Recycling Of Asphalt Pavement For Accelerated And Sustainable Road Development In Nigeria

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Abstract: The deliberate steps being taken towards total restoration of the road network in Nigeria and the huge sums of money committed to it by Governments are not yielding the anticipated results after all as the greater part of the network remains in deplorable state. This development is not farfetched from the inappropriateness of the old methods of road restoration i.e. total reconstruction and overlays that are being employed presently which are expensive, time consuming, wasteful and cause considerable inconvenience to the road user. There is an urgent need therefore to adopt an alternative but sustainable strategy in order to meet the target of very good condition set for the entire road network by 2015. This paper proposes one proven tool and technic that could come to the rescue - asphalt pavement recycling. Eco-friendliness, energy efficiency, cost effectiveness and significant reduction in construction time are major drivers behind this proposal. Projects in which such materials and methods were employed for road restoration in developed countries have been highly impressive and encouraging. Integration of such measures in road restoration practices in Nigeria, where available funds for road building are increasingly inadequate to meet demand, would enhance accelerated road restoration. This paper elucidates various methods of asphalt pavement recycling and factors to be considered for recyclability.

Index Terms: Asphalt, Recycling, Reclaimed Asphalt Pavement, Roads

1 INTRODUCTION

Huge sums of money are being committed to the development of roads generally in the developing countries of the world. UNECA [1] in recent estimates has it that the yearly infrastructural investment requirements in Africa are in excess of USD 250 billion over the next 10 years. In Nigeria alone, the Bureau of Public Enterprises (BPE) disclosed that about USD 2 billion would be required to standardise the nation's 34,123 km federal roads within the next ten years [2]. The Federal Road Maintenance Agency (FERMA), Nigeria recently reported that USD 18.7 billion is required to complete on-going road projects in Nigeria [3]. These amounts are justifiable, and in fact should be reviewed upwards as the Nigerian road network for example, which is about 194,200km (33% of which is in asphalt) with an estimated total value of about USD28.7 is indeed one of the nation's single largest assets [3], [4]. These assets are to be maintained and kept serviceable all the time since road transport is the preferred means of land transport the world over [5], [1], [6], [7]. During the oil boom years of the seventies, most developing/oil producing nations of the world witnessed a period of unprecedented road construction and Nigeria was not left out. The greater percentage of the road network was put in place at that time [4], [3].

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Many of those roads have, now already passed the end of their design lives since they were not designed to withstand today's traffic loadings, while some of those that were, have since failed prematurely due to a number of reasons. Shortly after the oil windfall in Nigeria, the economy nosedived and never showed any sign of recovery until recently, and as such, budgetary provisions for road maintenance and rehabilitation had for a while been dwindling. Nnanna [8] reported that, some roads constructed about 32 years ago in Nigeria have not been rehabilitated once, resulting in major cracks, depressions, broken down bridges and numerous potholes that make road transport slow and unsafe. The state of Nigerian roads has remained poor ever since despite the desperate efforts being made of late to revamp the road network. The roads are deteriorating faster than ever presumed [9], since the methods of rehabilitation and strengthening of the road network currently being employed are the old methods of total reconstruction and overlays which are very expensive, time consuming and non eco-efficient. Of course this is understandable because the available fund for such exercises is less than adequate for fixing the roads [8]. UNECA [1] recently confirmed this assertion that costs for infrastructural renewal and expansion of roads clearly exceeds the capacity of African countries! In a bid to salvage the situation of the road network in Nigeria, BPE [6] reported that the Government had initiated a programme aimed at reforming the road sector, which would thus facilitate its total recovery from its poor state. It is heart-warming that, among other things, a reviewing and updating of the Federal Ministry of Works standards with emphasis on the Highway Manual Part 1 Design FMW 1973 will be carried out. However, this exercise might not yield significant results, unless provisions are made in the new standard, and also backed with legislation which requires the use of innovative methods and alternative materials for road construction and rehabilitation that promote sustainable development which the old standard is bereft of. Good examples of such sustainable methods and materials are asphalt pavement recycling, reclaimed asphalt pavement (RAP) and bitumen emulsion respectively just to mention a few. It is now a general belief in most developed countries that recycling assists in stretching road funds since old materials are reused and less energy is consumed in the process [10], [11]. The economic, safety and environmental

benefits that these tools (materials and methods) offer would greatly assist in strengthening/overhauling and putting the entire road network into a serviceable condition within a reasonable time if embraced. More importantly, the recent increases in crude oil prices to the extent that a barrel of crude oil, the major source of bitumen [12] and also an essential ingredient for making flexible pavements, reached an all-time high of USD146.69 [13], should make these materials and methods highly attractive. Even more importantly, total expenditure compared to conventional practices for road rehabilitation could be about 40-60% less when recycling of roads is adopted [14], [15], [16].

