

A study of measurement methods for diesel sorbent performance, and the components of road user delay associated with diesel spills on the UK Strategic Road Network (SRN)

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A. Introduction: Diesel spills on the highway

Diesel spills on the highway may reduce skidding resistance and lead to long term damage to the road structure if not removed promptly. Clearing up diesel spills causes road user delay when carriageways are closed for operative access and generates contaminated materials from the clear up. If not removed in a timely fashion, both the spilled diesel and the contaminated sorbents can pollute the environment.



Figure 1: Diesel spill clear up is manually intensive and often closes the road (Photo credit: Cornish Guardian)

Figure 2: A sight and a sign no network operator wants to see (Photo credit: Express & Star, Wolverhampton)

Diesel fuel spillages of varying degrees occur daily on the highway and are typically associated with significant road-user delay; Figure 1 and Figure 2 above illustrate two typical incidents that closed lengths of UK arterial routes for several hours. Diesel fuel on the road surface not only has the potential to reduce the skidding resistance but can lead to the permanent damage of bituminous materials if not removed promptly (Balwin, Carmody et al. (2005)). There are many products available for use in the UK that may, or may not be, appropriate for diesel removal since there is little if any technical information concerning their performance.

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British, European and American standards already provide appropriate tests for the assessment of the various characteristics of granular diesel sorbents, however these were not immediately accessible to road network stakeholders: thus there were no simple means of knowing how well diesel sorbents performed on the road.

The UK Highways Agency (HA) contracted Atkins to undertake a combined research project both to produce a specification for the performance of diesel sorbents for use on diesel spills and to undertake timeline analysis for diesel spillage incidents recorded in the HA's Command and Control (C&C) during the period of the task to better understand the broader dynamics of the diesel removal process.

Both solid and liquid products are available to neutralise, stabilise or soak up spilled diesel, however the introduction of non-solid materials on to the road surface may introduce the potential for pollution of watercourses and the UK Environment Agency advocate the use of mechanical recovery and/or sorbents to remove oil (Environment Agency (2010)):

"We prefer the use of mechanical recovery and/or sorbents to remove oil from surface waters. These methods for removing oil don't add to the water pollution and are designed to remove the oil from the water... alternatives often require the introduction of further products to the water environment, some of which are pollutants in their own right."

Thus only solid sorbents were studied in this work.

The research identified a number of tests which can be used to benchmark, in a non-subjective manner, the performance of any granular diesel sorbent. It has also provided a simple guide to the terminology used to classify sorbents and provided a valuable insight into the components of road user delay associated with diesel spills (and how these delays might be further reduced).

B. Why diesel sorbents are used on the road following a diesel spillage

Liquid diesel fuel or other hydrocarbons are an unwelcome contaminant on the road surface following spillages from overfilled or leaking diesel fuel tanks, or following damage to vehicle fuel components in road traffic accidents or, the worse-case scenario, damage to a bulk tanker of diesel fuel.

Spilled Diesel fuel poses a potential risk to the road user, from the reduction in tyre/road friction it can create, and to the road surface itself, with the deleterious effect it has on the structural integrity of bituminous materials.



Figure 3: Otaraoa Rd Fairfax NZ 100m-long oil slick from leaking drilling equipment (Photo Credit: Cameron Burnell)

Access to the carriageway is in itself risky and creates road user delay when lanes are closed or when low speed maintenance vehicles are in operation, since standing traffic increases the risk of secondary collisions, the choice, placement and recovery of sorbents needs to be well orchestrated in a way to reduce road user delay and minimise risk to the operatives.

There are three key elements to address following a diesel spillage

- i. The diesel on the road surface may have greatly reduced the skid resistance of the road surface

The effect of both the diesel and the sorbent on the skidding resistance of the road can be more easily measured under controlled laboratory or track conditions.

Tests conducted on wet road surfaces contaminated by diesel fuel have shown that available friction may be reduced by as much as 90% when diesel fuel is placed on a wet pavement. In the case of the worn pavement, the resulting friction is in the same order as wet ice. (Whitehurst & Ivey (1985)).

- ii. A bituminous road surface may suffer structural damage from diesel exposure

Diesel exposure for as little as 120 minutes has been shown to result in structural damage to road surfaces (Balwin, Carmody et al. (2005)) When the effect of diesel on the durability of the road is studied in the laboratory, both immediate and longer term structural damage may result from only a relatively short period of exposure.

The scope of this work did not extend beyond a limited literature review on this subject as the SRN was composed of a range of road surface types, each of a wide range of different ages and with different degrees of cracking/fatigue: far too complex a population to quantify practically.

Since the duration of diesel exposure had been shown to be critical to limiting structural damage, as much of the liquid diesel from the road surface as quickly as possible was thought equally important to limiting damage across all bituminous surfaces.

- iii. Diesel on the road can readily be transferred into local water courses and ground water

Assessing pollution risk was beyond the scope of this work, however, the more diesel is left on the road surface and for longer, the greater the likely pollution risk.



Figure 4 Firecrew remove a diesel spill from Semiahmoo Bay BC. (Photo: The Surrey Now, British Columbia)

C. Why there is a need to assess the performance of sorbents for the treatment of diesel spillages

Clear up operations on the road or roadside generate road user delays and risk the lives of operatives, prolonged delays can result from the use of inefficient sorbents: the use of ineffective sorbents can also result in reduced skid-resistance during- and after- the clear up operations, and can lead to extended cleanup durations and unnecessarily high volumes of contaminated waste.

At this point it is appropriate to distinguish between sorbent that absorb diesel and those that adsorb diesel: the use of these two words mark a world of difference in how the sorbent works.

Sorbents that permanently retain any entrained diesel within their structure are known as absorbent

Sorbents that retain entrained diesel but then release it when squeezed or otherwise exposed to external forces are known as adsorbent

What should be noted is that the term 'absorbent' appears freely used to describe many sorbent products without any proven absorbent capability

Thus absorbents pose less of a risk to the environment than adsorbents as they do not leach diesel into their surroundings, similarly they are less likely to contaminate storage areas

Without non-subjective measures of sorbent performance and classification, it is impossible to estimate the volume of sorbent needed to treat a spill, how long the sorbent should be left on the road before it is saturated, or how or when it should be disposed of when contaminated.

Without a simple means of quantifying the performance of materials offered as diesel sorbents, valuable time may be wasted by using unsuitable sorbents leading to unnecessary road user delay and the potential for otherwise avoidable pollution.

