APPROPRIATE SOUTH AFRICAN ARCHITECTURE – CONCEPTS DERIVED FROM VERNACULAR TRADITIONS AND CURRENT PRACTICES

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Abstract

It is so ironical that while the announcement introducing this conference proclaims that "Climate change will impact the poorest countries and people the hardest", it is precisely the poorer people who have the smallest ecological footprints. South Africa is no exception; not only has the indigenous thatched rondavel with its earth walls, still found in rural areas, been described as "the ultimate in green architecture", the ubiquitous shack constructed entirely with recycled materials requires only 12 per cent of the embodied energy needed in building a similarly-sized low-cost house. Together they comprise approximately 25 per cent of our housing stock.

South African research agencies such as CSIR Boutek, as well as a number of universities, have been investigating appropriate technologies since the 1970s, focusing mainly on energy-saving and affordable construction techniques. The troubling reality, however, is that the potential savings in energy and capital from adopting more appropriate building technologies are insignificant compared to the consumption and costs resulting from urban sprawl and low densities, overstretched transport and engineering infrastructure, and the prevalence of climatically inefficient building types.

This paper proposes a conspectus of interdependent concepts that could collectively constitute a strategy for sustainable development, exploring not only appropriate technologies, but also appropriate policy, planning and design decisions. These range from neighbourhood and building types for improved population densities and access, and participative and small-scale construction technologies, to tectonic typologies for large public buildings. These concepts were informed and inspired by indigenous vernacular patterns and proven practices in other regions.

INTRODUCTION

In architectural terms, appropriate technology comprises, I believe, two interdependent aspects: technics and knowledge. "Technics" include the use of materials, energy, climate control and construction techniques. "Knowledge" is the historical dimension, the theory of settlement development including land use and typologies, socio-cultural needs, contextual considerations, and the creative use of space and form. Implied in the definition is unquestionably also the principle that appropriate technology should benefit economically disadvantaged people, which in South Africa constitutes approximately half its population.

A reader commented on a BBC News item entitled "Is Africa's Architecture dying?" as follows: "The industrialised world is coming to terms with the intelligence of environmental friendly architecture, a fact well incarnated in African architecture" [1]. This should be a sobering reminder for South African policymakers who still propagate Eurocentric settlement patterns and building technologies, to the total exclusion of indigenous wisdom.

A focus restricted to (say) simply reducing energy consumption is inappropriate to the needs of the developing world, including South Africa. In fact, the Malaysian Green Building Index rates site layout and management higher than energy savings per se. An interesting aspect of the GBI is the Township Tool and the weighing of its assessment criteria: Climate, energy and water (20%); ecology and environment (15%); transport and connectivity (14%); building and resources (15%); business and innovation (10%); and finally – and this is truly significant I think – community planning and design (26%) [2].

During the course of a decade of uninterrupted research into African urbanism and building dynamics I have formulated a number of concepts that could possibly constitute appropriate technologies. Six of them are briefly discussed below.

Concept No 1: Improving economic viability in the countryside – Balanced urban-rural development and improved interdependence

It is well known that the incidence and severity of poverty in South Africa's rural areas is much higher than in cities and towns. In pre-colonial times, the South African settlement pattern was that of evenly dispersed and relatively self-sufficient villages. By the end of the 19th century, the colonial and settler administrations had claimed the whole region. Today, the land between major urban centres and small towns is mostly controlled by large-scale concerns such as commercial farming, mining and nature reserves. On the expanding peripheries of big cities, good agricultural land is being occupied by large, low-density gated communities and huge RDP (Reconstruction and Development Programme) housing schemes. It should be noted that some authors, notably Kevin Lynch, wish us to accept urbanisation as irreversible and rural development as futile [3]. The inevitable result is of course over-urbanisation and the abandonment of the countryside.

We have learned from Mombasa and Malindi that a symbiotic urban-rural relationship can dramatically improve the living conditions in villages and small towns. The Rural Poverty Report 2001 claims that investment to reduce rural poverty is potentially more effective than spending in urban areas [4]; rural communities can often do more for themselves than urban people can, especially if they have access to indigenous technologies. In other words, it is easier and cheaper to improve conditions for the rural poor than for the urban poor.

An even spread of the population and economic activities throughout inhabitable and cultivable land could expose more people to opportunities to make a living. Accepting that the village, neighbourhood, town, city and metropolis must be spatially and socio-economically interdependent is a fundamental premise. These should be connected with a web of roads and railway lines, airports and communications links to create the regional network that would support both the countryside and metropolitan areas. An affordable public transport system, as well as cheap and quick ways to get fresh produce to markets in bulk are prerequisites for establishing good urban-rural relationships. The decentralisation of industrial production should again be considered. The regional diagram below was inspired by what I saw around Mombasa and Malindi, Kenya – all these elements and connections were present. There seems to be a natural tendency for the network, as displayed below, to develop in parts of Africa, but it needs a bold regional forward-planning framework in South Africa because it disrupts the established order.

