Ministry of Rural Development
Government of India

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Use of Alternate Technologies and Materials in the Construction of Low Volume Rural Roads

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INTRODUCTION

- WORLDWIDE, MANY COUNTRIES HAVE SUBSTANTIAL RURAL ROAD NETWORKS CONSISTING OF EARTH OR GRAVELED ROADS
- THESE ARE OFTEN POORLY DESIGNED AND MAINTAINED, SUBJECTED TO EXTREME WEATHER CONDITIONS AND HEAVILY TRAFFICKED – LEADS TO IMPASSABLE CONDITIONS AND POOR ACCESS DURING INCLEMENT WEATHER
- ALSO, UNACCEPTABLE SOCIAL CONDITIONS
  - LOSS OF COMMUNITY ACCESS
  - LOSS OF INCOME
  - LOSS OF ACCESS TO MARKETS
  - REDUCED ECONOMIC DEVELOPMENT OPPORTUNITIES
- COST OF UPGRADING THESE ROADS TO A PAVED STANDARD USING CONVENTIONAL DESIGNS GENERALLY MAKES IMPROVEMENT OF THE ROADS UNTENABLE

INTRODUCTION

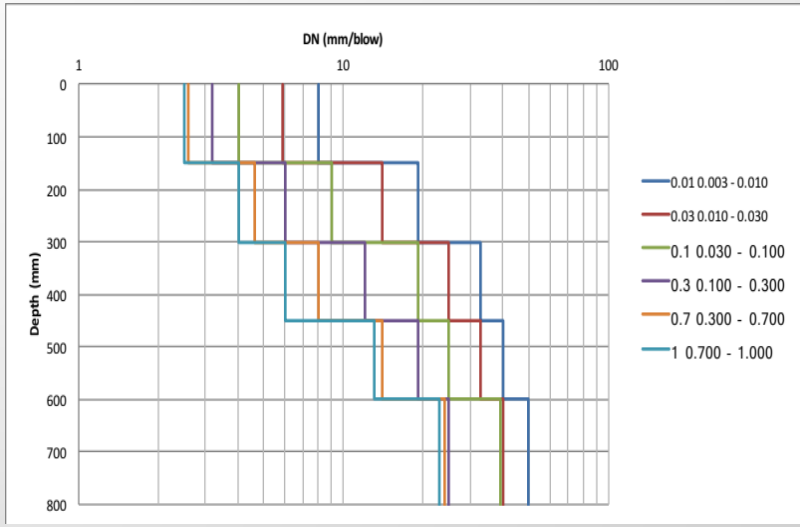
- A SIMPLIFIED DESIGN METHOD FOR RURAL LOW VOLUME ROADS HAS BEEN DEVELOPED - MAXIMIZES THE USE OF LOCALLY AVAILABLE MATERIALS, MINIMIZES THE USE OF IMPORTED MATERIALS AND PROMOTES SUSTAINABILITY WITH THE ADDED INCLUSION OF OPTIMIZING CLIMATE RESILIENCE
- THE PAVEMENT DESIGNS ARE NOT OVERLY CONSERVATIVE - MORE ATTENTION TO THEIR INPUTS AND ANALYSIS IS REQUIRED THAN FOR THE GENERALLY MORE CONSERVATIVE TRADITIONAL DESIGNS AND A GOOD UNDERSTANDING OF THE PROCESS, MATERIALS AND CONSTRUCTION AND MAINTENANCE IS REQUIRED FROM THE DESIGN ENGINEER
- THIS IS A BRIEF SUMMARY IN THE AVAILABLE TIME OF SOME OF THE FUNDAMENTAL CONCEPTS INVOLVED AND IDENTIFIES AREAS WHERE SIGNIFICANT SAVINGS MAY BE DERIVED

