Analysis of the Effectiveness of Bitumen Additives on the Performance of Surface Dressing

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ABSTRACT: Surface dressing is a maintenance technique that uses thin layers of bitumen emulsion and single sized aggregate to seal the surface of a road, protecting its substructure from water ingress. Loss of aggregate from a surface dressing is termed 'stripping' and can be a safety issue for road users. A range of additives used in bitumen have the potential to prevent stripping. This research investigates if the use of additives in the surface dressing process can improve their performance.
A range of bitumen emulsion additives were assessed on a laboratory scale to determine their suitability for the production of a bitumen emulsion. The adhesion properties of the emulsions were tested on an aggregate using the adhesion by water immersion test, Vialit plate shock test and the abrasion cohesion tests. A large scale field trial was then performed to validate the impact of the additive on the adhesion properties of the emulsion.
The additives tested were found to have a number of effects on the emulsion properties. Laboratory results demonstrated that a number of the additives had improved the adhesion properties for surface dressing emulsions. The field trial analysis of stripping, when compared to the reference section.

KEY WORDS:
Surface Dressing; Adhesion Promoters; Cationic Bitumen Emulsion; Determination of Adhesion by Water Immersion; Vialit Plate Shock Test; Abrasion Cohesion Test

1 INTRODUCTION

In 2018, a total of €417 million was provided to local authorities to supplement their expenditure for improvement and maintenance of regional and local roads [1]. Of this €417 million, €33 million was spent on restoration maintenance; this equated to 2,300 kms of Irelands roads [1]. Restoration maintenance is mainly the surface dressing programme [2]. There is approximately 95,000 km of regional and local roads in Ireland and it is recommended that a minimum of 5% (4,700 km) of these roads are surface dressed each year [3].
Surface dressing or chip seal is the process of sealing a road surface. It uses thin layers of bitumen emulsion covered with single sized aggregates or chippings. It seals and binds the surface of the road to protect its substructures from water ingress, thus prolonging the service life of new and existing pavements [4]. It also provides increased skid resistance for improved safety for road users. Surface dressing is a low cost maintenance technique and up to 80% of Irish roads are maintained in this manner.

One of the main components in the surface dressing process is the bitumen emulsion. This complex component is produced when a bitumen is milled and mixed with water. The addition of chemical emulsifiers allows the bitumen to mix with the water and thereby, remain in a liquid state at ambient temperature. One of the main benefits of using bitumen emulsion is that it can be applied to a road pavement at relatively low temperatures (60-85°C) [5]. The surface dressing process is also more cost effective when compared to hot mix asphalts, which require the bitumen and aggregate to be heated to 150°C and applied during the construction stage at these high temperatures [5]. The complex nature of the bitumen emulsion suggests that there may be an opportunity to use adhesion promoters within the bitumen to improve the performance of surface dressing applications.

The use of an adhesion agent in the bitumen emulsion, should give the surface dressing crews a better chance of achieving a durable surface dressing. On occasions where there is insufficient binder spread on the road surface, the modified bitumen emulsion should provide better adhesion with the aggregate, forming a stronger bond. Thus, the occurrence of loose chippings and striping of the aggregate from the road surface may be lessened. This would ensure that the required level of skid resistance is provided, which would in turn increase the safety of the road for all road users.

2 EXPERIMENTAL PROGRAMME

2.1 Materials

Emulsion: In Ireland, cationic bitumen emulsion are the most commonly used type of bitumen emulsion. The water and bitumen mixture that is created using an emulsifier in acidic phase is widely used throughout Ireland for the maintenance and construction of roads. One of the properties the bitumen must exhibit is a good ability to adhere to the aggregate used; this is its adhesion property. In a surface dressing, the bitumen portion of the emulsion materially interacts with the aggregate by chemical and physical forces. This adhesion forms a bond which is essential to retain the aggregate on the surface of the road. The separation of the water phase in the emulsion from the bitumen phase, is known as the "breaking" of the emulsion. The breaking properties of the emulsion are important to form a continuous binder layer that can established a maximum degree of adhesion with the aggregate.