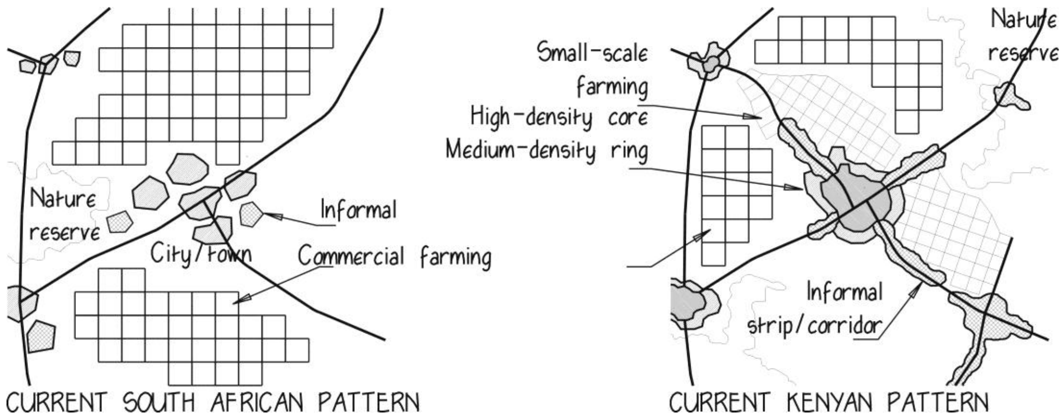

Figure 1 Regional development: An emphasis on inhabiting and diversifying the countryside, and on corridor development (Drawing by the author)

Concept No 2: Controlling sprawl – An African compromise

Sprawl is a major problem affecting the poor, cutting them off from employment opportunities, healthcare and access to the city or town. Late 20th century town planning introduced the principle of urban growth boundaries (UGBs). These are analogous to certain traditional walled African towns, for example, those of the Swahili and later Tswana agro-towns. Nowhere in southern and eastern Africa do we find such clear boundaries any longer. The edges are generally frayed out into the countryside and boundaries are blurred. However, sustainability of any kind cannot be achieved where sprawl prevails. Legislating UGBs is a practical and proven mechanism, which in South Africa, should be accompanied by a gradual densification and transformation – within the UGB – of traditional suburbs, historical townships and the recent RDP schemes, as well as the development of Apartheid-era buffer zones where these cannot be used as nature reserves for public enjoyment. It might even be advisable to demolish parts of particularly degraded and economically unviable historic townships that lie beyond the UGB. The edge, however, will be different and less defined than propagated in current European theory. It may consist of a ring road lined with informal settlement for maximum exposure to passing traffic and public transport, followed by a ring of relatively self-contained urban villages, all of which would be surrounded by mini-farms in close proximity to markets.

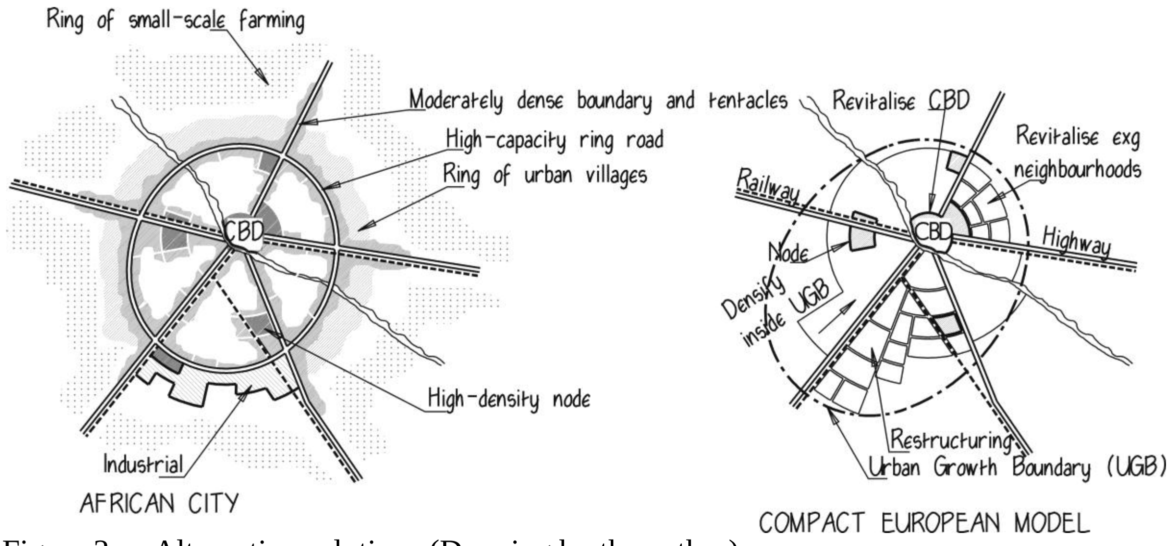

Figure 2 Alternative solutions (Drawing by the author)

