REFERENCE TEST TYRES FOR FRICTION COEFFICIENT MEASUREMENTS – PIARC XXIIND WORLD ROAD CONGRESS

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ABSTRACT

In the early seventies, PIARC Committee C1 initiated the manufacture of a special tyre for use on devices to measure friction coefficients. Although the tyre is not the only important factor in this measurement, the use of this special tyre by many countries has allowed – and still allows – easier exchange of results of measurements.

As the Swiss manufacturer of the PIARC tyre, MALOYA, ceased his activities in the years 1995-1996, Committee C1 was forced to look for a new partner for this specific production.

The Dutch manufacturer VREDESTEIN accepted to produce a new series in accordance with the original specifications for this special tyre. This series was released early in 1998 and supplied late in 1998 by the Dutch company KOAC/WMD to all clients.

As early as at the end of 1998, comparative tests conducted in France showed differences between results obtained on the same surfaces with the tyre of the 1990 series and the tyre of the 1998 series.

This finding was confirmed by other tests in 1999, and prompted PIARC Committee C1 to ask explanations from the manufacturer and supplier of these special tyres. The latter two made concrete proposals resulting in new tests performed in two member countries of C1 (the Netherlands and France) with their respective devices on commonly encountered surfaces. With the results of these tests two reports were produced in which different suggestions were made:

The Dutch suggested four models to correct the values obtained with the tyres of 1998;

The French suggested retaining the tyre of the 1998 series – and to change the ranges of references used in France.

The users of the tyres were informed on those tests, and a meeting was arranged for them in Delft in September 2002. Also invited to this meeting was a representative of the companies VREDESTEIN and KOAC/WMD. As an outcome of this meeting, working group D made recommendations to Committee C1, with a time schedule including stages to be completed within six months, one year and two years.

All this should provide C1 with the necessary information to decide whether there is a need for considerable developments in the characteristics of the present PIARC tyre before starting a new production.

1. HISTORIC

In the early seventies, PIARC Committee C1 initiated the manufacture of a special tyre for use on devices to measure friction coefficients. Although the tyre is not the only important factor in this measurement, the use of this special tyre by many countries has allowed – and still allows – easier exchange of results of measurements.

This special tyre was made either with a smooth profile allowing to have a good quality assessment of the upper drainability of the wearing course, or with a grooved profile which reproduced trade tyres characteristics for longitudinal braking. The ASTM 501 or E 524 standard defines the rubber blend used for this tyre.
As the Swiss manufacturer of the PIARC tyre, MALOYA, ceased his activities in the years 1995-1996, Committee C1 was forced to look for a new partner for this specific production. The Dutch manufacturer VREDESTEIN accepted to produce a new series in accordance with the original specifications for this special tyre. This series was released early in 1998 and supplied late in 1998 by the Dutch company KOAC/WMD to all clients.

2. NEW SERIES

As early as at the end of 1998, comparative tests conducted in France showed differences between results obtained on the same surfaces with the tyre of the 1990 series and the tyre of the 1998 series.
This finding was confirmed by other tests in 1999, and prompted PIARC Committee C1 to ask explanations from the manufacturer and supplier of these special tyres.
These two companies conducted a big explanatory study. It led to the following main conclusions:
There are a few differences between the two tyre series formulas, but it might be the 1990 series that would not be true to the specifications. On the other hand a few modifications was made to the formula in order to improve the tyre resistance to overheating. However according to VREDESTEIN, these minor differences might not cause significant modifications in the measurement results.
The most significant difference observed between the two tyre series seems to be the rubber hardness Shore A. The 1990 series tyres have a Shore A hardness value of 66,6 for 56,8 in the 1998 tyre series. VREDESTEIN and KOAC/WMD then suggested to artificially age several 1998 series tyres in order to increase this initial hardness value. The figure 1 shows the hardness increase after this ageing made in controlled oven (ageing as 5 years and 10 years).

Tyre series	Mean Hardness (MH)	Standard Deviation (SD)	[(MH-2SD)-(MH+2SD)]
1990	66.6	2.6	[61.4 – 71.8]
1998 L	56.8	3.1	[50.6 – 63.0]
1998 M	60.9	3.2	[54.5 – 67.3]
1998 H	66.4	2.9	[60.6 – 72.2]

Figure 1 – Table of hardness measured on PIARC tyres

3. TESTS CONDUCTED

Then tests were conducted with these new tyres. The results obtained with the so aged tyres, though being better than those obtained with original tyres, do not satisfactorily suppress the previously noticed gaps. Therefore, the solution suggested by the manufacturer does not seem to be the best, especially since this quick artificial ageing does not allow to ensure the homogeneity in the mass of the so modified rubber.
Two member countries of Committee C1 (Holland and France) conducted numerous comparative tests in their own countries with their own devices and on usual surfaces.
These tests led to the writing of two reports that you can obtain by M de WITT and GOTHIÉ (see references at the end of this report). These two studies show slightly different conclusions.

