ASPHALT RECYCLING AS A MULTIPURPOSE OPPORTUNITY FOR ECOLOGICAL AND "MONEY SAVING" PAVEMENT MAINTENANCE

Authors:

Widyatmoko I.
Associate – URS Infrastructure and Environment UK Limited, Nottingham, UK. –
daru.widyatmoko@urs.com

Cossale G.
Pavement Engineer – URS Infrastructure and Environment UK Limited, Nottingham, UK. –
gianluca.cossale@urs.com (formerly Politecnico di Torino, Torino, IT)

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ABSTRACT

Cold and hot recycled bituminous mixtures are becoming increasingly popular as alternative materials which may be used for the maintenance and rehabilitation of existing road and airfield pavements. However, in a world where more and more emphasize is being made on sustainability, road recycling should be the first choice as it offers in most cases a suitable solution to all road defects. This paper describes all existing road recycling techniques that are currently available in the UK and also relates to the latest technical specifications and guidelines. In order to visualize the benefits of the recycling processes, it incorporates some case studies listing some highly significant results that show the sustainable value of the processes. This paper emphasizes that sustainability also means being financially feasible and that recycling very often results in cost savings when compared to conventional construction methods. In addition to these, high attention is posed on the environmental benefits of reducing waste, lorry movements, energy consumption and CO_2 emission induced by recycling.

Keywords: Hot In-Place Recycling, Cold Recycling, Greenhouse Gases (GHG), CO_2 Emission.

PAVEMENT RECYCLING

Cold and hot recycled bituminous mixtures are becoming increasingly popular as alternative materials which may be used for the maintenance and rehabilitation of existing road and airfield pavements. In fact, both in-place and plant recycling techniques are being successfully employed for infrastructures of various levels of importance, ranging from minor rural roads to major motorways or airfield taxiways.

Recycling of pavement materials has been defined by WRAP (Waste and Resources Action Programme – www.wrap.org.uk) as "the reprocessing of wastes, either into the same material (closed-loop recycling) or a different material (open-loop recycling)". This is a long-standing process. Re-use of asphaltic (bituminous) materials can be dated back to the early part of the 20th century. The first documented case of asphalt recycling, in the form of Hot In-Place Recycling (HIR), was reported in the literature the early 1930s using a standard batch mixing equipment (Taylor, 1978, 1981). Taylor reported that the recycled surfaces had provided satisfactory performance for 25 years. In the late 1930s, the Road Research Laboratory in the United Kingdom (UK) was experimenting with a cold in-situ recycling process, but research was interrupted by the Second World War (Nicholls, 1996). However, the process was implemented following trials in 1948, and is still in use. This cold in-situ recycling process is currently known as "Retread".

More significant developments in asphalt recycling technology and equipment occurred with the petroleum crisis of the early 1970's and the development and introduction in 1975 of large scale cold planning equipment, complete with easily replaceable tungsten carbide milling tools, had triggered the interest in recycling to the similar level as shown in its worldwide use today.

At the end of the 1970s, hot in-situ recycling was introduced in the UK with the importation of equipment and technology from the United States of America. Two processes of hot in-situ recycling were developed, termed Repave and Remix, which are now recognized as standard rehabilitation treatments for asphalt pavements and are included in the UK Department for Transport Design Manual for Roads and Bridges Volume 7 (DMRB7) and Specification for Highway Works (SHW) 900 series Volumes 1 and 2, and Defence Estates Specification 27 (2008). Since the early 1980s, as reported at the 18th World Road Congress in 1987, recycling techniques have been used to provide a standard alternative material for both new construction and maintenance of roads in many countries around the world, from Australia to America. Since that time, the equipment manufacturing and construction industries have been proactive in the development of asphalt recycling methods and technologies which have advanced exponentially in the last 25 years.

RECYCLING METHODS

Recycling has been done in different ways: recycling in-situ (in place) or ex-situ (in plant), using the reclaimed materials only or with adding new materials, keeping or changing the function and the characteristics of the materials. The decision made is depending on technical, environmental and economical issues. Approaches vary with different countries, depending upon national needs, requirements, technologies, resources, etc. These have led to a research initiative to coordinate best practices in recycling road materials within the European countries, which has been rolled out from 2009 to 2011 under a DIRECT-MAT (DIsmantling and RECycling Techniques for road MATerials) project (Bock et al, 2011). This research presented an overview about various asphalt recycling techniques from Hot In-Plant Recycling, Cold In-Plant Recycling, Warm/Half Warm In-Plant Recycling to Hot In-Situ Recycling and Cold Recycling.

In addition to the above, a specific technique based on technical needs for rehabilitation or maintenance, the new function of the road, national policies aiming at a sustainable development and economical considerations must be selected. Figure 1 presents selection process that can be considered when maintenance or rehabilitation activities are required (ARRA, 2001):

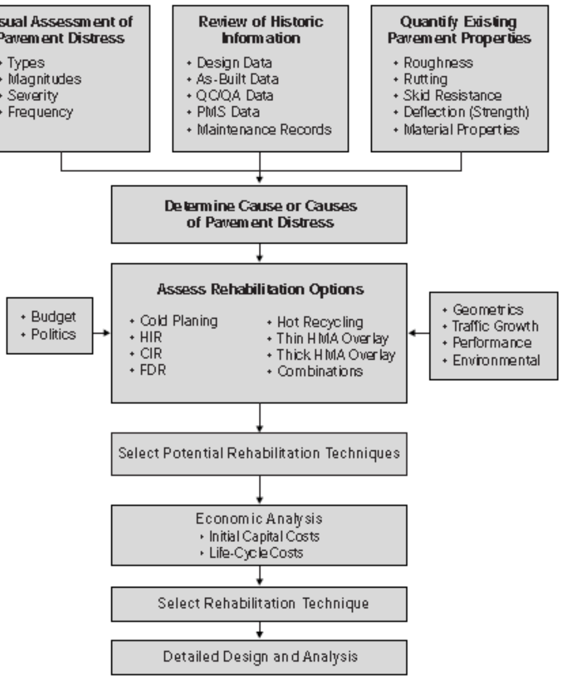


Figure 1 Rehabilitation technique selection process (ARRA, 2001)

This paper presents three of the in-situ recycling techniques commonly adopted in the UK, specifically: Retread, Repave and Deep Recycling. These techniques are schematically represented in Figure 2 and are subsequently discussed in more detail, presenting some significant case studies for each technology.

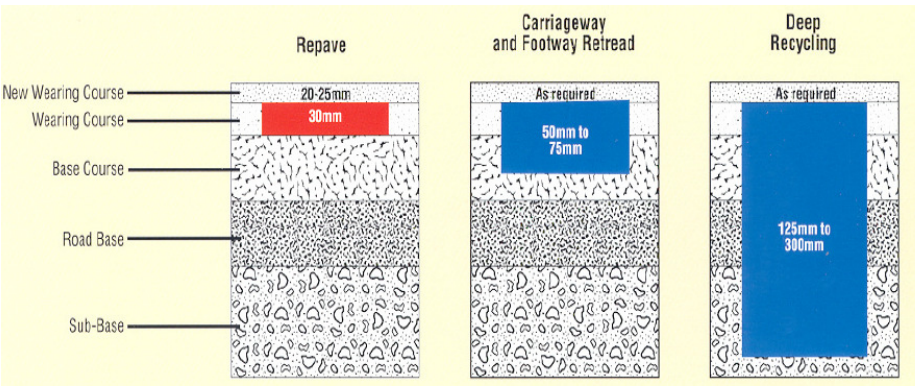


Figure 2 Some in-situ recycling techniques (after Richardson, 2010)

REPAVE

Repave involves a process of heating the top 25 – 35mm of the existing surface course, scarifying and re-profiling by adding new material (typically with a target of additional thickness around 20-25mm) immediately on top of the scarified layer, followed by compaction of both the scarified and new material in one pass (see Figure 3).

Figure 3 Repave process: heating, scarifying, laying and compaction

The main benefit of this process is that it can be applied to all classes of road and airfield provided that the asphalt surfaces and substrates met certain conditions. Whilst the surfacing may have some moderate signs of age hardening, the substrate should be in sound condition. In the UK, the two main specification and design guides are Clause 926 of SHW and DMRB7 HD 31/94; the decision making process is illustrated in Figure 4.

The benefits of the process are obvious: compared to a conventional surfacing which planes off 40-50mm of existing material off the surface and takes it off site the Repave process only takes away at maximum half of this. On roads where the conditions allow, only a channel plane might be carried out reducing the waste to an absolute minimum. As Repave uses heat to ensure the recycled layer is welded to the new thin surface course the application of a bond coat should be omitted. This reduces cost further and makes the operation on site easier and safer due to less number of vehicles.

The main cost saving and environmental benefits, of course, come from the reduction of import of new material. In recent years, prices for bitumen bound materials have increased drastically and reduction of import of hot asphalt produces therefore a significant saving in cost. Case studies from recently completed projects show that savings as high as 40% can be achieved when comparing to conventional methods.

Part of these savings as well is the fact that the process in normal circumstances moves quicker than a conventional process. Whereas the average speed of a paver laying 50mm is approximately 3.3m/min the Repave process moves at around 5m/min. This results in higher outputs per shift with the effect of shorter project completion times. Together with cost, disruption to the traffic is the main focal point for the Highways Agency (HA) and for most of the local authorities. It is known as the social factor that comes into the decision process when the HA values different processes. Operational advantages besides the omittance of the bond coat is the fact that Repave creates a wider weather window and is less susceptive to adverse weather conditions such as rain and low temperatures. By heating the existing surface the process allows to lay the topping thin surface course in conditions where other processes would have been abandoned. Repave increases the quality of longitudinal joints, which is broadly recognised being the weakest part of a surface course, as the heat ensures that the new surface course material is well bonded onto an existing joint that has been heated by the Repave machine. A closer and more durable longitudinal joint is the result increasing the lifetime of the road surface.

Above all, there are the environmental benefits of reduced CO_2 emissions, less energy consumption and fewer lorry movements together with little waste going off site. Local authorities are asked to reduce their carbon footprints in all aspects including the road maintenance sector and Repave is one way to contribute to this target. Carbon trading councils can use these savings to increase their budgets by using the achieved savings to trade for monetary advantages.

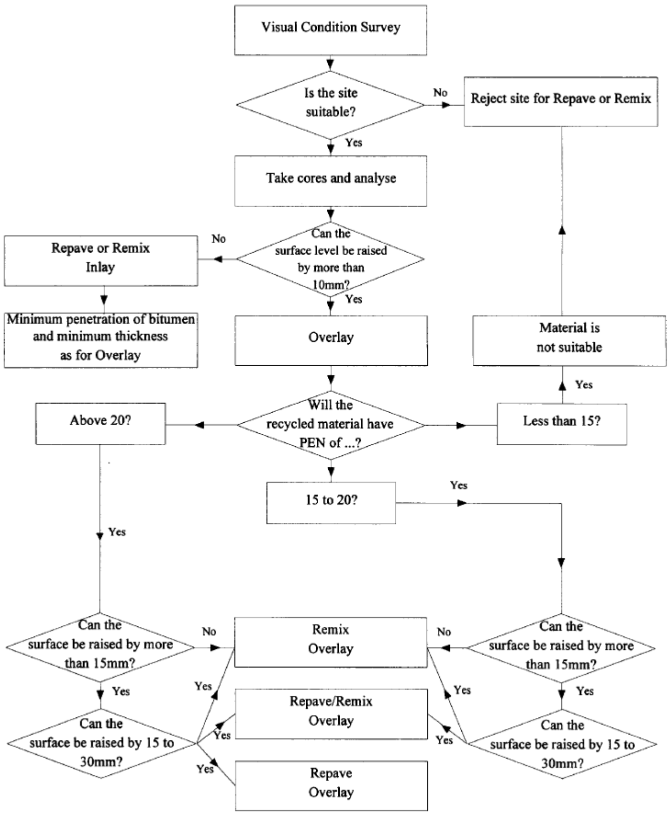


Figure 4 Selection Process for Repave/Remix and Overlay/Inlay (HD 31/94)

CASE STUDIES

Repave hot in-situ recycling was adopted during the resurfacing work at Blackpool airport runway. The work involved heating and scarifying the top 30mm of the existing Marshall Asphalt (MA), addition of 20-30mm thickness new MA and followed by a single pass compaction. URS carried out assessment of the materials recovered from this work. Samples of material before and after treatment were tested and the test results suggest that the good mechanical properties of the new composite layer at least similar to or better than that of the new (added) material. The results also showed that the interface between the existing and the new added MA was well bonded, as shown by the LST bond strength being greater than 0.8 MPa.

