACT

Title: **The design and management of surface mine haul roads**
Author: **Roger John Thompson**
Supervisor: **Professor A T Visser**
Degree: **Philosophiae Doctor (Engineering)**
Department: **Civil Engineering**

Unpaved mine haul roads provide the principal means of material transport on surface strip coal mines. Design and management of these roads was based primarily on local experience and adopted empirical guidelines. With the trend in increasing truck size, these current pavement design and management systems proved inadequate. Not only would the maintenance costs of existing roads increase, vehicle operating and maintenance costs would also increase prohibitively.

The primary objective of this research was the development of a practical total haul road design and management methodology that encompasses pavement strength, wearing course functionality and road maintenance scheduling and management components. A revised mechanistically derived optimal structural design is presented together with design criteria and recommended effective elastic modulus values for typical construction materials. The placement of those materials as pavement layers was analysed, such as to optimise their performance both as individual layers and over the entire structure.

The development and analysis of suitable material selection guidelines for use in haul road functional design was allied to the development of a qualitative defect assessment and ranking methodology. A revised range of material selection parameters was derived based on road-user acceptability criteria and actual material defect rankings. By analysing the trends evident in the individual defect rankings, the predictive capability of the specification was enhanced by depicting the typical functional defects arising when departures are made from the recommended material parameter limits.

Maintenance design concerns the optimal frequency of wearing course maintenance commensurate with minimum vehicle operating and road maintenance costs. A qualitative road roughness evaluation technique was developed as a precursor to the development of a model for roughness progression. Expressions were developed to enable direct comparison to be made between qualitatively derived roughness and International Roughness Index (IRI). Models of vehicle operating and road maintenance cost variation with road roughness were combined with roughness progression models to determine the optimal maintenance strategy.

Through an analysis of the current expenditure on mine haul road construction and operation, the adoption of these revised and improved haul road design methodologies have been shown to be associated with potentially significant cost savings and improvements in the structural, functional and maintenance management aspects of haul road design.

SUMMARY

THE DESIGN AND MANAGEMENT OF SURFACE MINE HAUL ROADS

Roger John Thompson

Supervisor: Professor A T Visser
Department: Civil Engineering
University: University of Pretoria
Degree: Philosophiae Doctor (Engineering)

Unpaved mine haul roads provide the principal means of material transport on surface strip coal mines. With the expansion of surface mining in South Africa and in particular coal strip mining, the use of ultra-heavy off-highway trucks, currently capable of hauling payloads in excess of 160t, has become commonplace. Design and management of these roads was based primarily on local experience and adopted empirical guidelines. This design method served its purpose in an era when off-highway trucks were lighter and less financial outlay was required, both in terms of initial pavement construction costs, ongoing road maintenance costs and vehicle maintenance costs. As the trend in increasing truck size continues, these current pavement design and management systems proved inadequate. Not only would the maintenance costs of existing roads increase, vehicle operating and maintenance costs would also increase prohibitively.

The primary objective of this research was the development of a portable and practical total haul road design and management methodology that encompasses both pavement strength, wearing course functionality and road maintenance management components. The structural design concerns the ability of a haul road to carry the imposed loads without the need for excessive maintenance. A revised mechanistically derived structural design is presented together with the associated limiting design criteria and recommended target effective elastic modulus values for the construction materials available. The placement of those materials as pavement layers, such as to optimise their performance both as individual layers and over the entire structure is analysed.

Functional design aspects refer to the ability of the haul road to perform its function, i.e to provide an economic, safe and vehicle friendly ride. This is dictated to a large degree through the choice, application and maintenance of wearing course materials. The development and analysis of suitable material selection guidelines for use in haul road functional design was allied to the development of a qualitative defect assessment and ranking methodology in order to assess the utility of established performance related selection guidelines and as a basis for revised functional performance parameter specification. A revised range of parameters was derived based on road-user acceptability criteria. By analysing the trends evident in the individual defect rankings, the predictive capability of the specification was enhanced by depicting the typical functional defects arising when departures are made from the recommended material property limits.

Maintenance design concerns the optimal frequency of wearing course maintenance commensurate with minimum vehicle operating and road maintenance costs. A qualitative road roughness evaluation technique was developed as a precursor to the development of a model for roughness progression. Expressions were developed to enable direct comparison to be made between the qualitative roughness defect score and International Roughness Index (IRI). The second element of a maintenance management system was based on models of the variation of vehicle operating and road maintenance costs with a road roughness model. The combination of these models enabled the optimal maintenance strategy to be sought based on the minimisation of these costs. Sub-optimal maintenance strategies were seen to be associated with unwarranted expenditure on total road-user costs.

This thesis makes a contribution to the state of knowledge through the development and synthesis of structural, functional and maintenance management aspects of haul road design. The adoption of these revised and improved haul road design methodologies are associated with potentially significant cost savings and operational improvements.

Keywords

Surface mine, road, design, structural, mechanistic, functional, maintenance, wearing course, hauling, transport.

