REDIRECTION OF THE EXPANDED PUBLIC WORKS PROGRAMME TO FACILITATE MOBILITY, SAFETY AND JOB CREATION IN COMMUNITIES

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ABSTRACT

One of the main objectives of the expanded national public works programme is to create jobs in order to address poverty alleviation. It is a well known fact that road works provide good opportunity for labour-intensive activities. However rather large and ambitious road projects are often selected with resulting high technical and specification barriers. In an effort to "spread the sunshine" projects are often unbundled to the point where the project management cost start to increase exponentially and the result is that less money reach the poor and affected communities. A philosophical approach is sketched where community facilities, schools, community centers, clinics, etc. are used as the focal point for the provision of such appropriate facilities for labour-intensive work like cycle-and footways. In this way road safety, accessibility and need for job creation can be "triangulated" to provide low cost facilities for cyclists and pedestrians alike. Community based construction friendly designs and technologies are provided in catalogue format. Various person and small medium and micro enterprise (SMME) friendly construction techniques, which make maximum use of local materials and low skills level and people friendly technologies, have been developed for road construction and are well published. These technologies are further unpacked for lower entry barriers and made more applicable for community based construction of foot- and cycle-ways. The end result is low cost appropriate technology applications for the improvement of accessibility and mobility needs of previously disadvantaged rural communities and creating sustainable jobs in the process.

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1. INTRODUCTION

Rural areas in South Africa suffer the most from lack of infrastructure and basic services (Muradzikwa, 2004) It is estimated that 52% of all South Africans live in rural areas, mainly in the Eastern. Cape, Kwa-Zulu Natal and Limpopo provinces. People living in rural locations also experiencing significant constraints on their ability to earn a living. These constraints include:

- Limited access to health and education facilities.
- Constraints on travel.
- Food scarcity in times of drought or crop failure.
- Limited access to fresh produce markets.
- Limited access to regional export infrastructure.
- The high costs of transport and vehicle maintenance.

Lack of mobility and accessibility are some of the main symptoms associated with the living conditions of the previously disadvantaged and the poor living in the rural areas of South Africa. The SABITA Infrastructure Development Assessment Project have shown that roads derive much of their value from their contributions to the value of other assets, such as schools, hospitals and business concentrations, which they make possible (Muradzikwa, 2004).

The Expanded Public Works Program (EPWP) was developed with the following objectives in mind (McCord, 2004):

- Aimed at alleviating and reducing unemployment
- Making use of labour-intensive construction methods which "*involve the use of an appropriate mix of labour and machines, with a preference for labour where technically and economically feasible, without compromising the quality of the produc*t"
- "*all public bodies involved in infrastructure provision are expected to attempt to contribute to the programme*"

McCord (2004) did a study on the impact of the public works programme in two rural communities and found that:

- Short term employment does not permit accumulation of capital in a community and to move out of poverty.
- The amount of money transfer does not permit accumulation of surplus for investment in income earning activity.
- The effective targeting and duration of employment are key factors in determining impact.
- There was a positive impact on human capital (e.g. education) discernable.
- Training, skills transfer and experience gained were not sufficient to impact on labour market performance.

Coupled to the research done by McCord (2004) the EPWP also run into the following problems:

- The design and project management cost and input required for current selected EPWP projects tend to be under-estimated. The lower the skill level of a community and the larger the gap associated with the applied or needed technologies, the higher the project management input requirement goes.

- There is a general notion to break the projects into smaller projects in an effort to improve community access and qualification for work. The truth is that there is an indirect relationship between the size of the project and the project management input required.
- Projects still tend to be merely conversions from machine intensive designs. The result is that the appropriateness of the selected technologies still tends to be limited in gearing up the labour content.

These observations are currently based more on anecdotal evidence than objective concrete research results as it is very difficult even with forensic type audits to get to real concrete information. However recent studies in this regard tend to confirm this notion. In a recent study on the effectiveness and impact of targeting Black Economic Empowerment (BEE) construction firms in the gravel up-grading project of the Johannesburg Roads Agency (JRA) van der Schyff (2006) found that there were a number of short comings in achieving these objectives. In Figure 1 below the rating of contracts over a three year period is shown. In each case the rating of all the contractors are shown as well as the portion making up the BEE contractors. It clearly shows that most of the average, poor and very poor rated contractors were made up virtually entirely of the BEE contractors. What is even more disconcerting is that the majority of the good and very good BEE contractors were found to be fronting for established contractors. These findings were made before the new rating system of contractors of the Construction Industry Development Board (CIDB) were established but strongly confirm the rationale of the rating system.

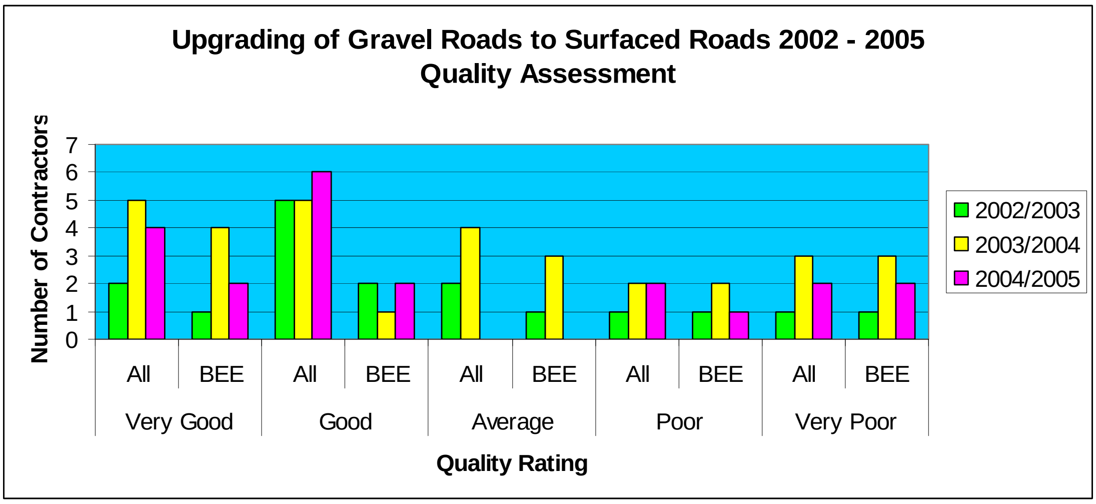

Figure 1. Quality evaluation of contractors on the gravel up-grading contracts in Johannesburg (Source: van der Schyff, 2006)