BACKGROUND

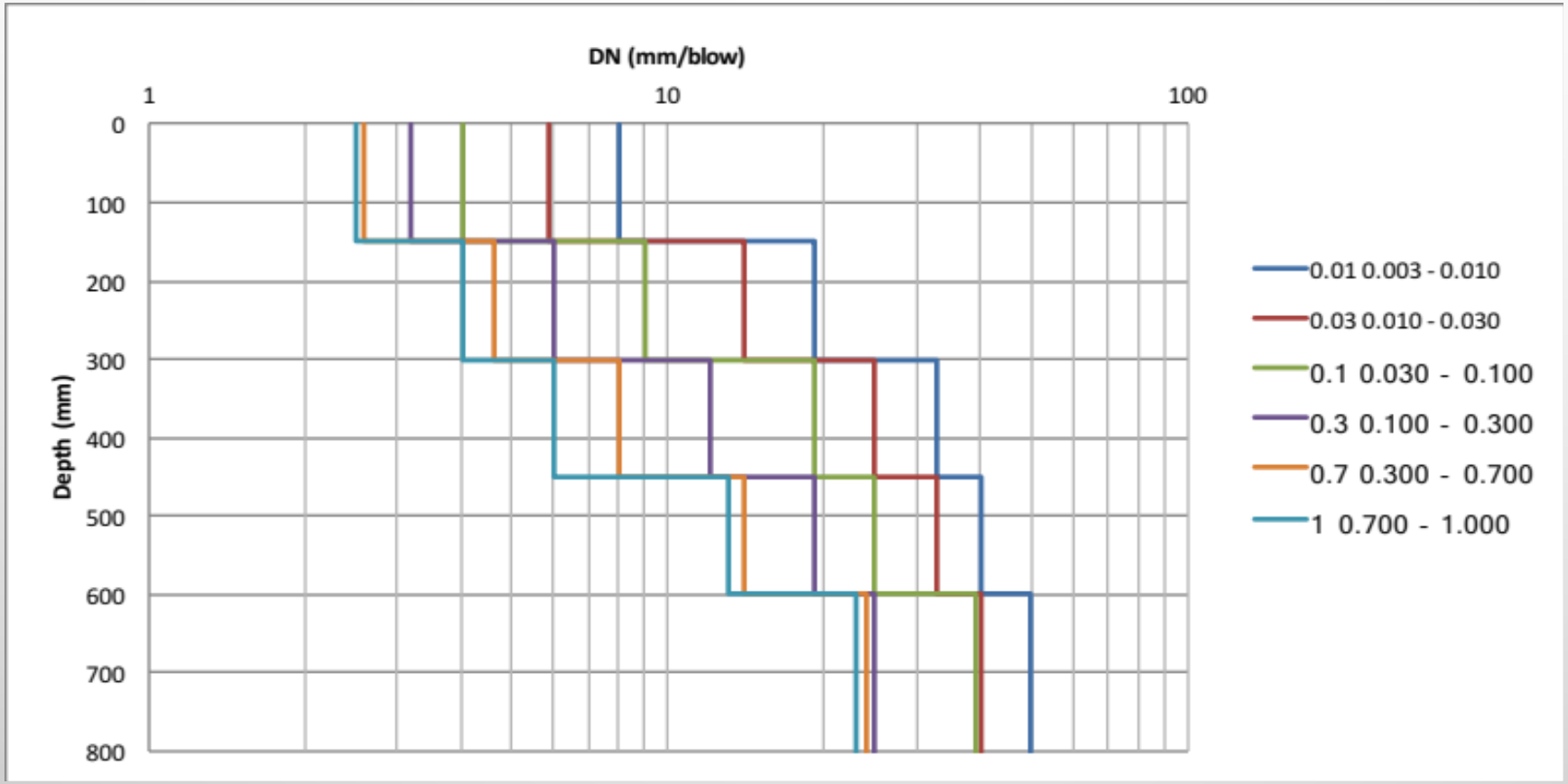
- THE DESIGN PHILOSOPHY FOLLOWS ONGOING RESEARCH AND INVESTIGATIONS COVERING MORE THAN FOUR DECADES IN SOUTHERN AFRICA
- BASED ON ACCEPTED SCIENTIFIC PRINCIPLES AND FULL-SCALE AND ACCELERATED PAVEMENT MONITORING (PAIGE-GREEN AND VAN ZYL 2019).
- THE DESIGN METHOD USES THE DYNAMIC CONE PENETROMETER (DCP) WHICH DIRECTLY MEASURES A PROXY FOR THE IN-SITU SHEAR STRENGTH OF MATERIALS AT THE TEST POINT, TYPICALLY TO A DEPTH OF AT LEAST 800 MM
- THE NUMBER OF DCP BLOWS REQUIRED TO ACHIEVE THIS DEPTH IS KNOWN AS THE DCP STRUCTURAL NUMBER (DSN_{800})
- THE MEASURED STRENGTH IS AT THE IN-SITU MOISTURE AND DENSITY CONDITIONS – MUST BE CONSIDERED IN THE DESIGN PROCESS

BACKGROUND

- DCP TESTING ALLOWS MANY TESTS TO BE CARRIED OUT QUICKLY WITH MINIMAL DISTURBANCE OF THE ACTUAL ROAD SURFACE
- SECTIONS WITH SIMILAR CHARACTERISTICS CAN EASILY BE IDENTIFIED AND THE ROAD UNDER INVESTIGATION CAN BE SUBDIVIDED INTO UNIFORM SECTIONS – ENVIRONMENTALLY OPTIMIZED DESIGN (EOD)
- LAYER STRENGTH DIAGRAMS (LSD) DEVELOPED FOR VARIOUS TRAFFIC CATEGORIES WHICH SHOW A PLOT OF THE REQUIRED DCP STRENGTH OR DN (MM/BLOW) WITH DEPTH FOR DIFFERENT TRAFFIC (STANDARD AXLE) CATEGORIES.
- PROVIDE A WELL-BALANCED DEEP PAVEMENT STRUCTURE AND DEVELOPED ON THE BASIS OF THE DCP STRUCTURAL NUMBER (DSN_{800}).



BACKGROUND



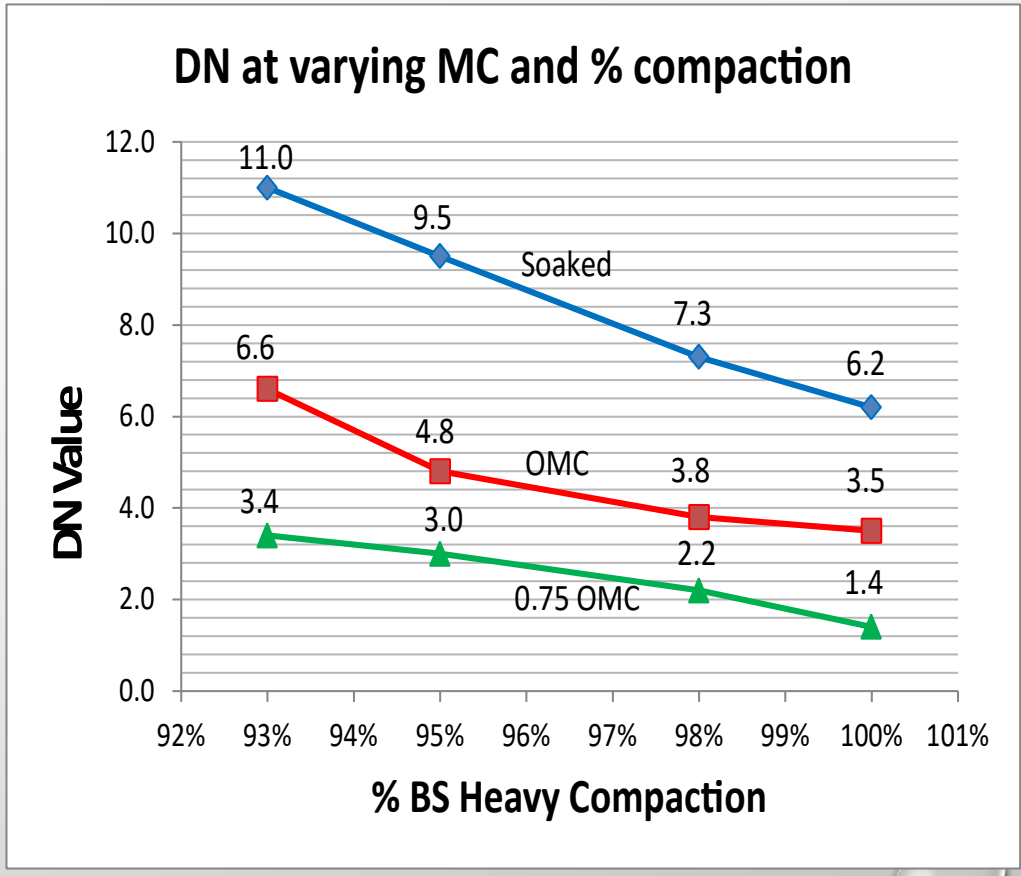
THE TEST IS ALSO USED FOR MATERIAL CHARACTERIZATION IN THE LABORATORY (PINARD, 2022) AS WELL AS FOR CONSTRUCTION QUALITY CONTROL