C.1 “Quick and Dirty” or “Clean and Steady”

Before any assessment is undertaken it is possible to visualise two possible scenarios for cleanups:

1. A “quick and dirty” method for rapid diesel recovery. This approach uses larger quantities of materials with a higher rate of sorbency. It is likely that these materials are adsorbents, thus this approach is heavily reliant on procedures to efficiently place, recover, remove and dispose of the sorbent since the entrained diesel can leach out again
2. A “clean and steady” method for diesel recovery. This approach uses smaller quantities of materials with a higher capacity of sorbency. It is likely that these materials are absorbents. As the diesel will be permanently held within the structure of the absorbent the potential for subsequent contamination of vehicles and the environment is greatly reduced.

Every kilo of sorbent needs to be placed, saturated, removed and disposed of with as little impact as possible on the road surface or its surroundings

C.2 The key requirements for an effective diesel sorbent

Taking into consideration both the environmental and the logistical elements of a diesel spill, an effective diesel sorbent needs the following properties:

1. **It needs to have little if any negative effect on the road surface it treats (e.g. it cannot make the road slipper when applied, nor can it damage it)**
2. **It needs to suit the available methods of recovery of the contaminated product (e.g. if it cannot be recovered, it cannot later lose any diesel it has soaked up)**
3. **It needs to have little if any negative effect on the ecosystem of the area it is used to treat (e.g. it cannot in itself be a pollution risk, nor can it lose entrained diesel following sorbtion)**

How can these characteristics be assessed?

D. How to assess the performance of granular diesel sorbents

Before testing could commence it was important to decide whether to test on “real” road surfaces out on the network or to use controlled surfaces in the laboratory.

Since a number of the sorbent we were likely to test were already in use on the network, the provision of a reliable benchmark for their relative performance under controlled conditions against other materials was deemed far more valuable than a measure of absolute performance on road surfaces out on the network that could not be duplicated at a later date.

The use of controlled surfaces and laboratory conditions also provide a platform for development work to improve materials on a like-for-like basis.

D.1 The AFNOR Procedure for Sorbent Assessment

Following a skidding accident and a fatality on the French trunk road network in 1999, caused by the use of a lubricous clay sorbent, an assessment programme for sorbents was developed by AFNOR (AFNOR NF P98-190:2002-02 AFNOR (2002)) to primarily exclude the use of swelling clay mineral based sorbents

Table 1: Tests within the AFNOR NF P98-190:2002-02 Protocol

AFNOR Test	Property Measured	Classification Criteria
Absorbent capacity	NF T 90-361	The minimum absorbent capacity for hydrocarbons (diesel) is set at 100%. The absorbent capacity for water is determined with no obligation for any minimum value.
Thermal analysis: ATG and DTG and the differential thermal curve (ATD) – Annex C	The proportion of certain compounds such as quartz, calcite, certain clay substances etc	n/a
Infra-red spectrometry analysis:	The identification of organic compounds and minerals.	n/a
Dust emissions: “TEP” (=French abbreviation for Dust Emission Rate) -	As determined by apparatus described in NF X 11-640	maximum dust emission rate is set as 10%.
Qualitative mineralogical analysis by radiology (DRX)	To establish the qualitative mineralogical composition and the presence of tumescent (swelling?) clay materials	

Determination of variation in adhesion of a road surface as brought about by the presence of contaminated absorbent product	Adhesion to treated surface - The coefficient of friction is assessed by means of the apparatus described in Standard P 18-578.	The minimum required value after application on wetted road surface: ≥ 0.90 coefficient
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Tests are for absorbent products intended for road usage generally belonging to the category of Type A bulk absorbent products (refer NF T 90-362)

Annex A: Reference test surfaces: The reference test surfaces are made up of replica road surfaces made of resin¹), of the bituminous concrete semi-granular 0/10 mm type, with a base SRT coefficient of friction in excess of 0.50 as defined in P 18-578 and an average macrotexture depth in excess of 0.6 mm as defined in NF P 98-216.1.

Annex A: Reference hydrocarbon: The reference hydrocarbon intended for contamination of the road surface and of the absorbent product is of the diesel-oil type. Its characteristics are as defined in NF T 90-360.

Annex A: Device for simulation of granular development in absorbent product: The absorbent product to be tested undergoes granular development using the apparatus described in P 18-576. This development is obtained by application of 200 rotational turns of the cylinder.

A unique element of the AFNOR protocols was the use of the pendulum skid tester to quantify the frictional impact of the sorbent (and optionally the post treatment, post removal effect on friction)

D.2 The need for additional testing

It was considered that simple pass/fail classifications cannot inform the sorbent user of the relative rate of sorbency between materials etc., thus additional tests were sought to provide that level of discrimination.

D.3 British Standards – Sensitivity in Sorbency Testing

BS 7959 2004 -1 (British Standards Institution (2004)) provides a measure of sorbent performance over time. This test measures sorbency at a number of time periods to discriminate materials that have a higher sorbency rate with lower total sorbency per kilo, as opposed to materials with lower sorbency rate with higher total sorbency.

D.4 ASTM tests: Measures of handle-ability

Standards ASTM F726-06 & ASTM F716-07 produced by ASTM International (formerly known as the American Society for Testing and Materials, ASTM) provide a means of quantifying the following properties (see Table 4). Samples of the sorbent in the dry, humid and soaked condition are tested

Table 2 ASTM Selected sorbent test procedures

Test Procedure	Property Tested	Information
ASTM F726.06 Part 10.4	Loss of Diesel from Centrifuging	simulates loss of diesel from sorbent after use
ASTM F716.07 part 11.2	Diesel Absorption after 2 Hours	give sensitivity to moisture
ASTM F716.07 Part 11.5	Sorbency before Transfer to Adjacent Materials	simulates transfer of diesel from contaminated sorbent after use
: ASTM F716.07 Part 11.3	Sorbency Change after 2 Hour Draining	simulates loss of diesel after use

E. The Proposed Portfolio of Sorbency Tests

Following the review of sorbency test procedures above a portfolio of tests were assembled that as a group:

1. Were all within the technical capability of most analytical labs
2. Provided meaningful and relevant insight into the practical performance of the sorbent
3. Classified the sorbent as an absorbent or an adsorbent.

Table 3, below, provides a list of the test protocols finally for use.

F. Sorbent Materials Tested

The following section describes the materials tested: they are all either currently in use on the SRN to treat diesel spillages, or likely to be used in the future (see Table 4 below).

