APPLYING WATER BLASTING TREATMENT POLICY AIMED AT REDUCING FIRST RAIN SKIDDING ACCIDENTS –THE ISRAELI EXPERIENCE

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ABSTRACT

The issue of skid resistance in Israel is influenced by the country's unusual climatic conditions, characterized by a long dry season with zero precipitation, followed by about 4 months of a rainy season. These conditions aggravate the problem of the “First Rain Skidding Accidents” (FRSA).

This problem is manifested by a higher risk of skidding accidents, occurring during and just after the first rain, following a dry period. This risk results from the slippery surface formed by a mixture of contaminants accumulated during the dry season, with rainwater.

The maintenance policy, applied in Israel to alleviate FRSA risk, includes Contaminant Removal Waterblasting (CRW) treatments at chosen sites. Those treatments are carried out during the end of the summer, in order to remove the accumulated contaminants, prior to the expected occurrence of the first rain.

This paper presents research efforts, initiated by the INRC, aimed at evaluating various aspects of this policy including: a literature survey, field studies of the effectiveness and life expectancy of CRW, a comparison of skid resistance (SR) values derived from CRW vs. those derived following the first rain, an examination of the selection criteria of road sections intended for treatment and effectiveness of QA/QC procedures applied during CRW treatment.

INTRODUCTION

The issue of skid resistance in Israel is influenced by the country's unusual climatic conditions. These conditions are characterized by a long dry season with zero precipitation, followed by about 4 months of a rainy season. The first rain events following the dry season are frequently accompanied by much higher accident rates. The main cause of this phenomenon is attributed to the slippery material which is formed by the mixture of contaminants accumulated during the dry season, with rainwater.

To a certain extent, this phenomenon of "First Rain Skidding Accidents” (FRSA) can also be "credited" to the road users. The drivers, accustomed to driving on dry and skid resistant pavements, suddenly have to change their driving behaviour, in order to comply with the slippery road surfaces. This aspect is covered by various activities, such as radio and TV programs and public service advertisement, and of course, by special signs posted along the roads.

The INRC decided that these warning activities are not enough, and since 2002, quite a lot of activities have been carried out in order to alleviate the problem of FRSA proactively. One of the main tools used for that subject is the Contaminant Removal Waterblasting (CRW). The main usage of that tool is for washing away the various contaminants off the road surface, prior to the rainy season.

The present paper summarizes the actions carried out during the past few years, in terms of field activities and research, and depicts the future INRS plans regarding that issue.

THE FRSA PHENOMENON – SUMMARY OF LITERATURE SURVEY

The change of skid resistance values during the dry period

It is considered as a common knowledge that road skid resistance decreases during periods of no precipitation. The main reason for the decrease in skid resistance is accredited to the accumulation of various contaminants on the road surface.

Some researches have investigated this phenomenon by trying to quantify the rate and extent of the skid resistance decline. These values are influenced by a variety of factors, such as:

- traffic volumes
- percentage of heavy vehicles
- geometric characteristics of the road, such as longitudinal slope and horizontal radii
- properties of the road surface
- existence of potentially contaminating activities or industries, such as agricultural activities, quarries and industrial areas
- intensity of the last rain episodes.
- Length of dry period between successive rain events

Figure 1 (Yaron & Nesichi, 2005) depicts the decrease in SR values at a major urban road in Israel, after about 2 months of no precipitation. The average decrease in SR values is about 20%. It should be mentioned that these low SR values were measured on May, about 6 months before the anticipated rainy season.

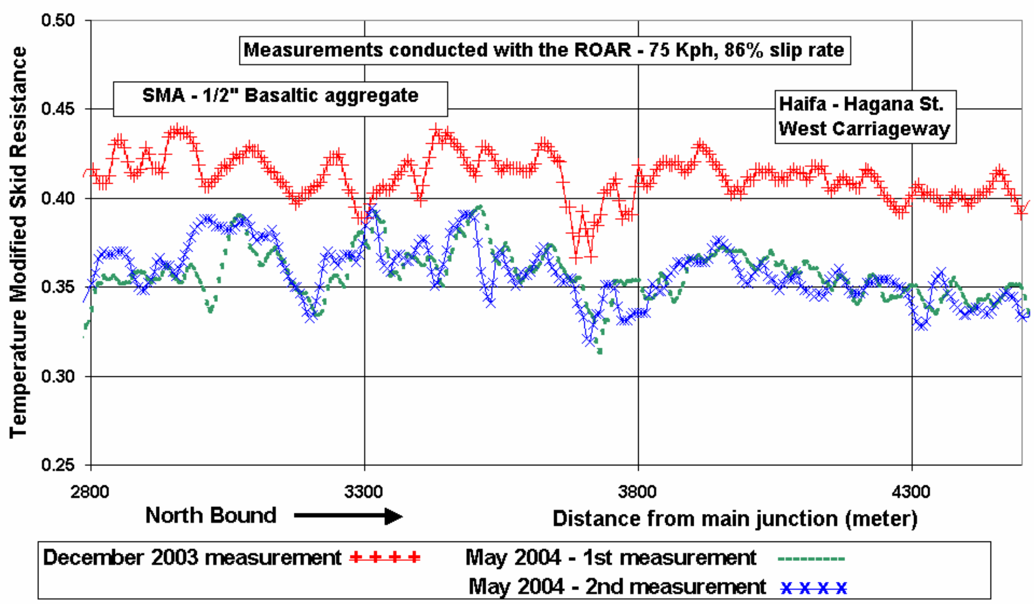

Figure 1: Decrease of skid resistance values after about 2 months of no precipitation (Yaron & Nesichi, 2005)

Kennedy et al (2005) estimated a linear decrease of about 0.01 in the skid resistance values (in terms of the SCRIM device) for every day after a significant rain event of more than 10 mm of rain. The skid resistance values continue to decrease down to a level of about 0.1 less than the maximum level obtained for a clean surface.

