ANALYSIS OF TEMPERATURE INFLUENCE ON SKID RESULTS

Marta Pagola , University of Rosario, Argentina

Oscar Giovanon, National University of Rosario, Argentina

ABSTRACT

Skid resistance results obtained with different type of equipments present differences that are influenced by many aspects, like: speed of skidding, thick of water, temperature, type of tire, and others. In addition, measurements made with the same type of equipment can be different because of individual particularities of each one. And more variations can be observed analyzing results of one equipment along the year because the effect of seasonality.

In this paper the influence of temperature will be analyzed, which is considered a relevant parameter that significantly affects the results. For example: in British Pendulum equipment the influence have been studied and standardized and its results are corrected to a temperature of reference, and correction coefficient was defined.

In Argentina, skid resistance measurements are making with different equipments: mu meter, scrim, and griptester. They are done in any moment of the year and without temperature control or measurement; and it is not defined a methodology to apply to minimize variations that are generated by temperature and seasonality.

This paper analyzes variations observed in results obtained with different equipments looking for the definition of correction factors to apply to minimize temperature variation influence.

INTRODUCTION

Skid resistance of road surface is not constant along the time. It has a permanent decrease along the years, and it also has different results in short periods of time. Measurements made in different days can be higher or smaller than previous one, without a totally defined behavior. And along the year skid resistance has seasonal variations, in summer results are lower than in winter. In Figure 1 theoretical behavior along the time is shown, where permanent decrease and a variable cycle can be seen.

Skid resistance results changes can be because different parameters variations, like: temperature, measurement speed, surface dirty, tire condition, etc.

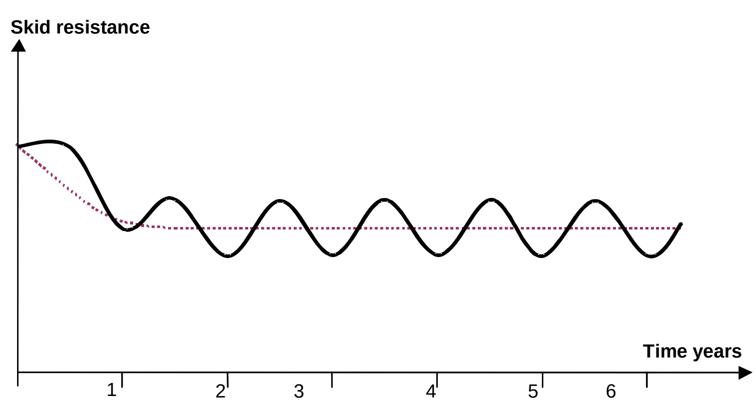

Figure 1: Skid resistance theoretical behaviour along time.

Considering this behaviour different situations appear to measure road surface skid resistance: to know the condition in a specific moment, to obtain the minimum value that surface can have in a year, and to take a result to be compared with specifications.

SKID RESISTANCE MEASUREMENT SITUATIONS

Measurements can be done in different situations:

- Situation 1: to know the condition in a specific moment,
- Situation 2: to obtain the minimum value that surface can have in a year, working in Pavement Management Systems and risk of accidents,
- Situation 3: to take a result to be compared with technical specifications.

Situation 1

It is the situation that happens in airports in service, where it is necessary to know runway surface condition in a specific moment, and to take the decision if the surface has the necessary security conditions for plane landing. It is common in winter during freezing time when surface is iced or snow covered, then results are valid only for short periods of time. Similar case is the evaluation of runway surface, to analyze the reduction of skid resistance due to rubber contamination and to take the decision of cleaning it.

Situation 2

This situation is related with security analysis and pavement management systems related with accident risks. Measurements are performing periodic and systematically, and they are used to take the decision of plan activities to improve surface condition. This type of analysis is applied in some countries, England for example, where roads are measured every year during summer period to know the minimum value of surface skid resistance. The skid value finally charged in pavement management system is an average of three measurements made during summer period, to minimize errors and dispersions of results. Then, analyzing results evolution, road sections with potential risk of accidents are defined, and road works are planned to improve these situations.