In order that the test results obtained are not used out of context by the manufacturers/suppliers of the sorbents, it was agreed that they would be identified only generically. The materials tested are therefore described as follows in the research testing (see Table 4).

Table 3: Test protocols identified for the research testing

Sorbent Property	Test Protocol	Performance Characteristic	How assessed
Classification of Sorbent as Absorbent or Adsorbent	ASTM 726-06	A Measure of potential for subsequent contamination from the used sorbent	Volume change of sorbent is indicative of an absorbent

Sorbent Property	Test Protocol	Performance Characteristic	How assessed
Diesel Sorbency	DD CEN/TS 15366:2009 or ASTM F716.07 or ASTM F726.06	A measure of diesel Sorbency by weight	Drained soaked weight after no further sorbtion of diesel
	BS 7959: 2004 Pt 1	A discriminator between short-term rapid and longer-term progressive absorption characteristics	Increase in drained soaked weight following at timed intervals
Release of Entrained Diesel from Sorbent to Other Materials	ASTM F716.07	A measure of the level of sorbency achieved before transfer of diesel occurs during storage on to adjacent materials (method of determination to suit intended manner of storage)	A measurement of the diesel sorbency of a material up to the point at which diesel is picked up on blotting paper
Water Sorbency	DD CEN/TS 15366:2009 or ASTM F726.06	A measure of water sorption by weight, relative performance (high water sorbency is undesirable)	Drained soaked weight after no further sorbtion of diesel

Sorbent Property	Test Protocol	Performance Characteristic	How assessed
Influence of Sorbent on Wet Friction	<p>DD CEN/TS 15366:2009</p> <p>Annex D Part 1 (Wet Friction of surface coated with Contaminated Sorbent)</p> <p>Annex D Part 2 (Wet Friction of Surface After Removal of Contaminated Sorbent)</p>	The effect of the sorbent on the wet friction of a simulated road surface during and after treatment	Wet friction measured using the Portable Skid Resistance Tester

Table 4: Sorbent Identification and Description

Sample Identifier	Description	Comment(s)
Sand 1	100% Childrens sandpit sand (soft sand)	As Used by supplier of Polymer 1 to mix with Polymer 1
50% Polymer 1/ 50% Sand*	Polymer 1 mixed 50:50 with Sand 1	Mixture as marketed in the UK by the supplier/importer
25% Polymer 1/ 75% Sand*	Polymer 1 mixed 25:75 with Sand 1	Mixture identified (but not tested) as a more cost effective mix in Meitei, Hannah et al (2011) - See Note 1
Organic Material 1	100% fibrous organic material	As marketed in the UK by the supplier/importer
Granular Material 1	100% Coarse white granular material	As marketed in the UK by the supplier/importer
Polymer 2	100% Polymer 2	Already sold for hydrocarbon capture in the UK and for diesel sorbtion on the highway in the USA

* Tests were carried on Polymer 1 as a 50:50 mix with sand and a 25:75 mix with sand to assess if the cost savings to be gained by reducing the polymer content were offset by retrograde performance in testing.

G. Test Results

Test results for the samples of the sorbents listed in Table 4 are provided graphically below along with short descriptive supporting text for each Figure to better aid in their interpretation, all results are mean readings for duplicate/triplicate tests.

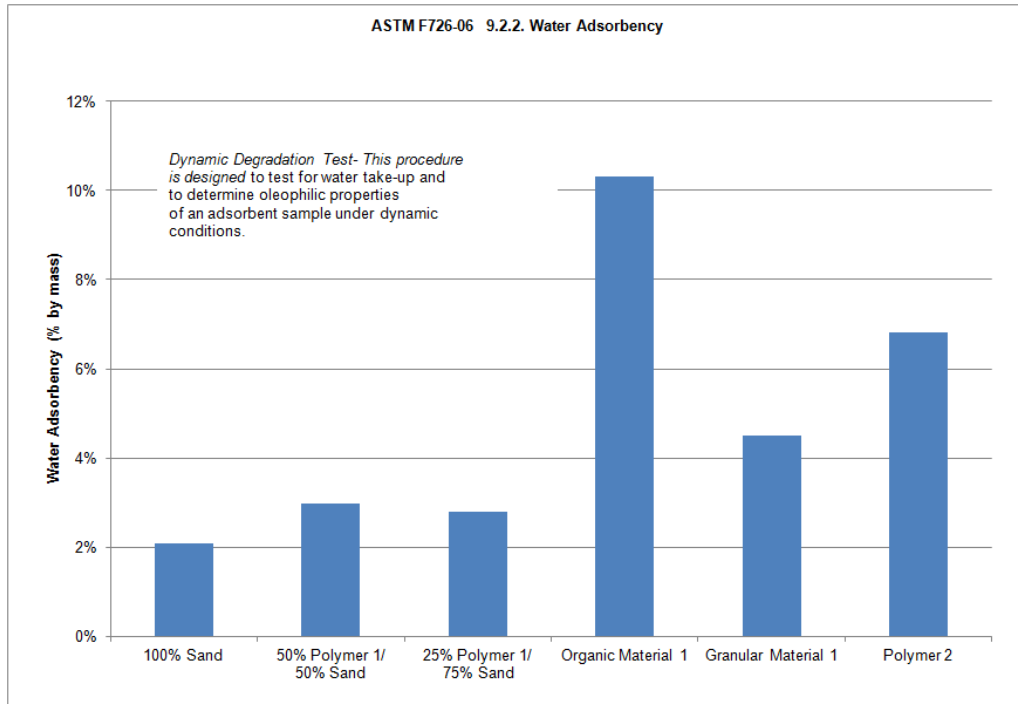


Figure 5: ASTM F726.06 Part 9.2.2 Water Adsorbency Test Results

For consideration when the environment where a sorbent is used may be wet, in this case Organic Material 1 may be less suitable as an oil sorbent if its capacity could be partially taken up by water in the same environment. Lower water adsorbency was associated with the 100% sand and 75% sand Polymer 1 mix, Organic Material 1, being porous in nature adsorbed 10% of its mass in water (see Figure 5)