Concept No 3: Integrating informal settlements

All over sub-Saharan Africa, shantytowns – politely called informal settlements – are the quintessential manifestation of urbanisation without official intervention. Many policies in the developed world offer incentives for developers to include a proportion of subsidised social housing units in their schemes – some even demand it. The inevitable result of this dispersal of low-income households is simply that they will always be the "poor neighbours". In an African situation, breaking up the shantytown has proven problematic. Poor people rely on mutual community support and critical mass for survival. Informal economic activities (especially internally and at the edge), social support and political clout demand collective community-based action.

Rather than distribute low-income households individually throughout the city, they should be allowed to form cohesive, largely self-reliant communities. At this level, shared goals and collective responsibilities could greatly enhance the well-being of a community, even when faced with harsh conditions. The greatest advantages of such cooperative housing are that it (1) provides an identifiable spatial unit to which to belong, (2) offers a setting for community support in matters such as surveillance and caring for children, the sick and the elderly, and (3) creates political pressure for municipal and other services. Considering the size of the shantytown studied, it seems as if such communities should not exceed five to seven hectares, in line with Alexander's norm for neighbourhoods, but should be much smaller than the prevalent norm of approximately 30 hectare. And the typology? Alan Lipman captures that succinctly: he suggests that local planners and architects can learn from the traditional South African settlement models of "grouped housing with shared open space" [5], which is also the typology of many informal settlements.

An informal settlement should form part of a neighbourhood, with its own open space, while sharing neighbourhood facilities. It will comprise between 10 to 25 % of the neighbourhood area, comprising one or more aggregated wards. A good policy should ensure not mere survival, but the accumulation of wealth, which means that when land is allocated in a favourable position for a poor community, it should not be assumed that it will always remain poor. It is envisaged that what starts out as a collection of shacks can in time be transformed into a morphology that combines individual houses and mixed-use medium to high-density low-rise buildings with small public squares. In some existing shanty towns, continuity could be achieved not only by restructuring the settlement, but also respecting nodes, paths and occupied territory. Community architecture is propagated and supported by professionals. Buildings should be clustered in open compounds suited to incremental expansion around paths and a hierarchy of courtyards. Since informal settlements should always be located off a major street; in some cases adjacent wards and neighbourhoods could share a "main street". There is no reason why the informal part cannot become the lively centre of a neighbourhood.