Situation 3

The objective here is to measure surface condition and to compare results with values specified in technical specifications. Two cases can be differenced: road work reception and in service road condition. This is the situation applied in Argentina, where a lot of road kilometers are under toll concession and companies have to respect specific quality limits. If results are out of limits the National Road Administration Control apply penalties to companies.

Mu meter and Scrim Tex are used to measure, Figure 2. Measurements are done in any moment of year and without considering the temperature in this moment; the only requirement is that pavement surface must be dry, looking for a better control of water thickness present during measurements.

The methodology in use indicates that must be performing one measurement to control the surface condition and compare these results with quality limits fixed in technical specifications. If results are over limits, then the surface is approved. If results are under limits, must be done two additional measurements to obtain the average of three numbers; then this average is compared with limits. This methodology tries to increase reliability results.

Figure 2: Mu meter and Scrim Tex used for National Road Administration in Argentina.

ELEMENTS PRESENT IN SKID RESISTANCE MEASUREMENTS

Elements that are present during measurements are: pavements surface, test tire and water, Figure 3. All of them have variations along the time, some are permanent and some are transitory, therefore measurement conditions are not always the same. In following points these variations are described.

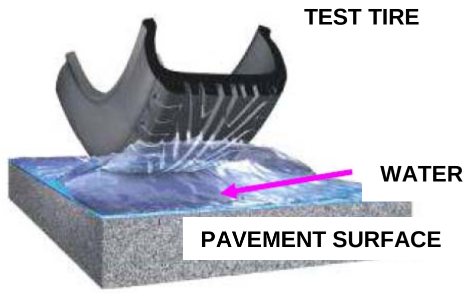

Figure 3: Elements present during measurements.

Pavement surface

Transitory variations

If pavement surface is contaminated with dirt and powder, skid resistance results can be different. This situation is very common. After long periods without rain surface has powder on it, and during measurement, when water appear, generates a type of mix with powder, changing water viscosity and then changing its behavior. If powder quantity is important, results can be very different. In this situation, powder nature is important, because if it is coming from clay the final mix viscosity cannot be the most appropriated to perform measurements.

Another situation can happen in road intersections with secondary unpaved roads. In this case, and after rain periods, vehicles that come from unpaved roads can have dirt accumulated in tires and then deposit it on road surface, generating places really dirty that can give wrong results of skid resistance.

Permanent variation

Pavement surface has permanent variation along time related with skid resistance: surface texture depth reduces with traffic, fundamentally with heavy loads; and aggregates exposed in surface and in contact with traffic become polished and then their capacity to give effective dry contact with tires is reduced.

Test tire

Transitory variation

Test tire behavior depends on rubber resilience and tire air pressure. Both of them are related with temperature present during measuring. Tire air pressure must be controlled periodically to reduce their influence. And rubber resilience is one aspect that cannot be controlled and it is one of aspects responsible of skid results variations.

Permanent variation

For all type of equipment, tire rubber surface has a permanent variation because of wear. When they are in use during measurements or during transfer their surfaces become worn.

In equipments with ribbed tires, ribbed has contribution to water evacuation, and when it disappears water has more difficulty to go out from measurement place. For these equipments Standards indicate the minimum rib depth.

If tire surface is smooth, wear affects all or part of their surface depending on equipment type. Standards say that they can be used up to wear affects their structure and it is when tire fabric is exposed.

Previous experiences done by the authors have analyzed wear tire influence using Mu meter equipment. Measurements were realized on road sections of few kilometers during some days up to tire became worn. In Figure 4 results are shown. Results of first kilometers are higher than the others because measurements began with new tires without previous conditioning as it is recommended in Standards. The experience showed that tires were in good conditions up to 400 Kilometers. As a conclusion, tire wear does not affect results.

