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Long Term Performance of MESL Road Sections in Australia

Essais de comportement de longue durée des chaussées MESL en Australie

Two pavement sections installed in 1974 in main roads in Australia, using the MESL method (basecourse material wholly enclosed in a geotextile) have been monitored ever since for their performance under traffic. This paper describes that performance over 7 years, giving information on the durability and performance of an MESL. The effectiveness of the design procedure, which had novel theoretical aspects, is also demonstrated.
The geotextile, whose upper surface is buried only 100 mm below the road surface, remains in excellent condition. Though the soil within each MESL was of lower than standard basecourse quality, both sections have performed extremely well, in one case so far better than the control sections that the latter have required reconstruction, whilst no distress is apparent in the MESL. The stress-strain characteristics of the geotextile appear to have conferred a degree of resilience under heavy traffic, since no appreciable permanent deformation was measured. The implications of these field trials for future practice are discussed

On a mesuré le comportement, depuis 1974, de deux sections de chaussée construites en Australie, selon la méthode MESL (une couche de base entièrement enveloppée d'un textile). Ce rapport donne des détails de ce comportement, et de la durabilité de ces sections MESL. L'efficacité de la méthode du dessin, qui a des éléments théoriques nouveaux, est aussi demontrée.
Le textile, dont la surface supérieure n'est emplacée que cent mm au dessous de la surface de la route, reste encore dans un état excellent. Tous les deux sections ont rendues un comportement très supérieur, en dépit d'une qualité inférieure de la couche de base dedans le MESL. Ce comportement fut si nettement supérieur à l'un des deux sites, qu'il faut reconstruire aujourd'hui à cet endroit les contrôles non-MESL, tandis que le MESL n'a souffrit jusqu'encore aucun défaut. Il paraît que le textile ait donné une certaine elasticité à la chaussée sous le traffic lourd, puisqu'on ne peut trouver aucune déformation permanente. On discute ensuite les implications de ces essais in situ pour la pratique future.

1. INTRODUCTION

The MESL (Membrane Encapsulated Soil Layer) concept has been successfully used in many short term field trials (for a full historical account, see Lawson(1)), and has been judged one of the most useful and practical concepts for future soil stabilization (Bell,(2)).

But because robust and durable geotextiles for civil engineering work have become available commercially at competitive prices only in the last decade, results of long term field trials of such materials have not yet appeared in the scientific literature.

This point is especially important considering that the organic nature of commercial geotextiles has frequently exposed them to criticism on the grounds of durability. As is well known, the durability of construction material is one of the most difficult parameters to measure, since no accelerated weathering test is able to simulate exactly the very complex field conditions which may be encountered.

This report therefore is thought to represent one of the first long term field appraisals, under normal service conditions, of an MESL (or its individual plastic layers) in a road pavement. Two test sections, with different subgrade and traffic patterns, have been intermittently monitored over a period of 7 years: equal to 50% of the current normal life expectancy* of a flexible pavement in Australia (12 to 15 years).

* i.e., to major maintenance: overlay, reconstruction, etc, Though the design life is usually reckoned for 20 years, this is not achieved in practice due to underestimated traffic growth, environmental factors, etc.

The test sections, described presently, were designed according to new principles particularly suited to semi-arid zones; but which are also relevant in other areas - e.g. frost regions - by appropriate adaptation of the design method. These principles were enunciated by Ingles (3) at the 1st International Conference on Geotextiles.

2. DISCUSSION

To provide adequate long term performance, the membrane itself must remain in a stable condition and must continue to perform its required functions throughout the design life of the pavement structure.

It has long been recognised that geotextiles incorporated in a road pavement may exert

(i) *a separation function*# - preventing loss of coarse material into finer, improving the compactability of superimposed layers, etc.
(ii) *a reinforcement function* - increasing tensile strength in unbound layers, inhibiting shear and cracking failures, etc.

Though we are well aware that this latter function has been challenged by proponents of the "analytical approach" to pavement design (e.g. Harrison & Gerrard (4); Brown, Brodrick & Pappin (5)), field performance has failed to

\# This function can sometimes be utilised as a *filtration* function, provided the pore sizes in the geotextile are controlled to allow the passage of liquid water and the retention of soil particles.

support* such analyses because, we believe, of defects in the modelling which assumes that only low strains are allowable - an overdesign situation quite inappropriate to these materials.