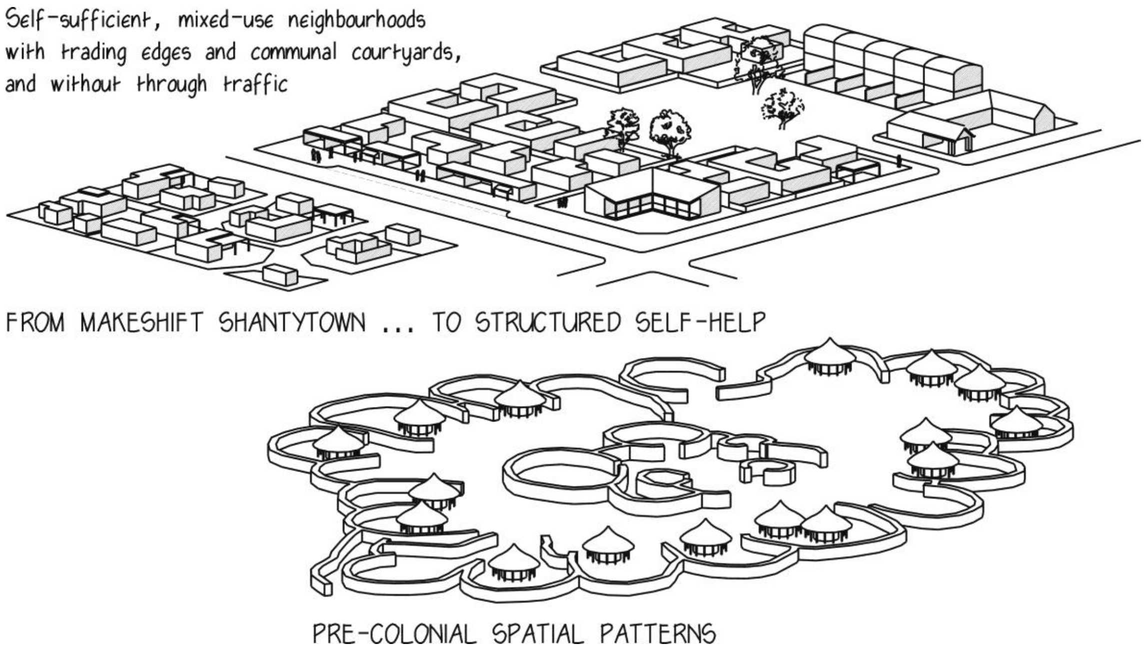

Figure 3 Development of a collectively owned site (Drawing by the author)

Concept No 4: Streets and lanes for pedestrian and vehicular circulation

Streets in African cities are very dangerous places, with minibus taxis, pavement traders and pedestrians all in conflict with one another. Pedestrian deaths account for a shocking 42 per cent of road accident fatalities in South Africa. Every year, more than 5,000 pedestrians are killed and 30,000 injured, 10,000 of which, seriously, partly due to what Macozoma and Ribbens describe as "an inadequate road environment which in many cases do(es) not cater for the needs of non-motorised road users, especially in the previously disadvantaged areas where facilities to walk alongside or to cross roads are often lacking" [6]. Traffic engineering still dominates urban planning and an unrealistic proportion of land is allocated to roads and parking, even in low-income areas where less than 10 % of the households own cars and rely on walking, bicycling and minibus taxis.

When considering circulation inside an urban village or neighbourhood, discrete parking, appropriate streets, shared lanes, and pedestrian walkways must all be considered. These depend on the morphology, density and prevalent activities. The New Urbanism movement encourages a reduced reliance on private motorcars and provides the necessary principles for narrower streets, pedestrian and bicycle-friendly environments as well as the provision of public transit [7]. In *A Pattern Language* (1977) Alexander et al. recommend that parking provision be limited to nine per cent, that is, local roads must be looped to avoid through-traffic, and that separate networks of pedestrian paths and streets for cars should be provided [8]. Where car ownership is low – or fast-moving cars can be effectively excluded – the total separation of vehicles and pedestrians need not be contemplated. Social space can still be created by making local vehicular traffic subservient to pedestrian activities, such as in the Dutch woonerf layout. Another way to do so is to widen the sidewalks and narrow the street. In a pedestrian-dominated environment, sidewalks are six to eight metres wide, with a concomitant narrowing of some major streets; this is not excessive at all. Even with safe, shared streets, the community will certainly appreciate the pedestrianisation of other streets.

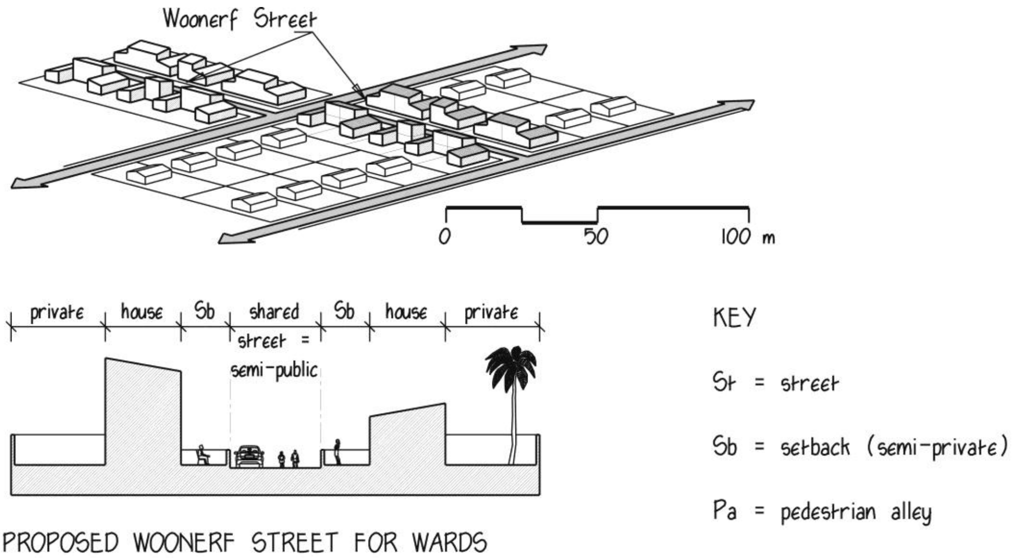

Figure 4 Proposed street configurations and their edges (Drawing by the author)

Concept No 5: For the housing fabric – Participative small-scale construction technologies

In spite of its excellent thermal properties, the technology of the traditional thatch and mud rondavel is not a culturally acceptable option in urban South Africa. The other prevalent type of African shelter, the shack with its metal sheeting over a timber frame, has no thermal mass, and inside temperatures fluctuate wildly according to the conditions outside.

However, shacks tend to provide positive outdoor living space, lettable rooms and home industries, which are easily achieved with thin houses, only one room deep. Buildings often consist of separate structures connected with canopies or pergolas. Such small-scale structures are responsive and ideally suited to incremental additions, compatible with the notion of "structure follows social space" (Alexander's Pattern #205). Authorities justifiably view these with suspicion; lack of cross-ventilation, climatic comfort, thermal and sound insulation, and risk of fire, flood and building collapse, often render living in a shack a hazardous experience. The problem, however, is not the metal-clad timber frame construction, which is also found in many parts of Australia and the United States, but the lack of potable water, sanitation, clean energy and insulation; these, rather than RDP houses, are what government should provide. As with site planning, there should be professionals on hand to advise on orientation, spatial organisation, fastening techniques, floor and foundation systems, the placing of openings in walls to allow cross-ventilation, and the shading of exposed walls.

The growth of a local building industry, and greater participation by communities, could be stimulated by a fusion of informal vernacular, conventional and innovative technologies. The Alexandrine Pattern #207 states simply that "good materials" should be used, explaining that they should be low-energy, recyclable and workable in-situ. The objective here is to facilitate the construction of functionally adaptable and climatically responsive buildings with sound structural-physical characteristics. Another solution is to entrench technologies which should utilise local and readily available materials and be suited to self-help and semi-skilled labour. Construction must be versatile, economical and contextually responsive.

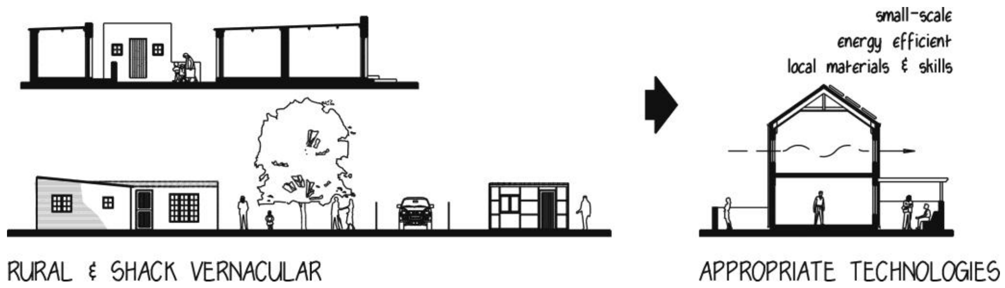

Figure 5 Appropriate small-scale technologies with a history (Drawing by the author)

Concept No 6: Technology for medium and big buildings

Medium-sized and large buildings are built by large contractors. This is top-down and offers little benefit to the community it is intended to serve. Other parts of Africa lead the way where bamboo scaffolding, mixing concrete by hand, and unskilled workers, including women, are making a major contribution. Le Corbusier in Chandigarh demonstrated what can be achieved with reinforced concrete, an easy and tolerant material with which to work.

Low-energy, low-maintenance buildings are non-negotiable in an envisaged appropriate technology dispensation, which means responding to the local climate mainly with passive measures to ensure natural light, temperature control and cross ventilation. Even large buildings must be designed for construction by small, local contractors. Hence, inevitably, our buildings will be rougher and less precise than most of the public buildings in, say, Europe.

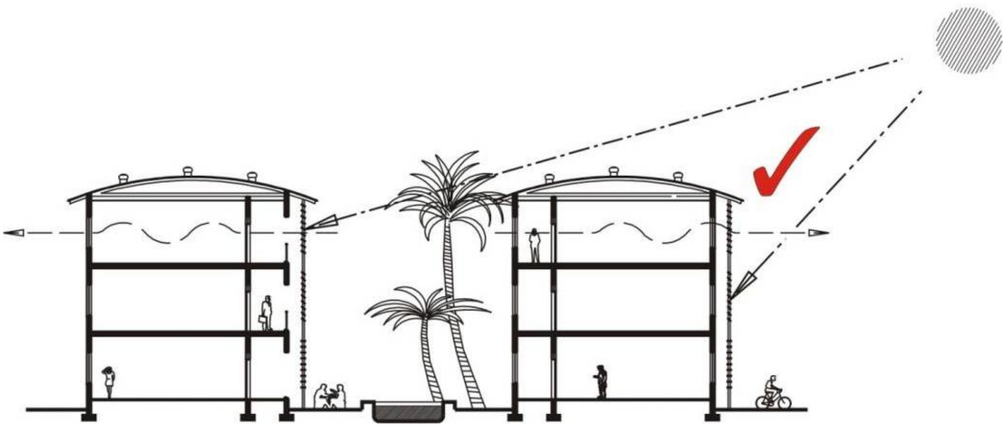

Figure 6 Low-energy climate responsive big buildings (Drawing by the author)

Conclusion

In an age where energy-saving is a major concern and ecological responsiveness an essential consideration, we must beware that functionality does not dominate to the exclusion of less measurable attributes. Ultimately we must strive for a good 'fit' with both the physical and metaphysical context, with the latter obviously including histories, symbolism and a satisfying aesthetic experience.

I have come to realise that the forms of buildings have just about nothing to do with Africaness. It is what those buildings can do for the community that counts. Allowing community participation at every decision-making level and on every scale, could involve communities, now given free homes but surviving on social grants, to become involved in shaping their own environment. Not only would this involvement create an internal economy, but it could even revive the spatiality, scale, textures, colours and materials that speak of Africa.

In the South African context, appropriate technology clearly comprises the manner in which the whole habitat is assembled. Government should focus on balanced urban and rural development, and on the provision of accessible spatial frameworks and affordable, serviced sites to allow diverse communities to establish and maintain habitats that would support their socio-economic needs and expectations. The needs of poor communities must be given the highest priority throughout the process. Built-environment professionals should develop the skills to support this process.

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Rubber Tyre and Plastic Wastes Use in Asphalt Concrete Pavement: A review

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KEY WORDS: Asphalt pavements; Plastic wastes; Crumb rubber tyre

Abstract

The increased diversion of waste from landfill to recycling due to their non-degradable nature is an attempt to sustainably manage waste. Thus the practice to incorporate waste products into highway construction and repair has become more popular in recent years. Construction and maintenance of South African roads consume large amounts of natural non-renewable resources in form of virgin raw materials. The use of recycled materials helps ease landfill pressures and reduces demand of extraction. However concerns over inferior road performance and additional costs of construction have hindered the widespread use of such secondary binders and aggregates in such applications. This paper presents an on-going research into the use of plastic waste and rubber tyre waste aimed at unlocking the effectiveness of the use of these major pollutants in solving environmental and transportation problems in South Africa. This research is aimed at optimisation of the use of rubber tyre and plastic wastes as partial replacement of aggregates and binder in asphalt concrete to improve Hot-Mixed Asphalt surfacing material to achieve good long-term performance of roads under a wide range of tropical conditions. This paper presents state of the art in recycling tyre and plastic waste in construction and maintenance of pavements through appropriate technology.

Introduction

Environmental concerns are becoming increasingly important and influence the techniques available; for example, encouraging the recycling of existing materials. For these reasons, amongst others, research into improving the design and performance of Hot-Mixed Asphalt (HMA) road surfaces continues to be undertaken. Asphalt has a short life cycle failing mainly due to temperature changes, traffic load, and UV solar radiation. One common way of increasing the performance of the bitumen is blending the asphalt with polymer modifiers (PMA) [1]. PMA has better mechanical properties and higher durability than the non-modified asphalt. In tropical and sub-tropical countries the performance of HMA has often been disappointing under severe climate conditions, with road surfaces sometimes failing within a few months of construction and rarely lasting as long as hoped. The principle roads in South Africa are surfaced with HMA. This is a mixture of aggregate materials bound together with bitumen. Under high temperatures, bitumen, a visco-elastic material can become very soft and undergo rapid chemical changes degrading the desirable properties of the HMA [2, 3]. Road conditions are not static due to continuing developments in vehicle and tyre designs as well as traffic volumes and loading [4]. These often increase the stresses applied to the road. Heavier loads, higher traffic volume and higher tyre pressure demand higher performance pavements. The situation is complicated by the climatic variation and the present climatic changes that are affecting road pavements. The demand for higher pavement quality from users is ever-increasing. The cost of a pavement failure is also mounting. Hence, there is a strong desire to have better asphalt mixture from high-way agencies [5]. A higher performance pavement requires bitumen that is less susceptible to high temperature rutting or low temperature cracking [6]. Research and feasibility studies have shown that bitumen rubber is the most cost effective modified binder in the South African bituminous product spectrum [7, 8]. It is possible to increase the capability of resistance to permanent deformation at the expense of a higher price and greater instability, therefore mixing the polymer with the bitumen has the potential of addressing the distress problems that exist in today's highways [6]. Another challenge is a shortage of materials of sufficient quality for road surfaces and therefore innovative solutions need to be sought [9].

