LONG-TERM PERFORMANCE OF LOCAL GOVERNMENT ROAD PAVEMENTS RECYCLED BY CEMENT STABILISATION

J.R. Hodgkinson[1]
Senior Engineer, Roads and Pavements
Cement & Concrete Association of Australia

SUMMARY

The long-term performance of Local Government roads recycled by cement stabilisation in the period up to 1975 is presented. Based on longevity and costs the recycling process is shown to have a service life of at least 75% at a cost of 35-50% that of new construction or reconstruction. The recycling process provides a valuable tool to Local Government in the management of road assets.

1 INTRODUCTION

Within the Australian public road system, and as a proportion of the national road network, very little in the way of new roads are being built by road authorities. This is equally the case for Local Government as for State governments. Even in housing estates the local Authority usually receives the road by a dedication process rather than building the roads.

Accordingly at a national level the contemporary and future emphasis is on maintenance, rehabilitation and upgrading Attention is being directed to matters such as asset management and pavement management systems. With funds generally not increasing in real terms the effectiveness with which available funds are allocated is important.

As a road asset management tool the process of recycling old or deteriorating flexible road pavements by cement stabilisation has been used by Local Government in Australia for about 25 years. Over the last decade or so approximately 60 Local Government Authorities have used this process.

A brief discussion of technical and operational aspects of the recycling process is presented. With the accumulation of experience since about 170, the paper concentrates on the long-term performance of Local Government roads which have been recycled by virtue of recorded experience in four States. The performance is evaluated in terms of the cost and longevity of the recycled pavements compared with expectations of a new or fully reconstructed flexible pavement.

[1] Paper from 6th National Local Government Engineering Conference, Hobart, August1991, Page 90.

2 THE RECYCLING PROCESS

Old Local Government streets may be paved and sealed full-width or have a central sealed section with unsealed shoulders. In addition to solutions involving complete reconstruction or routine patching and resurfacing, there are many instances where the existing pavement material has sufficient 'residual competence' to allow its reuse by cement stabilisation. The pavement recycling process is described in detail in References 1 and 2.

All the existing surfacing and base materials are pulverised and then stabilised. The pavement is then trimmed and compacted and a new surface applied.

The recycling process has two key advantages:

- It minimises interference to existing surface levels and underground services. The process provides a fast reinstatement of the road and does not normally require the pavement to be closed to traffic overnight. The pavement is reopened to general traffic at the end of the working day. Even during the course of the work access to properties or commercial premises is maintained, with only temporary discomfort.

- The existing material is reused. Very little, if any, material needs to be removed from the work site. Other than small quantities of material to correct surface cross-falls, the only new material required is the cement. The recycling process thus conserves the diminishing supplies of quarry resources for other uses.

The process has considerable flexibility with regard to utilisation of resources. The work can be carried out n a comprehensive basis by specialised contracting firms who can complete all of the necessary work.

As an alternative an authority can call for the specialised work to be done by contract and the water cart, grader, and compaction plant supplied from Council resources as a means of maintaining local employment.

3 TECHNICAL AND OPERATIONAL CRITERIA

It is an axiom that no two civil engineering projects are identical. This same axiom applies to the roads and particularly many Local Government roads which have been built up and improved over many years. Technical guidelines have been developed to take into account the condition and suitability of old pavement materials.

3.1 Material Suitability

Provided that the existing material has a maximum aggregate size not exceeding 40 mm and is reasonable uniformly graded with at least 50% by weight of granular material, ie material retained on a 425-micron sieve, and with a plasticity index (PI) not exceeding about 20, it is likely to be suited to recycling by cement stabilisation. This material should be present for about 80% of the thickness to be stabilised in trafficked lanes and 60% in the case of shoulders.

3.2 Strength Criteria

When evaluating material for recycling by stabilisation, the material is usually evaluated as a cement 'modified' rather than cement 'bound' material. The material remains fundamentally a 'flexible' material. This is discussed in Reference 2 and in NAASRA (Ref.3).