2 STATE OF FLEXIBLE ROAD PAVEMENTS IN NIGERIA AND REASONS FOR FAILURE

When a road is being designed to last for *N* years, and all things being equal during the construction, the assumption of the highway engineer is that such a road will be adequately maintained throughout its life time. This is also done knowing full well that the deterioration mode of flexible pavements could be accelerated by prevailing climatic conditions in the tropics. For example, the deterioration of bitumen is hastened when subjected to high temperatures in the presence of oxygen. This will lead to oxidation, loss of volatiles and quick ageing of asphalt. The combination of oxidation and loss of volatile effects leads to the hardening of bitumen, and consequential reduction in penetration, an increase in softening point and an increase in penetration index. These in turn make bitumen brittle at low temperatures and prone to failure by cracking [17]. Eyo [18] from his experience in Nigeria, noted that unprecedented traffic load among other causes accelerates the failure of a pavement long before its appointed life span. Das [19] in a more recent work stated that fatigue, rutting, and low temperature cracking are generally considered as the important modes of failure of a bituminous pavement structure. This position is perfectly in agreement with an earlier observation of Brown and Brunton [20] on the mechanism of pavement failure - dominated by fatigue and rutting. Basically, permanent deformation (caused by poor mix design, weak road foundation and excessive axle loads) and fatigue (caused principally by the repeated bending action of the pavement and ageing) among other factors are undeniably the major causes responsible for the deplorable state of flexible pavements. Each or a combination of these two factors eventually result in most surface and structural road defects. Mamlouk [21], PTCA [22], Petts [23] and Research and Development Division Highways Department [24], identify some of these defects as bleeding, cracks, ruts and depressions, edge subsidence and rutting, edge damage, joint sealant defects, spalling, local aggregate loss/ravelling, potholes and shoving, aggregate polishing. Once any of such defects occur, it is time for rehabilitation/restoration or even reconstruction. There are quite a number of flexible pavements in Nigeria that have and are still satisfying their intended design roles functionally and structurally. Good example of such is the Abuja municipal roads. Their outstanding performance is a consequence of the proper attention that they received during the various stages of pre-construction, construction and post construction. However, it is sad to note that the situation is different in other sections of the Nigerian road network system. Nnanna [8] observed that most of the roads especially in the southern part of Nigeria are in very poor condition, and require complete rehabilitation. FERMA [9] in a more recent report confirmed that most roads in Nigeria are distressed, and as such the entire highway network in the country might face a total collapse if urgent steps are not taken to rehabilitate, repair or reconstruct them at the appropriate time. It was recently estimated that fixing the federal roads alone in Nigeria will cost the sum of $20.5 billion [25], a sum just a little below the Federal Government's annual budget. Nigerian roads have remained poor for a number of reasons which are traceable to activities that characterized the construction and post construction stages of such roads. These mainly are in two categories: (a) Poor constructional practice and supervision, and (b) Lack of maintenance. The factors responsible are numerous, varied and diverse in nature. These have been discussed extensively elsewhere [4], [8]. The present condition of the Nigerian road network is as shown in Table 1 and Fig. 1.

Table 1
Road Network of Nigeria broken down to Federal, State and Local/Rural [4]

Type of Road	Federal Road	State Road	Local Govt. Roads	Total
Paved Roads	26,500	10,400	-	36,900
Unpaved roads	5,600	20,100	-	25,700
Urban Roads	-	-	21,900	21,900
Main rural Roads	-	-	72,800	72,800
Village Access Roads	-	-	35,900	35,900
Total Percent	**32,100 17%**	**30,500 16%**	**130,600 67%**	**193,200 100%**

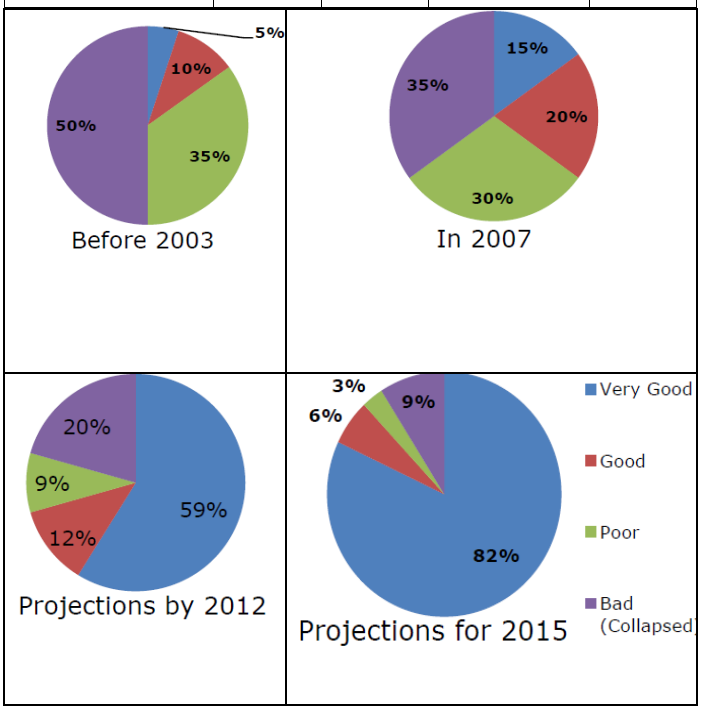

Fig. 1 Current and Projected Conditions (Due to Intervention) of the Nigeria Road Network [3]

UNECA [1] reported that, given the challenges of globalization, Africa is lagging significantly behind in the development of regional trade, particularly because of the lack of reliable and adequate transport. The existing transport facilities are completely outward-looking with the result that the transport infrastructure and services have been little developed and the physical network poorly integrated. UNECA [26] further reported that presently, only 22.5% of the road network in Africa is paved, and that the entire network is poorly maintained.

3 FLEXIBLE ROAD PAVEMENT RESTORATION PRACTICES IN NIGERIA AND TRENDS IN DEVELOPED COUNTRIES

By timely and proper maintenance, highway engineers can extend a pavement's usefulness. Eventually, however, even the best-maintained pavement will begin to disintegrate and will need to be rehabilitated. The traditional approach to pavement rehabilitation has been to either reconstruct it with all new material or patch, overlay it with a new wearing surface. In Nigeria, where a road has failed completely, the failed asphaltic pavements are normally scarified. The subgrade is reworked and now overlaid with fresh asphalt pavement. However, the scarified asphalt is discarded indiscriminately (see Figs 2 and 3) since environmental laws are not being fully enforced. In some cases where an asphalt pavement has experienced structural failure, though still passable, an overlay is normally applied to strengthen such pavement in order to keep pace with expanding networks and ever greater traffic loadings. These restoration practices are expensive, time consuming, wasteful and cause considerable inconvenience to the road user. Apart from these, they lead to the depletion of the natural resource base essential for future development, increased hydrocarbon pollution [28], the need to locate tipping sites for waste road stone, and transport required to remove waste material and bring in new material can add greatly to traffic congestion, reduction of the life cycle of existing pavements and safety problems.

Fig. 2 Ripped Asphalt Improperly Disposed Close to Farmland along Igede - Aramoko Road in Ekiti State, Nigeria

Fig.3 Indiscriminate Dumping of Scarified Failed Pavement Materials in Nigeria [26]

The present trend in road restoration practice in most developed countries of the world is recycling, and it is being driven chiefly by the resolve of the governments of these countries at enforcing the concept of sustainability in all human endeavours. The Asphalt Institute [29] defines pavement recycling as the reworking of in-place surface and base material while PIARC [10] defined the recycling of road materials as the reuse of existing road materials in road construction, with or without changing the characteristics of the materials. In a broader sense, recycling is reducing reclaimed materials from the road to a suitable size for processing, blending the reclaimed materials with virgin ones and relaying the materials as a base, binder or surface course. ARRA [11] stated that many countries have already enacted legislation which requires that certain percentages of material, particularly the ones used in roadway construction and rehabilitation must be recycled or include recycled materials. Shortage of funds needed for road management and energy crisis among others have also been responsible for this present trend. ARRA [11] reported that asphalt pavement is the most commonly recycled material in North America. Japan, Australia, UK and other European countries too are following this path [30], [31], [32]. Adopting this method of road rehabilitation in Nigeria will not only engender sustainable development. Recycling roads provides a lot of benefits. The first and most obvious benefit is the saving in the amount of fresh materials required. This saving is wide-reaching. Less material equals less quarrying (energy reduction as well as reduced environmental impact), equals less fuel used, equals less transport (reduced damage to road network and noise pollution). In the same vein, experience has shown that the in situ recycling process is up to 50% faster than conventional reconstruction [33]. This brings benefits through reduced site supervision costs. Also, a reduced construction period minimizes traffic delays caused by road works, which contributes to the economic benefit of the process. Reusing the existing road and footway materials leads to a reduction in the waste to landfill. This produces environmental and economic benefits.

4 METHODS OF FLEXIBLE PAVEMENT RECYCLING

Different classifications of asphalt pavement recycling have been advanced in literature. PIARC [10] maintained that classifications of the main types of recycling can be made according to:

- The place where mixing is carried out (whether *in situ* or *ex situ i.e.* in-plant),
- The temperature of the process (cold or hot recycling),
- The characteristics of the material to be recycled,
- The binder type (cement, bitumen emulsion, foamed bitumen, bitumen).

ARRA [11] on the other hand categorised recycling into:

- Cold Planing (CP)
- Hot Recycling (HR)
- Hot In Place Recycling (HIR)
- Cold Recycling (CR), and
- Full Depth Reclamation (FDR)

ARRA [11] further classified Hot In-Place Recycling into- Surface Recycling (Resurfacing), Remixing and Repaving. Cold Recycling was further classified into Cold In-Place Recycling (CIR) and Cold Central Plant Recycling (CCPR), while Full Depth Reclamation was classified into, Pulverization, Mechanical Stabilisation, Bituminous Stabilisation and Chemical Stabilisation. Fig. 4 illustrates these methods of asphalt pavement recycling as stated by Karlsson and Isacsson [34]. Information on all these classifications is well detailed in literature [11], [10], [34]. PIARC [10] opined that, the criteria for ascertaining the feasibility of recycling a pavement is to identify whether its deterioration comes mainly from the poor quality of the pavement itself (insufficient thickness, granular layers contaminated with clay, de-bonded bituminous layers, etc) or from problems related to the subgrade. They further submitted that the recycling feasibility should be established from knowledge of the structure of the pavement and of the characteristics of the materials present in it.

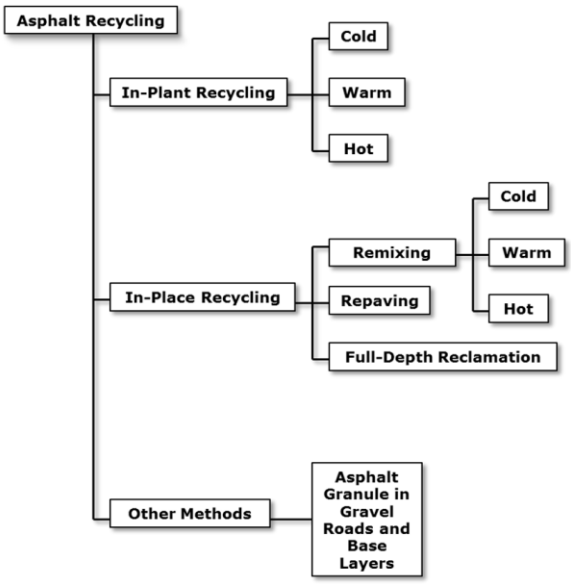

Fig. 4 Methods of Asphalt Recycling [34]

Thus for this reason, it is necessary to examine the road, to determine the characteristics of the materials of the pavement and to collect data on the traffic and climate. ARRA [11], while elaborating on this gave general guideline for the preliminary selection of roads that are candidates for recycling or reclamation methods for the rehabilitation of asphalt pavements. Table 2 details the guidelines. However, ARRA [11] cautioned that all of the candidate rehabilitation techniques have disadvantages and advantages since not all rehabilitation techniques are equally suited to treat the various pavement distress types. Also, the ability of a rehabilitation technique to correct pavement distress is dependent on the type of pavement distress, as well as the extent of the distress and its severity. A suggested guide by ARRA is shown in Fig. 5. The local aggregate quality, amount/type of traffic, and climatic conditions are also important factors which need to be considered. ARRA [11] further stated that, though economic analysis which includes life cycle costs must be done before a decision is made on the method to be adopted, the following factors must be generally considered:

- The type and severity of the existing distresses
- Age/condition of the existing pavement materials and their potential for recycling
- Expected design life and performance requirements of the rehabilitation
- Traffic growth
- Structural capacity of existing roadway
- Environmental conditions
- Acceptable future maintenance activities
- Geometric, drainage, underground and surface utilities
- Traffic accommodation and safety
- Construction limitations
- Project location and size

Table 2
Guidelines for the Preliminary Selection of Candidate Recycling or Reclamation Methods for Rehabilitation of Asphalt Pavements [11]

Pavement Distress Mode	Candidate Rehabilitation Techniques							
	Cold Planing	Hot In-place Recycling	Cold In-place Recycling	Thin HMA	Thick HMA	Full Depth Recycling	Combination Treatments	Reconstruction
Ravelling								
Potholes								
Bleeding								
Skid Resistance								
Shoulder Drop Off								
Rutting								
Corrugations								
Shoving								
Fatigue Cracking								
Edge Cracking								
Slippage Cracking								
Block Cracking								
Longitudinal Cracking								
Transverse Cracking								
Reflection Cracking								
Discontinuity Cracking								
Swells								
Bumps								
Sags								
Depressions								
Ride Quality								
Strength								

- Contractor availability and experience Impacts on adjacent businesses and public
- Available budget
- Good engineering judgement

5 CONCLUSION

The road Network in Nigeria is in a deplorable state due to long neglect as a result of lack of funds for maintenance and rehabilitation. The situation can only get worse under the present global economic recession. The few road restorations being embarked upon at the moment are not sustainable, time consuming and very expensive. There is therefore an urgent need to introduce alternative methods and materials in order to significantly cut down on costs (stretch funds) and also meet the 2015 target of achieving 82% 'very good' condition for the entire road network in Nigeria. With only an improvement of 10% achieved over a period of 4 years (2003 – 2007) using the conventional means of road restoration, the 2015 target is not feasible unless extra measures such as the use of alternative sustainable methods and materials are introduced where applicable. One method that appeals and which can be applied is recycling of asphalt pavement with a potential cut in costs in the region of 40-60% and 50% faster than conventional reconstruction in terms of construction time. Such methods and materials have been applied successfully in America, Europe and Asia and such developed countries have developed guidelines/manuals/codes for the use of such sustainable materials in road building. For the total integration of such sustainable materials and methods in road restoration practices, there is a need to develop guidelines that will assist in making provisions for the use of such alternative materials in the highway design manual of Nigeria.

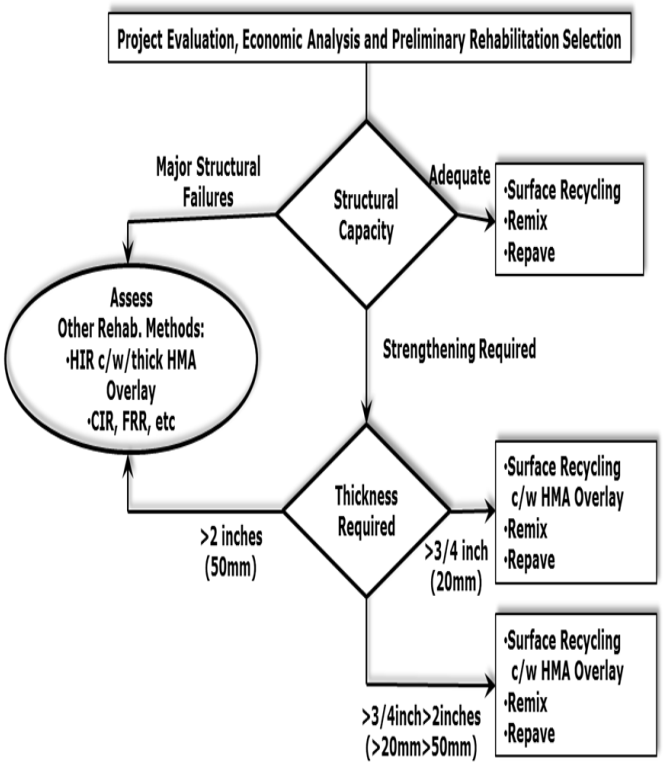

Fig. 5 A Guide for Choosing Recycling Type to Employ in Addressing Pavement Problems [11]

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