Repave was also adopted on taxiways Bravo and Echo at Isle of Man airport, where only small strength increase or non structural treatment was required. The Repave recycling process involved reheating and scarifying the existing pavement surface, followed by adding a new thin (30mm) layer of French Airfield Asphalt Concrete (BBA, Béton Bitumineux pour Chaussées Aéronautiques) (without the need for tack coat) and subsequently applying compaction on both layers at the same time. Saving to the environment was achieved by minimising asphalt planings that otherwise might have to go to landfill and by reducing import of new materials (being construction on an island this was a major cost saving). Using Repave on airfield and runway refurbishments shows that Repave can perform greatly and to the same standard and quality as conventional methods.

To take it further, the process was used on the slip road of a motorway in November 2010 and in September 2011 the first ever project on a UK motorway carriageway was completed. 14,300 m^2 of the M57 north of Manchester were resurfaced with the HA convinced that it was not only an environmentally friendly process that can save money but also one that can perform under the high volume of traffic of a motorway using Clause 942 surface course material on top of the Repave process. 9000m^2 of the UK main motorway M1between junction 35A and 36 was also resurfaced using this technique in spring 2012 (TransPro, 2012)

Another case study carried out by Colas in 2011 showed that the process will in normal circumstances show significant cost savings which is currently the main focal point for all local authorities (Troeger and Widyatmoko, 2012). Repave completed 33,000m2 on the A64 Melton Bypass in March 2011 resurfacing a worn out and partly cracked surface course. The HA originally planned to carry out these works in two phases due to budgetary restrictions but was pleasantly surprised by the fact that, by using the Repave process, it was actually able to complete the whole project in one phase with the same budget that was available. Counting all aspects into the equation such as process cost, traffic management and lining it was found that Repave would be 37% cheaper than a conventional method and could deliver it 20% quicker on top of this.

Table 1 Achieved savings on the HA Repave project A64 Melton Bypass

	Unit	Conventional	Repave	Savings	
Planings off site	Ton	3099.28	1549.64	1549.64	50%
Material to site	Ton	3507.08	1712.76	1794.32	51%
Lorry Movements	No	331	164	167	51%
Duration	Nights	10	8	2	20%
CO_2 Emissions	Ton	275.2	173.7	101.5	37%
Energy	GJ	4226.7	2589.1	1637.6	39%
Cost (based on 17,737m^2)	£	404,340	252,722	151,618	37%

RETREAD

Retread is a cold process involving the pulverization of the existing road construction to a specified depth in order to produce a uniformly graded material. Normally, the surfacing layers are milled or pulverised to a depth of approximately 75mm, broken up, levelled, a bitumen emulsion is applied together with some virgin aggregates to further improve the grading, reharrowed and rolled before completing it with a surface dressing layer. Further application of surface course treatments can be used to suit the traffic loading.

This process is also often referred to as Linear Quarrying as the primary sources of the material for this process is the one recovered during Retread recycling process, although a little portion of new aggregates are often added to correct the grading and target density. This may be considered a cost effective solution to recycle and reuse distressed asphalt surface course in urban and rural sites, on footway and lightly trafficked roads (DMRB HD 31/94).

CASE STUDIES

The economic and environmental advantage of Retread was assessed during a footway renewal contract along the A1400 in Woodford, north London and the findings were compared with a more conventional process (AsPro, 2008). Colas Environmental Calculator (EC) software was used to measure the carbon footprint, energy consumption and greenhouse gas emissions of any type of pavement reconstruction or surfacing process, from the data input on the binder and aggregate used, manufacturing process, transport and laying. As it is reported in Tables 2a and 2b, a reduction of 40% on all CO_2 emissions and a usage of 40% less energy during the project when compared with traditional reconstruction methods were found. Due to the recycling of the existing materials in-situ, the lorry movements were reduced by 70%. The conventional reconstruction method adopted comprised: plane off and disposal of 75mm of existing surface, relay with 55mm DBM binder course and 20mm of dense surface course. In conclusion, it was reported that the Retread process saved time, reducing congestion and delays.