The most commonly used and convenient strength criterion for cement-stabilised materials used in recycling programmes is the unconfined compressive strength (UCS). Compressive strength by itself has little if any direct relationship to pavement performance. However, experience has shown that UCS testing yields cement contents which have been shown to correlate very closely with those which give good field performance.

By reference to successful experience since about 1970 by a range of State and Local Government road authorities a UCS value in the range of 1.5-2.0 MPa is a suitable criteria for the cement-content determination of a modified material for pavement recycling.

3.3 Cement Types and Contents

The range of materials which are successfully used for stabilising granular pavement materials includes: -portland cement; fly ash; and ground, granulated-iron, blast-furnace slag (referred to as stag). Fly ash and slag may be used as a constituent of blended cement. Blended cements are being increasingly used as they provide a more economical binder cost and the effect of flyash and slag allow longer working times.

For materials which are essentially granular cement contents of 34% are most commonly used. Where a higher clay/fines content is present, as in the case of unsealed shoulders a higher cement content of 46% may be needed.

Successful recycling programmes usually involve a cyclical pattern of laboratory testing, field performance and evaluation. Until experience has been gained with particular pavements and existing pavement materials in particular locality, a laboratory testing programme is usually undertaken.

The question is often asked as to the suitability of lime stabilisation. In essentially granular materials lime will provide a short-term benefit but not a long-term benefit and is generally not used. This is discussed more fully in reference 4.

3.4 Investigation

To maximise the performance and economic benefits of a pavement rehabilitation it is important to undertake a detailed investigation of the existing pavement. When commencing initial rehabilitation activities in urban, residential or light-industrial areas, Local Government authorities with successful experience using this process have also benefited from a small pilot programme, including a trial pavement under field conditions, to verity or indicate the need for modifications to laboratory-determined design values.

3.5 Construction - Purpose Built Equipment

The construction consists of scarifying and preparation of the materials to be stabilised, spreading and mixing of cement and water, and the compaction, shaping and curing of the stabilised layer. The same degree of field control is required with stabilisation as with conventional road construction methods.

It is essential that purpose-built equipment is specified and used whenever possible. This means the use of purpose-built cement-spreading and mixing equipment. Details of contemporary mix-in-place equipment are given in reference 5.

Except in small or constricted areas, the use of agricultural hoes or of grader-blade or grader-tyne mixing is not recommended. The accuracy and thoroughness of mixing using these implements are not likely to produce accurate or uniform mixing which is essential for good performance in trafficked public roads.

Experience has shown that the best results are obtained when the various items of construction plant are closely coordinated. The equipment should be arranged in a closely located 'train'. The spreading plant (subject to testing for spread rate) should be closely followed by the mixing plant. The compaction equipment should follow closely behind the mixing plant.

4 EVALUATION OF LONG-TERM PERFORMANCE OF RECYCLED PAVEMENTS

Although records are limited on a national basis there is evidence in Queensland, NSW, Victoria and South Australia that pavement recycling by cement stabilisation commenced during the mid-1960s. In NSW in particular there was a massive increase in its use during the period 1970-1975 which continues. There is a similar but somewhat less extensive activity in Victoria which commenced at the same time. During the 1980s recycling began to see increased use in Queensland, principally in Brisbane, and South Australia.

Two factors are used in this paper to evaluate long term performance. cost and longevity. The predominant pavement in Local Government in Australia is a flexible pavement using either natural or crushed material as the basecourse with various combinations of bituminous seal and asphaltic concrete surfaces. It is this type of pavement which serves as the basis for comparative evaluation.

In terms of longevity the concept of the 'design life' or design period is used. NAASRA (Ref.6) defines the design period as the length of time expressed in years before it is anticipated that rehabilitation of the pavement is necessary to restore shape or provide additional pavement strength. Resurfacing with a spayed seal or thin asphalt does not constitute rehabilitation. NAASRA suggests typical design periods for granular pavements as 20-25 years. ARRB (Ref.7) suggests a range of suitable design periods from 10-30 years with a mean value of about 20 years.