Aggregate: The second major component in the surface dressing system is the aggregate. Single size aggregates are used for surface dressing and must comply with IS EN 13043

[6]. The most common size fractions of aggregate used for surface dressing in Ireland are between 2/6, 6/10, 10/14 and 14/16mm. The fraction size annotation comes from the lower/upper sieve size that contain the majority of the aggregate particles. It is important that the size distribution is limited to achieve a uniform surface dressing. For the purpose of this study, one quarry was used to source the aggregate. This was Roadstone's quarry located in Moyne Co. Longford, an aggregate widely used for surface dressing in Ireland. The type of aggregate used has a bearing on the adhesion properties of the emulsion [7]. Therefore, for this study the use of a single source of aggregate has eliminated the variables that can occur due to the aggregate. Bulk samples of aggregate were taken from the virgin aggregate stockpiles at Roadstone's Moyne Quarry, as per IS EN 932-2 [8]

Additives: In the context of this project the term additive describes the small quantities of chemicals added to the bitumen phase of the emulsion. The additives used during the course of this project are either amine, dimer, wax or silane based are listed in Table 1. These additives were assessed to determine if they have the effect of improving the breaking and adhesion properties of the emulsion. Emulsion testing specifications are outlined in I.S. EN 13808 [9] for the requirements of the performance characteristics associated with cationic bitumen emulsions. There are numerous different forms of additives that can be used in this process.

2.2 Laboratory Tests

In order to determine which additives were suitable for further testing in the field, a laboratory scale investigation was conducted. The investigation involved producing samples of the bitumen emulsion in the laboratory. A standard surface dressing emulsion formulation was used to produce an emulsion using the laboratory mill as a reference sample. This formulation was then modified to include one of the additive. Standard emulsion quality control tests were performed on each of these emulsion specimens. The emulsions containing additives were required to match the basic performance properties of the reference sample, before they were considered for further laboratory testing.

Emulsion properties tested include;

- Binder content, the amount of bitumen contained in the emulsion
- pH, the potential of the hydrogen ions in the emulsion
- Percent residue of bitumen remaining after sieving
- Breaking index, time taken for curing of emulsion
- Viscosity, measurement of the ability of the emulsion to flow.

Table 1: List of additives used during the project

Additives	Chemical Type	Manufacturer
CDML	Dimer	Chemoran
Corbit Adhesion	Organosilane	Orbita
CWM	Amine	Chemoran
Sasobit	Synthetic Wax	SASOL
TDC	Fatty Amidoamine	Chemoran
TPH	Alkyl-amidoamine/Polyethylene Amine	Chemoran
Trifol Wax	Wax	Trifol
Wetfix BE	Amine	Akzo Noble

2.2.1 Surface dressing tests

Any emulsion that was found to satisfy the basic emulsion quality control tests was then subject to further testing to assess their adhesion properties. For this analysis, the three tests used were those that are routinely used to assess the performance of surface dressing emulsions. The Abrasion Cohesion Test (ACTE Test) was performed using specimens of single layer surface dressing consisting of bitumen emulsion and 4/6mm aggregates applied to a disc of felt paper. Three specimens were each cured at ambient temperatures for a set period of time, either 15, 30 or 60 minutes. After curing, the specimen was subjected to abrasion by a rubber wheel for a period of one minute. The loose aggregate that was created by this abrading action was removed and the specimen with the retained chippings was weighed and recorded. The test results are expressed by the percentage of retained aggregate on the specimen.

The Vialit Plate Shock Test (EN 12272-3) [10] was performed to determine the degree of binder aggregate adhesivity as described in EN 12272-3. For this test, the required quantity of bitumen emulsion was heated to spraying temperatures (85°C) and spread evenly on a steel plate. Fifty graded aggregate chippings were then pressed into the binder. The plate with the emulsion and chippings were placed in a climatic chamber between 20 and 30°C for 24 ± 1 hour. After the curing stage, the sample plate was turned over, so that the emulsion and chippings were facing the ground. The plate was supported by three pointed spikes and a 50mm steel ball was dropped from a fixed height of 500mm three times within a 10-second period. The adhesivity value was determined by calculating the number of aggregate chippings remaining on the plate post testing.

The Determination of Adhesivity of Bituminous Emulsion by Water Immersion Test was conducted as described in EN 13614 [11] clause 8.3. Two hundred grams of aggregate (tolerance of plus or minus five grams) was washed, dried and placed into a dish. Fourteen grams of bitumen emulsion was added to a separate container, the aggregate was added and thoroughly mixed until a full coating of the aggregate was achieved. This mix was spread on a watch glass and placed in an oven at 60°C for 24 hours before being transferred to a beaker, 300ml of water was then added to the beaker before being placed in a ventilated oven at 60°C for a further 24 hours. The percentage of aggregate that remained coated with binder was visually assessed. Guidance on the resulting visual appearance was provided in EN 13614 [11] and a comparison was made between the test sample and reference sample post testing.

2.3 Field Trial

A site trial was conducted to varify the performance of the bitumen emulsion modified with one of the better performing adhesion agent. The site trial was facilitated by Colas Contracting Ltd. The surface dressing operation was performed using both the trial emulsion containing the CDML additive and a standard surface dressing emulsion (i.e. Cationic 70%) that was considered to be the reference emulsion. The site was sub-devided into 6 sections of equal area. The two emulsions were sprayed in alternate sections, with the only variable being the type of bitumen emulsion used (Figure 1 and 2). The construction process used on site was constant; the aggregate was from the same source (Roadstone Moyne Quarry) and was spread using the same equipment. The rolling process was also constant and performed in exactly the same manner for all sections of the trial site area.

In an effort to distinguish between the standard emulsion and the emulsion containing the CDML additive, the rates of spread for both emulsions were gradually decreased in a controlled incremental manner along the length of the trial site. A surface dressing design for the proposed single surface dressing was carried out and established a designed rate of spread of emulsion of 2.3 l/m². The rate of spread applicable to the site trial was decreased by 0.3 l/m² to 2.0 l/m² (for the third and fourth sections of the trial site) and again by a further 0.3 l.m² to 1.7 l/m², for the fifth and sixth sections (Figure 2).

Figure 1: Visual of Site Trial during construction

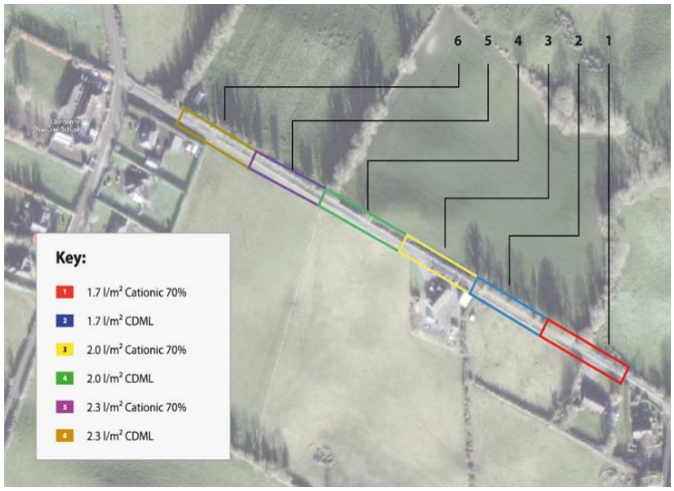

Figure 2: Aerial view of site trial including rates of spread of emulsion

3 DISCUSSION OF RESULTS

3.1 Emulsion analysis

All additives used during the labouratory study conducted as part of this project allowed for successful emulsification to produce a bitumen emulsion. Comparisons were made to the reference bitumen emulsion and target properties were identified. Each additive had specific effects on the properties of the emulsion. Adjustments were made to these properties to closely represent the reference emulsion. Where these adjustments were unsuccessful, the additive was discounted from further assessed.

3.2 Laboratory test results

Testing of the abrasion cohesion (ACTE test) of the emulsions allowed distinguishable differences between the emulsions to be realised (Figure 3). Two emulsions containing an additive were found to out-perform the reference emulsion and were selected for further testing.