The end result of these problems means less money and even skills development end up in the community. The duration of the project is short which further adds to sustainability concerns. What is advocated here is to address mobility needs on a more affordable level by concentrating on pedestrian and cycle-ways as EPWP projects. There is evidence from Kenya showing that increased pedestrian and cycling traffic, and other non motorized traffic can be coupled with an increase in informal retail activities in rural areas (Muradzikwa, 2004).

Muradzikwa, (2004 states that one important component for rural road infrastructure development is community involvement in project prioritization that generates some form of ‘ownership’ of projects. However there are huge rural road infrastructure backlogs and insufficient maintenance and construction budgets. Prioritisation of transport related infrastructure should ensure that the facilities which add the greatest capital-deepening value *(roads that will yield the greatest potential or opportunity for further income-generating capital projects)*, should be selected and financed ahead of other projects in a particular region. In this case the provision of cycle-and footway provision should therefore be promoted in rural communities as a priority as it would achieve the greater gearing up desired.

Another incentive for this shift to cycle and footway construction is traffic safety improvement. Pedestrian fatalities on rural roads are a disturbingly high portion of the generally horrific road fatality figures of SA Ribbens and Raborifi (2002) reported that pedestrians represented 38 per cent of all road fatalities. One of the reasons identified is the fact that rural pedestrians tend to use the paved roads as walkways. Where limited or no shoulders are present there is obvious conflict. In line with the stated objectives of the EPWP it is suggested that separate walkway and cycle-ways be provided for rural pedestrians and cyclists to lower the conflict with fast moving vehicles. Access to community centers, schools and clinics by means of such separate footways and cycle-ways are also directly in line with the EPWP objectives. Where there are no constructed roads yet such cycle and footway construction should have priority. In this regard Ribbens and Raborifi (2002) reported that a Pedestrian Facility Guideline Manual as well as the Bicycle Design Manual for Urban Areas have been revised , updated and combined into one user friendly manual.

Considerable work has been done in SA to promote cycle transport (Kie Song et al, 2000). Such design standards already exists and will not be reported here. As the focus of this paper is on the use of appropriate local material friendly construction and control procedures. However, the designs, required standards and technologies are better aligned with the skills level and abilities of community based contractors.

Cycle and footway construction also offer opportunity for a different design paradigm as well as a different design domain normally associated with road design and construction. It offers significant opportunities in utilization of local material, appropriate construction technologies linked to low entry barriers using low skill levels is small plant intensive and therefore also have more sustainability potential.

2. SYNTHESIS OF APPROPRIATE ROAD BUILDING TECHNOLOGIES

2.1. APPROPRIATE TECHNOLOGY AND COMMUNITY EMPOWERMENT

A short discussion is given here regarding the empowerment potential of appropriate technology as normally applicable to road construction and the extrapolation thereof for cycle- and footway construction. The use of direct labour in labour intensive construction can be seen as the entry point en route to community and previously disadvantaged individual (PDI) empowerment. Labour-intensive work must be coupled with access to material, plant and equipment and appropriate construction technologies in order to facilitate empowerment and basic skill development.

The key to such empowerment and skill development lies in the use of small plant and appropriate technology as stepping stones (Horak et al, 1996). In analysing known labour-intensive construction techniques and simulating the old construction technologies for road construction small plant like a plate vibrator, wheel barrows, rakes, forks and spades could be used very effectively to produce quality end products and empower budding entrepreneurs.(Potgieter and Pieters, 1995; Horak et al, 1996). In the case of footway and cycle-way design and construction the use of small plant and labour enhancement become even more relevant for appropriately lower standards than needed for even the lowest traffic volume roads. (Horak et al, 2003)

It has been proven that aspects of road construction, specifically selected person friendly construction technologies, can be done labour intensively with quality end-results. Road construction lends itself more ideally to increasing the labour content than most other infrastructure construction (NEF, 1994;McCutcheon, 1994 and Horak et al, 1995). As example Table 1 summarises the potential employment contribution of the various activities on road building projects. Using this information as a guide the labour potential for foot and cycle-way construction is also shown. This is estimated to be higher than the other activities normally associated with road construction.

Table 1. Summary of Employment Potential (adapted from DoPW, 1999)

Project type	**% Potential contribution**		
	Labour	**Plant**	**Material**
New Paved Road*	40	32	28
Rehabilitation*	29	26	45
Gravel Road*	49	35	16
Drainage (Culverts)	54	24	22
Bridges	22	8	70
Urban Street	36	27	37
Footways& Cycle-ways (*Estimated)*	***65***	***20***	***15***
* Earthworks and pavements only			

2. PARADIGM SHIFT IN DESIGN

2.1. DESIGN DOMAIN

In the design of low volume road and streets the design domain differs considerably from normal street and road designs. The “design domain” concept for low volume roads implies that the use of appropriate technologies range between practical upper and lower limits. Very low traffic volume street construction standards tend to congregate around the lower limits of guidelines (Horak et al, 2004). The values within this lower region of the design domain for roads are generally higher risk, probably less safe and less operationally efficient, but they are normally less costly than those in the upper region.