Accordingly this paper adopts a 20-year design period as the basis for evaluating the performance of stabilised recycled pavements.

5 PERFORMANCE LONGEVITY

5.1 General

Performance data has been obtained from Councils and specialist stabilisation companies in four states; New South Wales, Queensland, Victoria and South Australia. For reasons which will be explained later in this paper data was obtained basically in and before the period 1972-1975.

5.2 Queensland

Brisbane City Council has records of existing streets being stabilised during the late 1960s in the suburbs of Zilimere and Chermside. The subgrades in both localities is clay. The pavement basecourses were constructed from a decomposed granite material. The streets were of a mixture of residential-light business and commercial-industrial usage. Due to criteria in use at that time a cement content of 6% by volume was used. The depth of stabilisation was 150 mm. 'Rotomill' and 'P & H' stabilising machines were used. Rather than performing as a cement modified material the pavement has taken on the characteristic of a lean concrete.

Despite some cracking and the renewal of the surfacing these pavements are still very sound.

Since 1981 the same Council has recycled about 115 km of street by cement stabilisation (Ref.8). The depth of stabilisation has been 150-200 mm and the cement content typically 4% by weight. Benkelman Beam studies taken before and after stabilisation show average reductions of about 50% and meet target guidelines with only minor exceptions.

Based on trials in the late 1960s and their current good condition and the results of stabilisation programmes in the 1980s (Ref.8), Brisbane City Council considers that a typical life expectancy of at least 20 years can be achieved.

5.3 New South Wales

Extensive data have been obtained from three Councils in the Western Sydney Region. Fairfield, Bankstown and Blacktown Cities. Taken together it has been estimated that about 600 streets with a total area of about 2,000,000 m^2 have been recycled by cement stabilisation since about 1970.

Of relevance to this paper the following data has been obtained for the period 1972-1975 from Council and Contractor files:

FAIRFIELD CITY COUNCIL

Year	Road Sections Stabilised	Area (m^2)
1972	20	47,150
1973	17	49,005
1974	17	26,624
1975	31	70,437
Total	**85**	**193,216**

BANKSTOWN CITY COUNCIL

Year	Road Sections Stabilised	Area (m^2)
1972	11	27,152
1973	47	96,261
1974	42	68,832
1975	25	53,994
Total	**125**	**246,239**

BLACKTOWN CITY

Year	Road Sections Stabilised	Area (m^2)
1974	2	2,280
1975	25	84,702
Total	**27**	**86,982**

This represents 237 separate sections of road totalling 526 437 m^2 over the period 1972-1975.

There are many similarities between the roads in these three cities; they all have clay subgrades; the depth of stabilisation (which was usually close to the full existing pavement depth) was typically 150 mm; in the central carriageways cement contents were mainly 4% with an appreciable number stabilised with 3%; the stabilisation was carried out universally by the same company using P & H stabilising plant (Ref.5).

In many of the Bankstown City roads the areas stabilised were shoulders. Due to the lesser quality of the existing material the cement contents for these areas were frequently 6%. A detailed discussion of the recycling activities of Bankstown City Council is set out in reference 9.

Most of these roads were provided with bitumen seals at the time of stabilisation. As these initial seals have worn they have been overlain by either a further seal or asphalt, depending on the requirements of individual roads.

Quite clearly in an inventory of this size there will be a range of traffic conditions, existing pavement variability and hence serviceability. In terms of pavement longevity after stabilisation the following comments have been provided.

In the cases of Bankstown and Fairfield the number of roads stabilised during the period 1972-1975 which have suffered distress requiring maintenance have been minimal.

This of course excludes the replacement of bituminous surfacing. Due to industrial and residential development growth some of the roads have been rebuilt or considerably thickened to cater for expected future traffic loads. However the stabilised areas themselves are usually not distressed. The numbers of roads which have pavements which could be assessed as being still in a sound condition have been estimated to exceed 95%.

