Foamed bitumen road recycling

by F M L Akeroyd and B J Hicks

The Authors

Maurice Akeroyd

Maurice Akeroyd graduated from Leeds University with a BSc in civil engineering. He then moved to South Africa where he worked for civil engineering contractors and the Capetown City Council roads department before joining Mobil Oil. He was responsible for starting the CAPSA conference in Durban in 1969 and has since written and presented technical papers on asphalt technology at several international conferences. Now, in addition to managing the Special Products Division at Mobil Oil, High Wycombe, he is president of the Institute of Asphalt Technology and a member of the British Road Federation technical committee.

Brian Hicks

Brian Hicks graduated in 1969 with a degree in Civil Engineering. In 1973 he qualified to become a member of the Institute of Civil Engineers.

He gained his initial experience working for contractors primarily involved in road and airport construction. Prior to establishing his own company he worked for some years with Redlands in order to gain a wider management understanding.

Road Recycling was established to specialise in low cost reconstruction. Its aim, to meet the growing demand to carry out permanent maintenance to the rapidly deteriorating urban and rural road network.

Over the years the company has expanded as the demand grows for this rapid reconstruction method. The company undertakes recycling contracts using cement, lime, bitumen emulsion or foamed bitumen depending on the existing road construction throughout the United Kingdom.

The process

The Mobil patented foamed bitumen process involves the injection of cold water under controlled conditions and with certain additives into hot penetration grade bitumen before application through specially designed nozzles and spray bar. The foamed bitumen expands from 10 to 15 times its original volume and when sprayed and mixed into cold moist aggregate a unique mixture is produced. This mix will remain soft and brown until compaction and water migration, after which it becomes harder and blacker and ultimately (in a matter of days) reaches strengths comparable with hot mix bituminous materials.

The foamed bitumen process had been used for base stabilisation (FOAMSTAB) in the USA, Australia and South Africa for many years and more recently in Norway. Based on this work and the initial work in the UK over the past two years, stabilisation and recycling using FOAMSTAB appears to have many economic environmental and engineering advantages in the UK. It has a wide range of applications from *in situ* rehabilitation of failing roads through providing new low cost asphalt bases and sub bases to stabilising waterproof working platforms for all classes of road and other paved areas.

FOAMSTAB recycling restores *in situ* the structural integrity to road pavements, is rapid in execution and permits early reopening to traffic thus minimising traffic delays. The process also conserves available resources by re-utilising existing road materials and is very energy efficient.

Surprisingly high base stiffnesses equivalent to those of normal hot mixes have been measured by the Marshall test and in the University of Nottingham's repetitive loading apparatus. Falling Weight Deflectometer measurements of the initial trial sections have also given *in situ* stiffnesses similar to those measured for DBM with 200 pen bitumen.

The final wearing surface should be applied immediately in the form of surface dressing for light traffic or hot mix for heavier traffic but FOAMSTAB bases can also be opened to light traffic within hours of compaction using a temporary surface of emulsion spray and 'bitgrit'.

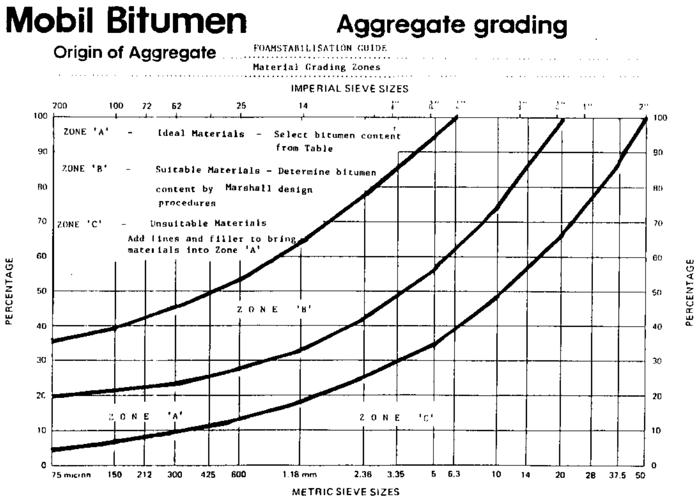


Figure 1

Use in the UK

The first UK FOAMSTAB trials were in East Sussex and Kent in 1986 and subsequently Mobil has undertaken an extensive laboratory testing and field investigation programme in order to develop a rational design method. In 1987 a successful commercial programme was completed in Kent, East Sussex, Grampian and Shropshire, including one project in Kent that was supported and monitored by the Energy Efficiency Office. Details are given in Table 1.