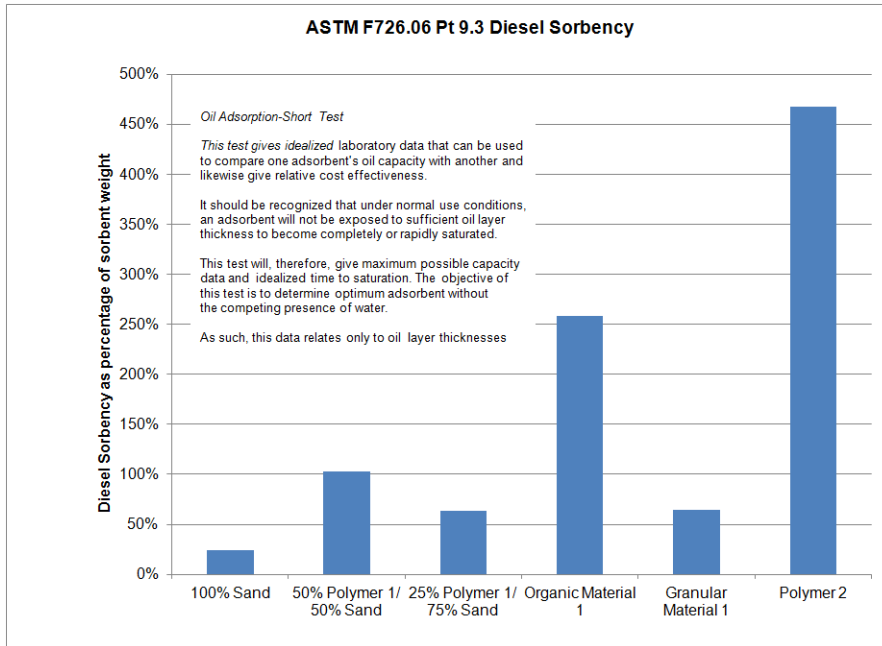


Figure 6: ASTM F726.06 Pt. 9.3 Diesel Absorbency Test Results

Sand will adsorb only 20% of its own mass in diesel whereas Polymer 2 could absorb nearly 500% of its own mass, surprisingly organic material 1 could absorb 260% its own mass! Organic Material 1 sorbency is 10x that of Sand 1. Polymer 2 absorbency x18 that of Sand (see Figure 6)

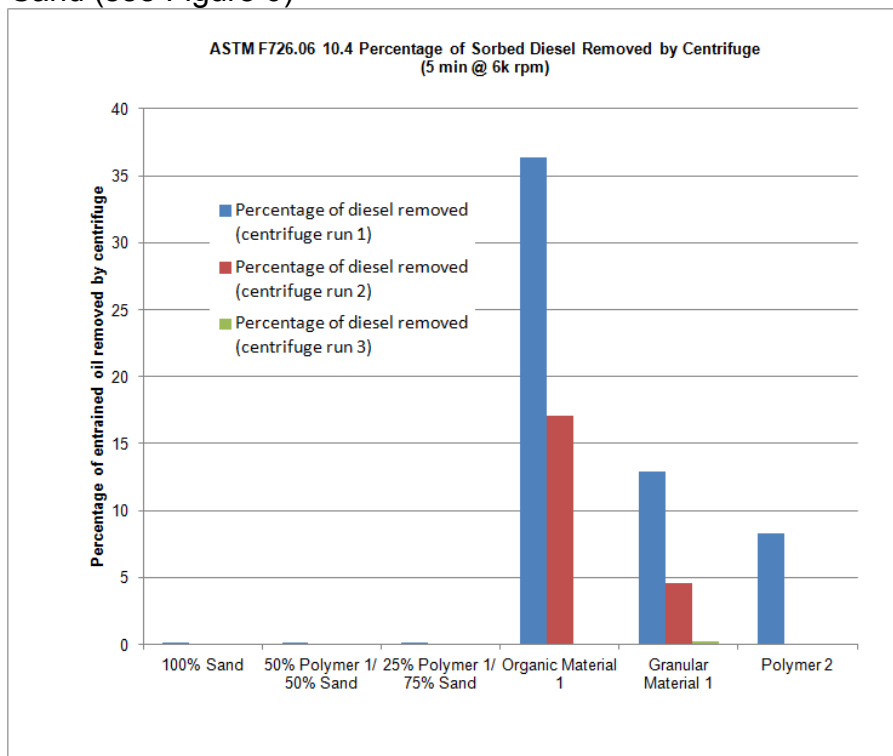


Figure 7: ASTM F726.06 Part 10.4 Loss of Diesel from Centrifuging

Organic Material 1 showed a noticeable loss of adsorbed diesel. Sand and granular material 1 are poor adsorbents with little entrained diesel to lose. Sand and the polymer/sand sorbents all showed low loss of diesel on account of the low volume of

diesel initially entrained . The degree to which unabsorbed diesel was held interstitially on the saturated sorbent could not be determined in this test (see Figure 7).

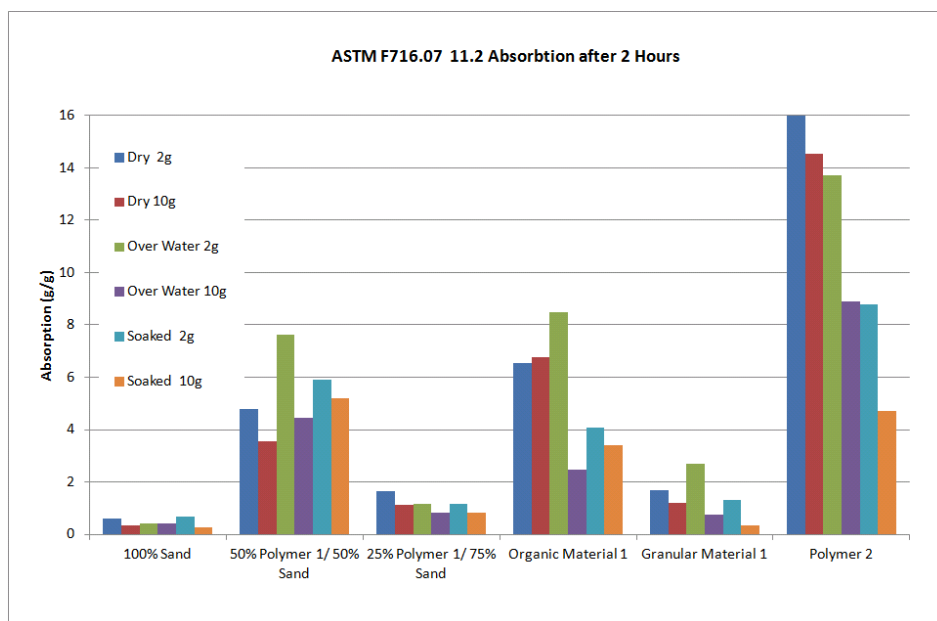


Figure 8: ASTM F716.07 part 11.2 Diesel Absorption after 2 Hours

These tests identify how sensitive the materials are to storage in humid conditions and also how they perform when used wet. Road conditions may be less than ideal and the storage conditions of unused sorbents poorly controlled. The 50% and 100% polymer materials very noticeably out-performed the others in all states. Polymer 2

loses a large proportion of its sorbency when wet (See Figure 8).