SAMEVATTING

DIE ONTWERP EN BESTUUR VAN MYNVERVOERPAAIE

Roger John Thompson

Promoter: Professor A T Visser
Departement: Siviele Ingenieurswese
Universiteit: Universiteit van Pretoria
Graad: Philosophiae Doctor (Ingenieurswese)

Ongeplaveide mynvervoerpaaie voorsien die primêre vervoer metode van materiaal in steenkoolstrookdagmyne. Met die uitbreiding van dagmynbou in Suid-Afrika en in besonder in die steenkoolstrookmynbou, het die gebruik van swaar vervoertrokke alledaags geword. Ontwerp en bestuur van hierdie paaie was hoofsaaklik gebaseer op plaaslike ondervinding en empiriese riglyne. Hierdie ontwerp metode het sy doel gedien in 'n tydperk waarin die trokke ligter en 'n kleiner finansiële uitleg nodig was, beide in terme van inisiële plaveisel konstruksie kostes en voortdurende padonderhoudskostes en voertuig instanthoudingkostes. Soos wat die tendens van toename in trokgrootte voortduur, sal die huidige plaveisel ontwerp en bestuursstelsels onvoldoende wees. Nie alleen sal die ondershoudskostes van bestaande paaie verhoog nie, maar voertuigbedryf en -instandhoudingkostes sal buitensporig word.

Die primêre doel van die navorsing was die ontwikkeling van 'n oordraagbare en praktiese totale vervoerpadontwerp en bestuursmetodiek wat die plaveiselsterkte, slytlaag funksionele werkverrigting en padonderhoudbestuur komponente insluit. Die strukturele ontwerp behels die vermoë van 'n vervoerpad om die toegepaste las te kan dra sonder die noodsaaklikheid van buitensporige onderhoud. 'n Hersiene meganisties strukturele ontwerp word aangebied tesame met die geassosieerde ontwerpkriterium en aanbevole effektiewe elastisiteitsmoduluswaardes vir die beskikbare konstruksie materiaal. Die plasing van daardie materiale as plaveisellae, om sodanig hulle werkverrigting te optimeer is, as beide individuele lae en oor die hele struktuur, geanaliseer.

verrig, naamlik om 'n ekonomiese, veilige en voertuigvriendelike rit te voorsien. Die ontwikkeling en analise van geskikte materiaal seleksie is gekoppel aan die ontwikkeling van 'n kwalitatiewe defek waardebepaling en ranglys metodiek om die bruikbaarheid van vasgestelde prestasie-verwante seleksie riglyne te kan bepaal en as basis vir hersiene funksionele prestasie parameter spesifikasies. 'n Hersiene reeks parameters is afgelei, gebaseer op padverbruiker aanvaarbaarheids kriterium. Deur analise van die tendens in die individuele defek ranglys, is die voorspelbaarheids vermoë van die spesifikasies verhoog deur die uitwysing van tipiese funksionele defekte wat voorkom wanneer afgewyk word van aanbevole materiaal parameter beperkings.

Die onderhoud aspek van vervoerpad ontwerp kan nie afsonderlik van die strukturele en funksionele ontwerp aspekte oorweeg word nie. Onderhoudontwerp behels die optimale frekwensie van slytlaag onderhoud eweredig aan die minimum voertuigbedryf en padonderhoudskostes. 'n Kwalitatiewe pad ongelykheid evaluasie tegniek is ontwikkel as 'n voorloper tot die ontwikkeling van 'n ongelykheid progressie model. Uitdrukkings is ontwikkel om direkte vergelyking tussen ongelykheid defektelling en Internasionale ongelykheids indeks (IRI) moontlik te maak. Die tweede element van 'n onderhouds bestuurstelsel is gebaseer op modele van die variasie van die voertuigbedryf en instandhoudingkoste en padongelykheid. Die kombinasie van hierdie modelle stel die verbruiker in staat om die optimale onderhoudstrategie te soek. 'n Sub-optimale padonderhouds strategië was geassosieer met buitensporige besteding op totale padverbruikers koste.

Hierdie proefskrif lewer 'n bydrae tot die staat van kennis deur die ontwikkeling en samevoeging van die strukturele, funksionele en onderhoud bestuurs aspekte van mynvervoerpadontwerp. Die ingebruikneming van die hersiene en verbeterde vervoerpad ontwerp en bestuur metodiek het die potensiaal om beduidende koste besparings te verwesenlik.

Sleutelwoorde

Dagmyn, mynvervoerpad, plaveiselontwerp, strukturele, meganisties, funksionele, padonderhoud, sluitlaag, vervoertrok, vervoer.

ACKNOWLEDGEMENTS

I wish to express my appreciation to the following organisations and persons who made this thesis possible:

- This thesis is based on a research project of AMCOAL Colliery and Industrial Operations Limited. The opinions expressed are those of the author and do not necessarily represent the policy of AMCOAL Colliery and Industrial Operations Limited.

- AMCOAL Colliery and Industrial Operations Limited for financial support, the provision of data and mine test site facilities.

- The assistance and advice offered during the course of this study by the personnel of Kleinkopje, Kriel, SACE Kromdraai and New Vaal Collieries is gratefully acknowledged.

- The Transportek Division of the CSIR for both the multi-depth deflectometer installation and instrumentation and the high speed profilometer measurements taken at each mine.

- Barlows Equipment Company and Komdresco for the provision of haul truck fleet simulation programs.

- Professor A T Visser, my supervisor, for his guidance and support.

- My wife for her encouragement, support and assistance offered during the study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES