Durability of White Thermoplastic Road Markings

Phase 1: Literature Review and Consultation

Final Report

Scottish Road Research Board

20 April 2015

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Executive summary

Over recent years Scottish roads authorities have experienced problems with regards to durability of Thermoplastic Road Markings (TRM) on their networks. These durability issues pertain particularly to the premature "wearing off" properties of the TRMs. The Scottish Road Research Board (SRRB) has therefore requested a study be undertaken to investigate the possible causes of this poor performance.

The "*Research Project Proposal*" which accompanied the tender invitation made reference to the particular issue of road markings "*often wearing off within 6 months of application*". This study therefore has concentrated solely on wear effects and the related deterioration mechanisms whereby markings "strip-off".

A two-phased approach has been proposed by the SRRB:

➔ "**Phase 1** is suggested to be a Literature Review, and an analysis of issues within the Road Maintenance Community.

➔ **Phase 2** will be dependent on the outcome of Phase 1, and could involve site trials and analysis of failure mechanisms".

This report focussed on Phase 1 only.

In summary, the key conclusions from the literature study noted that bonding of TRMs are affected by road surface characteristics, traffic volume and vehicle composition, climatic conditions, TRM thickness, material composition and various construction related issues.

Feedback from the consultation with various role players from within the industry raised the quality of the contractor and materials used, balancing cost and quality, the condition of the existing surface, programming of works, testing during and after application as well as the use of alternative procurement and performance requirements as issues that contribute to the premature failure of TRMs:

Following the literature study and the various discussions held with industry role players it is recommended that two areas be considered for further study. The first relates to undertaking material trials whereby various TRMs are evaluated with an emphasis on the material thickness (construction related issue), surface characteristics (in situ condition), moisture and temperature (construction related issue). The second relates to providing procurement requirements and performance specifications for use by Scottish Roads Authorities when procuring marking services on their networks.

1. Introduction

1.1. Background

Over recent years Scottish roads authorities have experienced problems with regards to durability of Thermoplastic Road Markings (TRMs) on their networks. These durability issues pertain particularly to the premature "wearing off" properties of the TRMs. The Scottish Road Research Board (SRRB) has therefore requested a study be undertaken to investigate the possible causes of this poor performance.

The "*LifeLines*" [Ref. 1] report which was published by the Road Safety Markings Association (RSMA) focussed attention on the standard of road markings in Scotland. The report summarised the results of retro-reflectivity surveys over 1,100km of Scotland's roads and concluded that:

- 43 per cent of markings on Transport Scotland's strategic road network need immediate replacement (or need to be scheduled for replacement).
- 62 per cent of markings on of Scotland's local authority-controlled road network dual carriageways need immediate replacement.

Retro-reflectivity is only one measure of in-service performance and there are likely to be numerous factors that have contributed towards these (unofficial) condition figures. However, to limit further deterioration and to safeguard investments made in addressing the maintenance backlog it is necessary to understand the factors which influence the long term durability of thermoplastic road markings (TRMs).

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This report focusses on Phase 1 only.

Road-markings can be deemed to "fail" under different criteria (i.e. wear/erosion, luminance, retro-reflectivity and skid resistance). The "*Research Project Proposal*" which accompanied the tender invitation made reference to the particular issue of road markings "*often wearing off within 6 months of application*". This study therefore has concentrated solely on wear effects and the related deterioration mechanisms whereby markings "strip-off" or "crumble".

1.2. Methodology

For the purpose of this desktop study we have undertaken a literature review to identify any relevant UK or international research in this field. This was an internet based study and we utilised the following resources:

- *ScienceDirect and Scopus* – leading full-text scientific databases offering millions of journal articles and book chapters from an extensive number of peer-reviewed journals and books.
- *Electronic Theses Online Service (EThOS)* – a British Library facility that offers free immediate download access to the full text of over 37,000 UK theses.
- *IHS* - an online suite of products that includes comprehensive collections of full-text publications, technical standards and an extensive range of product information.
- Common search engines.

Following the literature review, we have undertaken a consultation exercise to gauge both the scale of the perceived problem and gain from the first-hand experience and views of industry practitioners regarding potential remedies. The consultations included a Transport Scotland (TS) workshop attended by various industry role players, including members from the RSMA, as well as discussions with:

- Scottish local authorities;
- Scottish contractors responsible for maintaining local and strategic road networks in Scotland;
- A leading road marking materials supplier within Scotland (Prismo); and
- The Republic of Ireland, National Roads Agency (NRA).

2. Literature review

Various research papers and other documents were reviewed and are listed in the references of this report. Our literature review has found limited available information that specifically deals with the durability and in particular the premature wear-off of TRMs. This section discusses some of the key points that could be found from the available literature that addresses wear-off.

2.1. Thermoplastic Road Markings

TRMs are used on more than 95% of public roads in the UK since the 1950's. It was originally developed in United Kingdom (UK) between 1939 and 1944 primarily to aid motorists during "blackout" periods.

The definition of TRM paint is defined within BS EN 1871 as:

"*…a solvent-free marking substance supplied in block, granular or powder forms. It is heated to a molten state and then applied with an appropriate hand or mechanical applicator. If forms a cohesive film by cooling."*

Generally TRM material is a 100% solid, environmentally and user safe compound. TRM paints are a mixture of glass beads, pigment and filler, which are held together by a binder (plastics and resins). According to Kraton [REF.8] a typical TRM paint composition is as set out in Table 1.

Table 1: Typical thermoplastic road marking paint composition

	Range, weight %	Material
Binder (15-25%w)	8-15	Hydrocarbon resin
	1-5	Plasticizer
	0-5	Thermoplastic elastomer
Fillers (75-85%w)	5-10	Pigment (e.g. TiO_2, ZnO)
	20-40	Extender (e.g. $CaCO_3$)
	15-20	Glass Beads
	20-40	Aggregates

As its names suggests, the composition is temperature dependent and will become a liquid when the temperature is increased. TRMs are solid at ambient temperatures, and will become liquid at 200°C. They do not contain solvents and have an application speed of around 5 km/h. TRM's are generally constructed at a thickness raging between 1.5 mm and 3 mm.

Because the products are solid, they require less drying time in comparison to conventional paints and their use keeps traffic disruption to a minimum. The absence of solvent and the easier handling of waste reduce their impact on the environment.

The performance of thermoplastic road marking materials has improved significantly in recent years due to international developments in binder types. Most of these developments relate to the use of various polymers and other constituents to enhance certain properties of the road marking. However, information on performance is mostly supplied by manufacturers of these polymers; therefore it is difficult to validate the claims that are being made without independent research to back these claims.

As discussed in the introduction the wearing off performance is an area of concern to TS. The wearing off of TRMs relates to its bonding performance and hence this study has focused on the factors that contribute towards this aspect.

2.2. Key factors affecting wear performance

From literature, various factors were noted that would have an impact on the durability with regards to the bonding performance of TRMs. The major factors can generally be grouped into the following categories:

- road surface characteristics;
- traffic volume;
- climatic conditions;
- thickness;
- material composition; and
- construction related issues.

Each of the abovementioned categories play a role in the performance of TRMs.

2.2.1. Road Surface Characteristics

In general, three types of surfaces would typically be encountered in the UK, namely

- Asphalts (positive textured and negative textured);
- Pavement Quality Concrete (PQC); and
- Surface dressing.

It can be expected that road markings will perform differently on each of these surface types.

Based on the literature study it can be concluded that the three key pavement surface characteristics that affect the road marking's performance are:

- Surface texture;
- Heat sensitivity; and
- Surface porosity.

Surface Texture

Surface texture can play a major role in the way road markings perform over time. Positive textured pavement surfaces, such as surface dressings, generally lead to pavement markings having lower retroreflectivity and shorter service lives when compared to identical markings on negative textured pavement surfaces. [REF10] Figure 2-1 shows a typical TRM on new surface dressings [REF 10].

Figure 2-1 Typical TRM on new surface dressing (left). Glass beads and binder falling in between aggregates (right).

Positive textured surfaces could potentially have negative effects on TRMs. Some of these effects include:

- Lower overall reflectivity due to irregular pavement surface with a high percentage of binder and glass beads falling into the gaps between the aggregates;
- Low material adhesion on top of the aggregates. This is due to the binder that is exposed on top of the aggregate being worn off first.

The figures below illustrate examples of poor adhesion on positive textured surfaces.

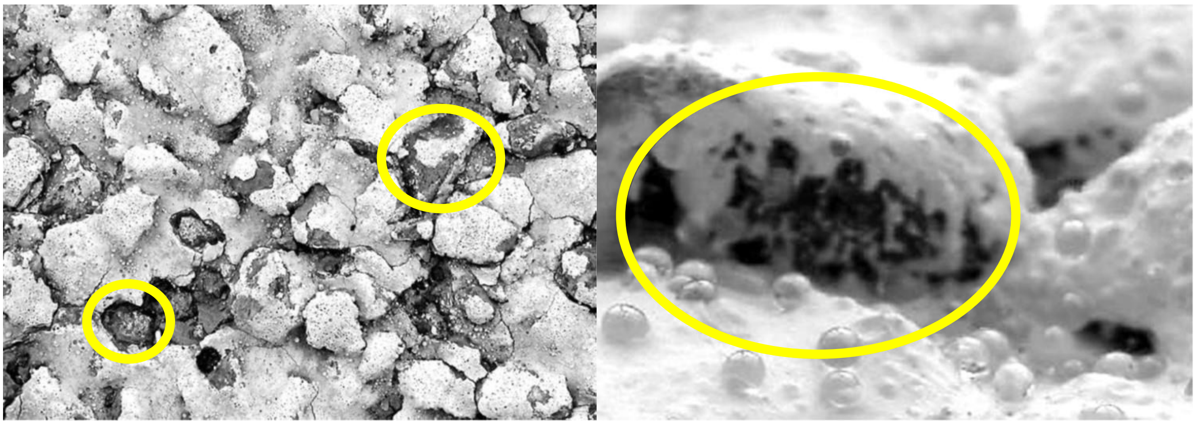

**Figure 2-2 Examples of poor material bond.
Left - on top of aggregates; Right - poor material coverage on underside of aggregate.**

Heat Sensitivity.

The heat sensitivity of a pavement surface determines the bonding characteristics between the surface and the TRMs. For typical penetration grade bituminous binder at temperatures ranging between 50°C - 60°C, asphalt behaves as a viscous liquid, which allows for thermal bonding to take place. TRMs bond to asphalt surfaces by melting and fusing with the asphalt binder.

Concrete surfaces do not bind by means of a thermal reaction to TRMs and hence a bonding agent (tack coat) will need to be applied prior to applying the TRMs.

In instances where asphalt bleeding occurs, the asphalt bitumen is often transported onto the TRMs, which causes permanent discoloration.

It is also possible for TRMs to be applied at too high temperatures, hence damaging the binder properties of the asphalt, which will affect the adhesion characteristics with the TRM.

Surface Porosity.

It has been noted within literature that the porosity of the road surface will influence the bonding characteristics of TRMs to the road surface. The TRM paint penetrates the gaps in the pavement surface and creates a mechanical bonding upon drying. It is therefore more difficult for the TRM to strip off the road surface. This will therefore require a greater rate of spread from the TRMs in order to ensure the desired material thickness is maintained.

2.2.2. Traffic volume and vehicle composition

The volume of traffic carried by the TRMs will have a strong influence on the performance of these paints in terms of its service life (bonding).

TRMs are often recommended on roadways with medium to high traffic volumes, due to its thickness (typically 1.5 mm – 3 mm) and the strong adhesion characteristics. Other road markings paints generally deteriorate much more quickly under high-traffic conditions due to being thinner.

Heavy goods vehicles (HGVs) typically wear pavement markings more quickly than do passenger vehicles. Various HGVs have different wear factors on a pavement structure due to its axle load and tyre configuration. The tyre pressure will also have an impact on the wear of the road TRM. The rate of wearing off of the TRMs will thus be affected by volume, HGV composition and tyre configuration and pressures.

The use of snow ploughs as well as other road cleaning operations (mechanical brushing) was also noted as mechanical action that TRMs may be exposed to and will lead to debonding taking place over time.

2.2.3. Climatic conditions

Throughout the literate reviewed it was clear that the climatic conditions will play a major role in the performance of temperature sensitive materials such TRMs. Two types of climatic conditions exist:

a) during construction; and
b) in-service conditions.

The climatic conditions during construction is viewed to be the most critical factor which will influence bonding performance. As discussed earlier thermoplastic road markings are temperature dependent and the bond durability will therefore be affect the fusing of the TRMs and the road pavement. The following conditions will have an impact on the bonding performance of the road marking material and should be considered prior to installation:

- Road and air temperature;
- Wind velocity;
- Moisture condition at the time of installation.

Road and air temperature will influence the drying and curing times of TRMs. Literature have indicated a poor bond will develop if road temperatures fall below 5 ˚C. [REF 9]

Wind velocity will impact the cooling of the paint as well as drying and curing times. In addition the wind speed will influence the bead spread onto the road marking. The moisture condition of the substrate will also affect the bonding characteristics. The extent of how severely the abovementioned factors influence the adhesion performance will need to be studied further. Limited information in literature could be obtained to quantify their impact on TRMs.

In service weather conditions will also have an impact on the long term performance of the road markings. Areas exposed to heavy snowfall and salt operations could potentially be exposed to more aggressive abrasive action. No studies particularly focusing on snow operations could be obtained at the time of writing.

2.2.4. Thickness

The thickness of thermoplastic road markings have throughout literature reviewed been attributed to ensuring long term bonding performance of thermoplastic road markings. Thermoplastic road markings vary in thickness between 1.5 mm and 3 mm. The general consensus is that the thicker the road marking is the longer it would last.

Inspection of marking thickness is important to ensure that the specified amount of material is being placed on the roadway. The recommended method of measuring thermoplastic thickness is by means of mechanical measurement of a sample with a needlepoint micrometer during the striping operation. Measurements should be made to the top of the binder material, excluding the bead. An example of a needlepoint micrometer is illustrated in Figure 2-3.

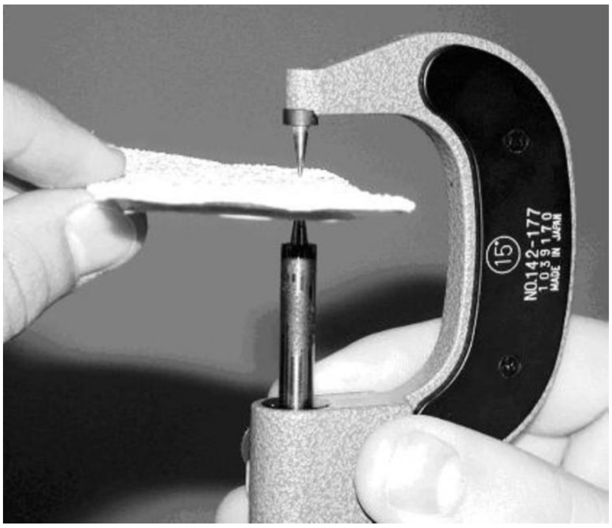

Figure 2-3 Needlepoint micro-meter used to measure a thermoplastic sample

2.2.5. Material composition

Thermoplastic road marking paints are a mixture of glass beads, pigment and filler held together by a binder. The binders of thermoplastic road markings consist typically of resins which could be mixed with a plasticizer to reduce the brittle nature of the resin. These resin binders provides the flexibility and bond strength while holding all the components together.

The amount and type of binder used within the formulation of the road marking paint would inter alia affect the bond and wear performance of the TRM.

The introduction of BS EN 1436 has removed previous restrictions on the composition of road markings and has provided manufacturers more freedom with regards to the materials they would intend to use, as long as it meets the required performance requirements.

BS EN 1436 specifies the performance for road users of white and yellow road markings, as expressed by their reflection in daylight or under road lighting, retroreflection in vehicle headlamp illumination, colour and skid resistance.

The requirements specified within the BS EN 1436 relate to the performance of road markings during their functional life. In order to ensure a durable product that would not debond, it would be recommended that the contract specification defines the functional life required applicable for the particular project.

It has been reported [REF 7] that Alkyd type TRMs have become more popular in recent years over hydrocarbon type TRMs. Alkyd TRM is made from wood-derived resins, whereas Hydrocarbon TRM is made from petroleum-derived resins. It has been reported that Alkyd TRMs has better resistance to petroleum products like engine oil and is less oil-soluble than the hydrocarbon type thermoplastic. The alkyd type thermoplastic is less oil-soluble than the hydrocarbon type thermoplastic. Hardened alkyd TRM has stronger cohesion bonding properties than hydrocarbon thermoplastic. This reduces the chance on formation of a sticky surface that may easily attract dirt from its surroundings. Therefore, alkyd type thermoplastic is often preferred to be used in dusty environments, e.g. in urban area. The differences and uses of these two types of materials are provided in Table 2. [REF 7].

Table 2: Recommendation on the Usage of Alkyl and Hydrocarbon Thermoplastic Materials.

Type of Thermoplastic Material	Merits	Drawbacks	Recommended Usage
Alkyd	More resistance to petroleum products	Cost is slightly higher than hydrocarbon type thermoplastics. Material may be more easily discoloured due to overheating.	Must be used on roads which are not high speed roads.
Hydrocarbon	Cost is generally lower than Alkyl type thermoplastics. Overheating has less effect on the colour of the material.	Material can be softened by petroleum and attracts dirt more easily.	More appropriate for use on high speed roads.

2.2.6. Construction related issues

Literature [REF 7,9 & 10] reviewed also noted the following:

- TRMs should not be held above 200 ˚C for more than six hours;
- TRMs should not be heated above 230 ˚C;
- TRMs should not be reheated more than three times;
- TRMs must be protected from traffic until fully set. Markings being trafficked prior to setting will be deformed. Un-beaded markings coming into contact with tyres while still warm and will draw carbon black and road grime from tyres.
- The road surface before applying the markings should be clean and dry. Oil and dust must be removed. Application of thermoplastic road markings on wet (or incompletely cured) or dusty road surfaces may induce early detachment of the material or the formation of air bubbles at the surface of the road markings;
- Moisture tests need to be conducted prior to application;
- Substrate should be prepared by hand / mechanical brushing or use of high velocity / high pressure air blowing to remove loose paint, dust and dirt;
- Preparation of the surface by applying a gas flame prior to applying the road marking could have a detrimental effect on the bituminous binder's ability to effectively bonding to the TRM;
- Road surface needs to be smooth and free of objects / shape changes that may affect the travel of the screed box (machine applied);
- The storage time for the powdered form of TRMs must not exceed the limit as recommended by the manufacturers (e.g. a maximum storage period of 6 months is a very common criterion).
- Screed forming. This method refers to the hand applied method of road marking, principally involving a laying barrow and hand moulds with jugs and buckets for pouring. In very general terms the material is laid between 180 and 190 degrees centigrade. [REF 17].
- Spray marking. This is air pressure applied using a lorry mounted machine or a smaller buggy/cart machine. General applied at around 210 ˚C. This provides a thin coating of thermoplastic material. The spray head is adjusted to achieve differing widths and it is possible to lay thicker by adjusting the

pressure and driving more slowly. By definition this is not as hard wearing as screed, but should be more cost effective. [REF 17]

- Extrusion – Applied using a lorry mounted machine or a small buggy/cart using an auger or pump. This in effect drops the line on to the road at preset thicknesses and widths and is laid at a similar temperature to screed. Most commonly used for new surfaces and surface dressing. Only consider using for the recovery of existing lines if the surface is totally clean and free of dust. Not advisable to use between October and March. [REF 17]
- Ribline – Applied by lorry mounted machine or a small buggy/cart, laying a base line and specifically spaced raised ribs in one continuous process. The raised ribs act as a sensory indication to the motorist along with providing better retro reflectivity in wet conditions. Laying temperature is lower at around 165 ˚C to allow for formation of the ribs. [REF 17]

Comparisons between the performances in bond strength of manual screeding and that of machine applied operations from literature was limited. This would be recommended as an area for further study during trials.

3. Industry feedback

3.1. Transport Scotland Workshop

Atkins attended a workshop on 7 October 2014 held at Transport Scotland's offices. This workshop was held to discuss the performance of TRMs in the UK and in particular Scotland. Presentations were delivered by George Lee, from the Road Safety Markings Association (RSMA) and John Lloyd from the Road Safety Surfacing Association (RSSA). George Lee presented the topic on road markings, while John Lloyd conducted a presentation on high friction surfacing.

Some of the key topics from RSMA presentation and subsequent discussions surrounding road markings are briefly discussed in this section.

3.1.1. Quality

The topic of quality was divided into two areas, namely the contractor quality and the quality of the material. Contractor quality is governed by the National Highway Sector Scheme as well as RSMA member standards. Material quality standards are governed by a range of European standards (BS EN).

The importance of quality management systems (QMS), management responsibility, measurement, analysis and improvement were discussed. It was also noted that all RSMA members are required to be registered under the National Highway Sector Scheme 7, have a QMS as well as a signed training commitment.

3.1.2. Consistency

On the topic of consistency it was discussed that specifications should be used that are understood by all parties, as this creates a clear understanding of what is expected of the product that will be constructed. The importance of effective work programming as well as clear performance measures were also noted as key contributing factors to ensure consistency in the product that will be delivered.

3.1.3. Quality versus cost

It was noted that in order to ensure that the intended benefit to the road used is achieved, a balance needs to be struck between quality and cost. In order to do so a contract mechanism needs to be in place that will ensure this balance is achieved.

The importance of quality (contractor and material), specification (understood by all parties) and end product measurement was also discussed as key contributing factors to achieve this balance.

3.1.4. Monitoring of the road marking condition

The importance that monitoring plays to ensure a quality product is achieved was also discussed. It was noted that the use of consistent, mutually agreed monitoring procedures together with the use of benchmark surveys are important to achieve a consistent product outcome.

3.1.5. Republic of Ireland experience

It was noted that the Republic of Ireland has moved towards a performance based specification with a guarantee covering material durability, reflectivity, skid resistance, luminance and chromaticity. With regards to the retro-reflectivity after installation, a 200 mcd (millicandela) requirement has been set with a minimum of 100 mcd which should be achieved after 36 months.

A payment mechanism has also been incorporated into the road marking contracts. The mechanism typically consists of 60% being paid after installation and the remaining percentages are only paid after 12 months, 24 months and 36 months upon successful demonstration of performance.

3.1.6. Group discussion

Some of the points raised during the question session were the following:

- Programming of works

  It was noted that programming of surfacing works, and in particular surface dressing, plays a role as a possible cause of premature failures of road markings. If delays in the construction of the road surfacing are experienced, this will have a knock-on effect on the road marking operation, which potentially would have to be performed during the colder and wetter months of the year.
- Condition reporting (banding) of road marking

  In the past some service providers experienced differences in the way the condition of road markings was reported (banding). It was noted that standardised condition reporting should be used for high speed asset condition assessments as well as on maintenance contracts.

3.2. Local Authorities

Telephone discussions with 4 local authorities were conducted in order to ascertain their experience of thermoplastic road markings within their network. A selection of urban, city and rural areas was made. The following local authorities were approached:

- Angus situated towards the east coast and is a mixture of towns, villages and rural areas;
- South Lanarkshire is a mixture of towns, villages and some rural areas;
- Glasgow City is a major city within Scotland; and
- Renfrewshire is a mix or urban and some rural areas.

3.2.1. Angus

Angus noted that they have experienced poor performance of TRMs over the last few years, in particular at traffic junctions and heavily trafficked areas. They have generally experienced 5 years life of their thermoplastic road marking materials and 2 years at traffic junctions. They aim to only undertake maintenance during favourable weather conditions and programme the maintenance works accordingly (late spring and summer periods). They operate on a procurement partnership model as one contractor can't do all the work and is in great demand. They aim to strike a balance between good quality whilst ensuring the Heath, Safety and Welfare of their suppliers.

They attribute the early failure of various road markings to a combination of factors:

- Poor condition of the road surface, for example ravelling of the surface course, in particular Stone Mastic Asphalt (SMA) materials;
- Road marking operation being undertaken during frosty and moist conditions;
- Heavy traffic flows at particularly junctions;
- The introduction of super single wheels onto heavy goods vehicles (HGV);
- Material formulation of road markings have changed. The volume and quality of binders (resins) used in current thermoplastics have changed.

They have not noted a change in the thickness of the road markings. They require a maximum thickness of 5 mm, due to the risk that thicker road markings pose to motorcycles.

3.2.2. South Lanarkshire

South Lanarkshire has experienced early performance issues with the TRMs used on their network. The most notable areas of poor performance have taken place at junctions and roundabouts.

They used to get 2 to 3 years life at high volume areas like junctions and roundabouts. However, this has now reduced to a few months. They make use of mostly hand laid construction operations. The road marking operations are mostly done in-house by trained and accredited maintenance operatives.

Road marking operations are generally undertaken during summer when the weather conditions are favourable. Some emergency operations have to be undertaken during other periods of the year, however this is viewed as temporary.

They attribute the key reasons for early performance issues to:

- Material quality and formulation changes;
- Condition of surface onto which the road marking is placed;
- The use of super singles on HGV's; and
- HGV's from Europe driving close to and on road markings;

They noted that the thickness of the road marking materials is difficult to measure and would not attribute the premature failures they have experienced to the thickness of the material.

3.2.3. Glasgow City

Glasgow City noted that they are generally satisfied with the condition of their road markings. The life of the road markings range typically between 2 to 5 years, with the lowest life being experienced at junctions and slow moving trafficked areas.

They make use of hot applied thermoplastic road markings. They have experimented with Methyl Methacrylate (MMA) cold applied products and have found them to have long curing and drying times for their applications.

They make use of both hand and machine applied operations, employing traffic management procedures to ensure sufficient drying times. They require that surfaces are swept and blown to ensure the surface is clear of any dustiness and no moisture or standing water is present. Painting operations are not allowed in temperatures below 6 ˚C.

They name the key reason for poor performing TRMs to the condition of the existing surface on which it is installed. They have not experienced issues with the thicknesses or changes in the material composition of the TRMs. They indicated that programming of the road marking operations during more favourable climatic conditions plays an important role in ensuring the success of the product.

3.2.4. Renfrewshire

Renfrewshire Council noted they have not experienced poor performance from TRMs. They replace the road markings every 2 years. They make use of a term maintenance contractor who applies the TRM paint by mechanical means. As part of their requirements they do not allow the contractor to undertake road marking works during wet conditions.

Based on their experience they attribute the TRM performance to the competency and experience of the road marking contractors that they make use of. According to their experience they have not seen changes in the thickness or quality of the thermoplastic road marking materials used on their network.

With regards to the programming of the road marking works they have had reasonable experience and aim to conduct road marking operations during favourable weather conditions. They do not see programming as a problem for them.

3.3. Road Marking Contractors

3.3.1. Mainline Road Markings – Glasgow

They attribute the early deterioration of TRMs to:

- The condition of the surface course and the distresses already evident within it for example joint failures, cracks and ravelling;
- The use of low cost binders within the TRMs;

- Reduction in thickness (due to material composition changes);
- Skill of the labour force; and
- Weather conditions during installation (wind, moisture, air and surface temperatures).

They recommend the use of MMA products which is a two part cold applied product with a good coverage. From their experience there should not be a difference between machine and manual applications as long as the road surface is in sound condition.

When TRMs are installed under ideal conditions on an intact surface it would be expected to last between 2 and 5 years under medium traffic volume. They note that they have experienced issues with regards to programming of the road markings works. They feel that the road marking is only an afterthought on many of the contacts and they end up having to conduct their works during the least ideal period of the year.

3.3.2. Markon – Glasgow, Scotland

Markon noted the following as key contributing factors to the potential premature failure of traditional hot applied TRMs:

- Historical shortages of resin supplies increasing prices of the products to close to double their original prices. Historically this has forced contractors to make use of lower cost resins of lower quality. It is understood that resin shortages are currently no longer in effect and hence this is not currently an issue;
- Historical weather patterns like flooding combined with snow and extremely cold spells have had adverse effects on TRMs, which are temperature sensitive;
- The quality of the end product is not tested and “policed” thoroughly enough;
- Highly skilled staff are lacking generally within the industry and those with the right skill set are over stretched (contractors, consultants and clients);
- More training, information and knowledge sharing needs to take place within the industry;
- General road condition is not good (distresses like ravelling, cracking and potholing);
- Programming: road marking takes place mostly during less than ideal climatic seasons;
- Grit being applied on top of SMA surface courses to provide adequate skid resistance, has an adverse effect on TRMs; and
- Differences in the adhesion and chemical bonding that takes place on different asphalt and concrete surfaces.

Markon noted that they would welcome end performance requirements being placed on the TRMs. They noted that their experience of the model used by the National Road Agency in the Republic of Ireland works well for all parties. The contractors work directly with the client body and not through a management consultant. Procurement options which are driven by price without enough emphasis on quality have in their experience resulted in substandard quality products being delivered.

3.4. Material supplier

3.4.1. Prismo Road Markings

The key comments noted by the supplier are:

- High performance TRMs are dependent on using binders (resins) that will ensure bond;
- The emphasis on cost rather than quality has forced contractor to purchase lower quality TRMs;

- The specification of the right product for the right application is key. They would welcome a performance based approach;
- The general condition of the road surface is a key factor in the premature debonding of TRMs;
- Correct application of the glass beads is also key to ensuring a durable end product. Over application could potentially lead to cohesion failures; and
- They feel that there is not enough emphasis on "policing" the end product.

3.5. National Roads Agency

A discussion with the National Road Agency (NRA) in Ireland was also undertaken to obtain their view on the subject matter.

The NRA noted that European Union (EU) is moving away from specifying particular material components to rather specifying an end performance. Within the United Kingdom, the Transport Research Laboratory (TRL) is often appointed to conduct testing on various materials.

The NRA have found that hot applied thermoplastic road markings works well for them on the majority of their roads. They only make use of MMA products for specific high stressed situations. The use of spray (water bound) products is generally reserved as a refreshing product on low volume roads.

For their hot applied TRMs they require a high level of performance for the first 3 years after construction of the product. Their experience and that within the EU has been that if the product lasts for 3 years it should last for 7 years.

They believe that this requirement forces the contractors to think about their approach and place a lot of attention on the quality of the material and the installation during construction. If the product is constructed during cold and damp conditions adhesion will be an issue.

The 100 mcd reflectivity requirement that is traditionally used by various road agencies after construction is not good enough in their view. Their experience has been that this generally drops to approximately 60 mcd within 3 months. The NRA has therefore taken a performance requirement approach for their roads. For national roads a 200 mcd reflectivity requirement, combined with a 3 year sliding guarantee is typically required. For non-national roads a minimum of 100 mcd with a 2 year guarantee is typically required.

Contractors are paid on a sliding scale typically consisting of:

- 60% after installation;
- 20% on initial proof of quality (typically at year end);
- 20% after 36 months.

From their experience in using the performance requirements, some of the benefits they have gained are:

- Contractors place emphasis on quality and high quality work is rewarded;
- Contractors frequently check the depth of embedment and spread of glass beads as well as material thickness;
- Contractors thoroughly clean and prepare the surface prior to installing the new road markings;
- Work is only undertaken in favourable weather conditions;
- Contractors make use of well-maintained equipment;
- Contractors make use of the best available materials (incorporating enhanced binding properties);

They have simplified their bills to incorporate items such as:

- Prepare, scabble, spray;

- Prepare, scabble, extrude;
- Brush wash and spray (rumble areas);
- Remove.

The NRA have also incorporated a testing regime to ensure that the quality of end product is achieved. They make use of a combination of independent, employer and joint testing regimes.

Some of the items worth pointing out from a typical NRA Work Requirements specification and which relate to ensuring adhesion (or durability) and reflectivity of the road markings are as follows:

- "*9. The Contractor shall not carry out any work when the weather conditions or the road conditions (e.g. dampness, dust and cold) are such that the quality of the work might be adversely affected. <u>In particular, application of markings shall not be carried out when the road temperature is less than 5°C.</u> Where the Engineer is of the opinion that such adverse conditions exists, he/she may instruct the contractor to suspend the works, but this shall not relieve the contractor of the obligation to suspend the work in the first place where such adverse weather conditions or road conditions exist. In addition, the <u>Contractor shall remove loose debris, mud and all other materials likely to affect adhesion between the thermoplastic road marking material and the road surface</u>. A mechanical suction sweeper shall be used to clean and prepare all roads, including side roads at junctions."*

- **"***Thermoplastic Road Markings under Guarantee*

  17. The minimum period of guarantee shall be for 3 years after completion of markings and shall apply to markings laid on all cement-bound and bituminous-bound road surfacings including surface dressings.

  18. All markings in this Contract shall be laid under guarantee and shall be applied to the thickness specified in the Contract.

  19. The following properties of the markings are required to be covered by the guarantee:-

  - *<u>Durability</u>*
  - *Reflectivity*
  - *Skid Resistance*
  - *Luminance Factor*
  - *Chromaticity***"**

  22. On application and during the period of guarantee, these properties, when measured in situ in an approved manner, shall not be less than the values stated below.

  Durability:

  At least 90 per cent of the marked areas shall contain a uniform coating of marking material through which the underlying surfacing has not penetrated. Discontinuities, due to wear, shall not be accepted in continuous lines and at least 75 per cent of each marked segment of a broken line shall remain intact."

  Reflectivity:

  - *R4ª ≥200 mcd/m². 1x, following application of longitudinal markings.*
  - *R3ª ≥150 mcd/m². 1x, after 24 months following application.*
  - *R2ª ≥100mcd/m². 1x, after 36 months following application.*

    when measured by the digital retroreflectometer LTL. 2000 in accordance with Annex B of IS EN 1436:1998."

4. Conclusions

4.1. Literature

In summary, the following conclusions regarding factors that could influence the bonding performance of TRMs can be drawn from literature:

4.1.1. Road surface characteristics

Various types of pavement surfaces are generally encountered within the UK. This ranges from asphalt, surface dressing to concrete. The bonding performance will differ depending on the types of surfaces encountered. It was concluded that surface texture, heat sensitivity and surface porosity will influence how effectively the TRMs will bond to the surface.

4.1.2. Traffic volume and vehicle composition

The traffic volume and vehicle composition will influence the rate at which the TRM will wear off. HGVs typically wear TRMs more quickly compared to passenger vehicles. It was concluded that the rate of wear will be affected by traffic volume, HGVs, vehicle axle configuration as well as tyre pressures. Limited information relating on how these factors influence TRMs could be obtained.