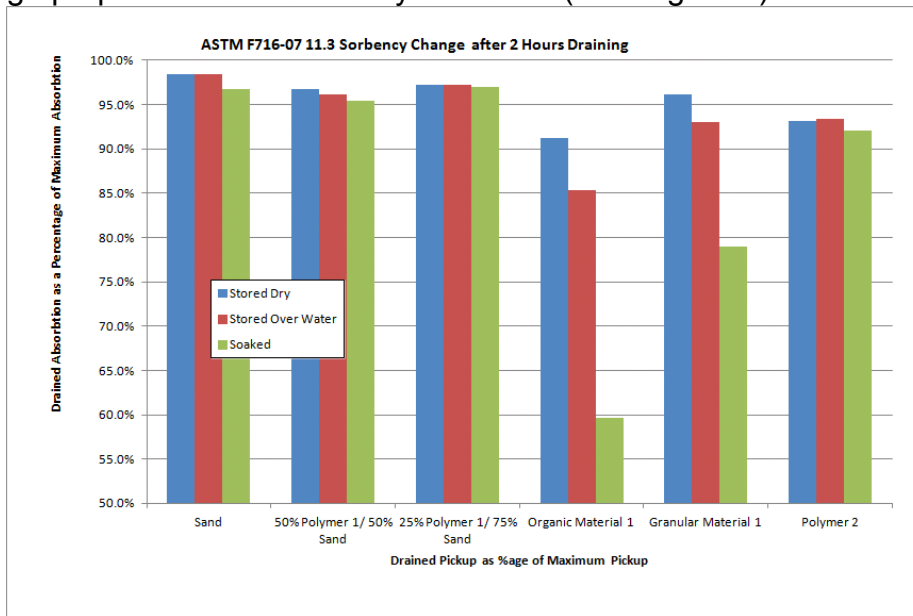


Figure 9: ASTM F716.07 11.3 Sorbency Change after 2 Hours Draining

This test quantified how much diesel would be lost from sample of sorbent during storage when they were dry, “humid” or wet sample before use. The values are relative and not absolute, since the small losses seen for sand mostly reflect the minimal sorption capability of the sand. The adsorbents Organic Material 1 and Granular Material 1 show the greatest losses, Polymer 1 and Polymer 2 samples the least (see Figure 9).

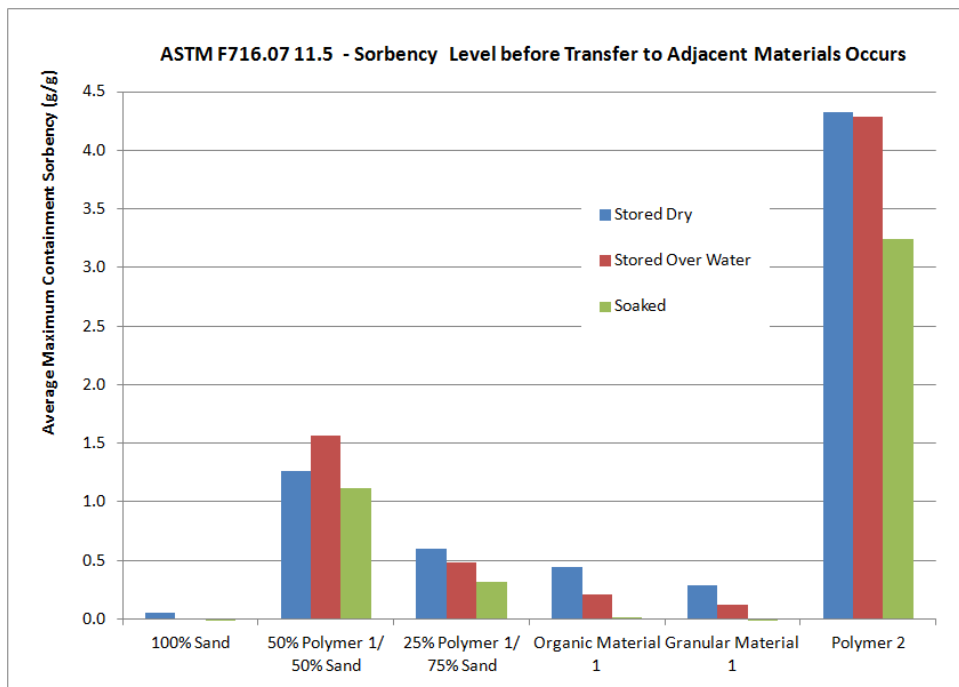


Figure 10 ASTM F716.07 11.5 Sorbency before Transfer to Adjacent Materials

This test provides a good measure of the likelihood of diesel being transferred from a saturated sorbent on to vehicles interior and on to the clothing of personnel taking

part in the clear up process: The polymers typically held 100% to 400% of their own mass in diesel before diesel was transferred to surrounding filter papers. Sand, with little if any sorbency, was virtually incapable of holding any diesel without it subsequently being transferred to its surroundings (see Figure 10).

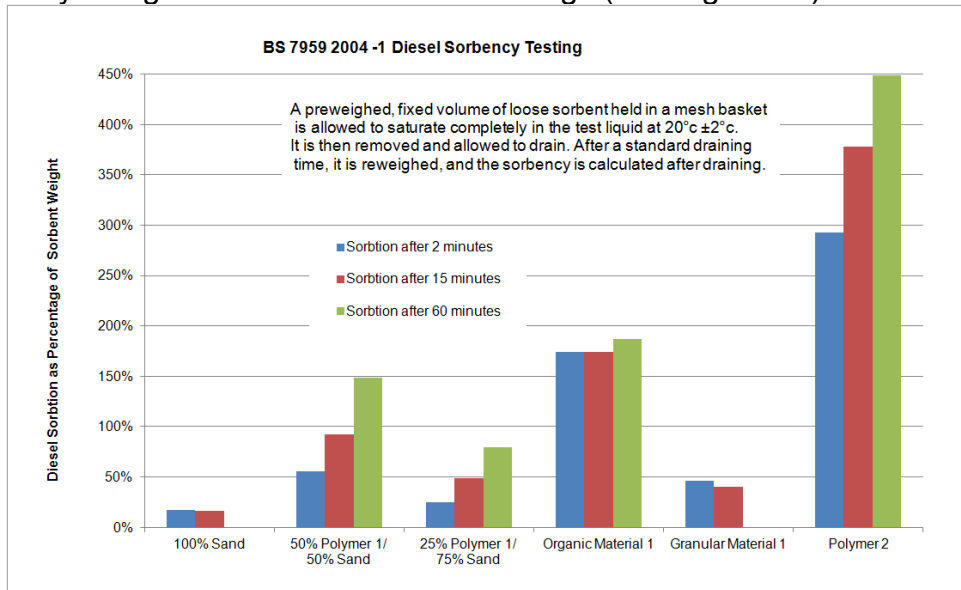


Figure 11: BS 7959 2004-1 Sorbency at 2, 15 and 60 Minutes

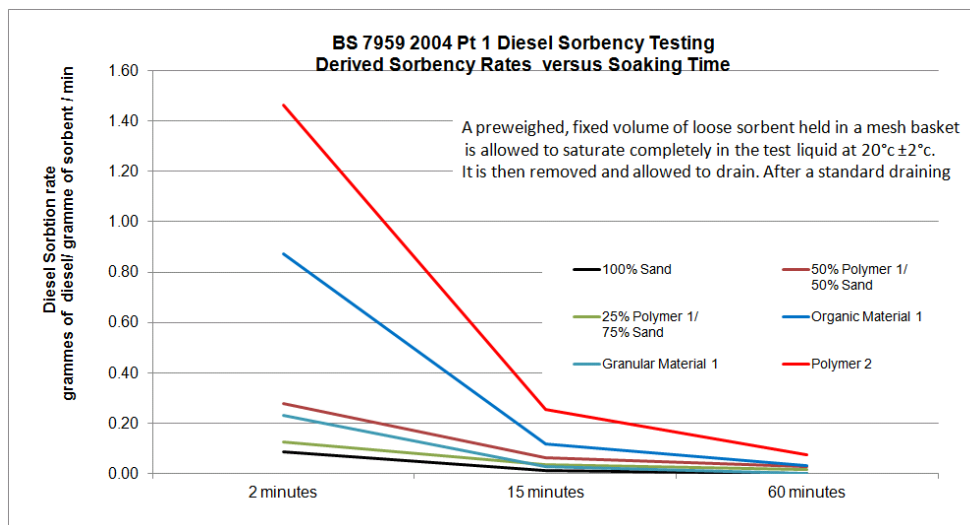


Figure 12: Derived Sorbency Rates at 2, 15 and 60 Minutes

The short term rate of sorption of diesel tested here (see Figure 11) is an important measure of the usefulness of a sorbent when labour can be mobilised to treat large spillages and contaminated sorbent can be stored in a manner that is not reliant on whether it is adsorbent or absorbent.

The difference in the sorbency rates for the 2, 15 and 60 minute soaking times (see Figure 12) can be used to identify quick acting adsorbents such as Organic Material 1 (“quick and dirty”) that may be a viable alternative to superior progressive absorbents such as Polymer 2 (“clean and steady”).

The effect of sorbents on the wet friction of the road surface has already been quantified in the procedure given in AFNOR NF P98-190:2002. Identifying a laboratory actually capable of undertaking these tests was problematic since it was thought that the simulated asphaltic concrete road surface panels needed could only be manufactured by a single test house in France.

CEDRE (Centre de documentation, de recherche et d'expérimentations sur les pollutions accidentelles des eaux) were contracted to test the wet frictional properties of samples using the AFNOR NF P98-190:2002 procedure. The results of these tests were as follows (see Table 5 below).

Table 5: AFNOR NF P98-190:2002 Annex A - Wet Friction Tests undertaken by CEDRE

Material	Initial SRT (wet)	Final SRT (after treatment with absorbent)	SRT (final) SRT (initial)	SRT (final) SRT (initial) >0.9?
Sand	64	44	0.69	No
50% Polymer 1 /50% Sand	65	59	0.91	Yes
25% Polymer 1 /75% Sand	72	46	0.64	No
100% Polymer 2	60	52	0.87	No
Organic Material 1	65	45	0.69	No
Granular Material 1	72	56	0.78	No

The results of this limited testing indicated that a change in the proportion of sand in a mix such as was engineered with Polymer 1, can make a large difference to the wet frictional properties of the system. The 50.50 mix of polymer 1 was the only material that satisfied the requirements for the preservation of at least 90% of the original wet friction during the use of the sorbent on the road.

It should be note that further testing on the sample road surface AFTER removal of the sorbent is given in DD CEN/TS 15366:2009 Annex D Part 2 (Wet Friction of Surface After Removal of Contaminated Sorbent)

H. Observations on the Test Results

The use of plain sand as a diesel sorbent provides a good example of why we need to test the performance of sorbents for soaking up diesel spills:

Only 100kg of polymer sorbent is capable of absorbing 350-450 litres of diesel within 15 minutes of placement, creating 450-550kg of stable waste suitable for incineration that will not drain or leach out at any time before disposal

To adsorb the same volume of diesel (350-450 litres) using sand would require c.2250 kg of sand to be placed on the road, the clear up option generates c. 2750 kg of contaminated sand (unsuitable for incineration) to be recovered off the road surface and disposed of before the diesel drains out of it (whether on the side of the road or in the back of a maintenance vehicle).

H.1 Cheaper materials which adsorb rather than absorb, and do not hold on to the diesel, may offer the best value for money if they are promptly removed for disposal when saturated. If left on the road or in storage, any entrained diesel is more likely to drain out and contaminate vehicles and watercourses than if absorbents are used..

H.2 If a sorbent cannot be recovered from the road surface after use, a 100% polymer absorbent offers the best environmental option as the diesel is permanently held within the structure of the sorbent. It is, however, important to

ascertain that any sorbent that is to be left on the carriageway does have a retrograde effect on skidding resistance (See).