It is suggested that standards for footway and cycle-way design and construction can be explored to the lower side of the typical lower practical limits for very low traffic volume roads due to the fact that the traffic loading is substantially lower.

In the case of roads and streets structural design should cater for the environment and wheel loads expressed as equivalent standard axles (ESAs) as primary design factors. In Figure 2 the influence or impact of these two main design considerations are shown with variance in traffic volumes. It is clear that for very low traffic volume situations (e.g. basic access streets) the influence and contribution of traffic to design standards are very low. (Horak et al, 2004). The environment on the other hand totally dominates the design considerations in this domain.

Cycle- and footways would require much lower traffic loading than even the very low traffic road situations and therefore the designs are dominated by considerations for environmental aspects. This implies a paradigm shift in the designs which is not currently well addressed in road design philosophies or guidelines. It implies better use of in situ materials and less costly layer work. As stated in the introduction such cycle and footway provision and placement is separated from the roadway. Therefore there should be no possible dual usage. Sidewalks in urban areas often serve as parking areas for delivery vehicles leading to substantial damage (Horak, 1993). It is advocated that road drainage channels and shallow swales in rural communities be placed between the road and the cycle and footway to ensure such accidental use by heavy vehicles will be prevented.

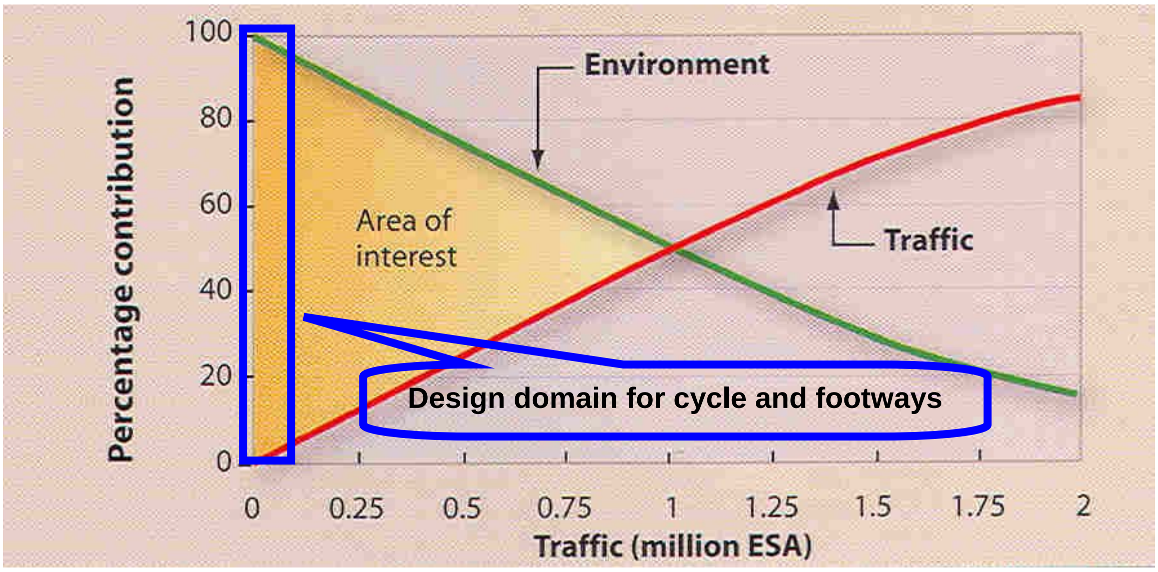

Figure 2. Design influence of traffic and environment (Adapted from DADC, 2002)

2.2. BEARING CAPACITY DETERMINATION

In order to maximise the labour content for cycle-and footway construction the use of local or in situ material should be maximised. Simple yet reliable methods to classify in situ materials should be used. Road building materials are normally classified in terms of their bearing capacity. Subgrade or the in situ material is therefore normally classified by means of a California Bearing Ratio (CBR) value. Based on this classification additional layers are normally added to ensure that there is adequate structural strength in the road layered system which can bear or carry the traffic under all conditions.

The traffic loading requirements for cycle- and footways have been shown to be much lower than that of even a very low traffic volume road. For that reason maximum use can be made of the in situ subgrade material with little or no additional material being required for structural strengthening. Even though much less structural strength is required, the in situ material must still be classified to ensure adequate structural strength will be provided and to provide uniform strength and support. Normally the CBR is determined in a laboratory and density of the material is used as a simple method to infer the constructed bearing capacity. What is advocated is using simple field testing apparatus which can accurately determine the in situ CBR. These equipment and associated technologies are briefly discussed in the next section.

2.2.1. DYNAMIC CONE PENETROMETER (DCP)

The Dynamic Cone Penetrometer (DCP) (Kleyn, 1982) is an ideal instrument to be used extensively in measuring CBR values of the subgrade and whole pavement structure at field moisture conditions. A cone tipped steel shaft is driven into the soil by repeatedly dropping a known anvil weight through a constant drop height. The penetration rate is correlated with laboratory determined CBR values and other performance related engineering properties of road building materials and pavement systems (de Beer, 1991). The operation of the DCP is labour intensive and robust. Normally densities are measured of compacted layers as a way to determine bearing capacity in an indirect way. The DCP is an ideal instrument to be used in lieu of the traditional measurement of densities and can classify material qualities very accurately in situ. (Sampson, 1984 and de Beer, 1991)

2.2.2. RAPID COMPACTION CONTROL DEVICE (RCCD)

The Rapid Compaction Control Device (RCCD) was developed as a relatively simple penetrometer device which can be operated by a semi-skilled operator. The RCCD is a scaled down DCP device which ejects a cone tipped steel rod into the constructed layer via a spring loaded mechanism. The resistance to penetration is correlated with actual material qualities. This includes laboratory determined CBR values and DCP correlations (De Beer et al, 1993 and Horak, 1994). The RCCD is ideal for layer construction control as the penetration is limited to the constructed layer only.