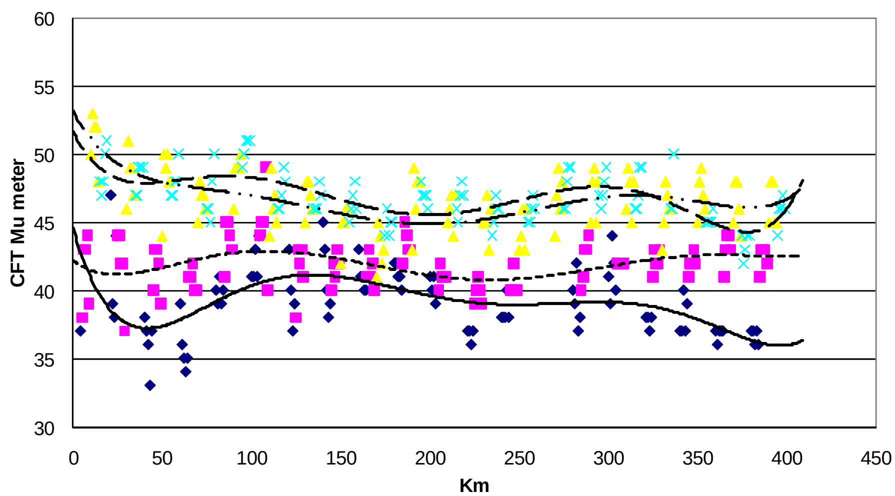

Figure 4: Mu meter results vs. Km driven.

Water

Water thickness is a very important parameter. During measurements water thickness is related with measurement speed. In general, equipments water a constant quantity of water in front of tires, and water thickness is calculated to obtain a value indicated in standards, considering a specific speed of vehicle (for example: 0.5 mm, 1 mm, etc.).

Analyzing vehicle behavior, if vehicle moves at high speed, water has difficulty to go out from tire–surface interface, and it is difficult to obtain dry contact between both surfaces, then the driver would lose the capacity of vehicle control. In extreme conditions, vehicle does not touch road surface and driver loses vehicle control totally. In Figure 5 dry contact area reduction when speed goes from 50 Km/h to 100 Km/h can be seen, in a hypothetic situation with smooth tire and surface without texture depth.

50 Km/h	100 Km/h
	

Figure 5: Dry contact area related with vehicle speed.

In this analysis, texture depth has participation. The theoretical analysis of water thickness is done considering that pavement surface has no texture depth. Then, during measurements on real road surfaces, if pavement surface has high texture depth the effective water thickness is lower than specified, and it is reflected in skid resistance results, obtaining better results.

In Figure 6 can be seen how skid resistance reduces when measurement speed increases, for three types of surfaces identified with their texture depth. In this experience, equipment water different quantity of water at each speed in the way to always obtain 1 mm of water thickness. As can be seen, when pavement surface has high texture depth, results are always similar, but in a section with low texture depth results have an important reduction, reflecting that water cannot go out from interface and then dry contact is very low.

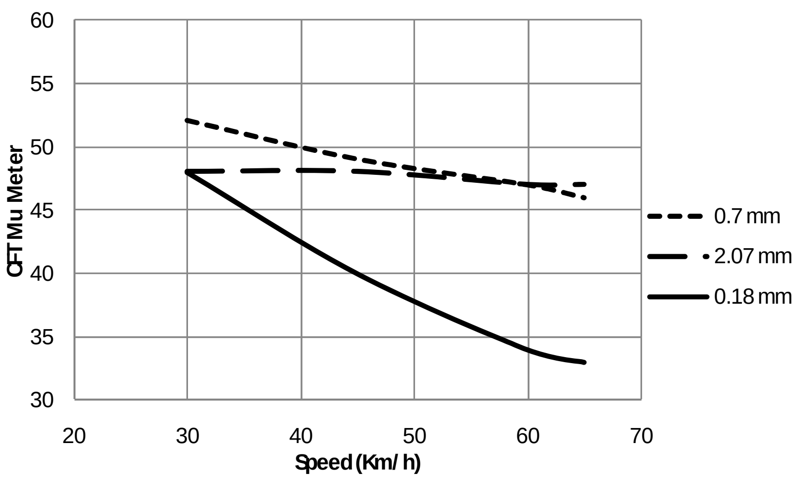

Figure 6: Skid resistance vs. speed for different texture depth, Mu meter equipment.