- H.3** Expensive polymers which perform the best in laboratory tests (BS 7959-1-2004 & BS 7959-2-2000, ASTM 716-07 & ASTM 726-06) do not automatically give the best value for money if a fast acting adsorbent can be cleared up after use.
- H.4** Though inexpensive, sand alone is an inefficient sorbent, excessive quantities may be needed to be effective, thus it should, based on test performance alone, be considered a sorbent of last resort. However, since sand is readily accessible in large quantities, it can be effective in containing rather than sorbing, diesel spills.
- H.5** Friction tests on sorbent-treated standard road surfaces (AFNOR NF P98-190 2002) have shown that a selection of materials currently in use as sorbents to deal with diesel spills can have a detrimental effect on road surface friction (SRV measured using the Pendulum Skid-resistance tester).
- H.6** It is strongly suggested that all diesel sorbents should be removed from the road surface after use unless they can be shown to deliver an acceptably small reduction in SRV (the local investigatory level of wet skidding resistance may represent an appropriate threshold) [
- H.7** The addition of sand to polymers appear to greatly reduced the effectiveness of one of the polymer absorbents tested, it solely performed as an inert bulking agent to reduce the unit price of the sorbent mixture and its use also had a retrograde effect on the skidding resistance of the test surfaces

I. Proposed Sorbent Performance Limits & Classification

On the basis of the results obtained for the specific selection of sorbents tested, and in consideration of the pre-existing standards including AFNOR and CEN procedures for the classification of sorbents, the following proposal (Table 6) was put forwards for the classification of sorbents for the treatment of diesel spillages

Any sorbent proposed for use on the SRN (Strategic Road Network) shall also be labelled and packaged as per DD CEN/TS 15366:2009 (including Annex B) and must satisfy the end-users' Health and Safety requirements including packaging and unit weights.

J. Best Value from Real World Comparisons

To undertake a "real world" assessment of the relative merits of the sorbents tested it was important to consider the purchase costs of the sorbents, the likely labour costs of the placement and recovery process and the disposal costs of the waste that their use would generate.

As service providers operate under local arrangements for the provision of highway services, it has not been possible to incorporate these costs, rather the focus was placed on estimating the sorbent cost, the sorbent requirement and the disposal cost

of the contaminated material associated with remediating a notional 50 litre diesel spill.

As can be seen in , when the relative cost of the sorbent needed to treat a 50 litre diesel spill (using the average sorbency performance across the laboratory tests) and the disposal costs are taken into consideration the cheapest sorbent (sand) is not the most cost effective as it generates the greatest weight of waste, conversely the best performing sorbent (polymer 2) is not the most cost effective as it has the greatest material cost.

Table 6: Proposed Diesel Sorbent Classification Test Procedure

Sorbent Property	Test Protocol	Suggested Limit	Performance Characteristic
Classification of Sorbent as Absorbent or Adsorbent	ASTM 726-06	Informative only: Classification as Absorbent or Adsorbent	A Measure of potential for subsequent contamination from the used sorbent
Diesel Sorbency	ASTM F716-07	Class 2 sorbency >50% or Class 1 sorbency >100% (From Procedure in NF T 90-361)	A measure of diesel Sorbency by weight, a 2 level classification
	ASTM 726-06		
	DD CEN/TS 15366:2009 or		
Diesel Sorbency	BS 7959: 2004 Pt 1	Informative: establish the sorbency at 2, 15 & 60 minutes	A discriminator between short-term rapid and longer-term progressive absorption characteristics
Release of Entrained Diesel from Sorbent to Other Materials	ASTM F716.07	Informative: Maximum Effective Pickup and Maximum Practical Pickup	A measure of the level of sorbency achieved before Transfer of diesel occurs during storage on to adjacent materials (method of determination to suit intended manner of storage)
Water Sorbency	DD CEN/TS 15366:2009 or ASTM F726-06:	<15%	A measure of water sorption By Weight, relative performance (high water sorbency is undesirable)

Sorbent Property	Test Protocol	Suggested Limit	Performance Characteristic
Influence of Sorbent on Wet Friction	DD CEN/TS 15366:2009 Annex D Part 1 (Wet Friction of <u>Contaminated Sorbent</u>)	Class 2 wet friction ≥ 80 % SRT initial Coefficient Class 1 rating if material achieves ≥ 90 % SRT initial Coefficient (as required in NF P 98-190 Annex A)	The effect of the sorbent on the wet friction of a simulated road surface during and after treatment, a 2 level classification Though from published standards, the source of these threshold values of wet friction preservation are yet to be determined
Influence of Sorbent on Wet Friction	DD CEN/TS 15366:2009 Annex D Part 2 (Wet Friction of Surface <u>After Removal of Contaminated Sorbent</u>)	≥ 85 % SRT initial Coefficient both classes	Better performing sorbents may be indicated by an SRT initial Coefficient In the Part 1 test of in excess of 80%

Thus should the use of an adsorbent be deemed appropriate (when the soiled sorbent can be removed and stored where subsequent loss of the entrained diesel is not an issue), the use of Organic material 1 is the most cost effective as well as generating the least waste. If an absorbent has to be utilised, the material costs for Polymer 2 may be five times that of Organic Material 1 but with greatly reduced waste.

With effective control on the storage of the contaminated waste, the use of a good ADSorbent is the most cost effective solution.

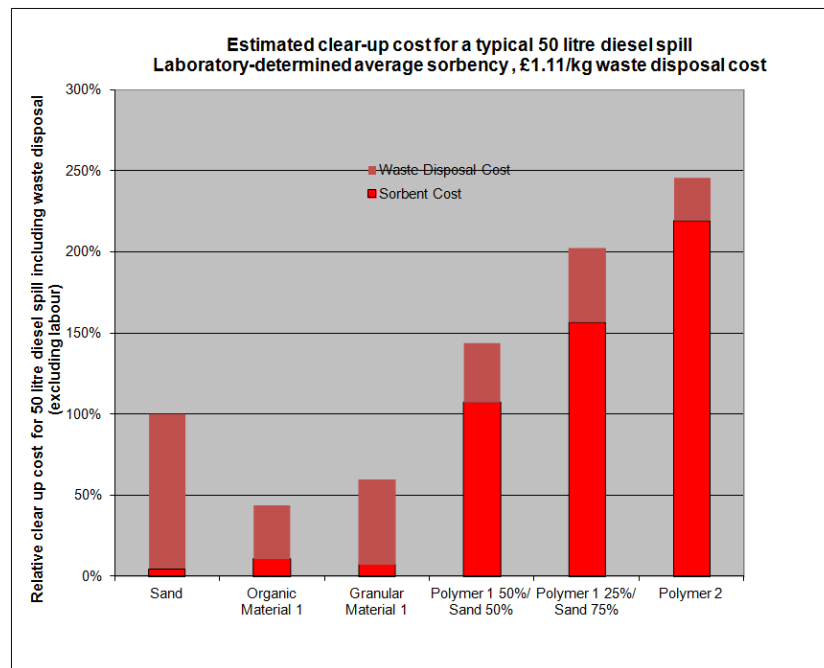


Figure 13: Relative sorbent costs and disposal costs for a notional 50 litre diesel spill

K. Command and Control (C&C) timeline studies for diesel spill incidents

Though the duration of the diesel sorbent placement, saturation and recovery elements of a diesel spill are a function of the characteristics of the sorbent, the logistics of the larger event (the removal of any vehicles involved, the provision of traffic management etc.) has to be understood to get the bigger picture.