The RCCD was originally developed for use by unskilled labourers on trench re-instatements in roads and subsequently adapted for semi-illiterate workers by adding a colour coded material standard template (Horak, 1994). It has been used on major road contracts as a screening device for detailed quality control with follow-up investigations with the DCP and density measurements (Horak et al, 2004). Therefore the RCCD can be used with confidence for compaction and bearing capacity control on cycle-and footway construction by low skilled community members.

2.2.3. INFLUENCE OF MOISTURE

Bearing capacity of a street or road foundation is strongly influenced by the presence of moisture. Soaked CBR values are traditionally being used as the CBR values of gravels and soils. The CBR values normally show a significant lowering when soaked. However, there is strong recognition (Emery, 1987) that large regions of SA are classified as dry and arid.

There has long been an approach advocated to use CBR values closer to the in situ or field moisture conditions when evaluating CBR of a subgrade instead of the conservative soaked CBR values (Emery, 1987 and 1992). Remember cycle-and footways have considerably lower vehicle loading conditions. Therefore greater leniency can be exercised in determining bearing capacity in terms of CBR at field moisture conditions for such cycle-and footway design and construction without significant risks involved. This leniency is therefore even more appropriate for foot- and cycle-way design and construction. In Table 2 this relationship between soaked CBR and field CBR values (DCP determined) are shown (Emery,1992) as adapted for application to footway and cycle-way designs.

Table 2: Subgrade material classification based on DCP determined CBR

TRH 14 Material Classification	Soaked CBR (Minimum) Roads situation	Approximate Field DCP determined CBR values
		Subgrades of cycle-and footways
G4	80	Significantly strong enough for application
G5	45	
G6	25	65
G7	15	50
G8	10	43
G9	7	37
G10	3	24

What this table implies is that even a low quality road material will have more than adequate bearing capacity for a cycle- and footway and can be used as long as the moisture condition in the pavement is kept low or prevented form being soaked.

2.3. PAVEMENT STRUCTURE

The pavement structure for cycle-and footways should make maximum use of the in situ bearing capacity with the minimum of structural layers. All subgrade layers need to be levelled and compacted to form a work platform. Horizontal alignment aspects need to be addressed during this preparation phase and will not be addressed here. This may involve cutting and filling to be done to provide low vertical gradients which are person and cycle operation friendly. Close to community centres, clinics and schools the cycle-and footway should be constructed 3m wide for dual direction accommodation and increased traffic, but beyond 200m from it the width can be reduced to 1.5m as a shared direction use. An analogy can be found in the success of the old strip roads and single carriageways constructed in some SADC countries in the past. The narrower width will also ensure vehicular traffic will not be tempted to use such facilities and leading to early destruction.

Drainage provision is of paramount importance. For that reason lessons learnt from the Roman engineers still apply. The footway should as far as possible be lifted above the surrounding environment and the cross fall should be slightly crowned or falling to one side consistently to ensure water is not trapped or retained on the pavement structure or bogged next to it. Occasionally lowering to ensure water passage with the normal topography is advised. No subsurface drainage facilities is necessary, but in can be provided in some selected cases where it interacts with other infrastructure such as paved roads next to it. Large natural rocks can be used as kerb stones and confinement of the elevated footways as done traditionally with road construction and done by the Roman road builders.

If the in situ or shaped subgrade has a DCP determined CBR of 45 and above no additional structural layer is required. If the in situ determined CBR is below 45 a base layer of 75mm will be needed. A discussion on the various proposed labour-friendly technologies for base and surfacing layers will follow. The selection of such technologies will depend on local material conditions and types available. If the selected base layer technology does not include a waterproof surface, the latter must be provided in all cases in order to prevent water intrusion. The basic pavement structures for the two subgrade situations are shown in Figure 3 to follow.

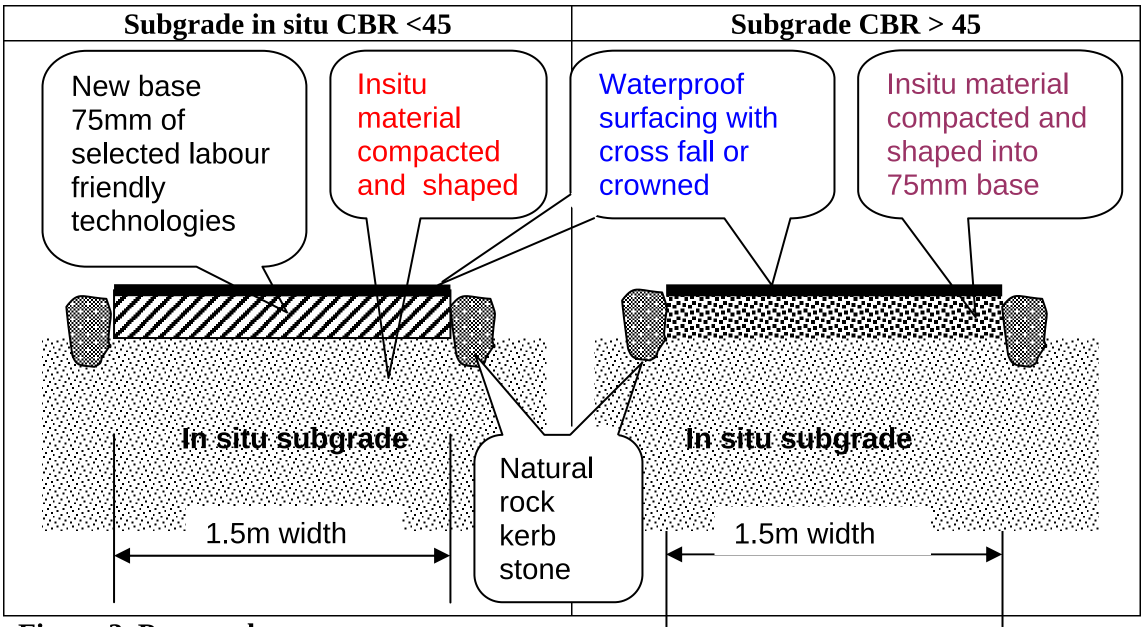

Figure 3. Proposed pavement structures

3. BASIC METHODS TO IMPROVE IN SITU MATERIALS

3.1. COMPACTION

Compaction is normally the first method to improve material bearing capacity. Proper densification normally requires considerable energy input. Therefore in the case of road construction compaction it is the one area where labour intensive construction with light pedestrian rollers cannot provide the desired density. Proper heavy rollers should always be used for road construction. (McCutcheon, 1994).