Cenek et al (2004) and Wilson (2006) have indicated another connection, in which a decrease of about 10% in the skid resistance is to be expected after about 10 days (Figure 2, whereas a general logarithmic function will cause another decrease of about 10%,100 days after the last rain event.

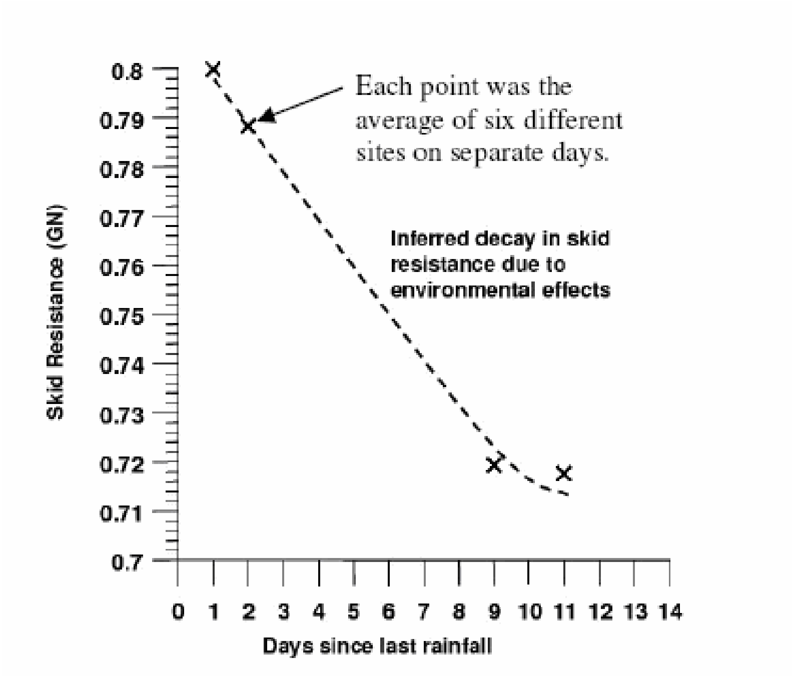

Figure 2: Decrease of skid resistance values after a short period after rainfall (Wilson, 2006)

Earlier works (Dahir & Henry (1979) and Hill & Henry (1981)) conducted in the US also tried to correlate the decrease in skid resistance with the intensity of the rain, and the time which has passed since its occurrence. The results showed a fast decrease during the first days after the significant rain and stabilization of the skid resistance values, after about a week.

Figure 3 depicts the results reported in Wilson (2006). The measurements were conducted in an effort to understand the behavior of skid resistance decrease up to 30 days and more, after the last rain event. A linear correlation has been suggested to exist between the SR and time that has elapsed after the last rain event.

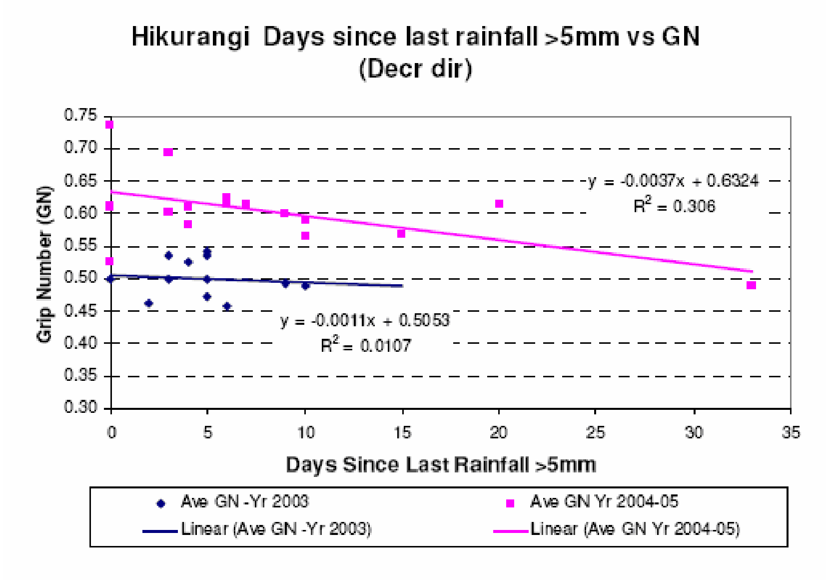

Figure 3: Decrease of skid resistance values after a rainfall event (Wilson, 2006)

Another example of the influence of contaminants in various Israeli roads is easily seen in figure 4, taken from Craus et al (2010). Consecutive runs over the same section show a substantial increase in the SR values (measured by a Dynatest 6875 RFT device). These differences can be attributed to the partial cleaning effect of the water used during each test run. Comparing the results of the 1st run with the 3rd run shows an increase of 40-50% in the SR values. More than that, the SR values obtained during the winter survey are 25% or more, higher than those obtained during the 3rd summer run.