Environmental Waste

Waste is an inevitable consequence of development; and hence it must be managed in an integrated and sustainable manner [10]. As the population increases and development takes place, a concomitant increase in waste generation is expected. There are a number of problems associated with increased waste generation, i.e. additional risk of air, soil and water pollution, and lack of suitable locations for landfill sites. In order to prolong the life of current landfills and optimally manage new landfills, the waste disposed to landfill sites has to be minimised. The total global production of plastics reached 245 million tons in 2008. However, the apparent annual consumption of plastic materials in South Africa was 1.25 million tons in 2009 [11] Out of the total production of plastics, South Africa recycles about 18 percent and out of this percentage 28 percent is from packaging waste. This is in line with the world average given that plastics are 100 percent recyclable [11]. The vision of the Polokwane Declaration [12] is to reduce waste generation to 50% of current levels by 2012 and to zero waste by 2022.

Department of Transport reports that up to 53% of vehicle component failure accidents are caused by tyre failure [13]. Many vehicles on the SA roads have a problem with its tyres. The use of second hand tyres is considered the biggest contributor. Owners of tyres discard them as being either worn or damaged. These are collected, patched or re-grooved and fitted by unscrupulous traders to vehicles often with fatal results. These tyres burst after short use and people are killed in the process. The root of this problem will be removed once the waste tyre collection starts. The utilization of spent rubber materials, including automobile tyres, is currently one of the most important environmental problems on a global scale because of the rapid growth of the automobile industry [14]. Scrap automobile tyres do not undergo natural degradation and decay; therefore, they are accumulated in open landfills to occupy considerable ground areas or scattered in ravines, forests, and water bodies to pollute the environment. The estimated mass of the tyres sold annually in South Africa is 275,000 tonnes. This translates to over 10 million scrap tyres every year [15]. Such tyres end up as an environmental problem, as pollutants and as breeding grounds for mosquitoes. Such tyres cannot be economically recycled with the current know-how. There are an estimated 60 million scrap tyres lying in stockpiles in South Africa. Many of these stockpiles are illegal and unsafe or in the veld. Thus the primary challenge is to recover the estimated 28 million tyres that are dumped illegally every year

It can be seen that plastics and rubber tyre wastes form a major proportion of pollutants of our environment. The use of crumb tyre from waste tyres in asphalt gave origin to the term ***asphalt rubber*** or ***bitumen rubber*** and the use of plastic waste gave origin to the term ***plastiphalt*** [16]. These attempts have been an alternative to minimize their ecological impact and simultaneously improve the mechanical properties of asphalt concrete.

Asphalt Concrete Pavements

Structural failures in a flexible pavement are of two types, namely surface cracking and rutting [17]. Cracking is due to fatigue caused by repeated application of load in the bound layer generated by traffic. Rutting is developed due to accumulation of pavement deformation in various layers along the wheel path caused by repeated applications of traffic loads and it is a stress controlled cyclic loading phenomenon [3, 6]. Research has been done on the use plastics [3, 6, 18] and crumb rubber [5, 19-23] as a bitumen binder modifier and partial aggregate replacement in asphalt pavement independently.

The use of tyre rubber and plastics in asphalt generally has two distinct approaches. One is to dissolve crumb rubber or plastic wastes in the bitumen as binder modifier, the other to replace a portion of fine aggregates with ground rubber or plastics that is not fully reacted with bitumen [16]. These are referred to as 'wet processes and 'dry processes', respectively. Modified binder from the 'wet process' is termed 'asphalt rubber' and asphalt made by the 'dry process' is rubberized asphalt [24]. Many studies have shown that the addition of rubber and plastics separately to asphalt concrete mixtures increases the viscosity and resistance to moisture damage and reduces the susceptibility to temperature and tendency to flow [22].

Rubber Tyre

The principal source of raw material for producing crumb rubber modified (CRM) asphalt is scrap tyre rubber [24]. Shredded tyre rubber is the preferred and logical alternative as a raw material for producing CRM. Liu et al. [23] evaluated the performance of different crumb rubber modified (CRM) asphalt and reported that in general the crumb rubber content is the primary factor affecting the performance of CRM asphalt.

Plastic Waste

With the increase in demand for plastic and lack of suitable/appropriate sources of separation, collection and recycling facilities, plastic waste problem is expected to be even worse in future [25]. Polymer-modified bitumen (PMB) has been increasingly used to enhance pavement performance.