Site investigation

Before any FOAMSTAB project goes ahead or is tendered for, a full site materials and traffic evaluation must be undertaken to obtain the following information essential for accurate design:

1. Thickness, type and grading (after crushing) and uniformity of the existing road pavement layers from surface to subgrade.
2. A measured traffic count of commercial vehicles per day in one direction.
3. Subgrade CBR (measured rather than estimated) at several intervals along the road.
4. Key features e.g. steep hill, sharp bend, lane width, intersections etc.
5. Construction limitations, e.g. underground services depths, ironwork that cannot be temporarily lowered or covered below recycling depth, will the road be closed or will it be single alternate lane traffic, local residents' requirements etc.

In the early work in the UK the few problems that have occurred have generally been associated with unknown weak subgrade conditions and an impatience to open to traffic too quickly, (i.e. in less than 24 hours after compaction).

Materials

The existing material's suitability for FOAMSTAB can first be checked by reference to the Aggregate Grading Chart, Fig.1. Materials whose grading after pulverising falls in Zone A have from experience and analysis proved suitable for FOAMSTAB. Zone B are fine graded materials which can be successfully stabilised as long as any clay fractions are modified by treatment with hydrated lime. Zone C are coarse materials lacking in fines and can only be used if selected fine material is added to bring the grading within Zone A.

A critical aspect of the grading is the amount passing the 75 micron sieve that is NOT clay. At least 5% and not more than 20% passing 75 micron are the recommended limits for acceptable FOAMSTAB. Where clay is present the addition of 1.0% of hydrated lime is very effective in reducing its influence.

Bitumen

The bitumen contents required for FOAMSTAB are generally proportional to the percentage mass passing the 75 micron sieve, and as a guide vary from 3.5% for materials with 5% passing the 75 micron to 5.0% for materials with 20% passing the 75 micron sieve size. Ideally a full mix design including Marshall Stability, Flow and Quotient, Immersion Strength and Voids in the Mix at various bitumen contents should be undertaken.

The optimum bitumen content is not as clearly defined in FOAMSTAB as in hot mix and good strengths can be obtained over a wide range of bitumen contents. Hence it is not as critical to be accurate with bitumen content and 3.75% ±0.75% would be a typical spec. Normally 200 pen bitumen is the basis of the special foamable bitumen and although other grades can be used it is rarely necessary. Existing bitumen in old recycled material is not considered to be totally active and is only partially included in the total bitumen content. A key element of the tests is measuring Marshall Stability after Immersion in water for 24 hours at 60°C to simulate performance in saturated ground. A Stability after Immersion of at least 3.5kN and Marshall Quotients greater than 1.5kN/mm are current acceptance criteria.

Pavement design

The surfacing and FOAMSTAB base thicknesses recommended in Table 2 were derived from DTp's HD14/87 *Structural Design of new Pavements* and TRRL Report LR1132 by increasing the stipulated bituminous base thicknesses by 25% to allow for the greater variability in thickness resulting from the *in situ* method, the possibility of lesser compaction at the underside of the FOAMSTAB layer and the lower initial strength at opening. Table 2 lists these designs. The above thicknesses assume that beneath the FOAMSTAB layer there is a substantial and stable subgrade.

Where the subgrade is weak it may be feasible to remove the overlying materials and stabilise the top 150mm of the subgrade with lime, then put back the material for foamstabilisation.