Speed and texture depth influence depend on equipment configuration, tire size, load and tire pressure. In Mu meter equipment the influence is high, because tires are wide, smooth and load is low. In equipments like Scrim these parameters are less important, tire is narrow and load on measurement tire is important.

Water viscosity characteristic has influence on results, in Standards is indicated that water must be reasonably clean, with no chemical added such detergents or wetting agents. Water with high content of salts must not be used.

Water temperature has influence too, combined with air and pavement temperature. About this point some experiences with Mu meter and Scrim Tex equipments were done, results are presented in following points of present paper.

TEMPERATURE INFLUENCE ANALYSIS

During measurement, the three elements involved are influenced by temperature. The real temperature that takes part is one combined between water, tire and pavement. This temperature cannot be measure. Temperatures that can be measure are: air, water and pavement, each one in separate way. Some equipment has sensors incorporated and measure air and pavement temperature. In other equipments, temperature has to be measure as an extra activity, this is indicated in Standard or Methodology adopted.

TRRL Pendulum equipment

In ASTM Standard it is indicated the working methodology to perform measurements using this equipment. The temperature is taken as an extra activity. It is indicated that must be measured the temperature of water that remain on pavement surface after measurement. It means that this temperature is a combination between water and pavement.

Skid resistance results obtained with TRRL Pendulum are corrected by temperature; and final results are expressed at reference temperature of 20 ºC. For this equipment, the influence is 1 point of skid resistance each 3 ºC. Measurements made at temperatures over 20 ºC have to be increased, and on the other way, measurements made at temperatures under 20 ºC have to be reduced.

This methodology tries to correct results and to express them in a comparable way, correcting some variations due to temperature at the moment of measuring; it does not correct seasonal variations. This is a good criterion at the moment to compare results with limits of quality. This situation was described previously and identify as Situation 3. It can be applied in Argentina, where skid resistance is a parameter specified in routes under concession and it must be over certain limits of quality.

Scrim equipment

References show different temperature influence depending on country.

In Spain, as it is said at ASEFMA monograph nº 11, measurements are made in any moment of the year and corrected with air temperature to a reference temperature of 20 ºC; the influence considered is 1 point each 3 ºC.

In England, as it is said in HD 28/04, Design manual for roads and bridges, measurements are made in a specific time of the year (summer period, 1 May – 30 September), and temperature correction is not necessary for surveys carried out under conditions set out in the Standards.

Experiences in Argentina

As was said previously, in Argentina the National Road Administration uses Mu meter and Scrim Tex equipments; and private companies use TRRL Pendulum and Griptester. There are different Technical Specifications, the newer one specifies limits in IFI and it can be obtained with any equipment, and there are other older that have limits expressed in Mu meter units.

There are no correction indicated in Technical Specifications, results obtained in any moment of the year are directly compared with limits. The only whether condition to be respected is that pavement surface must be dry before measure. Then, measurements made following this methodology can give good or bad results depending on “luck” or weather condition during measuring.

The objective of present work was to study temperature influence on results obtained with Mu meter and Scrim Tex in Argentina, and to analyze if it is necessary to plan some type of correction. To perform the analysis, measurements were made in some sections during a short period of time to avoid seasonal variations but with different air and surface temperatures.

Mu meter equipment

Mu meter equipment does not have temperature sensor incorporated, then at the end of measurement were taken the three possible temperatures: air, dry pavement and remanent water on pavement surface. Remanent water on pavement surface temperature is the same that is indicated in British Pendulum methodology, and it is a combination between surface and water temperature.

Were measured 4 sections of 4 Km of length approximately, sections have different characteristic of texture depth, and air temperature was between 8 ºC and 32 ºC.

Tendencies between skid results and each one temperature were analyzed. From all tendencies obtained, the one that relates results with remanent water on pavement surface was the best. In Figure 7 this relation is shown; each skid resistance result (CFT) is expressed as a difference between each result and an average result of section, while temperature is expressed as a difference between each measurement temperature and an average temperature of all measurements of each section. This way of representation allows for representing results of different sections in the same graph, with different levels of skid resistance and temperature.