However, in the case of cycle- and footway construction the bearing capacity requirements are significantly lower and therefore such pedestrian rollers and people friendly compaction equipment (e.g. even heavy hand tampers or hand towed rollers) can be used very effectively and monitored in terms of CBR by using the DCP or the RCCD as described before.

3.2. COMPACTION AID: LUBRICATION

Marginal materials for road construction can benefit from the use of lubrication agents during the compaction process. Lately a lot of non-traditional road material additives are available on the market. There is proof that some of these materials can be used effectively as a compaction aid. As example sulphonated petroleum products (SPP) have a proven lubrication effect during compaction of marginal materials without destroying the marginal crushing strength of the granular structure of the material (Roux, 1991; Bennet et al, 2002 and Bennett and Paige-Green, 1993). It has also been shown that such lubricated assisted compaction of marginal materials improve the bearing capacity. Old “padmakers” (road construction experts) will also testify that a little bit of Teepol, a soap, in compaction water also enhances lubrication of the material particles and greatly reduces compactive effort required.

4. PERSON AND MATERIAL FRIENDLY CONSTRUCTION TECHNIQUES

A number of person friendly labour-intensive construction techniques have been identified which would be applicable to cycle- and footway construction. The focus is on the use of natural or even in situ material, but the end product will still deliver quality and durable cycle- and footways. There are a number of additional construction techniques which may be appropriate and be person friendly, but which involves big plant and equipment in the preparation (Horak et al, 1996 and 2004). These additional potentially person friendly technologies have been excluded here in order to enhance the labour content, lower the entry barriers and skills required and also increase the money retained in communities. A brief description is given on each appropriate technique with reference to some historic developments to illustrate the philosophy behind the person friendliness and to describe essential construction aspects.

4.1. NATURAL LARGE ROCK CONSTRUCTION

Large sized rock, the size that one man can handle with relative ease, has been used with great success to construct road layers through the centuries. Thomas Telford (1757 - 1834), a Scottish road engineer pioneer, improved on the construction technique which Pierre-Marie Tresaguet (1757 - 1796), a great French engineer, adapted from the original Roman road construction. Telford construction is most probably the best known in SA as such constructed bases are still found in roads in the older cities in South Africa (*Horak, 1983*). Telford used dump rock, about 100mm by 125mm by 175 mm, to pack on a prepared level subbase or subgrade by hand. Smaller stones (keying stones) were placed in the openings between these hand placed dump rocks and rammed in with hammers. Protruding sharp edges were broken off by hammer in levelling the surface. (*Horak et al, 1996).*

Telford construction, using dump rock, has been used in a labour enhanced manner with success in road construction in the Doornkop and Lusaka township area of Greater Johannesburg, Krugersdorp and Kwa Thema near Springs in 1995 to 1997 and subsequently elsewhere. Even though manually taxing, Telford construction proved that strong quality road subgrades and subbases can be constructed with the minimum of initial skill required. Admittedly such a road base normally provides an uneven surface and may therefore need an additional surfacing layer to provide a smoother ride.

Telford construction can be used with success in rocky environments where such larger single sized rocks can be “harvested” by the communities. This local material sourcing is used in countries like Zimbabwe where communities are paid for stockpiles of such large single sized rocks delivered by community members at the construction site. This same size rock is often also useful in constructing gabions for retention walls and stormwater erosion protection. This is also very labour intensive and essential features for road as well as cycle and footway protection as the discussion on the design domain eluded to. The performance of cycle- and footway construction is mostly dependant on protection against the environment (e.g. stormwater erosion). The crossing of wetlands and streams can also be facilitated by using such reno mattresses (typically 6x2m)

4.1.1. SINGLE SIZED NATURAL STONE MACADAM LAYERS

It is well known that single sized large crushed stone (aggregate) type base construction has a track record of high quality bases with good performance records in SA (Burrow, 1975). The construction technique is derived from John Louden Macadam, a Scottish road building pioneer which replaced the large stones of Telford with smaller single sized stone (about 63 to 53mm), very much like the present day railway ballast (Horak, 1983). The construction process has historically been labour-intensive and has been at the forefront of labour-intensive construction techniques for public works programmes since the early 1990s (Phillips et al, 1991 and Hefer, 1997). A brief history of the evolutionary development of various types of Macadam construction techniques are given to explain the rationale for the optimisation of natural material in this quality layer construction applicable to cycle-and footway construction.

Macadam bases get their structural strength from the large single size aggregates which interlock, ensuring a high internal angle of friction. The large aggregates were traditionally hand-laid with ballast forks on a prepared subbase or directly on a subgrade. After initial levelling and orientation of the large aggregate layer, it is compacted or smoothed, prior to the voids being filled with fines via a separate actions afterwards.