Table 2a Environmental savings calculated by Colas Ltd (Energy Consumption, MJ/m^2)

Structure	Binder heating	Aggregates heating	Asphalt mixture manufacture	Asphalt mixture transport	Asphalt mixture laying	Retread equipment	Total
75mm DBM	40.7	9.6	48.0	25.5	9.5	-	133.2
55mm Retread + 20 mm DBM	31.0	3.2	13.0	10.1	6.7	16.4	80.5
				Savings total			52.7
				Savings			39.6 %

Table 2b Environmental savings calculated by Colas Ltd (GHG Emission in Equivalent CO_2, kg/m^2)

Structure	Binder heating	Aggregates heating	Asphalt mixture manufacture	Asphalt mixture transport	Asphalt mixture laying	Retread equipment	Total
75 mm DBM	2.39	0.35	3.69	1.07	0.73	-	8.23
55mm Retread + 20 mm DBM	1.74	0.12	1.00	0.36	0.43	1.23	4.87
					Savings total		6720 kg
					Savings		40. 8 %

In 2008, a separate assessment was carried out by URS on Retread materials recovered from 11 relatively low HGV trafficked roads in Leeds having been in service for 1 to 7 years. The Retread materials constructed during the 1997 – 2005 period, tested in as received condition (i.e. with the surface treatment) showed relatively high variations in air voids but with comparable performance with respect to stiffness, i.e. in the 630MPa – 1050MPa range. The recovered binder data showed that binder hardening occurred at a greater rate during the first 4 years in service and then stabilised during the next 6 years in service. Some deviations from the expected changes in binder properties in service (decrease in penetration, increase in softening point and increase in stiffness) were observed for the Retread materials constructed in 2006 and 2007, consistent with the different mineral aggregate gradings. Overall, these results suggest that the Retread process has been able to restore the mechanical properties and the profile of distressed surface course, providing an extended life to the surfacing of lightly trafficked roads.

DEEP RECYCLING

Deep recycling makes use of aggregate from the existing pavement and mixes it with additional binders to produce a material with different properties to the original layer. In-situ recycling could be more cost effective when the reclaimed materials are sufficiently uniform and meet the volume required to carry out the construction. On the other hand, ex-situ recycling may offer better production control where there is a large variation in the reclaimed materials and/or requirements for size adjustment (screening) and/or additional aggregates. For each option, various stabilising agents (i.e. 'the binder') can be added to the recycled materials during the recycling process, improving the strength and consequently the load-carrying capacity of the pavement, the durability and the resistance to moisture. This recycling process can be used during major maintenance activities or weathering and address potential weaknesses that may occur deeper in the pavement, as the presence of severe deformation and rutting, together with cracking and potholing.

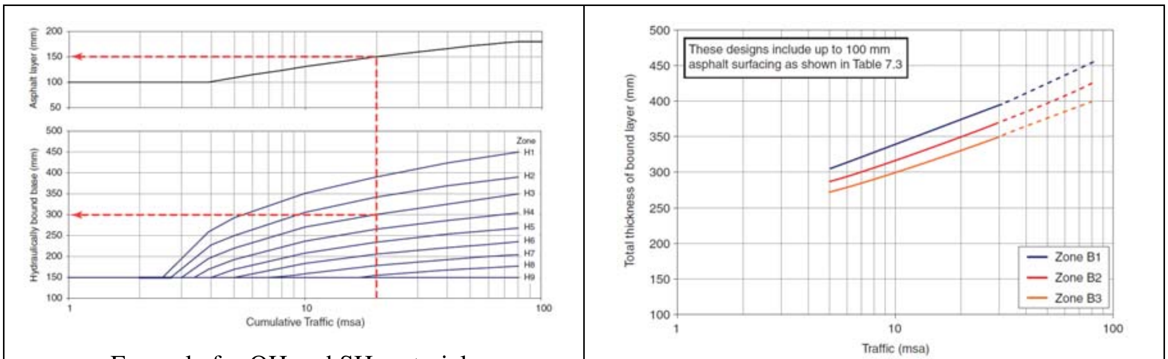
Over a decade ago, the UK HA, Local Highway Authorities (LHA), Colas and TRL completed a 3 year research programme, involving deep recycling and monitoring of nine trial sites incorporating cement bound and foamed bitumen bound recycled materials. Findings from this research were published as TRL 386 (Milton and Earland, 1999). Their work subsequently led to the introduction of new classifications of cold recycled materials and their respective design guides; these were based upon three distinct material families namely fully hydraulically bound, fully viscoelastically bound and quasi-hydraulic-viscoelastically bound materials, published in TRL Report 611 (Merrill et al, 2004). These new families were further classified according to the primary binder type and their rate of curing, specifically:

- Quick hydraulic (QH) with hydraulic only binder(s) including Portland Cement;
- Slow hydraulic (SH) with hydraulic only binder(s) excluding Portland Cement;
- Quick viscoelastic (QVE) with bituminous and hydraulic binder(s) including Portland Cement;
- Slow viscoelastic (SVE) with bituminous only or, bituminous and hydraulic binder(s) excluding Portland Cement.

The above research projects have led to the recent update of SHW Clause 947 and Clause 948, presenting a number of options for in-situ and ex-situ recycled bound materials respectively. For in-situ recycling, Clause 948 only covers the use of QVE and SVE binders.

In TRL Report 611, the foundation design suggested by Milton and Earland (1999) was taken forward and was enhanced to accommodate higher design traffic (an increase by extrapolation from 20 to 80 msa) and design charts were available for each material family:

- QH and SH materials were classified into one of nine zones (labeled H1 to H9) depending on the combination of stiffness and strength of the recycled materials. Once classified the design thickness is looked up in the appropriate design chart, as illustrated in Figure 5(left).
- QVE and SVE materials were classified into three classes (labeled as B1, B2 and B3) depending upon the minimum long term stiffness. Similar to those for QH and SH materials, the design thickness can be looked up in the appropriate design chart; an example is also shown in Figure 5(right).



Example for QH and SH materials

Example for QVE and SVE materials

Figures 5 Examples of foundation design charts for Type 2 road with Class 2 foundation, extracted from TRL Report 611

Many LHA come across the problem of dealing with tar bound material when dealing with existing pavement material. Environmental regulations request that excavated material is to be tested for these substances and any material containing more than 0.1% of tar is classified to be hazardous. In these cases the options to treat the pavement are limited. If taken off site a costly disposal at a suitable site can be chosen but licensed disposal stations charge up to £400 per tonne and a elaborate waste management is required to monitor the disposal. By using the in-situ recycling process no material is taken away and the hazardous material is encapsulated with a suitable binder avoiding any costly disposal. This complies with Environmental Agency’s regulations and is the preferred way of dealing with tarbound material.

CASE STUDIES

An operationally challenging project was carried by Colas out in November 2010 reconstructing parts of the A350 in Limber Lost near Poole, where tarbound pavement material had moved under the high volume of traffic (Figure 6). Due to the lack of strong enough roads around it to burden the traffic the road could not be closed and had therefore to be reconstructed in several phases under traffic lights conditions.

A design mix according to TRL 611 was established by choosing a Fly Ash Bound Quick Hydraulic option that was able to withstand the 5msa traffic load. Recycling to a depth of 290mm created a H2 strength class that was consequentially overlaid with 100mm of new hot asphalt.

By using the in-situ recycling process tarbound material remained on site and was dealt with within EA’s regulations. The alternative to dispose off this hazardous material would have cost the client an additional £300,000 (Troeger and Widyatmoko, 2012).

Figure 6 A350 Limber Lost, material movement due to tar contaminated pavement material

At the Isle of Man Airport, the existing asphalt material was excavated and mixed with a hydraulic binder to produce a Hydraulically Bound Material (HBM) which would perform as the new pavement base layer. This layer was subsequently overlaid by heavy duty macadam (HDM) binder course and BBA surface course. This recycling process was adopted for areas in need of structural strengthening; a summary of different recycling options topped by application of BBA surface course on the Isle of Man airport taxiways is presented in Table 3.