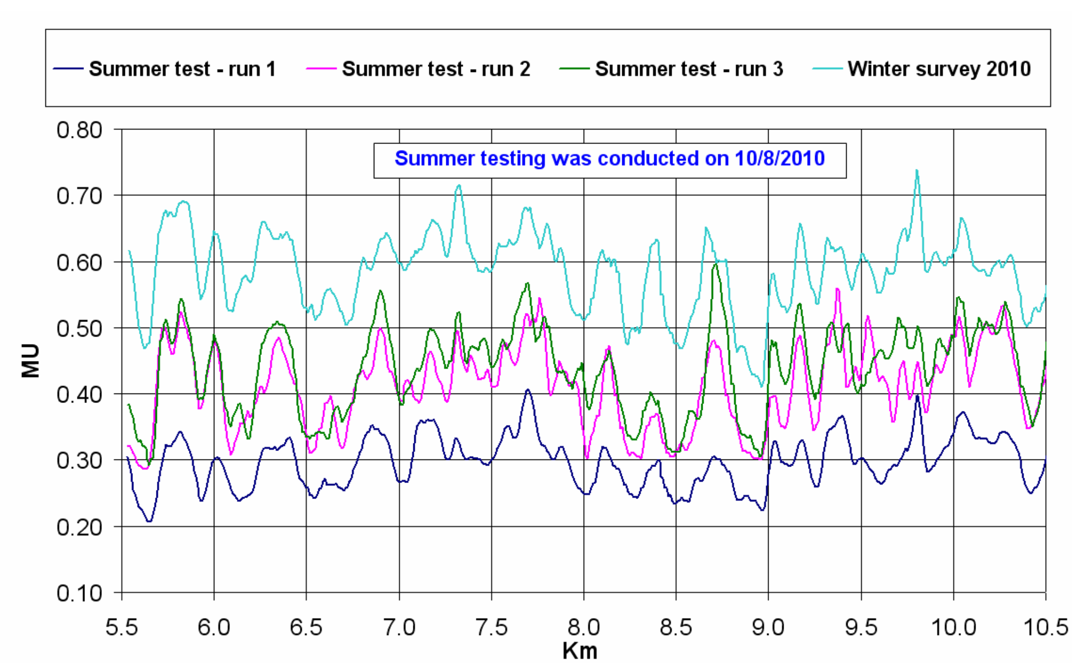

Figure 4: Road no. 383 –SR values in consecutive summer runs and VS winter survey results (Craus et al (2010))

Concluding the above results, most of the researches have investigated only the short term influence of dry periods over SR values. In many cases it was assumed that SR values become stable after a period of 7-10 days. Other results, most of them found in Israel show that after long periods of time, SR values may decrease by 20%-60%, relatively to the values attained during the rainy season.

The results of all of the research testing programs were quite scattered, a fact which made it difficult to reach highly conclusive recommendations. There are many reasons for the above, including:

- The many parameters which affect the accumulation of contaminating agents on the road surface, such as traffic, weather conditions, temperature, surface characteristics and more.
- In most of the countries it is very difficult to conduct a monitoring program which lasts more than a month without any rain events.

FRSA, road safety, and preventive actions

Many road authorities around the world are conscious of the higher risk during the occurrence of the first rains after a period of zero precipitation. Eisenberg (2004) investigated the relations between precipitation and crash rates, which occurred in 48 states during the years of 1975-2000. From the analysis it is evident that the accident rates increase with the time which has elapsed since the last rain event. For example, 10 mm of precipitation was found to increase the fatal crash rate by about 3% if 2 days have passed since the last precipitation and by about 9% if more than 20 days have passed. This same pattern was also found for non-fatal crashes.

A study which was conducted in Israel (Professional Committee Report (2006)) also addressed the issue of FRSA. In total, about 3000 road sections were investigated; in which 254 "wet" accidents were recorded during the period from October 2002 to the end of March 2003. First rain conditions were defined as rain events of more than 0.5 mm (or 1 mm), occurring after at least one month of no precipitation. The results of the analysis showed that the risk of a "wet" accident during the first rain is on the average 2.65-3.81 higher than the risk of a "wet" accident during other rain events (The different numbers indicate different model assumptions). The confidence intervals for the different models varied in the range of 1.5 to more than 6.0. Since the research concentrated on "wet" accidents, the results pinpoint the net contribution of the first rain to the accident risk.

Keay & Simmonds (2006) investigated the influence of rain events on accident rate in Melbourne, Australia. The research examined accident and weather data relating to the years 1987-2002. The results showed a substantial increase of the accident rates during first rain days, relatively to other rainy days. The increase in accident rates was about 9-10% after a dry period of 1-5 days, and 18-19.5% after a dry period of more than 5 days.

From the literature it is clear that dry periods increase the accident rates during the first rainy day. In many countries around the world, dry periods between rain events are quite short, in the range of a few days to no more than a couple of weeks. Israel in this aspect has a much drier climate, and dry periods can last up to 8 months. These long dry periods increase the accumulation of contaminants and the effect of the first rain phenomenon is much more pronounced.

In spite of the documented phenomenon of FRSA, and its known impact on road safety, most road authorities around the world do not play an active role in its prevention.

Some road authorities (including the INRC) engage in posting warning signs, aimed at increasing the drivers' attention and caution as to the increased risks during first rain events. In some places these signs are electronic ones which are activated during the rains, in order to better attract the drivers' attention. In some countries, including Israel, use is made of the media, in order to remind the drivers of the required changes in their driving behavior during the first winter rains.

In that sense, the measures taken during the past few years by INRC, to actively remove contaminants from the pavement surface before the rainy season, are exceptional.

WATERBLASTING AND OTHER SURFACE TREATMENT TECHNIQUES

Since 2001, the INRC has adopted an array of techniques aimed at the mitigation of skid resistance problems in the Israeli rural highway network. The main reason for the above was to have handy available maintenance tools which will enable the authority to treat slippery road sections at a short notice, and in a relatively inexpensive way. This, in addition to other more conventional alternatives, such as asphalt overlays, slurry seals, microsurfacing and more.