Much less well recognised, except in drainage applications, has been their potential role in

(iii) *a permeability control function.*

As pointed out by Ingles & Lawson (6), and Ingles (3), this role assumes paramount importance in regions of intermittent, seasonal, or sparse rainfall (and, by extension, of seasonal frost, etc.). In such conditions it is not essential that the geotextile be impermeable, only that its pore sizes be sufficiently small that water transfer is by vapor phase rather than by bulk flow.

For road pavements incorporating MESL's, the membrane imparts improved pavement performance by utilising these 3 basic membrane functions - boundary separations of distinct soil layers (the separation function), suppression of crack propagation (a form of reinforcement function), and control of moisture movements in the pavement.

The membrane encapsulating a soil acts as a separator, preventing intermixing of the surrounding soils with the encapsulated soil. This can be of particular benefit at the *underside* of the MESL if the encapsulated soil layer is constructed directly on top of a highly moisture-susceptible (strengthwise) subgrade (e.g. silts and clays). If the moisture-susceptible subgrade is prone to severe wetting during periods of excess moisture, then the bottom membrane of the MESL will prevent migration (under traffic) of the subgrade material into the encapsulated soil layer. Such migration causes premature pavement failure. To act as a separator over a long period of time, the membrane must have the required stress/strain properties which will render it immune to damage during installation, and that caused by traffic stresses. The pore sizes of the membrane must also be small enough to control soil particle migration.

The membrane may also act to prevent the migration of cracks through both bound and unbound materials in contact with it. This could be of advantage at the underside of the MESL if the subgrade was subject to volume change; but more than likely be of most advantage at the *top* of the MESL where the upper membrane could inhibit the propagation of cracks in the surface layers of the pavement, caused by horizontal stress components of the traffic loading. For maximum crack propagation suppression in the upper pavement layers, it is important for the membrane to be placed at the underside of the layer of material to be protected. To control the propagation of cracks it is important for the membrane to behave in an elastic manner and to be robust enough to resist traffic-induced stresses. Another important requirement is for the membrane to be bonded adequately to the surrounding material so as to minimise membrane slippage.

The use of membranes to control the flow of moisture has also long been recognised. However, the requirements for a water-repellancy function have tended to concentrate on the realisation of highly impermeable characteristics (e.g. plastic liners). Less well recognised has been the potential for commercial geotextiles to be utilised for moisture *control.*

To control moisture movement (both liquid and vapor) it is essential that the wetting pressure (sometimes termed water head support) of the membrane remains greater than the water pressures in the surrounding soil. When this condition is observed, water vapor movements are the only moisture flows which can occur across the boundaries of the membrane.

The rate at which water vapor migrates across the boundaries of a membrane can be determined by the use of Fick's Law:

$$\frac{\partial w}{\partial t} = K.A.\frac{\partial c}{\partial x} \qquad (1)$$

where, $\frac{\partial w}{\partial t}$ is the rate of water vapor diffused (by weight)

$\frac{\partial c}{\partial x}$ is the vapor pressure gradient acting across the membrane

A is the surface area of the membrane

K is a diffusion constant for the membrane

The diffusion constant K is a measure of the rate at which water vapor permeates through the membrane, and is termed the membrane *permeance*# (as distinct from membrane permeability, k, which determines the flow of bulk (liquid) water).

The degree of water vapor migration control required of a membrane in an MESL pavement may be determined using the following relationship (assuming that moisture can penetrate the MESL from all directions):-

$$K = \frac{(w_{t_n} - w_{t_o}).\gamma_d.H}{2(t_n - t_o).\Delta c.F} \qquad (2)$$

where, $(w_{t_n} - w_{t_o})$ is the allowable moisture content change in the MESL over the time period $(t_n - t_o)$

γ_d is the dry density of the MESL

H is the thickness of the MESL in the pavement

Δc is the mean vapor pressure difference across the membrane during time $(t_n - t_o)$

F is a safety factor (normally equal to 2)

Since commercially available geotextiles very rarely exhibit wetting pressures greater than 80 mm, it is normally necessary (for design purposes) to apply an inert filler compound to the geotextile to ensure that the wetting pressure of the membrane remains greater than the external water pressures, and to control the migration of water vapor. Relatively small additions of inert filler compounds (saturants) are required to reduce significantly the permeance of the geotextiles, as is shown in Figure 1.