Table 3 Pavement Design Options and Actual Recycling Treatments (Hakim and Fergusson, 2010)

Taxiway	Conventional Design	Recycling Design	Actual Treatment Performed on Taxiway
Charlie South Delta East Delta West	Remove 160mm existing pavement materials and replace with 50mm surface course on 110mm HDM binder/base.	Remove 365mm existing pavement materials and replace with 100mm surfacing on 265mm cold recycled H1 HBM material.	Remove 365mm existing pavement materials and replace with 100mm surfacing (comprising 40mm BBA surface course on 60mm HDM binder course) on 265mm cold recycled H1 HBM material.
Foxtrot South	Remove 160mm existing pavement materials and replace with 50mm surface course on 110mm HDM binder/base.	Remove 350mm existing pavement materials and replace with 100mm surfacing on 250mm cold recycled H1 HBM material.	Remove 365mm existing pavement materials and replace with 100mm surfacing (comprising 40mm BBA surface course on 60mm HDM binder course) on 265mm cold recycled H1 HBM material.

Based upon the construction record taken from the Isle of Man project, the recycling option delivered a sustainable solution with substantial saving in cost (40%), energy consumption (44%) and carbon dioxide emissions (32%), when compared against the conventional design (i.e. planing and replacing with new materials). Breakdown details regarding these cost savings and environmental benefits have been published separately (Hakim and Fergusson, 2010).

CONCLUSION

The report shows that recycling should be considered as first option for any road maintenance issues before turning to conventional hot mix solutions. It is evident that the existing processes have been established over decades now and are not just a fashionable alternative due to environmental pressures. In times where oil resources and virgin aggregates become rarer and bitumen products become increasingly expensive local engineers and designers should opt for recycling solutions that enables them to carry out the same quality of road maintenance on a lower budget and contributing to reducing the carbon footprint of the construction industry.

REFERENCES

ARRA (2001). “Basic Asphalt Recycling Manual”, Asphalt Recycling and Reclaiming Association, US Department of Transportation, Federal Highway Administration

AsPro (2008). “Environmental Calculator proves Retread’s credentials”, Technical Paper, Asphalt Professional No 32, May.

De Bock, L., Arm, M., de Lurdes Antunes, M., Descantes, Y., Gaspar, L., Mollenhauer, K., and Thogersen. F. (2011). "Developing best practices on recycling or safe disposal of road materials in Europe – the DIRECT-MAT project", *XXIV PIARC World Road Congress*, Mexico City, 25 – 30 September.

Defence Estates (2008). "Recycled Bound Materials for Airfields", *Specification 27*, Ministry of Defence, Sutton Codfield.

Department for Transport (2008). Manual of Contract Documents for Highway Works, Specification for Highway Works, Volume 1.

Department for Transport (1994 (1998)). "Maintenance of Bituminous Roads", Design Manual for Roads and Bridges (DMRB) Volume 7: Pavement Design and Maintenance, HD31/94.

Hakim, B. and Fergusson, C. (2010). "Sustainable Pavement Construction at the Isle of Man Airport". *Asphalt Professional*, No. 46, November.

Merrill, D., Nunn, M., and Carswell, I. (2004). "A guide to the use and specification of cold recycled materials for the maintenance of road pavements", Transport Research Laboratory, TRL Report 611.

Milton, L.J., and Earland, M.G. (1999). "Design guide and specification for structural maintenance of highway pavements by cold in-situ recycling", Transport Research Laboratory, TRL Report 386.

Nicholls, J.C. (1996). "Asphalt Surfacing", published by E & FN Spon, London and New York.

Richardson, J.T.G (2010). "In Situ recycling", *Recyling & Re-using Asphalt*, SCI, London, November.

Taylor, N.H. (1978). "Life expectancy of recycled asphalt paving", *Recycling of Bituminous Pavements*, ASTM STP 662, The American Society of Testing Materials.

Taylor, N.H. (1981). "Recycling of asphalt paving in Singapore and India", *Construction Industry International Conference on Road Surfacing Recycling Technology*, Imperial College, London.

TransPro (2012), "Reputation of recycling technique boosted with M1 job". Transportation Professional. June.

Troeger, J and Widyatmoko, I. "Development in Road Recycling", 11th Annual International Conference on Pavement Engineering and Infrastructure, Liverpool, 15 – 16 February 2012. ISBN 978-0-9571804-0-6.