4.1.3. Climatic conditions

The literature review indicated that TRM paint is temperature sensitive and therefore the weather conditions during and after application plays a key role in the long term bonding performance of TRMs. The more critical of these two aspects is the conditions during application. Cognisance of ambient and road temperatures as well as wind speed and moisture conditions will need to be considered prior to applying TRMs. Literature noted that poor bonding may be experienced at road temperatures below 5˚C. This will need further investigation to better understand what the critical temperature ranges are.

4.1.4. Thickness

TRMs typically vary in thickness between 1.5 mm and 3 mm. The general consensus is that the thicker the road marking is the longer it would last. Measuring the thickness of TRMs is difficult and some documents reviewed make reference to the taking of samples and undertaking tests with a needlepoint micrometer.

4.1.5. Material composition

The material composition of TRMs consist of a mixture of glass beads, pigment and filler held together by a binder. The type, percentages added and the inclusion of polymers will have an influence on the bonding performance. BS EN 1436 has removed previous restrictions on the composition of road markings and has provided manufacturers more freedom with regards to the materials they intend to use, as long as it meets the performance requirements. It can be concluded that in order to ensure a durable product is used, the specific functional life and performance should be specified, rather than the actual material composition.

4.1.6. Construction related issues

Various construction related issues are known from literature to affect the bonding performance of TRMs. The key aspects noted relate to the temperatures and duration at which TRMs are kept on site prior to application. The bonding performance will be reduced by overheating of the product as well as the amount of times the product is reheated. Aging of the binder will also contribute to its long term bonding performance. The road surface condition should be clean, dry and removed of any dust and oil prior to applying the new TRM. No information could be obtained comparing the performance in bonding strength achieved from manual application compared to mechanical application. This could be a potential area of further investigation.

4.2. Industry Feedback

Discussion with various local authorities within Scotland, contractors, suppliers and the national roads agency (NRA) were undertaken and the following key aspects were noted:

1. Quality of both the contractor and the material was seen as areas that will influence the end product performance.
2. In order to ensure consistency of the end product, a clear understanding between all contracting parties needs to be established in terms of what the performance that is required is and how it will be measured.
3. It was felt that a balance should be achieved between quality and cost in order to ensure a product is delivered that meets the expectation of the road user.
4. It was noted that programming of surfacing works, and in particular surface dressing, plays a role as a possible cause of premature failures of road markings. If delays in the construction of the road surfacing are experienced, this will have a knock-on effect on the road marking operation, which potentially would have to be performed during the colder and wetter months of the year.
5. The condition of the existing road surface was noted as an area that affect the bonding performance of TRMs. Distresses like ravelling, cracking and potholing are viewed to be key surface distresses that affect TRMs.
6. Types of vehicles trafficking the material as well as their wheel configuration will affect the bonding performance.
7. The use of low quality binders in order to reduce costs has in the past affected the bonding performance.
8. Climatic conditions during and after application have an effect on the bonding performance of TRMs. Some of the role players have specific requirements with regards to the conditions whereby no road marking work could be undertaken.
9. The use of grit to improve the skid resistance of new surface construction was noted to have an adverse effect on TRMs.
10. It was noted that not enough testing is undertaken during and after construction in order to ensure the product meets the requirements set for the particular project.
11. The procurement and end product performance requirements used by the NRA in the Republic of Ireland was viewed as a good example of what works well. Extracts of these performance requirements are provided within the report.

5. Recommendations

Following the literature study and the various discussions held with industry role players it is recommended that two areas be considered for further study. The first relates to undertaking trials (combination of field and possibly laboratory) and the second relates to providing procurement requirements and performance specifications for use on the Transport Scotland network.

5.1. Material trials

It is recommended that various TRMs (applied using both manual and machine operations) be compared within the field and possibly under laboratory conditions. Similar types of traffic could then be applied to various TRM paints, where by the influence of various factors as discussed below, could be tested.

5.1.1. Material thickness

It is recommended that trials be conducted to investigate how rapidly (for example after how many axle loadings or cycles) debonding of various TRMs will occur at different material thicknesses. An indication could therefore be established for use within a performance specification with regards to what the allowed minimum thickness should be.

5.1.2. Surface characteristics

It is noted from the study that bonding performance of TRMs are influenced by the surface characteristics to which it is applied. It is recommended that trials be conducted to investigate, for a defined thickness, to what extent debonding is affected by the surface type (for example positive and negative textured asphalt surfaces, surface dressings and concrete).

5.1.3. Moisture and temperature

Moisture and temperature plays a key role in ensuring sufficient bond is achieved. It is recommended that trials be undertaken to establish to what extent bonding is influenced by dry and moist surfaces as well as over a range of temperatures typically applicable to Scotland.

5.2. Procurement requirements and performance specifications

It is recommended that procurement options as well as the use of performance specifications (of similar nature to that noted from the NRA) be considered. This would aim to ensure that a balance is found between quality and cost.

6. References

Ref.	Detail
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