As a separate component from the laboratory based research, a study was undertaken of the Command and Control (C&C) timeline records for a number of diesel spill incidents.

K.1 The Command and Control (C&C) timeline monitoring period

Data was collected in two phases with the first review point covering the period of 23rd July 2012 through to 16th August 2012 (Phase 1), providing a few days either side of the Olympic Games to allow for a potential change in network behaviour. Phase 2 lasted from 17th August 2012 through to 9th September 2012 covering the period between the Olympic and Paralympic Games and the duration of the Paralympics themselves. 212 incidents were recorded.

K.2 The aim of the data analysis and the key finding

It was important to understand how much of a typical diesel spill event on the SRN was attributable to the actual clearance of the diesel spill rather than to any associated elements of the incident.

The C & C timeline data was examined to try to understand the root causes of prolonged diesel spill incidents of more than 2 hours duration, from this data it was possible to create an average timeline representative of the 212 documented incidents.

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 Figure 14 shows this “typical” timeline to illustrate how the vehicle recovery phase of the diesel spill incidents could last almost as long

as all the other components added together. The diesel recovery phase itself lasts only 7% of the whole event.

What must be mentioned is that the components shown at the right of Error: Reference source not found can overlap rather than simply taking place sequential as implied in Error: Reference source not found, since the call for vehicle recovery could easily be made whilst the diesel spill cleanup was still in progress.

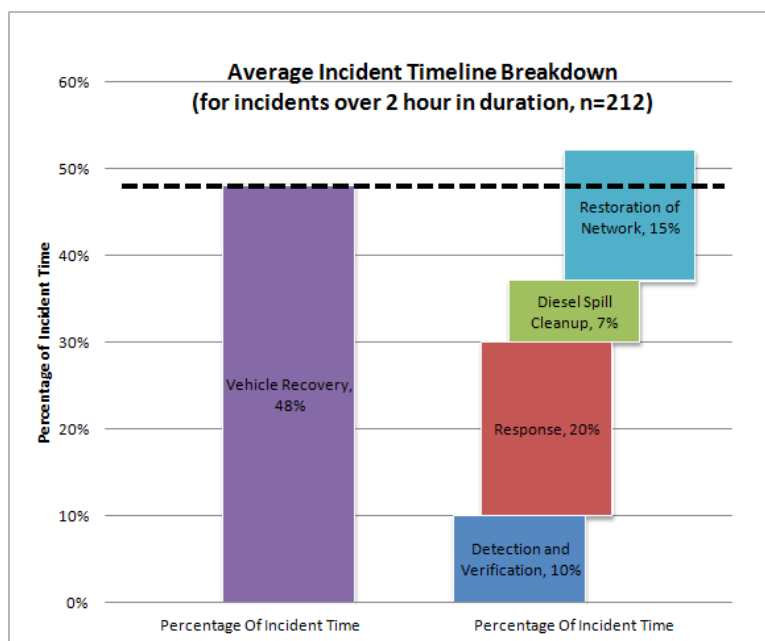


Figure 14: Typical Durations of Timeline Components for a Diesel Spillage Cleanup

L. Overall Conclusions

1. There is generally a lack of performance data for granular sorbents currently in use on diesel spills on the UK SRN
2. The UK Environment Agency prefer the use of granular sorbents
3. Test procedures and a draft European Standard exist for assessing granular sorbents
4. Laboratory-based rather than road-based testing provides a controllable environment for sorbent assessment and development
5. A number of the granular sorbents such as sand currently in use perform badly in laboratory tests
6. The right sorbent for the job can easily be specified using the appropriate laboratory tests
7. Adsorbents with a high sorbency rate but lower a total adsorbency capacity may be preferable to more progressive absorbents with a higher level of total absorbency
8. The cheapest sorbent may not be the most cost effective when the time and cost of recovery and waste disposal are considered.

M. References

Association Française de Normalisation (AFNOR) (2002). NF P98-190:2002-02 "Road maintenance equipment and products — Absorbents intended for road usage — Specifications". 93571 La Plaine Saint-Denis, Cedex, France.

ASTM International (2006). ASTM F726-06 "Standard Test Method for Sorbent Performance of Adsorbents". ASTM International, West Conshohocken, PA, USA

ASTM International (2007). ASTM F716-07 "Standard Test Methods for Sorbent Performance of Absorbents" ASTM International, West Conshohocken, PA, USA

Balwin, B , Carmody, O , Collins, T (2005) "Degradation of Asphalt due to Diesel Spills on Roads" in "Skid resistance: district implications and applications" - Road System & Engineering Technology Forum- August 2005. Technical Training Solutions, Department of Main Roads, Brisbane, Australia,

British Standards Institution (2004). BS 7959-1:2004 "Materials used for the control of liquid spillages Determination of sorbency". British Standards Institution, London, W4 4AL, UK

British Standards Institution (2009). DD CEN/TS 15366:2009 "Winter and road service area maintenance equipment. Solid absorbents intended for road usage". British Standards Institution, London, W4 4AL.

Environment Agency (2010) "Oil clean-up products and their application in England and Wales" Environment Agency, Sheffield, S9 4WG.

R F Lambourn and H E Viner (2006). PPR073 – "Friction tests on contaminated road surfaces". Transport Research Laboratory, Crowthorne.

B Meitei, M Keigan et. al. (2010). PPR509 - "Review of diesel spillage clean-up procedures".. Transport Research Laboratory, Crowthorne, UK.

B Meitei, A Hannah et al. (2011) CPR 1005 – Task Reference: 183 (1308) HALC "Diesel absorption trial", Transport Research Laboratory, Crowthorne.

E A Whitehurst & DL Ivey (1985). Surface Contaminants in State-of-the-Art Report HS-038 006, Transportation Research Board, NW Washington, DC 20001 USA