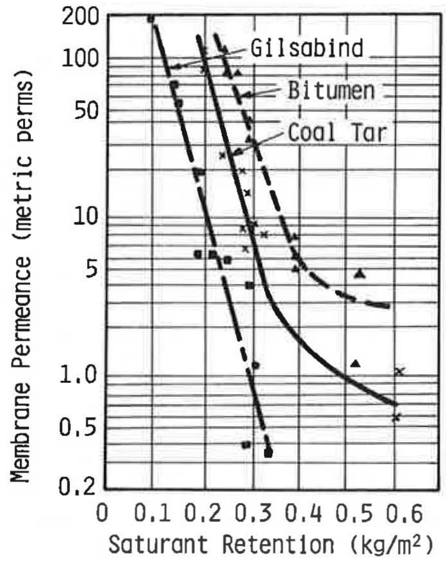

Figure 1 : Relationship between Membrane Permeance and Saturant Retention Weight for an impregnated 140 g/m^2 Melt-bonded Non-woven Geotextile (after Lawson (7)).

* cf. Ingles & Lawson (6)

\# An A.S.T.M. standard test exists for the measurement of the constant K - A.S.T.M. E96, 1966.

If the maximum duration time for saturated conditions external to the MESL can be calculated from climatic records, the foregoing equation (2) can be used to calculate the geotextile permeance required to reduce moisture changes within the MESL below any chosen level. The saturation technique makes reductions of geotextile permeance by more than 2 orders of magnitude relatively easy (see Fig. 1).

During the dry season following saturation of a soil, the moisture content within an MESL will again fall. The role of the geotextile is thus to reduce (markedly) moisture changes in the protected pavement layer. This in turn allows thickness calculations to be made, not on the basis of soaked strengths, but rather on the basis of construction moisture content strength or near thereto: with considerable economy of materials. It permits also a resistance even to totally flooded conditions within the design period; and it allows the use of otherwise inferior (i.e. non-standard) materials inside the MESL, thus increasing local resources of pavement materials. A further benefit is that compaction can be effected somewhat drier of optimum, using heavier rollers, giving additional strength to the pavement layer.

Fully to utilise the maximum benefit of all three membrane functions, it is important that the bottom membrane layer of the MESL be in contact with the top of the subgrade (for possible separation benefit) and the upper membrane layer of the MESL be as near the surface of the pavement as is practicable having regard for the expected traffic stresses at that level. This maximises possible crack suppression benefits.

Achieving maximum benefit from the membrane would result in the MESL forming a substantial unit of the pavement structure, with the encapsulated soil required to resist high traffic loading stresses in the upper part of the MESL. Most soils, even heavy clays, exhibit high deformation resistance when compacted (CBR's 80 - 110%) provided the ingress of moisture is controlled. Thus the extension of the MESL from subgrade level to the upper levels of the pavement should not present a problem, provided the encapsulating membrane is able to control moisture movements into and out of the encapsulated soil layer.

The principal problems involved in achieving these objectives are

(a) the lack of guidance data on thickness and placement depth for such MESL layers in a pavement,and
(b) whether the durability of the construction is comparable to that of normal pavement construction materials.

To examine these matters, two sections of MESL construction were laid in 1974 in inland Australia, on main roads, and their performance monitored intermittently since that time. Both sections carry approximately the same traffic loading in terms of standard axles (circa 240 per day), but the traffic pattern is different, being in one case 2000 v.p.d. with 5% heavy, in the other 400 v.p.d. with 35% heavy.

The performance of these MESL sections has been compared with those of control sections, constructed according to normal practice, immediately contiguous to each end of the MESL.

In one MESL section, an attempt was made to obtain information pertinent to the minimum permissible design thicknesses by tapering the MESL section to a minimum of 100 mm. (Site 2). At the other site (Site 1), the MESL section was deliberately placed across a T-junction so that any adverse influence of turning vehicles could be detected. The sections adopted are shown in Figure 2.

Both sites were subject to water infiltration into the subgrade, and possessed low CBR values even in the dry season. Subgrade properties at the two sites are shown in Table 1. It should be noted that even assuming the best (dry season) values of CBR, pavement thickness required by current Australian rules (NAASRA,(8)) is 320 mm. Though the control sections appear somewhat underdesigned by this standard, such practice has been usual in the semi-arid interior, and performance is normally found to be satisfactory because stage construction procedures mostly result in some old relict pavement material stiffening the subgrade immediately below the new pavement.