Fines or soil with a prescribed grading (CSRA, 1985) are spread on this layer to flow into the voids to provide stability for the large aggregate matrix. Modern specifications for road construction require that the fines should be a crusher dust meeting grading specification with low plasticity. However, traditionally the fines had high plasticity indices (Horak, 1983). A clay soil, for instance, was used in the technology transfer project on the Xavier Street project in Johannesburg (Calitz et al, 1995) from the same source that was used in Johannesburg in the 1940s. Other macadam street constructions in Pretoria and Johannesburg also still have such high plasticity values and are performing very well. Therefore even soil can be used for such macadam construction on cycle-and footway construction.

Macadam bases can be constructed without water. This technique is particularly suitable for arid areas. (Visser and Hattingh, 1999). Low plasticity fines such as windblown sands can be used. Cape Flats sands and the Berea red sands in Kwa-Zulu Natal have been used with great success as fines for macadam construction (Horak, 1983). Mine dump and slimes sand have been used in this drybound fashion on macadam road construction in Johannesburg more recently (Calitz et al, 1995). Such fines are spread in a thin layer on top of the coarse aggregate layer and dried by the sun before it “flows” into the voids during vibration compaction with a pedestrian vibratory roller. This operation is repeated until the voids are filled to the top.

However, drybound macadam does leave a surface which can easily be disturbed by construction traffic. Experimental work done on the south coast of Kwa-Zulu Natal (McCall et al, 1990) led to the development of a bitumen emulsion slurry which fills the top 10 to 25 mm of the exposed large aggregate voids as a type of working carpet. This can also serve as final riding surface for cycle- and footways and is labour friendly in its application. Only a very light vibratory plate compactor is needed for this compaction/orientation. (Potgieter et al, 1995 and Balmaceda et al, 1995).

The need to optimise the use of available natural gravel material led to the development of composite macadam on projects in Doornkop, Johannesburg (Horak et al, 1996). Composite macadam is a drybound macadam base constructed with good quality single sized natural gravel. Normally the top layer is then constructed of smaller and harder coarse (freshly crushed if a single stage crusher was available) aggregate (maximum stone size 37mm) as a thin slurrybound macadam surfacing. This layer then acts as a durable “key-in” or surface layer.

Considerable lengths of footpaths and sidewalks have been constructed successfully in this way in some of the Johannesburg townships (Visser and Hattingh, 1999). In some cases natural gravel was hand selected and sorted in the required single size dimension. Therefore “harvesting” such single sized natural stone can be done similar to the process described for Telford construction.

Roux (1991) further advocates the use of marginal aggregate of slightly larger dimension than the normal large aggregate size in labour intensive macadam construction. It is accepted that this marginal aggregate will have limited break down under normal compaction activity. Voids are filled with soil fines to provide the matrix stability. Over and above the construction aspect, the sieving action and separation of the course aggregate offers additional opportunity for labour enhancement in the total construction process. Originally Macadam aggregate was broken by hand tools and measured by using a small metal loop the size of an open mouth (Horak, 1983). In some developing countries such material production for concrete work is still in practice with obvious job creation opportunities even though it may border on using persons merely as “sweat machines”!

5. UTILISING NATURAL GRAVELS AND SOILS

5.1. MECHANICAL STABILIZATION

In situ material may often not meet the design standards required. Blending of two or more materials can be considered. The procedure involves the mixing of materials that have different properties (typically particle size distribution and/or plasticity) to form a material with improved bearing capacity (Paige-Green and Jones, 2003).

Blending of material normally takes place on the road or in this case footway. Mixing can be done by spades, rakes and forks. Oversized stone removal should preferably be done at source. A rule of thumb is to remove any stone larger than 2/3 of the constructed layer. (Paige-Green and Jones, 2003). It is envisaged that such mechanical stabilization could be done in cases where a claye or silty material occurs. If gravelly material is available nearby this mixing on site can be done to provide such mechanical stabilization and thereby increase the labour content in the provision of the material.

5.2. EMULSION TREATED MATERIALS

Emulsion treated gravel can be produced labour intensively using natural gravel material stabilised with low percentages of emulsion and cement. Layer thicknesses of 75mm to 100mm are suggested. When natural gravel is used with such emulsion treatment it is called Gravel Emulsified Mixes (GEMs). Medium to marginal quality natural gravels are modified with the addition of 2 to 3 percent emulsified bitumen and 1 to 2% of cement or lime. Design specifications for GEMs were developed and performance evaluated (Grobler et al, 1994 and De Beer and Grobler, 1995 and SABITA, 1993).

The CSIR proved that such a quality end product was well suited for labour-intensive friendly construction (Hendriks, 1995) on a pilot project in Phutaditjaba in Qwa Qwa in the Free State Province and subsequently on a number of other projects elsewhere. This type of base construction does not need a surfacing to be applied immediately as it is able to carry traffic virtually immediately.

The natural gravel is mixed on site in batches and constructed in layers of 75 mm to 100mm with manual labour. The mixing process is done by hand or preferably with small concrete mixers. If covered with an enriched emulsion or thin slurry layer adequate water proofing is provided. It is also ideal for appropriate surfacing types ranging from slurry surfacing to sand seals done labour-intensively

In some parts of Southern Africa sand and soil is the only available road construction material. Lately techniques to construct labour friendly soil treated with emulsion (STE) has been developed in Mozambique to emulate old construction techniques where hot sand asphalt was produced and had very good performance over time (van Wijk et al, 2003 and Hartman et al, 2005). What is significant is that this construction of STE is done only with emulsion and no cement or lime filler addition. Care is taken in identifying soil or sand based on standard material criteria though. An enriched slurry serves as the surfacing which adds to the waterproofing.

5.3. CEMENT AND LIME TREATMENT

Lime and cement are traditional soil stabilisers and modifiers (Paige-Green et al, 2003). Although mostly used in subbases in road construction, cementitious base construction has been used very successfully in various regions of SA. Lime or cement are mixed with the natural gravel on a basis of 1 to maximum 3% by volume. It is watered and compacted. Even though soils have different demands for lime and cement such standardised recipe methods can be used on cycle-and footway construction. Cracks may form due to the hydration process, but should not be a problem on cycle-and footway construction. A slurry surfacing or equivalent can provide for the waterproofing. All the mixing can be done by spades and the watering can be done manually by spray water cans. The down side is the extra cost of the cement and lime, which implies procurement, additional costs and storage.