AUTHORITY	LOCATION	TRAFFIC	DEPTH	BITUMEN	LIME	GRANITE DUST
East Sussex C.C.	Bishops Lane Robertsbridge	Rural	125mm 150mm	3.5% 4.0%	– –	– –
Gravesham B.C. Kent	Valley Drive Gravesend	Urban	200mm	3.5%	–	–
East Sussex C.C.	Freezeland Rd/Bexhill Dorset Road/Bexhill Eversley Rd/Bexhill Pebsham Lane/Bexhill	Rural Urban Urban Urban	200mm 200mm 200mm 200mm	4.0% 4.0% 4.0% 4.0%	– – – –	– – – –
Grampian R.C.	A941 Elgin	Rural	200mm	2.0%	–	20%
Shropshire C.C.	Moss Lane/Whixall	Rural	200mm	3.0%	–	20%
Rochester upon Medway C.C., Kent	Knight Road/Strood Priory Road/Strood	2160 cv/d 2160 cv/d	300mm 300mm	4.0% 4.0%	1% 1%	– –
Dartford B.C., Kent (Energy Efficiency Office Project)	Lunedale Road/Dartford	130 cv/d	150mm	3.5%	1%	–
Swale B.C. Kent	Roman Road/Faversham Park Road/Sittingbourne	Urban Urban	150mm 140mm	4.2% 4.1%	1% 1%	– –
Dartford B.C. Kent	Park Road/Dartford	1000 cv/d	300mm	4.0%	1%	–

Table 1 Foamstab recycling sites 1986-1987

Commercial Vehicles in one direction – cv/d	Surfacing (Thickness in mm)	FOAMSTAB (Thickness in mm)
Up to 20	Surface Dressing	150
20 – 100	40 Wearing Course	150
100 – 200	40 + 60 Basecourse	150
200 – 300	100	180
300 – 400	100	200
400 – 500	100	210
500 – 600	100	225
600 – 800	100	250
800 – 1000	100	275
1000 – 1250	100	300

Table 2 Foamstab Pavement Designs

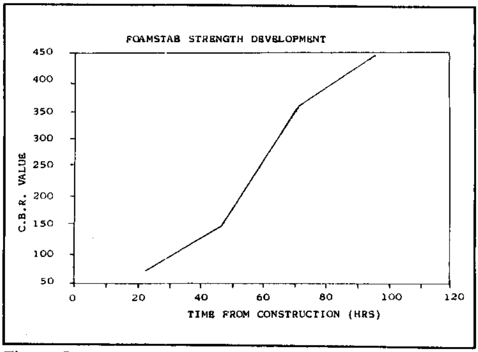


Figure 2

Construction

The specialist plant that contractor Road Recycling Ltd employs is a modified Bomag MPH100R Recycler. The machine has an on-board bitumen circulating system from which it is fed along a spray bar into expansion chambers which provide controlled conditions for the hot bitumen and the water to mix and foam. The plant is fully computerised to ensure accurate measurements of bitumen and water.

The MPH100R Recycler can work to depths of up to 350mm in a single layer effectively pulversing together the blacktop, (if not recoverable) the roadbase and the sub base layers. The blended material after a single pass usually has a grading similar to that of Type 2 material with a maximum 50mm stone size.

To date most FOAMSTAB layers have been 150mm and 200mm thick but 300mm layers have been successfully processed and compacted in a single layer on two very heavily trafficked road projects.

After initial pulverisation samples are taken and tested to establish the grading and uniformity of the prepared layer and if it does not fall into 'Zone A' of Figure 1, suitable fine material is imported and added to the layer before the foamed bitumen is added.

The specially converted bitumen tanker is coupled up to the MPH100R and the bitumen is circulated through the system at a temperature of ±165°C. Water from the Recycler's on-board tanks is injected into the stream of bitumen at each nozzle on the spray bar system creating foam. This foam is sprayed into the machine hood where the vigorous mixing process together with the expanded foam bitumen ensures intimate mixing of the finest material.