Tendency shows that influence is 1 point of Mu Meter each 3 ºC or 0.33 points each 1 ºC, the same that TRRL Pendulum, and considering the same temperature parameter, remanent water on pavement surface. The graph also shows that when temperature increases skid resistance coefficient decreases. Influences are similar, but absolute values are different because both equipments have different configurations and different methodology of working (speed and water thickness).

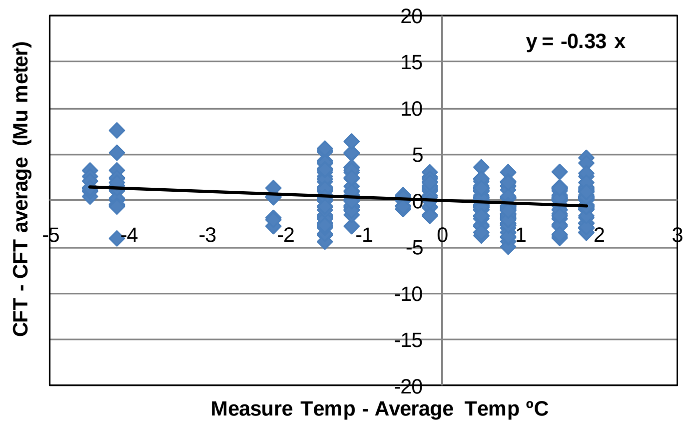

Figure 7: CFT Mu meter vs. remanent water on surface temperature.

Scrim Tex equipment

Were measured 2 sections of 2 Km of length approximately, sections have different characteristic of texture depth and air temperature was between 8 ºC and 18 ºC.

This equipment has two sensors incorporated, one measure air temperature and another dry pavement surface temperature. Tendencies with both temperatures were analyzed, and one additional analysis was made between results and average temperature between both available temperature results. The objective here was to use available results without incorporate additional temperature measurements.

The tendency obtained indicates that when temperature increases skid resistance result (CFT) decreases, but it influence was really low, in the order of 1 point Scrim each 12 ºC. In Figure 8 results of all sections together are shown.

In a comparative way the same relationship using average temperature was done for Mu meter results. The tendency obtained does not show appreciable variation, one point Mu meter each 190 ºC, see Figure 9.

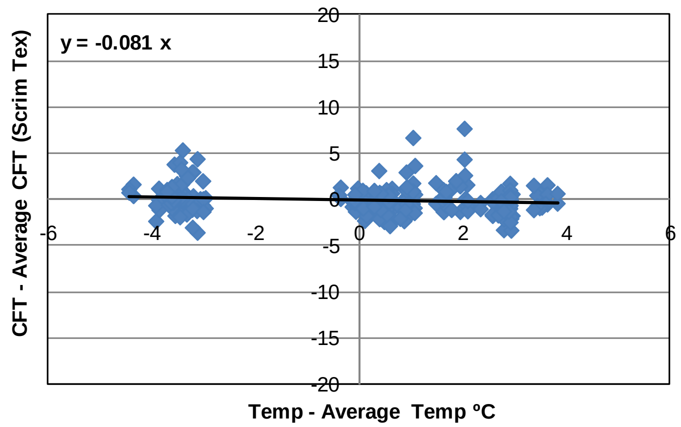

Figure 8: CFT Scrim Tex vs. average air-pavement temperature.

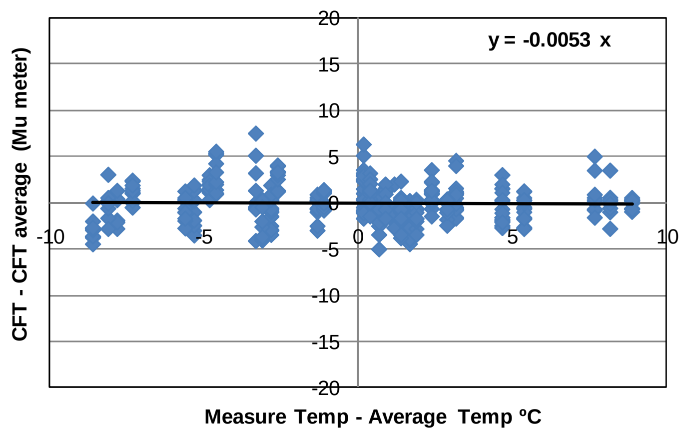

Figure 9: CFT Mu meter vs. average air-pavement temperature.