5.4. CONCRETE BLOCKS AND BRICKS

Block and brick paving is a well known labour-intensive road construction technique (Kelly, 1995). Traditionally block paving had been associated with footways, parking areas, pedestrian areas and loading areas. Design standards were developed for block paving (CUTA, 1987) for street application and parking areas.

Cement brick making on site has obvious cost saving implications and entrepreneurial development opportunities, but quality should be carefully controlled. The link with other construction activities, like house building, has added empowerment potential.

Recycling of bricks from building rubble to be used on footways and sidewalk construction has been done with success in Soweto, Johannesburg (Horak et al, 1996). The broader job creation and community self-help aspects of rubble sorting and recycling in itself also have community empowerment merits.

5.5. GEO-CELLS

Geo-cells are made of strands of durable material, like plastic, which when stretched horizontally on a prepared subbase or selected layer creates openings and pockets in which soil is poured to form a layer of interlinked geo-cells. Due to the confinement created by the inter-linked geo-cells, the vertical bearing strength is dramatically improved. Geo-cells have originally been developed to stabilise sands and cohesion less material *(Horak et al, 1996*), but have developed into erosion protection mats, moulds for in situ concrete block making and other labour-intensive applications. (*Visser and Hall, 1995*). The cell dimensions can vary in height and size, but generally resemble a standard paving block size. It is advised that this type of construction is used mainly for strengthening cohesion-less sands as the basic geo-cell framework material tend to be a costly and sourced form outside the community and thereby limiting the portion of funds retained in the community.

5.6. THIN CONCRETE

Concrete roads are well known for solving surfacing problems on steep gradients and are mostly constructed in panels in a labour intensive way. The best know in situ concrete base is roller compacted concrete (rollcrete). Rollcrete is a dry-mix concrete produced from a continuously graded crushed stone product. It was originally used for dam construction. Work done in Spain since the 1970's on lightly trafficked roads led to the use of Rollcrete in heavy duty pavements by the US Corps of Engineers and led to further use in various countries as a mechanised road construction method (Gill, 1988). Rollcrete was also tested in SA with success on major road projects. (Wright et al, 1990).

Applications in townships were mostly on steep gradients where concrete normally does have better constructability application and where the drainage channels were incorporated as shallow V-shaped roads (Horak et al, 2003). This application was done with hand operated vibratory compaction devices with great success. This is clearly a road building technology with great potential for Small Plant Intensive (SPI) applications.

Success with ultra-thin concrete layers (as thin as 75mm) in townships have led to a pilot demonstration project in the Roodepoort area (Steyn et al, 2005). Some of these unconventional thin concrete layers have mesh reinforcement (even standard meshed wire) with remarkable performance success. The only down side to this type of construction is the requirement for quality freshly crushed rock and cement. Both these aspects make this an expensive alternative and not totally in line with the stated objective to concentrate on the use of natural local material for community based cycle and footway construction.

5.7. CONCLUSIONS REGARDING PROPOSED TECHNOLOGIES

In Table 3 the advantages and disadvantages associated with each listed appropriate technology for cycle-and footway construction are summarised. The appropriateness ranking for each technology is also shown on a scale of 1 to 5 with 5 being the most appropriate. This ranking takes into consideration the set objective of using local materials, increase labour content, skills level requirement, equipment and small plant requirement, functionality of finished product, cost, maintenance requirements and skills transfer opportunities. Based on this insitu material with adequate CBR values or improved by means of compaction and mechanical stabilisation scored the highest followed by composite Macadam construction and emulsion treated gravels and soils. The final selection of base type is however still largely dependent on the quality and availability of local material.

Table 3. Weighing up appropriate technologies

Appropriate Technology (Ranking)	**Advantages**	**Disadvantages**
Telford (2)	• Rock harvesting increases community and labour content • Low skills level required • Can be used for road construction too	• Limited to rocky areas • May provide uneven surfaces unsuitable for cycles
Composite Macadam (3)	• Rock and gravel harvesting and sieving increase labour content • Small plant intensive • Provides strong and durable pavements • Skills can be retained and used for road construction with ease • Easy to repair	• May provide uneven surface depending on skill development
Insitu adequate CBR material compacted or mechanically stabilised(5)	• Labour content increased in material mixing • Maximise local material usage	• Only applicable when material is sandy • Still needs waterproofing
Cementitious gravel material (2)	• Low skill level needed • Natural local material uttilised	• Water needed • Costly cement with procurement and storage problems • Should only be used if gravel is claye and marginal
Emulsion soil and gravel treatment (4)	• Provides material with good water resistance • Skills can be retained for road construction • Make optimum use of local gravel	• Emulsion and cement are costly and pose problems regarding procurement and storage • Easy to repair and maintain • Water needed
Geocells (1)	• Ideal for sandy areas • Easy to construct	• Costly geocell materials • Not easy to repair and maintain
Concrete blocks and bricks (2)	• Block making or brick recycling creates jobs • Can be used for other building activities • Easy to construct with low skill levels	• Costly cement with procurement and storage problems • Quality crushed material preferred requiring either crushers or sourcing from commercial sources • Water needed
Thin concrete (2)	• Ideal on steeper gradients • Low skill level required • Skills can be retained for road and building construction	• Costly cement with procurement and storage problems • Water needed • Quality crushed material preferred requiring either crushers or sourcing from commercial sources • Difficult to maintain

6. SURFACINGS AND WATERPROOFING

Environment has been identified as a major or over riding design factor for cycle-and footway performance. It is therefore important to provide water proofing to bases constructed and prevent water intrusion. Some of the base construction technologies already proposed have people friendly surfacings included. A number of bituminous surfacings which are applicable to low traffic volume situations on roads have been identified and adapted for cycle and footway construction and are listed in Table 4. Only those which require small plant and are person friendly have been listed here. Concerns associated with each surfacing type is mentioned as well as associated advantages.