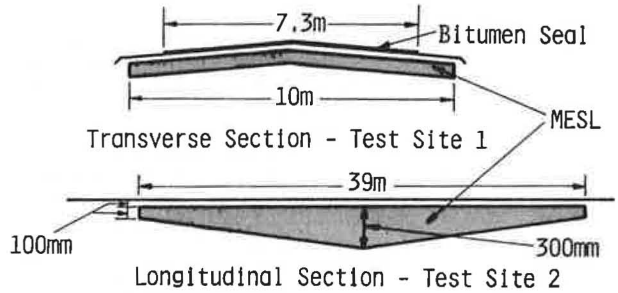

Figure 2 : Sections at Sites 1 and 2

Table 1. Test Site Soil Conditions

	Site 1 subgrade	Site 2 subgrade	Encapsulated Soil
Soil Type	MH/CH	MH/CH	GW
CBR "wet season"	4%	3%	-
CBR "dry season"	7%	7%	-
Depth of water table			
"wet season",mm	350	50	-
"dry season",mm	750	450	-
Grading			
Gravel (%)	nil	nil	51
Sand (%)	36	36	23
Silt + Clay (%)	65	62	26
Plasticity Index (%)	34	30	9
Linear Shrinkage (%)	14	14	5
Specific Gravity	2.69	2.69	2.65
Cover required (CBR = 7)	320 mm	320 mm	-
Cover provided (control)	300 mm	200 mm	-
(MESL)	320 mm	200 to 400 mm	-

3. PERFORMANCE OF THE TEST SITES

Monitoring at the test sites comprised detailed surface profile surveys to detect permanent deformations, Benkelmann beam deflection surveys to detect elastic strains, and moisture content measurements both within and without the MESL: together with pavement condition surveys to detect cracking, etc.; and a roughness count at each site. A photographic record has been maintained throughout.

The short term performance has been reported elsewhere (Ingles & Lawson,(6)). The surface profile measurements were pursued for some 5 years, without significant rutting being detected in either MESL (less than 5 mm maximum) and only minor rutting (5mm) found in one control section at Site 2. These results have also been reported elsewhere (Lawson & Brunner,(9)), with details of the measurement techniques. No measureable longitudinal movements were observed (accuracy attained, ± 0.5 mm). However, transverse movements in the surface layer, reaching to 15 mm, occurred on the low side at test site 2.

Longitudinal gradient at both sites was negligible, but the transverse gradient at site 1 averaged 1.5% and at site 2 averaged 3%. It is interesting to note that the higher gradient at site 2 corresponded with transverse movements which were greatest in the very areas where subsequent distress appeared (see Figure 3).

Of more immediate interest are the beam deflections, and the moisture content changes, as well as pavement condition changes. The two sites will be discussed separately.

At site 1 (with T-junction and uniform MESL thickness), the MESL has fulfilled its role of "smoothing-out" moisture fluctuations admirably. It remains, as at the time of construction, *drier* than the control. Deflection follows a similar pattern, showing much steadier values over the MESL section than over the controls. Though all deflections are somewhat higher than would normally be desired,# the MESL shows the better deflection. At site 1, *all* sections continue to perform very well, notwithstanding: and no signs of any type of failure (except perhaps some edge fretting along the control sections only) can be discerned.

Though these observations do not thus permit any firm conclusions to be drawn about the relative performance of the MESL and the normal construction sections (but residual life has been calculated to be three times greater in the MESL than in the northern control, on the basis of the deflection readings), they do confirm that the MESL is a durable construction under traffic, and that it does perform the envisaged design role of controlling moisture fluctuations. Despite a thickness slightly less than the NAASRA design standard, performance suggests that no section is underdesigned. This is thought to be due, at least partly, to some old pavement gravel remnants below the present basecourse : and core recoveries have suggested that a depth of 420 mm to wholly natural subgrade might apply. This would correspond reasonably well with the NAASRA design thickness requirement over CBR 4 (440 mm), which is near to the wet season value for this site.