ALTERNATIVE TECHNOLOGIES

- THE ENTIRE PAVEMENT DESIGN IS BASED ON THE DCP TEST RESULTS
- SOME BASIC TESTING OF THE IN SITU AND POTENTIAL BORROW MATERIALS IS REQUIRED (PINARD ET AL, 2021) TO ENSURE THAT THE MATERIALS IN THE EXISTING ROAD ARE FUNDAMENTALLY SUITABLE FOR USE
- PROBLEM MATERIALS SUCH AS EXPANSIVE OR SOFT CLAYS, DISPERSIVE, SALINE OR COLLAPSIBLE SOILS NEED TO BE IDENTIFIED AND AVOIDED BASED ON THESE PRELIMINARY ROUTINE TESTS.
- THE DCP SURVEY IS THEN CARRIED OUT WITH TESTS BEING CONDUCTED AT REGULAR INTERVALS DEPENDING ON THE VARIABILITY OF THE IN-SITU MATERIAL

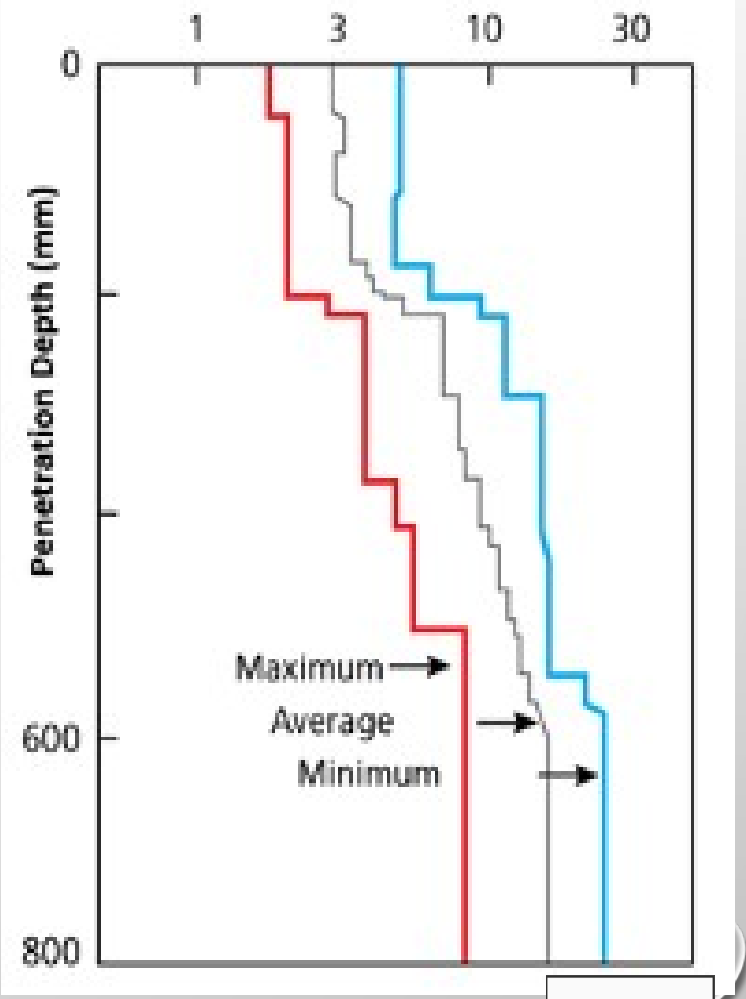
ALTERNATIVE TECHNOLOGIES

- ONCE UNIFORM SECTIONS ARE IDENTIFIED IT IS NECESSARY TO OBTAIN REPRESENTATIVE SAMPLES OF THE MATERIALS AND THE PREVAILING IN SITU MOISTURE CONTENTS
- FOR EACH POTENTIAL PAVEMENT LAYER - LABORATORY TESTING AND ANALYSIS
- TESTING INCLUDES A SERIES OF DCP TESTS IN CONVENTIONALLY COMPACTED CBR MOLDS - VARIOUS MOISTURE AND DENSITY COMBINATIONS.
- ALLOW AN UNDERSTANDING OF THE MOISTURE - DENSITY-STRENGTH RELATIONSHIPS
- IDENTIFIES BOTH THE STRENGTH VARIATION WITH MOISTURE AND DENSITY CHANGES AS WELL AS BEING INDICATIVE OF THE GRADING AND PLASTICITY OF THE MATERIAL