In Blacktown City the first stabilisation programme in 1974-1975 met with mixed results. Many of the roads which were stabilised were in a condition much worse than would now be considered suitable for stabilisation due to the wet condition of the subgrade and in many cases only a minimal pavement thickness, in some cases only 75 mm of granular material. These particular roads were stabilised as a low cost 'holding' operation pending full reconstruction. Some of these showed immediate distress but many nonetheless survived 10-12 years. However of this initial 1974-75 programme it has been estimated that better than 70% are still in a sound condition. With improved experience since 1975 the percentage of survivability is now over 80% (Ref.10).

Although slightly later than the period considered in this paper, Benkelman Beam deflection studies were made in 12 streets recycled in Blacktown in the period 1975-1977.

At the 85th percentile-level, average reductions of 46% in before-after deflections were observed in residential streets, some catering for local distributor bus services. Before and after deflections in these streets were generally in the range 2-3 mm (before) and 1-2 mm (after).

5.4 South Australia

Although not considered exhaustive, Payneham, Woodville, Noaliunga and Marion City Councils have all reported pavements which were stabilised either in the late 1960s or early 1970s which are still in good condition.

In Payneham at least six streets are known to have been stabilised in this period (Ref.11). The pavements contain about 150 mm of quarry supplied dolomitic rubble. In keeping with practice in that period the cement contents were higher than used today and were typically 6%. This introduced some cracking in the pavement. Despite these cracks and replacement surfacing the pavements have generally not lost shape or acceptable recycling quality.

At Noarlunga available records have indicated that three residential streets which were stabilised in the mid 1960s are currently in ground condition. Again they were stabilised with 6% cement, the existing material being a low-average quality crushed rock material. At the present time further streets are being recycled. With improved techniques and the experience of earlier work, a life expectancy of at least 20 years is considered achievable.

In Woodville at least 16 streets with a total stabilised area of 26,500 m^2 were recycled during the 1 960s. The earliest of these was stabilised in 1961. The depth of stabilisation was typically 125 mm with a cement content of 4%. These streets are still in sound condition.

6 COST PERFORMANCE

Many case studies and papers are available indicating the cost performance of local government roads recycled by cement stabilisation and of particular importance the relativity of the cost of recycling with that of full reconstruction using a replacement flexible pavement.

Brisbane City Council (Ref.8) has reported recent costs as follows; stabilisation only - $4.50 per m^2; cost of stabilisation plus 50 mm asphalt surfacing - $12.90 per m^2; cost of reconstruction - $27 per m^2. This represents a recycling cost (with new surfacing) of 48% that of reconstruction.

In the Sydney Region, Blacktown City (Ref.10) recently reported stabilisation costs in the range $4.60-$5.00 per m^2. Combined with a two-coat seal, total recycling cost in the range $7.50-8.50 per m^2 represents 30-35% of the cost of reconstruction.

The rural Shire of Buln Buln in Victoria has undertaken a series of pavement recycling programmes since the mid-1980s (Ref.12). The cost of the stabilisation and a new bituminous seal surfacing is typically $12 per m^2 compared with $29 per m^2 for the alternative of total reconstruction, that is 42% of the cost of reconstruction.

Recent recycling operations in the City of Keilor near Melbourne (Ref.13) showed the cost of stabilisation and a new surface to be about 35% that of full reconstruction.

All of the above cost refer to pavements stabilised to depths in the range of 150-200 mm with 3 or 4% cement.

With a spread of urban and rural applications in these States the general order of cost of pavement recycling by cement stabilisation with a new surfacing is 35-50% that of the alternative of reconstruction.

7 DISCUSSION OF PERFORMANCE RESULTS

Repeating the axiom that no two road projects are identical and allowing for variability in regional conditions and cost, it is possible to draw together the cost and longevity of recycled pavements as an alternative to reconstruction.

Based on a wide range of experience up to 1975, there is a very high probability of pavements which have been recycled by cement stabilisation surviving for periods well in excess of 15 years without further significant pavement maintenance. This represents a long-term performance better than 75% of typical expectations of new or fully reconstructed flexible pavements.