At site 2 rather different circumstances pertain. Here the subgrade is almost permanently saturated by water seeping from irrigation trenches parallel with the road. One of these trenches is, indeed, superelevated with respect to the road. The magnitude of this effect was not wholly appreciated at the time of construction, with the result that the MESL section at this site has no significant dry-out period and has, in fact, steadily wetted up internally until a saturated or near-saturated condition applies.* This has, in turn, resulted in very high beam deflections, both over the MESL and also the controls.

Despite these adverse conditions for pavement performance, the MESL has continued to perform impeccably at site 2, and retains its original surface shape without any indications of failure at the pavement surface. The control sections have, by contrast, so far deteriorated that extensive alligator cracking was already in evidence before 1979, and necessitated extensive patching. Complete reconstruction of the control sections has now had to be scheduled, whilst the MESL remains sound. Figure 3 shows the surface condition at site 2 in November 1979, and further deterioration has followed.

Moisture content within the MESL and in the external controls at this site has now approximately equalised, and the deflections in both are accordingly similar. Hence the break-up of the control sections - chiefly due to cracking caused both by subgrade failures and transverse movements in the surface layer - can only be attributed to a *lack* of the internal confinement and shear restraint that is afforded by the MESL. Again, the long term field evidence has confirmed the excellent durability of the geotextile itself under service conditions: recovered samples showed no evidence of any deterioration after cleaning from soil and saturant (in this case, bitumen).

Wallace (10) considers that for traffic of the present type, beam readings should not exceed about 1.0 mm.

* Moisture content within the MESL is now almost 50% above optimum moisture content, due partly also to the original construction density falling below standard.

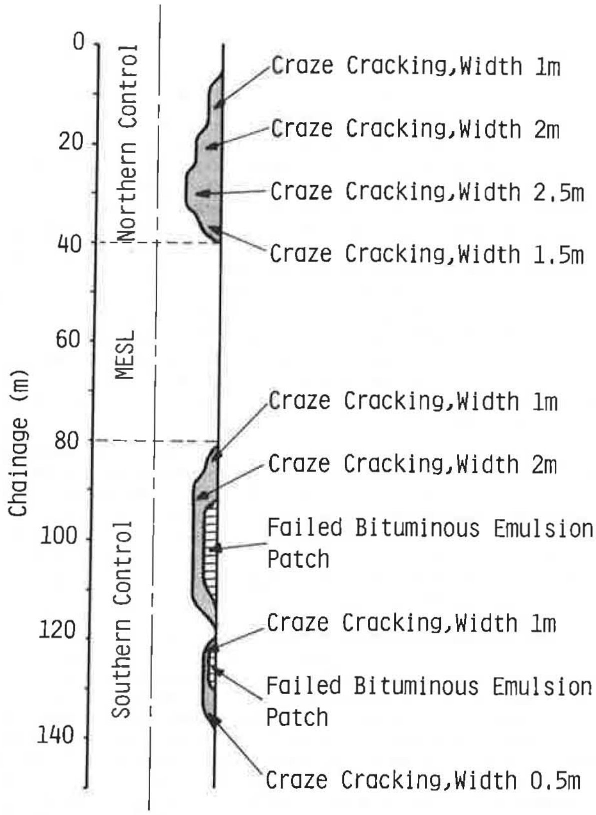

Figure 3 : Surface Condition Map at Site 2, November 1979+

Table 2 displays the moisture and deflection behaviour at the two test sites. The data suggest thata "settling-in" period of 2 - 3 months after construction may have applied for the beam deflections.

Table 2. Moisture Content and Deflection Changes at the Test Sites++

Reading Date		May 1975	Sept. 1975	Dec. 1975	May 1976	Aug. 1976	Dec. 1976	May 1979	Jan. 1982
Moisture Content# (Site 1)	control*	9.3	12.3	10.9	10.5	12.6	11.9	10.0	-
	MESL	9.4	8.4	8.6	7.6	7.4	7.7	7.0	-
Deflection** (Site 1)	control	2.2	0.8	1.8	1.0	1.3	1.9	1.6	1.0
	MESL	2.2	1.3	1.5	0.8	0.8	1.0	1.0	0.8
Moisture Content# (Site 2)	control	17.1	19.0	-	18.1	17.7	18.0	16.0	-
	MESL	10.0	13.2	-	15.0	15.0	15.5	15.8	-
Deflection** (Site 2)	control	0.8	1.3	1.0	0.8	0.8	0.9	2.3	1.5
	MESL	1.8	1.2	-	1.0	1.2	1.4	1.6	1.4