The treated layer is then shaped to the designed road profile by grader and thoroughly compacted. Whilst vibratory rollers are good for deep compaction they should be used without vibration for the early passes until the layer integrity is obtained. Should the processed layer craze or appear unstable it can be reprocessed (without adding further bitumen) and left uncompacted to lose moisture if the weather conditions are favourable. It can then be recompacted up to 1 or 2 days later. When thick layers of up to 300mm are recycled it is more difficult to get complete compaction to the full depth of the layer than it is with hot mixed asphalt. The right roller and the right technique then becomes critical.

Following satisfactory compaction the surface can be opened to light traffic on a temporary 'bitgrit' surface until the final wearing surface is constructed. Densities are preferably measured with a nuclear gauge because in the early days after processing, FOAMSTAB may not be sufficiently cohesive to full depth to provide a smooth uniform core. Before opening to traffic the client and contractor must agree that compaction and stability are adequate to carry the initial traffic, particularly if it is heavy and concentrated on one side of the road. If in doubt about initial stability,

continued on page 45

continued from page 43

it is better not to open to traffic because FOAMSTAB continually gains strength as it cures and even one extra day results in a large improvement, as indicated in Figure 2.

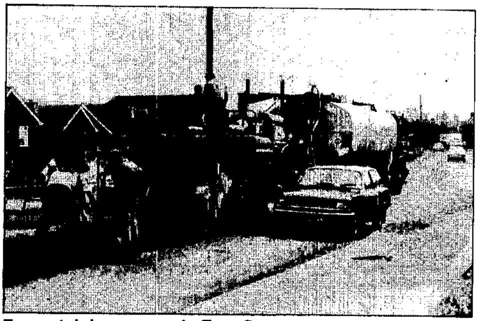
FOAMSTAB is an *in situ* recycling process of existing materials and as such the tolerances for quality control must of necessity be wider than those required for traditional methods. The following are believed to be realistic and achievable and should result in satisfactory performances:

Layer Thickness — ±20mm

Surface Finish — ±10mm

Bitumen Content — ±0.75%

Density — 93% Refusal Density.



Foamstab in process in East Sussex

Energy Efficiency

The greatly reduced consumption of energy for reconstruction by the FOAMSTAB process has attracted the attention and financial support of the Energy Efficiency Office of the Department of Energy. Their demonstration project in Dartford, Kent is being monitored by W S Atkins and TRRL for the EEO. Some typical energy usage is given (right) assuming 200yd by 5yd wide sections, with the base bitumen and surfacing common to both. The calculations are based on the Asphalt Institute's publication *Energy Requirements for Roadway Pavements*— 'IS173' (in old units).

Traditional Construction	**BTU's × 10^6 per 1000 sq. yd**
Excavate, load and haul away 21" of old road	100
Process, haul and lay new 13" sub base	59
Process, haul and lay new 8" hot mix base	224
TOTAL:	**383**

Foamstab	
Pulverise existing materials in situ	23
Load and haul away 4" to allow for surfacing	16
FOAMSTAB and compact 10" existing material	6
TOTAL	**45**

Energy consumption for FOAMSTAB recycling in this example is only 12% of that required for traditional reconstruction methods. In addition, the delays to traffic are usually only 30% of the delays associated with traditional reconstruction methods and hence these are further substantial savings in traffic energy use which have not been included.

Conclusion

FOAMSTAB is a flexible tolerant bituminous material and whilst its processing is a specialist operation it is relatively easy to ensure success provided design and construction follow good engineering principles.

The National Road Condition Survey is showing a gradual worsening of road structural condition in the UK, particularly on non-trunk roads and hence there is a great need for a low cost, rapid and low energy solution to rehabilitate many miles of county and urban roads.

FOAMSTAB could be the most significant breakthrough in value for money road rehabilitation ever introduced into the UK because experience so far suggests that reconstruction costs can be as low as half that of traditional methods, traffic delays only a third and energy consumption only a tenth. Its success to date is very encouraging for the future but obviously continuing experience is necessary to evaluate fully its potential.