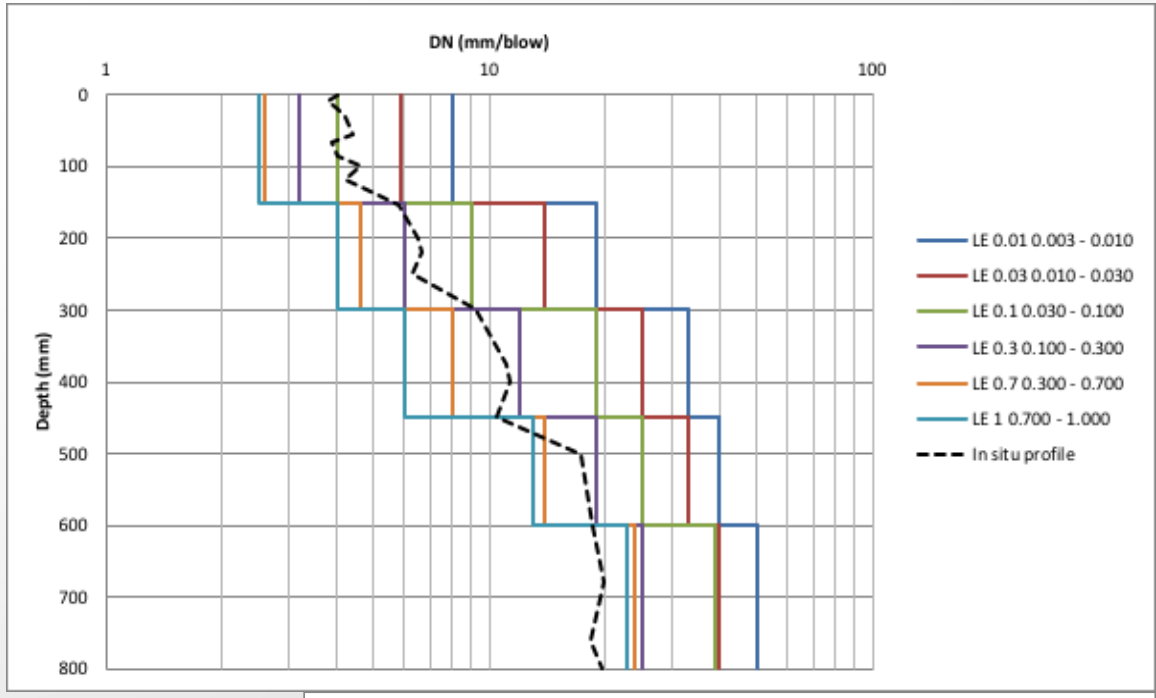
ALTERNATIVE TECHNOLOGIES

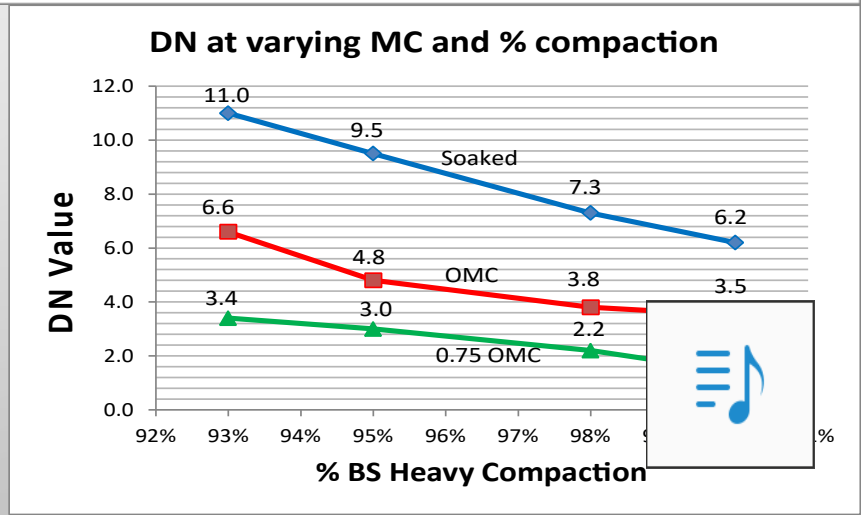
- THE USE OF THE DCP PENETRATION RATE (DN IN MM/BLOW) IS PREFERRED TO THE CONVENTIONAL CBR STRENGTH
- POOR REPEATABILITY AND REPRODUCIBILITY OF THE CBR TEST AND TO AVOID CONVERTING THE DCP PENETRATION RATE TO CBR
- THIS RELATIONSHIP IS STRONGLY MATERIAL DEPENDENT (LIVNEH, 2007) AND THE INACCURACIES DUE TO THIS LACK OF CORRELATION (FOR ANY SPECIFIC MATERIAL) CAN BE AVOIDED
- THE AVERAGE PLOT OF THE DCP PROFILE FOR EACH UNIFORM SECTION WILL TYPICALLY APPEAR AS SHOWN AS THE GRAY TRACE.
- THE MAXIMUM (RED TRACE), MINIMUM (BLUE TRACE) OR ANY SELECTED PERCENTILE CAN ALSO BE DERIVED.



ALTERNATIVE TECHNOLOGIES

- THE DESIGN METHOD INVOLVES COMPARING THE SELECTED DCP PROFILE FOR EACH UNIFORM SECTION WITH THE REQUIRED LAYER STRENGTH DIAGRAM FOR THAT TRAFFIC
- WHERE THE IN SITU DCP PROFILE LIES TO THE RIGHT OF THE SELECTED “DESIGN CURVE”, THE MATERIAL HAS INSUFFICIENT STRENGTH - WHERE IT IS TO THE LEFT OF THE “CURVE’, IT HAS ADEQUATE STRENGTH AT THE IN-SITU MOISTURE CONTENT
- MOISTURE CONTENTS IN THE PAVEMENT STRUCTURE MAY VARY WITH TIME AND THE MATERIAL WOULD WEAKEN IF THE MOISTURE CONTENT INCREASES
- ASSESS IMPACT FROM THE LABORATORY TESTS.
- MUST COMPACT TO REFUSAL



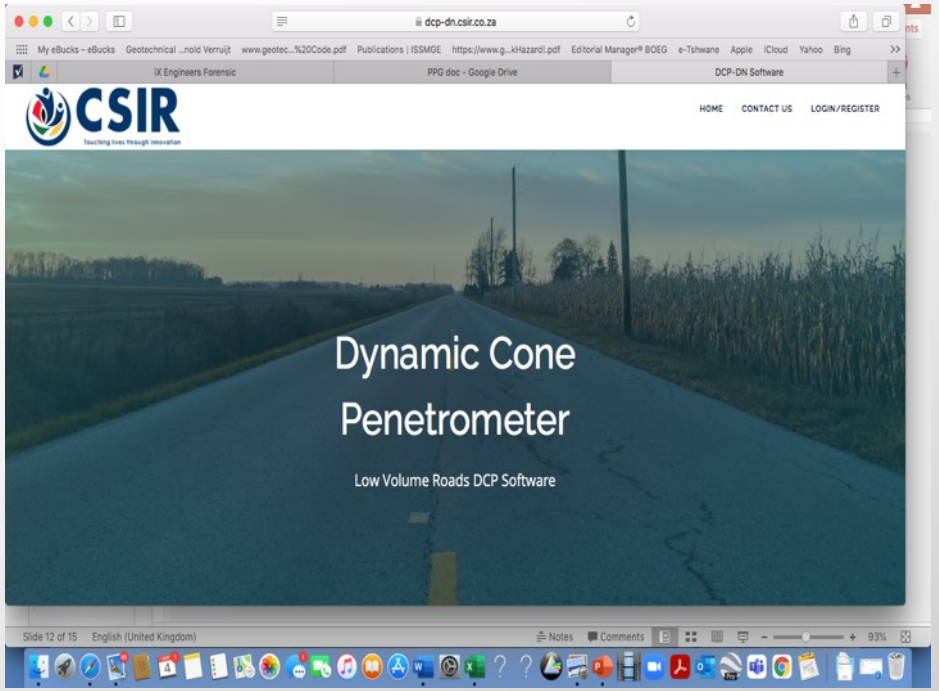


ALTERNATIVE TECHNOLOGIES

- FIELD INVESTIGATIONS HAVE SHOWN THAT THE MOISTURE CONTENT IN PAVEMENT LAYERS SELDOM RISE ABOVE OPTIMUM MOISTURE CONTENT (OMC)
- AN ESSENTIAL PART OF THE DCP DESIGN METHOD IS STABILIZING THE MOISTURE REGIME BY INCORPORATING AN ADEQUATE AND EFFECTIVE DRAINAGE REGIME INCLUDING:
  - HIGHER THAN NORMAL CROSSFALLS ON THE CARRIAGEWAY (PREFERABLY 3 TO 4%) AND SHOULDERS (> 5%)
  - A MINIMUM HEIGHT BETWEEN THE CROWN OF THE ROAD AND THE BOTTOM (INVERT) OF THE SIDE-DRAINS (DEPENDING ON CLIMATE, TERRAIN, DRAIN LINING AND TRAFFIC BUT USUALLY ABOUT 750 MM),
  - EFFECTIVE MOVEMENT OF WATER FROM THE SIDE DRAINS AWAY FROM THE ROAD (GOOD SMOOTH GRADE AND EFFECTIVE MITER DRAINS (OR TURNOUTS)), AND
  - REGULAR AND EFFECTIVE MAINTENANCE OF THE ROAD SURFACING AND DRAINAGE SYSTEMS.

ALTERNATIVE TECHNOLOGIES

- EFFECTIVE AND REGULAR MAINTENANCE IS ALSO ESSENTIAL TO ENSURE CLIMATE RESILIENCE
- THE CAPACITY OF ALL DRAINS MUST BE SUCH THAT THE EXPECTED INCREASE IN EXTREME STORM EVENTS IN FUTURE (HIGHER AND MORE INTENSE RAINFALL DUE TO CLIMATE CHANGE) IS ADEQUATELY CATERED FOR
- ALL OF THE CALCULATIONS AND IDENTIFICATION OF THE PAVEMENT DESIGN AND STRENGTHENING NEEDS CAN BE SIMPLY CALCULATED USING THE AFCAP DCP DESIGN SOFTWARE, FREELY AVAILABLE FOR DOWNLOAD (HTTPS://DCP-DN.CSIR.CO.ZA).



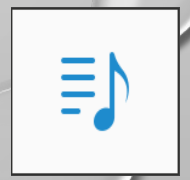
ALTERNATIVE TECHNOLOGIES

- TO OPTIMIZE THE DESIGN AND CONSTRUCTION COSTS, APPROPRIATE COST-EFFECTIVE BITUMINOUS SURFACINGS SHOULD BE EMPLOYED
- MANY OF THE LOW VOLUME ROAD PAVEMENT STRUCTURES MAY BE QUITE FLEXIBLE AND HAVE HIGHER DEFLECTIONS THAN CONVENTIONAL PAVEMENTS
- THE FLEXIBILITY OF THE SURFACING TO ABSORB AND TOLERATE THESE DEFLECTIONS IS AN IMPORTANT CONSIDERATION - SEPARATE PAPER AT THIS CONFERENCE BY GERRIE VAN ZYL

ALTERNATIVE TECHNOLOGIES

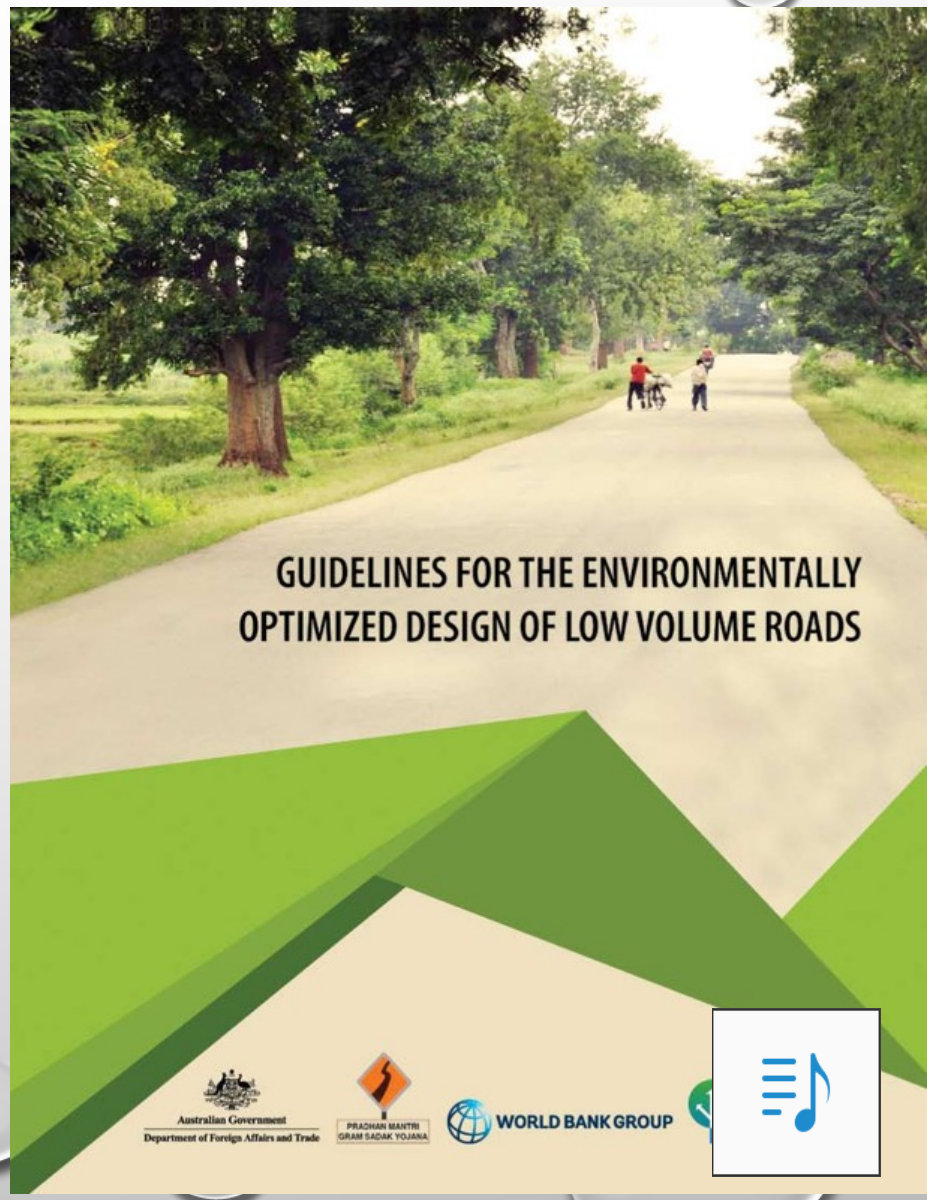
THERE ARE OF COURSE SOME LIMITATIONS TO THIS DESIGN METHOD

- MOST SUITABLE WHERE AN EXISTING UNPAVED ROAD WILL BE UPGRADED TO A PAVED STANDARD FOLLOWING MOSTLY THE EXISTING ALIGNMENT AND GRADE
- IF THE ROAD IS TO BE RE-ALIGNED SIGNIFICANTLY OR RAISED ON A HIGH EMBANKMENT (NECESSARY FOR CLIMATE RESILIENCE ADAPTATION) THE METHOD IS NOT TOTALLY SUITABLE
- SOME ASPECTS OF IT CAN BE USED IN THE DESIGN INCLUDING
  - SUBGRADE EVALUATION
  - STRENGTH ASSESSMENT OF THE PROPOSED MATERIALS
  - CHECKING THEIR COMPLIANCE WITH THE REQUIRED LAYER STRENGTH DIAGRAMS - STILL APPLICABLE AND APPROPRIATE FOR THE UPPER PAVEMENT STRUCTURE.



ALTERNATIVE TECHNOLOGIES

- THE TECHNOLOGY HAS BEEN WIDELY IMPLEMENTED IN SOUTH AFRICA
- RECENTLY ALSO IMPLEMENTED IN MALAWI, GHANA AND INVESTIGATED IN UGANDA AND ZAMBIA
- ALSO CUSTOMISED FOR INDIA AND FULLY DETAILED IN A WORLD BANK DOCUMENT.



ALTERNATIVE MATERIALS

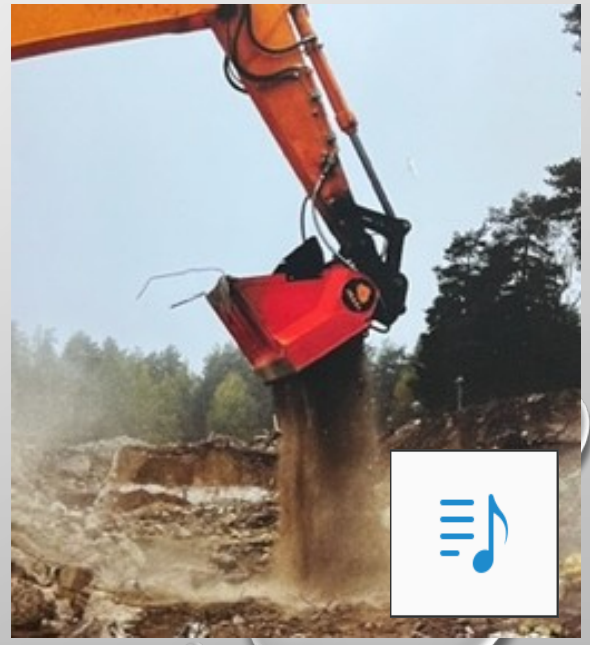
- NOT ALL MATERIALS THAT ARE ECONOMICALLY AVAILABLE ARE SUITABLE FOR THE PAVEMENT LAYERS
- PARTICULARLY THE MORE IMPORTANT STRUCTURAL SUBBASE AND BASE
- THE NEED FOR IMPROVING THESE MATERIALS ARISES
- MATERIAL IMPROVEMENT CAN BE ACHIEVED IN A NUMBER OF WAYS
  - MECHANICAL STABILIZATION
  - CHEMICAL STABILIZATION
- THE DIFFERENCE BETWEEN MODIFICATION AND STABILIZATION IS IMPORTANT
  - MODIFICATION - IMPROVES THE MATERIAL PROPERTIES WITHOUT ANY MARKED CEMENTATION (I.E., THE MATERIAL REMAINS IN A GRANULAR STATE)
  - STABILIZATION - CAUSES CEMENTATION AND THE DEVELOPMENT OF A TENSILE STRENGTH.

ALTERNATIVE MATERIALS

MECHANICAL STABILIZATION

- STANDARD CONSTRUCTION PRACTICE THAT INCLUDES:
  - BLENDING OF DIFFERENT MATERIALS
  - REMOVAL OR BREAK-DOWN OF OVERSIZE MATERIAL
  - DENSIFICATION

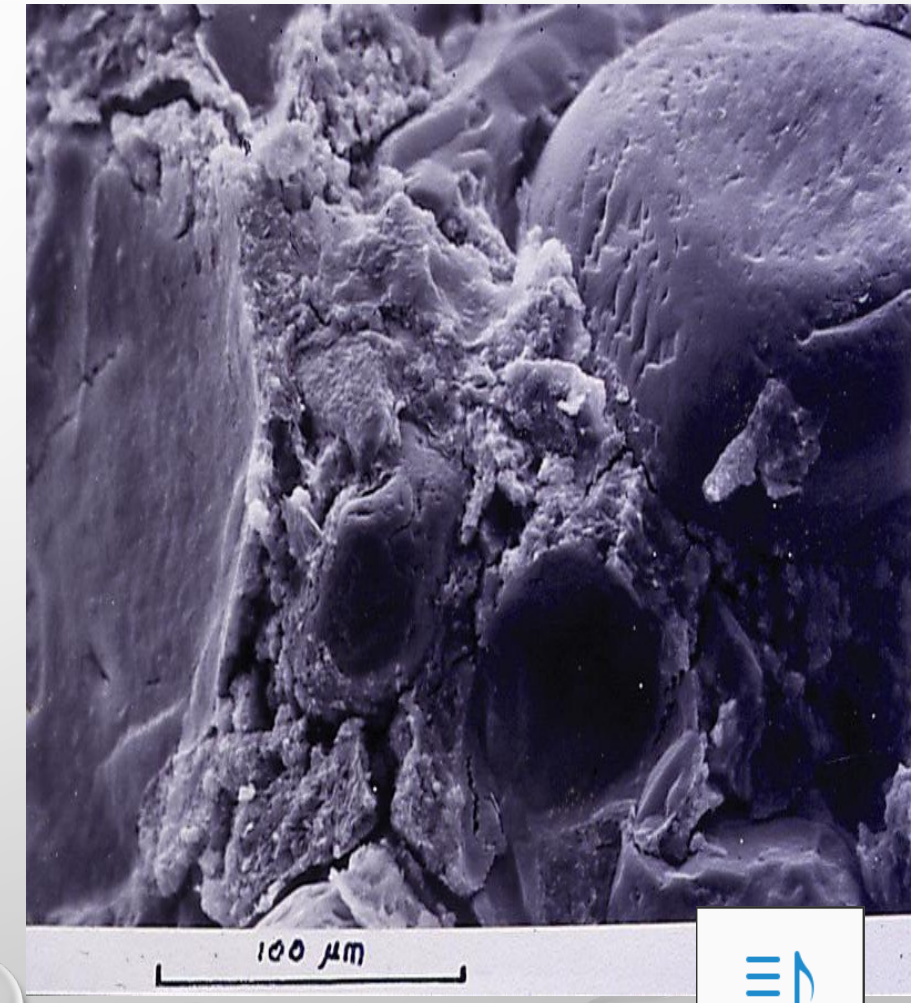
- MODERN EQUIPMENT SUCH AS BUCKET-CRUSHERS AND SCREENERS WHICH ATTACH TO CONVENTIONAL EXCAVATORS ALLOW ON SITE BREAKING DOWN AND SCREENING OF MATERIALS.



ALTERNATIVE MATERIALS

CHEMICAL STABILIZATION

- INVOLVES THE ADDITION OF A PRODUCT TO THE MATERIAL SUCH THAT BONDING BETWEEN INDIVIDUAL PARTICLES WITHIN THE MATERIAL MAY OCCUR.
- COULD BE DIRECT BONDING (SUCH AS WITH BITUMEN) OR THE CREATION OF NEW BONDING PRODUCTS AS IS THE CASE WITH LIME OR CEMENT
- THE USE OF THE BONDING PRODUCTS (CEMENT, LIME, BITUMEN) IS WELL ESTABLISHED AND NOT COVERED IN THIS PRESENTATION BUT IS DISCUSSED ELSEWHERE AT THIS CONFERENCE.



ALTERNATIVE MATERIALS

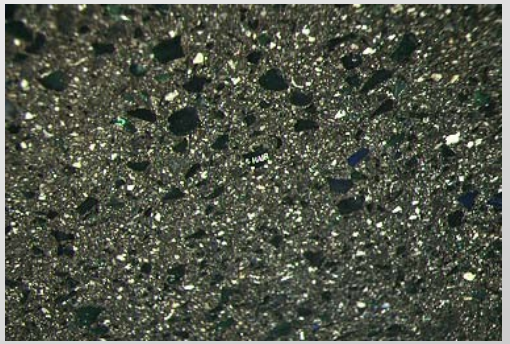
CHEMICAL STABILIZATION

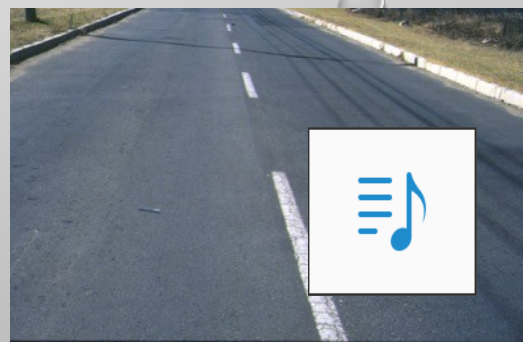
- THERE ARE NUMEROUS MODERN *PROPRIETARY* SOIL IMPROVERS ON THE MARKET
- EACH OF THESE HAS A PARTICULAR MECHANISM OF "REACTION" AND NEEDS TO BE TESTED ON THE PROPOSED MATERIAL TO BE TREATED TO ENSURE THAT THE REQUIRED MATERIAL PROPERTIES ARE ACHIEVED (USUALLY AN END-PRODUCT SPECIFICATION" IN TERMS OF STRENGTH OR STIFFNESS.
- THERE ARE ALSO NUMEROUS MATERIALS/CHEMICALS THAT ARE COMBINED WITH CEMENT, LIME OR BITUMEN THAT ARE BEING INCREASINGLY USED FOR SOIL IMPROVEMENT. THESE INCLUDE NANO-POLYMERS IN BITUMEN, WHICH IN PARTICULAR ARE SHOWING SIGNIFICANT SUCCESS

ALTERNATIVE MATERIALS

USE OF BY-PRODUCT MATERIALS

- MOST COUNTRIES ARE LITTERED WITH THE RESIDUES FROM MINING, INDUSTRIAL, MANUFACTURING OR CONSTRUCTION PROCESSES
- THESE ARE ALL POTENTIALLY USEFUL CONSTRUCTION MATERIALS AND INCLUDE (BANDYOPADHYAY, 2018):
  - CRUSHED CONCRETE AND CONSTRUCTION AND DEMOLITION WASTE
  - ALUMINUM INDUSTRY WASTES
  - TIRES
  - FOUNDRY SAND
  - CEMENT KILN DUST
  - GLASS
  - PULVERIZED FUEL ASH (PFA OR FLY ASH)
  - BLAST-FURNACE AND STEEL SLAGS
  - OTHER METALLURGICAL SLAGS
  - MINE AND STONE PROCESSING WASTE
  - SPENT OIL SHALE
  - RECLAIMED BITUMINOUS MATERIAL (RA)
  - PHOSPHOGYPSUM
  - USED RAIL BALLAST





ALTERNATIVE MATERIALS

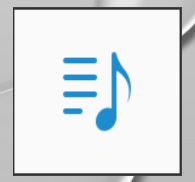
- SIGNIFICANT RESEARCH HAS BEEN CARRIED OUT ON MANY OF THESE MATERIALS SUCH AS BLAST FURNACE SLAG AND CONSTRUCTION AND DEMOLITION WASTE
- THERE ARE STILL MANY OF THESE PRODUCTS THAT REQUIRE ADDITIONAL RESEARCH
- THE GENERAL BEHAVIOR OF A LOT OF THE MATERIALS IS SIMILAR TO CONVENTIONAL AGGREGATES
- HOWEVER CERTAIN MATERIALS MAY HAVE SPECIFIC PROBLEMS (E.G., UN-HYDRATED MAGNESIUM OXIDES IN BLAST-FURNACE SLAGS AND SOLUBLE SALTS IN MINE WASTES)
- BANDYOPADHYAY (2018) IDENTIFIES POSSIBLE USES AND SOME OF THE POTENTIAL PROBLEMS AND SPECIAL REQUIREMENTS OF EACH MATERIAL
- RESEARCH INTO OTHER MATERIALS ABOUT WHICH LITTLE EXPERIENCE HAS BEEN OBTAINED IS RECOMMENDED.

ALTERNATIVE MATERIALS

- HOWEVER, THE USE OF SUCH BY-PRODUCT MATERIALS COMES WITH MANY ADVANTAGES, INCLUDING:
  - LESS ENVIRONMENTAL DEGRADATION
  - RELEASE OF LAND USED FOR STORAGE OF THESE MATERIALS
  - REDUCED PROCESSING COSTS
  - REDUCED HAULAGE COSTS, AND
  - CONSERVATION OF EXISTING NON-RENEWABLE MATERIAL RESOURCES THAT ARE BECOMING MORE COSTLY AND DIFFICULT TO OBTAIN.

CONCLUSIONS

- TO REDUCE THE BACKLOG OF UNPAVED ROADS REQUIRING UPGRADING, INNOVATIONS AND NEW TECHNOLOGIES ARE ESSENTIAL
- WE HAVE DISCUSSED A SIMPLE DESIGN METHOD FOR LOW VOLUME ROADS BASED ON THE USE OF A DYNAMIC CONE PENETROMETER (DCP)
- A SIMPLE COMPARISON OF THE IN-SITU SOIL PROFILE WITH THE STRUCTURE REQUIRED TO CARRY THE DESIGN TRAFFIC ALLOWS SPECIFIC PAVEMENT DESIGNS FOR EACH UNIFORM SECTION ALONG THE ROAD
- THE USE OF THIS PROCEDURE TOGETHER WITH INNOVATIVE SOIL IMPROVEMENT TECHNIQUES AND THE USE OF LOCAL AND/OR AVAILABLE BY-PRODUCT MATERIALS CAN RESULT IN HIGHLY COST-EFFECTIVE AND SUSTAINABLE ROAD PROVISION
- CLIMATE RESILIENCE AND ENVIRONMENTAL ISSUES ARE ALSO BRIEFLY INTRODUCED.



SOME REFERENCES

BANDYOPADHYAY A (2018) ‘MAINSTREAMING THE USE OF GREEN CONSTRUCTION MATERIALS IN RURAL ROADS IN INDIA’. HTTPS://WWW.GTKP.COM/ASSETS/UPLOADS/20180203-075643-7798-613.PDF

PAIGE-GREEN P AND VAN ZYL GJ (2019) ‘A REVIEW OF THE DCP-DN PAVEMENT DESIGN METHOD FOR LOW VOLUME SEALED ROADS: DEVELOPMENT AND APPLICATIONS’. JOURNAL OF TRANSPORTATION TECHNOLOGIES, 9, 397-422. DOI: 10.4236/JTTS.2019.94025

PINARD MI AND HONGVE J (2020) ‘PAVEMENT DESIGN OF LOW VOLUME ROADS USING THE DCP-DN METHOD’. LONDON: RECAP FOR UK AID.

HTTPS://ASSETS.PUBLISHING.SERVICE.GOV.UK/MEDIA/5FCBDC80D3BF7F5D02B218F6/PINARDHONGVE-INFRAAFRICA-2020-PAVEMENTDESIGNLVRUSINGDCPDNMETHOD-MANUAL-RECAP-GEN2189A-201004-COMPRESSED.PDF

PINARD MI, PAIGE-GREEN P, HONGVE J AND MUKANDILA E (2021) ‘A PROPOSED FRAMEWORK FOR OPTIMISED UTILISATION OF MATERIALS FOR LOW VOLUME ROADS USING THE DYNAMIC CONE PENETROMETER.’ JOURNAL OF TRANSPORTATION TECHNOLOGIES, 11, 14-36. DOI: 10.4236/JTTS.2021.111002


THANK YOU
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