Table 4. Typical functional and construction features of surfacing types (Adapted from SADC, 2003)

Types of surfacing	Advantages in the context of Cycle and Footway construction	Concerns to address
Otta seal	• Simple process • Little sensitivity to standards of workmanship • Relaxed aggregate requirements using local gravel • Good durability	• Little known concept • Requires input of skills and knowledge • Empirical approach to design relying on prior experience and site trials.
Sand seal	• Simple process, forgiving in respect of method and workmanship • Relaxed requirements regarding aggregate quality • Very economical concept	• Single sand seal has limited service life
Slurry seal	• Simple operation well suited for all areas • Good texture for mixed type of traffic including pedestrians • Rolling is not essential (provided by traffic)	• Little known concept in many areas • Requires use of bitumen emulsion and cement- potential problems with supply and storage, especially in remote areas • Concerns over durability- dries out easily over time.
Combination seal: Single Otta seal plus sand seal	• Improved durability • Reduced sensitivity to workmanship • Economical concept that offers optimal use of natural aggregate sources	• Same as for Otta seals

In Table 5 the production of aggregate for various bituminous surfacings are summarised. This gives an indication of possible sources and some practical measures to obtain the necessary materials for such surfacings. In Table 6 the relative friendliness to labour intensive construction methods are summarised for a number of surfacing types. It is clear that Otta seals and sand seals are particularly labour friendly as it also tends to make use of local natural materials which enhances the potential for labour content.

Table 5. Production of aggregate for bituminous surfacings (Adapted from SADC, 2002)

Type of seal	Type of aggregate	Winning and processing of materials
Otta seal	Graded gravel (natural or crushed)	Stockpiling. Normally screening is also required.
Sand seal	River sand (crusher dust may be used, but can be expensive)	Stockpiling (while river is dry). Screening out pebbles
Sand cover seal (over Otta seals)	Any non-plastic sand	Stockpiling if sand is not available along the roadside
Slurry	Crusher dust	Crushing and screening

Table 6. Labour friendliness of various surfacing types (Adapted from SADC, 2002)

			"Friendliness" for labour based methods		
			Otta seal	**Sand seal**	**Slurry***
Aggregate Production	**Quality**				
	Output				
Surfacing Construction	**Quality**				
	Output				

Key Good= Moderate = Poor =
* Output of aggregate production for slurry (crusher dust) depends entirely on availability on the commercial market

The approach to use unconventional soil stabilisers primarily for erosion protection and gravel preservation versus merely structural strength or dust palliation have great validity in the application as surfacing for cycle-and footways construction (Range et al, 2006). A number of these unconventional soil stabilisers have been tested with an erosion test device and a classification system based on this is now possible. Basic gravel material characteristics can be used to classify materials in terms of their erosion potential even without such treatment. Therefore such unconventional soil stabilisers should also be considered for cycle-and footway construction as it can also be applied labour friendly with low skills levels needed.

7. SUMMARY AND CONCLUSIONS

The Extended Public Works Program (EPWP) has as basic objective to create jobs for poverty stricken rural communities by doing construction projects which maximize labour – intensive construction. Research has shown that such EPWP projects often do not achieve these objectives and limited actual poverty alleviation and capacity building takes place. Sustainability of job creation and wrong level of appropriateness of the selected technologies or design standards are identified as factors leading to misalignment of objectives and accrual application.

Some of the symptoms of poverty stricken rural communities are lack of mobility and accessibility. While there is a considerable backlog of rural road provision and clear understanding that such provision not only creates short term jobs, the developmental and economic growth enablement of road infrastructure is also clearly recognized. Access to community facilities such as hospitals, schools and clinics are important considerations in the prioritization of such projects.

Mobility and accessibility by means of cycle-and footway provision from and to such community facilities can be strongly aligned with the objectives of the EPWP as well as solving important road traffic safety problems.

The objective to increase community involvement via increased labour intensive construction technologies can be achieved in various ways. One important aspect is to make as much use as possible of local material in the construction. This enables the increase of labour content in the sourcing by means of harvesting, sorting and preparation even before construction. Design standards were adapted to the required design paradigm and design domain for such constructed cycle and footways. Large plant and machinery associated construction technologies were excluded to enhance labour content and to lower entry barriers to community involvement on a sustained manner. Small plant and equipment usage associated with such construction techniques are however promoted.

Simple and reliable construction and bearing capacity testing techniques are advocated to enhance the optimum use of local material. Basic design parameters are proposed based on such easily determined bearing capacity of in situ materials. A number of person friendly construction techniques are proposed, described and evaluated against the set objectives of increased in situ material use, labour-friendliness and quality of end-product.

Design considerations for horizontal and vertical alignment are excluded as it is adequately addressed elsewhere. The basic designs ensure that such constructed cycle-and footways would be waterproofed by means of person friendly and local material friendly technologies. The environment, therefore mostly storm water drainage, is the main design consideration and is further addressed by lifting the pavement structure above the surrounding environment and either giving the surface a slight crown or sloping it consistently slightly to one side.

Lastly, the relaxed design and construction technologies promoted here are acknowledged to have higher risk of failure attached to it if applied for normal road construction However applied to cycle- and footway construction lowers such risks considerably to practical and manageable levels.

Lastly it is known that maintenance activities are more job sustainable than just new construction alone. These technologies are also maintenance friendly and therefore enable skill retention as well as portability and use on larger projects such as for road construction and maintenance, too.

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