The cost of the recycled pavements including a new surfacing has been shown by current experience to be 35-50% that of full reconstruction. Therefore in overview, as an alternative to total reconstruction of Local Government flexible pavements, the recycling process offers at least 15 years or 75% of the life at a cost less than 50%.

The data presented is up to 1975. It is known that the usage of the cement stabilisation recycling process has accelerated considerably since that time. With the continued observation of roads recycled in the period 1970-1975 and the growing inventory since then, it is highly likely that a further update of the information in this paper in another 3-5 years would demonstrate an increase in the life expectancy of recycled roads.

In the introduction to this paper, the growing emphasis on rehabilitation rather than new construction in the Australian road network was outlined. Coupled with this is a growing trend to limit the annual increase in the availability of funds for roadworks in real terms.

Therefore, in terms of asset management, road infrastructure renewal and pavement management systems, the favourable cost and long-term performance of the recycling process become significant. Those funds which are available can be extended to improve two-three times the length of road which would be possible by reconstruction. Combined with the speed of the process and the lack of interruption of access to residential and commercial premises, this particular recycling process can provide a powerful asset management tool for local government.

8 CONCLUSIONS

Local Government roads recycled by cement stabilisation have good long-term performance with a high probability of longevity exceeding 75% of the normal expectations of a new or reconstructed flexible pavement.

With a cost of 35-50% of that of full reconstruction the economic performance of the recycling process is very favourable.

The technology of pavement recycling is now well established and documented within the Local Government.

With a combination of established technology, favourable costs and good long-term performance, the recycling process provides a valuable tool to Local Government engineers in asset management and pavement management systems for the Local Government road network in Australia.

9 ACKNOWLEDGMENTS

The author wishes to thank those Local Government Engineers in Brisbane, Fairfield, Bankstown, Blacktown, Buln Buln, Keilor, Payneham, Woodville, Noarlunga and Marion Councils together with the engineers at Road Stabilisers (Victoria) and BORAL-Stabilex (Sydney) who have provided information and made available records to help in the preparation of this paper.

The conclusions drawn are those of the author and should not be referenced or attributed as specific policies of any of these Local Government bodies.

10 REFERENCES

1 Hodgkinson J R *Recycling Urban Flexible Pavements By Cement Stabilisation* Proc. 2nd National Conference on Local Government, Brisbane, 1983.

2 *Recycling Pavements by Cement Stabilisation* Cement and Concrete Association of Australia T37, 1988.

3 National Association of Australia State Road Authorities *Guide to Stabilisation in Roadworks* 1986.

4 Metcalf JB *Principles and Applications of Cement and Lime Stabilisation* Australian Road Research Board ARR No. 49, 1977.

5 *Stabilisation Plant Operating is Australia* Cement and Concrete Association of Australia, Road Note 15, 1981.

6 National Association of Australia State Road Authority *A Guide to the Structural Design of Road Pavements* 1987.

7 Mulholland *P J A Structural Design Guide for Flexible Residential Street Pavements* Australian Road Research Board, Special Report No 41, 1989.

8 Tan B T *Process Approach to Insitu Cement Stabilisation as a Method of Rehabilitation of Failed Pavements* Proc 5th National Conference on Local Government, Sydney 1989.

9 *Bankstown City Council - A Review of 10 Years of Recycling Streets by Cement Stabilisation* Cement and Concrete Association of Australia, Road Note 14, 1981.

10 *A Councils' Experience with Stabilisation* Earthmover and Civil Contractor, September 1987.

11 Amey D J *Performance of Cement Stabilised Pavements in Payneham, South Australia* Cement and Concrete Association of Australia, Technical Report 1987.

12 Tabensky W *Rejuvenating Roads - Stretching the Dollar A Councils Experience (In Pavement Recycling)* Proc 15th Australian Road Research Board Conference Darwin, August 1990.

13 *Pavement Recycling in the City of Keilor* Cement and Concrete Association of Australia, Road Note 26, 1987.