* control values averaged over both sides
# in %, dry basis.
**in mms, by Benkelmann beam

+ crack widths shown are greater than 3 mm
++ optimum moisture content of the MESL and basecourse (control) material was 11.0% (standard compaction)

4. IMPLICATIONS AND CONCLUSIONS

The performance of these MESL pavement sections has important implications for conventional pavement design procedures, inasmuch as new materials (membranes) and unsaturated soil strength parameters may be used in the design of more economical pavement structures. The MESL sections have shown that membranes perform adequately over a long period of time with no visible loss of performance due to membrane degradation or function reduction.

The degree of moisture control the encapsulating membrane exerts on the encapsulated soil enables materials which would normally be rejected because of low saturated strength parameters to be utilised as structural layers in a pavement. Particular examples of where MESL's could be used effectively are to stabilize substandard granular materials, to stabilize expansive or heavy clays, to stabilize frost susceptible soils, and to protect against pavement failure due to unforeseen "random" events (e.g. flooding).

Certain types of granular materials are considered substandard for road pavements if their saturated strength parameters are too low to support repeated traffic loads. Most of these materials have high deformation resistance provided they are kept in an unsaturated condition. The MESL can be used to control the migration of moisture into these materials, thus ensuring maintenance of the required deformation resistance. An added benefit of the MESL for this application is that if the subgrade becomes saturated then the bottom membrane layer will also act as a separator, inhibiting intermixing of subgrade and MESL soil particles and thus protecting against premature pavement failure due to loss of effective subgrade support.

Expansive and heavy clays may be used as structural pavement layers when encapsulated in a controlled permeability membrane. The membrane protects the expansive (or heavy) clay from the effects of fluctuating external moisture content changes, thus ensuring negligible volume change or cracking of the encapsulated soil. The membrane could also inhibit the propagation of cracks up through the MESL if the subgrade was also subject to fluctuating moisture conditions.

Frost susceptible soils could be encapsulated in controlled permeability membranes to ensure that critical loss of strength does not occur during the thaw period. The membrane of the MESL would inhibit the entry of water into the frost susceptible soil layer during the freeze cycle, thus preventing saturation of the MESL during the thaw. The bottom membrane layer of the MESL could also act as a separator, to prevent loss of subgrade support from the unstabilised frost susceptible subgrade during the thaw period.

Protection from random events such as flooding, could be afforded by an MESL, using a controlled permeability membrane. The membrane would inhibit the entry of excess moisture into the encapsulated pavement layer during periods of flooding. This enables the encapsulated pavement layer to remain structurally sound throughout. The membrane would also protect the encapsulated pavement layer from scour during the flood inundation.

From observations of two MESL test sites in main roads in Australia, made over a period of 7 years, corresponding to approximately 0.3×10^6 standard axles, a substantial part of the design life. It is concluded from measurements of deflection, permanent deformation, moisture changes and visual observation of the pavement surface conditions, as well as recovered sections of the geotextile, that:

(i) *no degradation* is yet observable in the geotextile membrane itself, though this thermally bonded, non woven fabric was only 0.6 mm thickness

(ii) *a strong bond* was at all times evident between the soil and the mebrane saturant. This appears to have contributed to the performance of the MESL, especially at test site 2, where crack growth was successfully inhibited only by the MESL.

(iii) *the improved performance* due to moisture control followed the expectations included in the original designs at test site 1, where deflection variations were reduced in the MESL although performance of all sections was considered adequate.

(iv) the improved performance of the MESL section at site 2 was clearly distinguishable from the controls; and this must be attributed solely to the crack suppression and separation functions of the membrane, since at this site the moisture control function was largely inoperative. It is especially notable that the MESL section tolerates, without any observable distress, what would normally be considered as excessive deflections. We attribute this to the stress-strain properties of the geotextile, and to the soil-membrane bond.

(v) it is noteworthy that no estimate of equivalence could be obtained from these trials, since even the *thinnest* MESL section (100 mm) has continued to perform impeccably for 7 years under traffic.

(vi) the new design principles adopted in these trials appear so far to be justified, and to warrant more investigation

5. ACKNOWLEDGEMENTS

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