The analysis indicates that this average temperature between air and pavement is not a good parameter to use to correct results.

To apply corrections for Scrim Tex results it is recommended to take an additional measurement of remanent water on pavement surface temperature like is made in Mu meter measurements, and analyze this influence in future experiences. It is an additional activity that can be done at the end of measuring, taking the temperature of a bit of water on road surface.

CONCLUSIONS

Was analyzed temperature influence on results obtained with Mu meter and Scrim Tex in Argentina.

From all temperatures present during measurement the one that presented a reasonable tendency is remanent water on pavement surface.

For Mu meter equipment the temperature influence obtained is 1 point each 3 ºC or 0.33 points each 1 ºC, the same that TRRL Pendulum, and considering the same temperature parameter, remanent water on pavement surface. The tendency also shows that when temperature increases skid resistance coefficient decreases.

For Scrim Tex, analysis was made between results and average temperature between both available temperature (air and pavement); tendency obtained indicates that when temperature increases skid resistance result (CFT) decreases, but it was really low, in the order of 1 point Scrim each 12 ºC.

The analysis indicates that the temperature obtained as an average between air and pavement is not a good parameter to use to correct results.

To correct Scrim Tex results would be recommended to measure additionally remanent water on pavement surface temperature, like is made in Mu meter measurements, and analyze this influence.

It is recommended to correct Mu meter results to a reference temperature of 20 ºC like is made with TRRL Pendulum results. This temperature could represent average temperature existing in Argentina.

To correct Scrim Tex results it is recommended to make an additional measurement of remanent water on pavement surface temperature like is made on Mu meter measurements, and analyze this influence with more experiences.

The correction presented here does not pretend correct seasonal variations; it only corrects results to a reference temperature and reduces dispersions due to temperature at measurement moment.

REFERENCES

ASTM E 670. Standard test method for side force friction on paved surfaces using Mu meter.

ASEFMA. Monograph 11. Skid resistance of pavements. Spain.

HD 28/04. Design manual for roads and bridges. Volume 7. Section 3. England.

Bulletin des Laboratoires des Ponts et Chaussees. Special Adherence. Number 255. 2005.

Long Term Study of Skid Resistance on in-service roads in England. Donbavand and Kennedy. International Safer Road 2008. England.

Modeling of pavement skid resistance. PhD Thesis. Echaveguren Tomás. 2008. Chile

AUTHOR BIOGRAPHIES

Marta Pagola

Civil Engineer, National University of Rosario, Argentina, 1981. Master on Roads, National University of Rosario, 2002. PhD candidate. Road researcher and Professor of grade and postgraduate level at National University of Rosario, Argentina. Professional activity related with Pavement Management Systems, Pavement Design, Surface and Structural Characteristics Surveys. Author and speaker of papers in National and International Congresses.

Oscar Giovanon

Civil Engineer, National University of Rosario, Argentina, 1981. Master on Roads, National University of Rosario, 2002. PhD candidate. Road researcher and Professor of grade and postgraduate level at National University of Rosario, Argentina. Professional activity related with Pavement Management Systems, Pavement Design, Surface and Structural Characteristics Surveys. Author and speaker of papers in National and International Congresses.

- publish the work in printed format
- publish the work in electronic format
- publish the work online.

The author retains the right to use their work, illustrations (line art, photographs, figures, plates) and research data in their own future works

The Author warrants that they are entitled to deal with the Intellectual Property Rights in the works submitted, including clearing all third party intellectual property rights and obtaining formal permission from their respective institutions or employers before submission, where necessary.