One of the main surface treatment techniques is waterblasting. Water blasting techniques have been used for many years in a range of civil engineering fields, for the controlled removal of materials from various surfaces. Since 2004 these techniques have been utilized by the Israel National Road Company (INRC) for surface treatment of asphalt roads.

All waterblasting devices which have been employed in Israel for road surface treatment are heavy equipment, capable to treat a strip of 2 m width, and more in one pass. Similar or even the same equipment (with a different configuration) can be used for the cleaning of porous asphalt (in order to restore its draining and acoustic properties). In the context of highway skid resistance, this technique has been used in Israel for the main following uses:

Macrotexture improvement waterblasting (or water-retexturing)

In that mode the waterblasting equipment is operated at very high water pressures, up to 1000-atm. The high-pressure water jets remove the less durable upper bitumen film, sand and fine aggregates at the upper part of the wearing course, along with various contaminants. Unlike the fine milling and the disk hammering methods, this method does not chip the existing aggregates.

After about three years of experience, it was found that this technique can be useful for the treatment of asphalt mixtures that have a "stone to stone" contact, like SMA, or SUPERPAVE-SHRP type mixtures. On dense graded asphalt mixtures, this technique was found to be problematic and to have a relatively short "life span". The main disadvantages of this method were found to be:

- The inability to control the effects of the treatment, due to differences in the asphalt composition, problems of local segregation, and more. It was required to have a very skilled foreman or field engineer to make sure that the treatment was effective enough, while not harming too much the surface of the road.
- The intensive treatment was found to be problematic when used on cracked areas, due to the penetration of water into the cracks.

Water blasting for contaminant removal

The same water blasting equipment is used for the removal of contaminants from the road surface.

For contaminant removal waterblasting (CRW), the water blasting equipment is operated at much lower water pressure (usually up to 500 atm) and the waterblasting equipment is moving at a relatively high speed. The daily production can mount to more than 15,000 m2.

This use of the waterblasting equipment is known to have a relatively short durability, since its main purpose is just the removal of dust and contaminants of the road surface. More details about the operation of this method are given in the following section.

The INRC employs an array of surface treatment methods in order to restore the skid resistance of road surfaces. In addition to waterblasting techniques, two other surface treatment techniques are employed in Israel. These methods are fine milling and disk hammering (Yaron & Nesichi (2005)). Most of these surface treatment methods are used all year around, in an effort to alleviate skidding risks at deficient road sections. The waterblasting contaminant removal method is the only method which is knowingly used as a short term method.

THE ISRAELI POLICY REGARDING FRSA

General

Until the first years of 2000, the road authorities in Israel have taken only educational and advertising measures, in order to ease the problem of FRSA. These measures included:

- Use of various signs along the roads, with emphasis on road sections with relatively low SR, or with known problematic history in connection with FRSA. Most of the signs addressed the issue of driving during rain events, without directly addressing the issue of FRSA.
- Use of the media, including radio, TV, and commercial road signs, in order to caution and help change the drivers' behavior. This type of action is especially intensified during the period of early winter.
- Integrating the issue of driving in wet conditions and during first rain events, in the curriculum of special educational programs in high schools, and during the theoretical education of obtaining a driver's license.

During the last decade, the INRC has initiated a very intensive program aimed at improving the SR values of the interurban roads in Israel. This program included the use of:

- SMA and SUPERPAVE-SHRP type asphalt mixtures and reducing to minimum the use of the dense graded mixtures as a wearing course.
- Slurry seal and other special mixtures for road rehabilitation.
- Special methods for asphalt retexturing, including fine milling, disk hammering and waterblasting.

All these measures have helped to ease the problem of FRSA, since the higher the SR value is, the less vulnerable will the pavement be to the masking effect of the contaminating agents. Moreover, it is believed that asphalt surfaces with high texture depth like the SMA, or open graded mixtures, or Chip seals (which are not used in Israel), are less vulnerable to the effect of contamination than dense graded asphalt surfaces.

In addition to the above, the INRC decided to directly address the issue of FRSA by removing the accumulated contaminants from the surface of sensitive sites of the road network

Contaminant removal activities

The routine that was adopted by the INRC for contaminant removal consists of the main following activities:

1. In addition to the main network SR survey, which is conducted during winter, an additional SR survey is conducted during the summer. This survey is aimed at identifying contaminated sections, which should be dealt with in regards with the FRSA problem. The yearly summer survey includes up to about 10% of the network length, especially those sections which are more prone to problems of contamination.
2. The results of the summer survey are used to pinpoint road sections to be treated by waterblasting. The usual criteria for the selection of these road sections, include:
   - skid resistance (SR) values VS the threshold values
   - skid resistance decrease VS the measured values during winter surveys
   - traffic volumes

- past accidents history
- past known "dry period" contamination history.

  In addition, more sections are added to the list of surveyed sections, according to requests from each of the INRC regional offices, based on specific data or citizens' complaints.

3. Performance of contamination removal waterblasting at the selected road sections.

In the present, the contamination removal waterblasting treatment is taken into action as an annual work, starting at the end of August, about 1.5-2 months before the anticipated time of the first rain events of the rainy season. The above is done in order to be able to accomplish as much work before the first rains. The average annual work amounts to about 500,000 m^2 of treated surface area.

Since the beginning of the above process, the timing of the CRW has always been an issue. During some of the years, this above work plan has worked well, but in other years the rain started either too early, or too late. If the rain starts too early, some of the problematic road sections are still untreated. On the other hand, if the rain starts too late, part of the road sections become contaminated again. The following section shows the results of a recent study made in order to unveil some of the uncertainty around this issue.

It should also be mentioned that in addition to the end of summer activities, the INRC uses CRW to treat road sections that were contaminated by accidental or unintended events, such as oil or other liquid spillage from vehicles.

Quality Control procedures

One of the most important matters related to CRW is the way to ensure that the waterblasting process will be performed in the best possible way, by removing all the dust and other contaminants from the road surface.

The efficiency of the process is dependent on many parameters, some of them are related to the local conditions (such as sources of contamination, properties of various contaminants, time passing since the last heavy rain event, and more). On the other hand, the process efficiency is highly dependent on the waterblasting equipment and the working procedures.

For a given type of waterblasting equipment and working procedures, two of the main control parameters are water pressure and the driving speed of the waterblasting truck. These parameters are easily regulated by the equipment operators. The CRW process will be more intensive, as applied water pressure increases, and as driving speed decreases.

Since the waterblasting needs vary from point to point according to the local conditions, it is very important to constantly fine-tune the process. This is necessary, in order to apply the right amount of energy to each road section. Applying less energy than needed will not accomplish the purpose of the work, while applying too much energy is wasteful and may even harm the pavement surface.

It should also be remembered that working under a limited time frame, and trying to accomplish as much work before the first rains of the season, the operators of the equipment are sometimes tempted to increase the driving speed (thus increasing the production rate), and to decrease the water pressure (in order to reduce the need to stop the work for water refilling).

Due to that, the technical specifications of CRW include special QC requirements. These requirements are based on regular skid resistance measurements, performed just after the waterblasting process. The work is performed by a dedicated on-site technician. At each testing point (about 40-60 m apart), two sets of measurements are performed with a British pendulum. The first set is conducted after the CRW process has been carried out. The second test is carried out at the same point following a scrubbing process that is performed with water and a hand brush with plastic bristles. If the results of the two measurements differ by more than 2-3

BPN, there is an indication that the cleaning process was not performed properly and should be repeated.

It should be mentioned that the requirements for continuous on-site QC is also needed since the only time one can measure the true outcome of the CRW process is if it is performed just behind the waterblasting equipment. After a short time the process of contaminant accumulation can mask some of the CRW results and complicate the ability to hold the contractor responsible for defective work.

ESTIMATING THE EFFICIENCY AND DURABILITY OF CRW

A major question which has remained open until recently is how efficient and durable the CRW treatment really is.

Regarding the efficiency of the process, it was assumed that since the process involves the application of high water pressures (up to about 500 atmospheres), the cleaning process should be very efficient. More than that, the QC procedures which involve manual scrubbing of the road surface, should ensure the CRW process properly cleans the surface.

On the other hand, the issue of durability was quite unknown. In theory, and according to the existing literature, one might suppose that the durability of the treatment is extremely short. Such a situation would render the CRW treatment rather unproductive.

In order to unveil some of the uncertainty around these matters, the INRC initiated a research effort. As part of the research (Hershkovich et al (2009)), 5 road sections that were candidates for CRW were monitored for their skid resistance values, before the CRW process and a few times after the CRW process. Skid resistance measurements were performed by two devices:

- **The ROAR device by Norsemeter** – The measurements were conducted continuously along the various sections, at a driving speed of 50-75 km/h (depending on the section), 86% slip and 0.5 mm water film thickness. The ROAR was employed in testing before the CRW process and in all the monitoring events following the CRW.

- **The British Pendulum device** – The measurements were conducted at intervals of about 60 m. In part of the cases the measurements were also performed after a manual scrubbing of the pavement with the aid of water and a brush with plastic bristles. The Pendulum testing was conducted only before and after the CRW process.

Figures 5 and 6 show an example of the results obtained for road no. 807 located in the Galilee region in the north of Israel. Figure 5 depicts the continuous results obtained by the ROAR, while figure 6 shows the average values along the whole road section. As can be seen, the CRW process increased the SR values by about 20%. This increased level of SR stays practically unchanged for about a month, when a rain event (of about 20 mm) happened and probably caused some change to the SR values. The last monitoring event was held on October 15th 2009, and the SR values were still about 20% more than the original values measured before the CRW process.

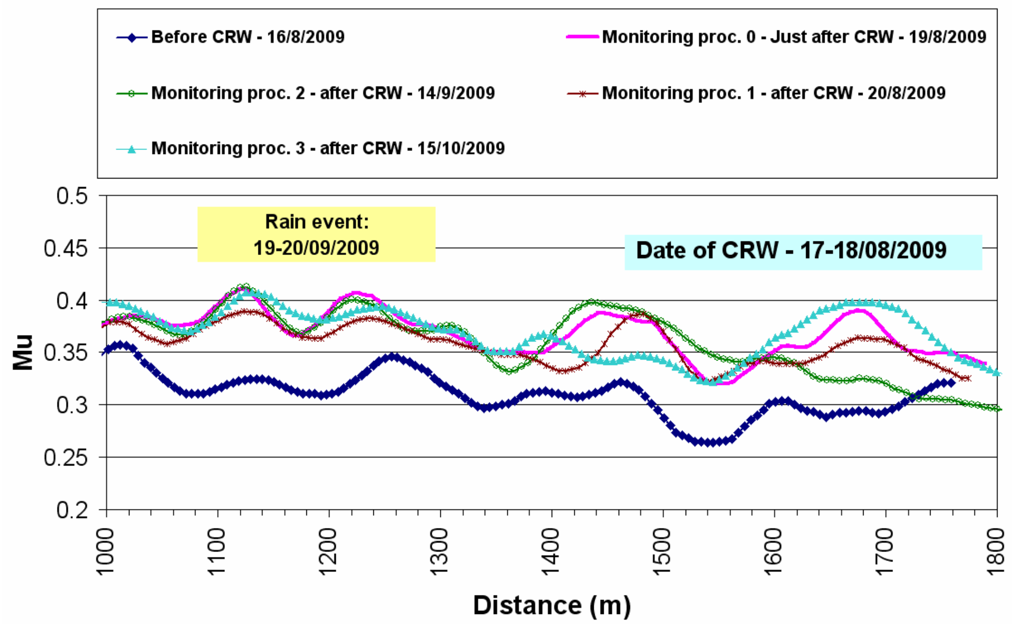

Figure 5: Road no. 807 – SR changes after CRW treatment (Hershkovich et al (2009))

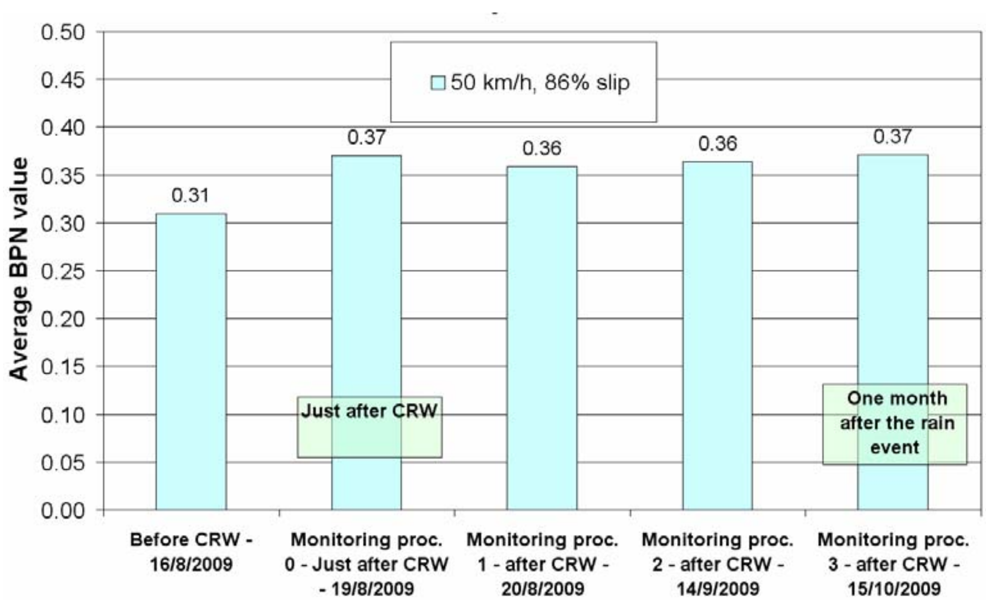

Figure 6: Road no. 807 – SR average changes after CRW treatment (Hershkovich et al (2009))

The above behaviour was essentially found in most of the road sections that were investigated. During the first days after the CRW process, some minor decrease in SR values happened, but these values remained quite stable for a period of at least one month. The research timetable was synchronized with the annual CRW work plan, starting at the beginning of August. Therefore, the "rain free" period until the first autumn rains was limited. In all cases some rain interrupted the continuity of the investigations.

Figure 7 and figure 8 show the BPN and MTD values measured in road no. 65 (by the British Pendulum and the Sand Patch method, respectively). It can be seen that the CRW improved the SR of this road section by about 30%. In this case it is very evident that the CRW process greatly decreased the risk of first rains accidents. The manual scrubbing which followed the CRW process further increased the SR values by about 3-4 BPN units. On the other hand, it can be seen in figure 8 that the CRW process did not change the texture depth of the surface. The CRW, in contrary to the process of water retexturing (mentioned above), is a relatively fine treatment, so the texture of the surface remains essentially without change. The same picture regarding texture depth was found in other road sections.

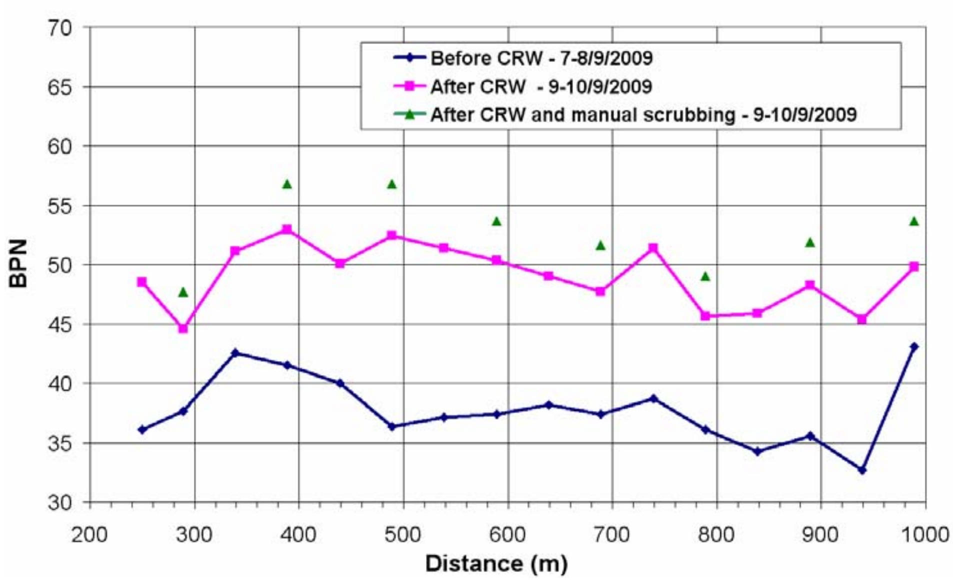

Figure 7: Road no. 65 –BPN values (by the British Pendulum) before and after CRW treatment (Hershkovich et al (2009))