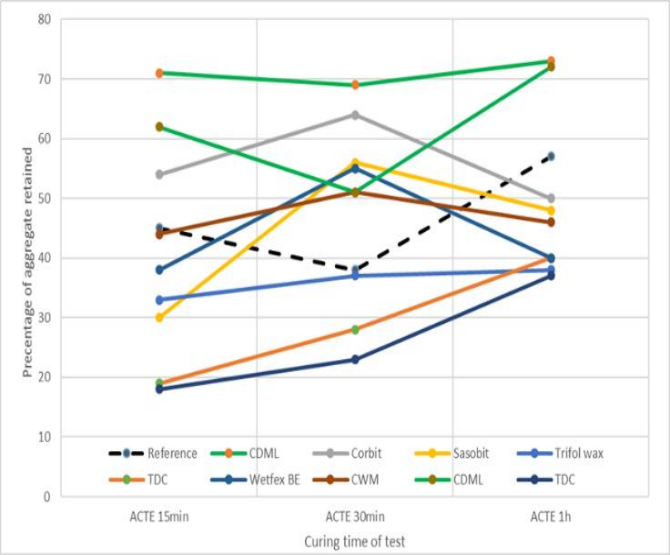

Figure 3: ACTE testing results (dotted line represents the reference emulsion)

Both the CDML and Corbit Adhesion additives were compared during further testing. Testing of adhesion by Water Immersion Test (Table 2) and adhesion by Vialit Plate Shock Test (Figure 4) showed that the CDML additive presented the strongest results for binding and aggregate retention.

The CDML additive then was utilised during site trial for direct comparison to the reference standard 70% Cationic Bitumen Emulsion.

Table 2: Determination of Adhesivity by Water Immersion Results

Evaluator	19-113 Reference	20-017 CDML	19-127 Corbit
	Percentage Coated	Percentage Coated	Percentage Coated
AA	90	100	95
SI	85	95	85
EA	75	80	75
SC	80	90	80
DC	80	95	90
JW	85	95	90
Average	83	93	86

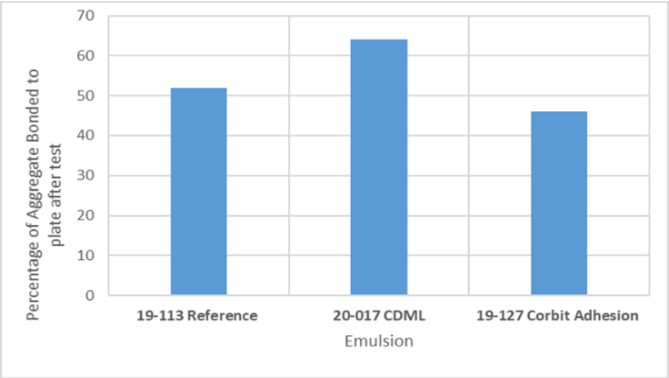

Figure 4: Vialit Plate Shock Test Results

3.3 Field trial test results

Visual analysis of the site trial took place on three separate occasions over a twenty week period. On all three occasions distinct aggregate loss was observed for the section constructed using the reference emulsion at a rate of spread of 1.7 l/m^2, compared to the section constructed using the emulsion containing the CDML additive at the same rate of spread.

Figure 5: Visual Comparison of section constructed using reference bitumen emulsion (left) and emulsion containing the CDML additive (right) at a rate of spread of 1.7 l/m^2

4 CONCLUSION

Chemical additives are routinely used in the bitumen industry to improve adhesion promotion between bitumen and aggregate. A range of additives were used in this project to investigate if their incorporation would affect the performance of a surface dressing.

The reference emulsion used for this project was a 70% cationic bitumen emulsion without an additive. This provided baseline information for comparison purposes. Eight chemical additives were incorporated into test specimen bitumen emulsion and were found to allow for successful emulsification.

Further laboratory testing of these emulsions was conducted to determine the adhesion promotion properties of these emulsions when used in the surface dressing process. A majority of the additives were omitted from further testing based on the test results achieved. The CDML and Corbit Adhesion additives exhibited improved results when compared to the reference emulsion and were selected for further testing. Incorporation of these chemical additives to the emulsion allowed a greater bond to form between the aggregate and the binder i.e. a higher degree of adhesion.

The best performing emulsion containing an additive, for this project was found to be on containing the CDML additive and it was selected for further testing in a site trial. Visual assessments of the site trial were carried out and found a reduced rate of aggregate loss on the sections constructed using the emulsion containing the CDML additive The findings of this study indicate that the use of the CDML additive in the surface dressing process increase the resistance to chip-loss or stripping.

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