Research Findings

The study by Chen et al. [6] aimed at developing the procedure to determine the proper polymer content to be mixed with bitumen using two styrene butadiene-styrene (SBS) copolymers. The storage stability, shear rheometer and scanning electron microscopy (SEM) tests were conducted to investigate visco-elastic properties and microstructure of the polymer PMB. The investigation revealed that the addition of polymers increased the viscosity, softening point, toughness and complex modulus of bitumen. SEM results indicated that, as the polymer content increased, SBS gradually became the dominant phase and resulted in an increase in PMB's mechanical properties. Good compatibility produced an elastic network into the PMB up to 6% polymer concentration. The optimum polymer content was determined based on the rheological properties and formation of a critical network. Adding higher polymer contents could lead to the separation of polymer and bitumen.

Zoorob and Suparma [26] discussing the laboratory design of continuously graded Asphaltic concrete (AC) mixtures containing recycled plastics aggregate replacement (Plastiphalt) reveals that recycled waste plastics, predominantly composed of low density polyethylene (LDPE) in pellet form, used in dense graded bituminous mixes to replace (by volume) a portion of the mineral aggregates of an equal size, i.e., 5.00.-2.36 mm. The results obtained in this investigation indicate that at the same air-void content, the compacted Plastiphalt mix has lower bulk density than that of the conventional control mix. A 30% aggregate replacement by volume with the LDPE, results in a reduction in bulk compacted mix density of 16%. This reduction in density is advantageous in terms of haulage costs. LDPE partial aggregate replacement also results in a 250% times increase in the Marshall Stability (strength) value and an improved Marshall Quotient value (resistance to deformation). The value of creep stiffness of the Plastiphalt mix after 1 h loading at 60°C is found to be slightly lower than the control mix; however, the Plastiphalt gives 14% recovery after 1 hr unloading time compared to 0.6% for the control mix. However Marais (2011) reports that for Bitumen Rubber recovery does not take place.

Chen et al. [6] shows that SBS improves the rheological properties of PMB. Rut depth decreases with increasing polymer percentage. The most significant in reduction on rutting occurs at the addition of 6% SBS. Adding more than 6% SBS may not be, however, economically feasible because the limited benefits on reducing rutting. Cao in a study to minimize waste tyres pollution and improve properties of asphalt mixtures investigated the properties of recycled tyre rubber modified asphalt mixtures using the dry process. Tests on three types asphalt mixture containing different rubber content (1%, 2% and 3% by weight of total mix) and a control mixture without rubber were conducted. Based on the results of rutting tests (60˚C), indirect tensile tests (-10˚C) and variance analysis, the addition of recycled tyre rubber in asphalt mixtures using dry process could improve engineering properties of asphalt mixtures, and the rubber content has a significant effect on the performance of resistance to permanent deformation at high temperature and cracking at low temperature.

In a paper by [3] it is reported that an increase in stiffness modulus of bituminous mixes is achieved by incorporation of waste polymeric packaging material (WPPM) through an optimum dose of WPPM of 0.3 to 0.4% by weight of bituminous mix for modification of bitumen and bitumen mix.

According to Mustafa et al. [27], pavements made of rubber and plastic modified asphalt concrete have better skid resistance, less cracking and a longer pavement life in comparison to conventional asphalt pavements. Early investigations on the use of discarded tyres in asphalt mixtures showed that rubberized asphalt had better skid resistance, reduced fatigue cracking and longer pavement life than conventional asphalt [20]. Cao [22] studying the properties of recycled tyre rubber modified asphalt mixtures using the dry process concludes that the long term performance of recycled tyre rubber modified asphalt mixtures using the dry process requires further study. There is little information to date about the use of PET in hot mix asphalt [18]. A number of neither asphalt properties when using recycled plastics and tyre rubber are yet to be reported, nor are the certain cost and environmental implications due to limited practice so far.

Conclusion

The problem of waste in developing countries like South Africa is escalating in terms of quantity and complexity. This requires an increased capacity in terms of technology and utilization. Legislations have been put in place but their implementation still remains a challenge to the respective authorities. This research could provide an effective channel of utilization of the polymer wastes forming the bulk of the municipal non-biodegradable wastes.

To a large extent, the stiffness and strength of mixtures determines performance of asphalt pavements. Similar to tyre rubber in the ‘dry process’, a number of asphalt properties when using recycled plastics are yet to be reported, nor are the certain cost and environmental implications due to limited practice so far. Studies have been done before focused on either the use of plastics or rubber wastes separately using both the wet and dry processes with results showing significant improvement in the engineering properties of the modified asphalt concrete. However, there has been little work done in blending the two wastes to achieve more desirable results. There is therefore a need for further research in the use of both plastics and rubber tyre wastes to improve the engineering properties of the asphalt mix. The optimization process and cost benefit analysis in terms of life cycle costs are of particular significance in this research as it would be the vital link between research and industrial practice for policy making purposes.

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