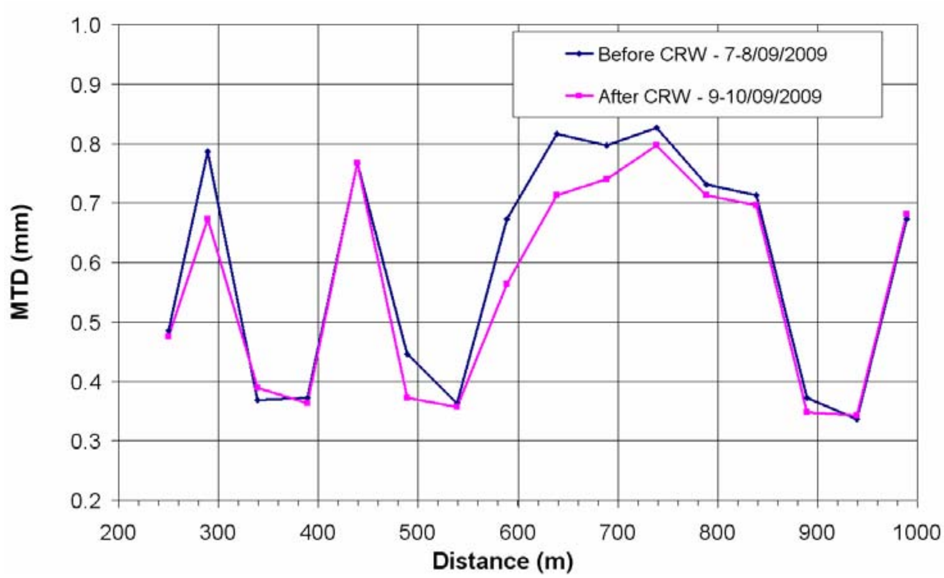

Figure 8: Road no. 65 –Mean Texture Depth values (by the Sand Patch method) before and after CRW treatment (Hershkovich et al (2009))

Figure 9 summarizes the results of the British Pendulum testing that were conducted before and after the CRW process, at 4 of the 5 road sections. It can be seen that the CRW process improved the skid resistance of the road sections, but by varying improvement rates. It seems that part of the treated road sections (like road no. 90 in figure 9) were chosen incorrectly to be treated by CRW, since the CRW resulted in only minor SR improvement.

In addition, figure 9 depicts the influence of the manual scrubbing on the SR of the sections that were treated by CRW. It can be seen that in all of the road sections, the manual scrubbing caused additional improvement of the SR. On the average, this improvement was about 10% of the SR values before CRW.

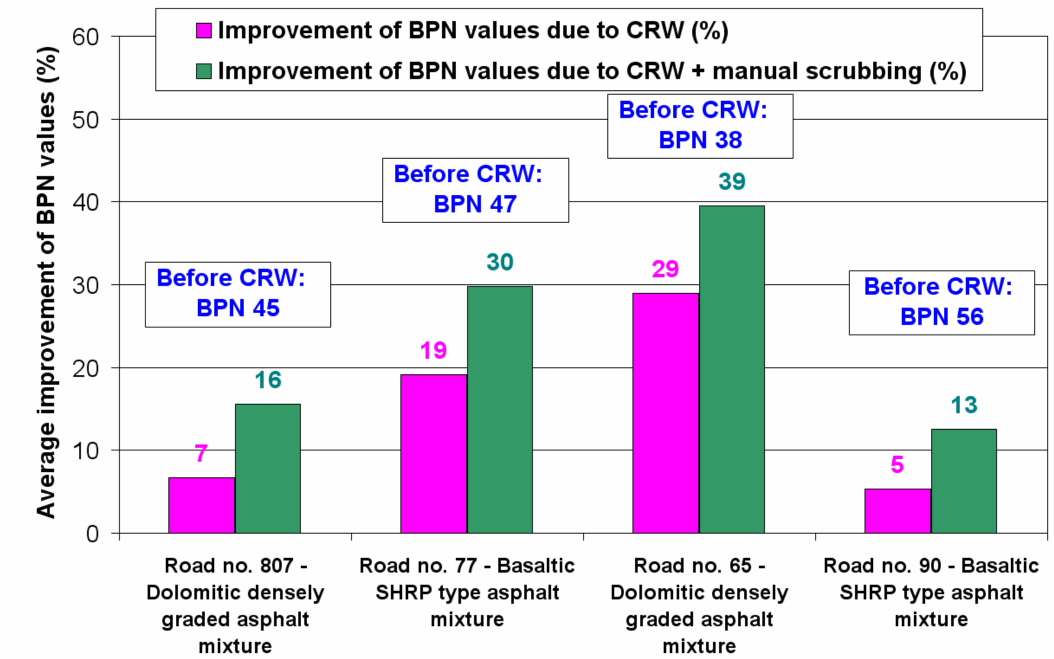

Figure 9: SR relative average improvement after CRW treatment (Hershkovich et al (2009))

Figure 10 shows more information that was gathered in other road sections of the rural highway network in Israel. The figure shows the relative improvement of SR values, caused by the CRW process. It can be seen that the improvement of SR values gets much higher, as the values before CRW are lower. For road sections with SR values of about 30 BPN, the average improvement caused by the CRW can get to about 40%. The main explanation to the above is that in many places, the masking effect of contamination at this time of the year is in the range of 8-15 BPN. When the basic SR of the road is high, this masking effect is less pronounced.

Figure 10 also shows the additional effect of manual scrubbing on SR values, in the range of 2-4 BPN and more.

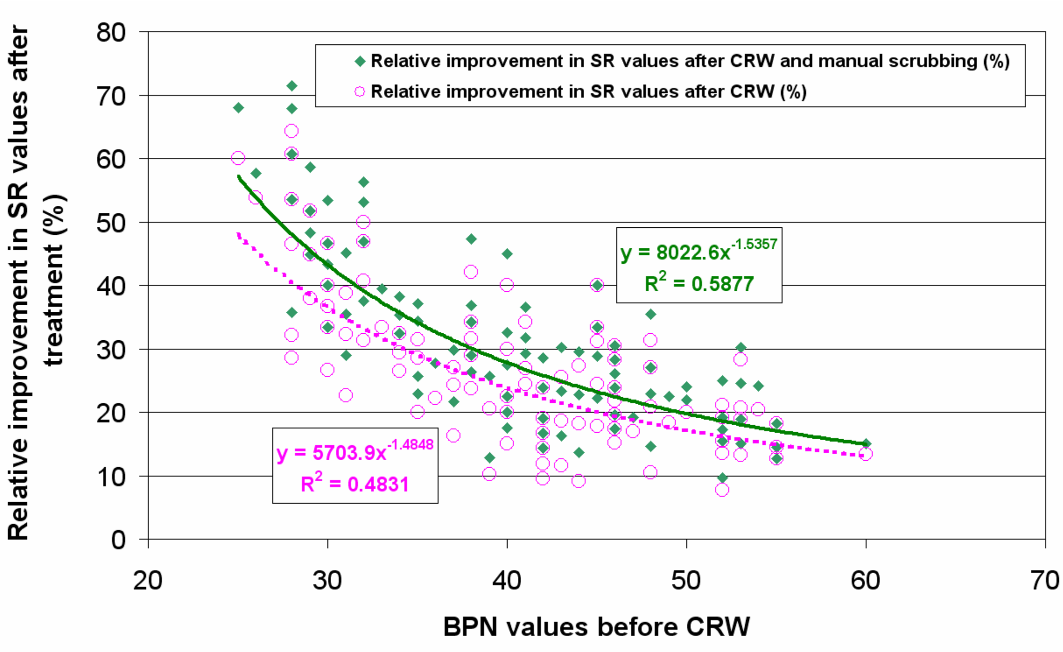

Figure 10: Relative improvement of BPN values as a result of CRW treatment

In all of the sites, a manual process of scrubbing the pavement with water and a plastic brush showed a further increase in SR after the end of the CRW process. In quite a lot of instances, the additional improvement was 4 BPN and more. In theory, all these places should have been retreated, since the QC specifications require that manual scrubbing after CRW will result in an improvement of no more than 3 BPN. Possible explanations for the above phenomenon can be:

- It might be that the CRW process was not intensive enough, and the QC processes failed to mend it on time. In such cases higher water pressures, slower speed of the waterblasting equipment, and in some cases, a change of the waterblasting technical details (like changing the angle of the water nozzles) could help in getting a better outcome. In some of the projects, problems in the operation of the vacuum system (responsible for the suction of the dirty water) could have caused an inefficient waterblasting process.
- There is a possibility that the CRW, in spite of its intensity in terms of water pressure is not efficient enough. One potential reason is that the process is too short, so part of the contaminants (especially those which are water soluble) are not removed by the waterblasting process, but do respond to slower brushing with water.

A supporting point to the above is the fact that in some of the sites, the SR after a rain event (including events of no more than 20mm per day of rain) was found to be higher than the SR achieved after a CRW process. It might be that the soaking action of the rain, accelerate the removal of at least part of the contaminants which still remain following the CRW process.

SUMMARY

The ongoing research and work which has been done in Israel during the last years, regarding the issue of First Rain Skidding Accidents (FRSA) and Contaminant Removal Waterblasting (CRW) can be summarized by the main following points:

- Due to the Israeli specific climate conditions of a long rainless summer, various contaminants tend to create a "masking effect" on the road surface. These contaminants may cause a substantial decrease of the roads SR values, during the first rain events. The decrease depends on various parameters, including traffic, local land uses and more. The temporary decrease in SR values is especially pronounced in road sections that have basic ("clean surface") low values of skid resistance.

- Contaminant Removal Waterblasting (CRW) may continue to be used as a tool to reduce the risks of first rain skidding accidents. If conducted in the right places, the process can significantly enhance the SR, and keep the road with much less contaminants, for a period of more than a month.
- In order to maximize the effects of CRW, QC and QA procedures must be conducted in very strict manner. The BPN testing, including the manual scrubbing procedure, was found to be a good testing procedure for the above.
- There is a need to reexamine the procedures for the selection of road sections which should be treated by CRW. This, in order to ensure that the limited number of CRW devices can be utilized in the most effective manner, within the limited time frame until the beginning of the rainy season.
- It is recommended that the CRW techniques be revised, in order to make the process more effective. One of the assumptions is that maybe a pre-wetting of the pavement before the main CRW process, might better simulate the rain effects and help in removing a larger part of the contaminants of the pavement surface.

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