3.1. Study done by Dutch

From measurements carried out with DWW trailer measuring a longitudinal friction coefficient with a slip ratio of 86%, Dutch people propose 4 models (see in annexe) in order to correct the values obtained with the 1998 tyres. These 4 models use the following explanatory factors:

3.1.1. Explanatory factors: tyre type and surface type :

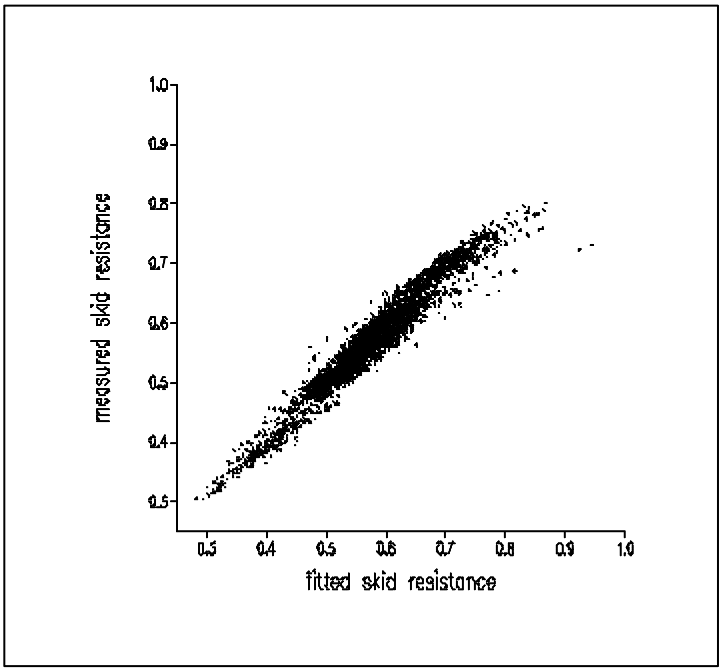


Figure 2 - Measured skid resistance plotted against fitted values from a model with surface-type specific corrections for temperature, tyre type, and speed; R=1.125.

Five tyre types and six surface types have been used to determine this model.

$$F = A_i + B_j + C_{jk} + (\alpha_0 + \alpha_j + \alpha_k)(v - 53.43) + (\beta_0 + \beta_j + \beta_k)(T - 12.94)$$

Here, the letters i, j, and k are indices for equipment, tyre type, and surface type, respectively. The parameters α_0 and β_0 model the contributions of speed and temperature for SW5, tyre series '90, and ZOAB, respectively. The parameters α_j, α_k, β_j, and β_k model modifications in case other tyre types or surface types are under consideration; there is a single modification factor for the measurement system. Parameters are given in the report referenced [1].

3.1.2. Explanatory factors: tyre type and surface macrotexture

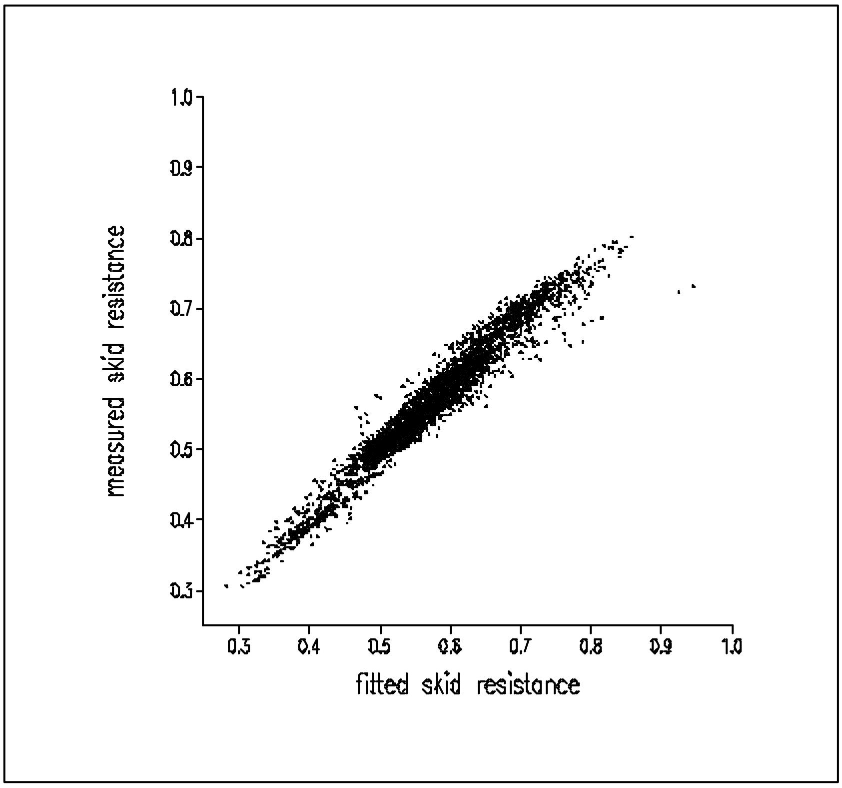


Figure 3 - Measured skid resistance plotted against fitted values from a model with texture-specific corrections for temperature, tyre type, and speed; R=1.117.

Five tyre types and six macrotexture values were used to build the model

$$F = A_i + B_j + \gamma_{j1}\, mpd^* + \gamma_{j2} mpd^{2*} + (\alpha_0 + \alpha_j + \alpha_1 mpd^* + \alpha_2 mpd^{2*})\,(v - 53.43) + (\beta_0 + \beta_j + \beta_1 mpd^* + \beta_2 mpd^{2*})\,(T - 12.94)$$

with $mpd^* = mpd - 0.8004$, and $mpd^{2*} = mpd^2 - 0.7673$
Here, the parameters specific to the categorical variable 'surface type', as indexed by the letter k, are replaced with those needed to handle the continuous variables mpd and mpd^2.

3.1.2. Explanatory factors: rubber hardness and surface type

In this model tyre type has been replaced with hardness and 6 surface types were used:

$$F = A_i + (\delta_0 + \delta_k)\, H^* + (\alpha_0 + \alpha_h\, H^* + \alpha_k)(v - 53.43) + (\beta_0 + \beta_h\, H^* + \beta_k)(T - 12.94),$$

$$\text{with } H^* = H - 64.28$$

Parameters are given in the report (SCHOEN, 2001).

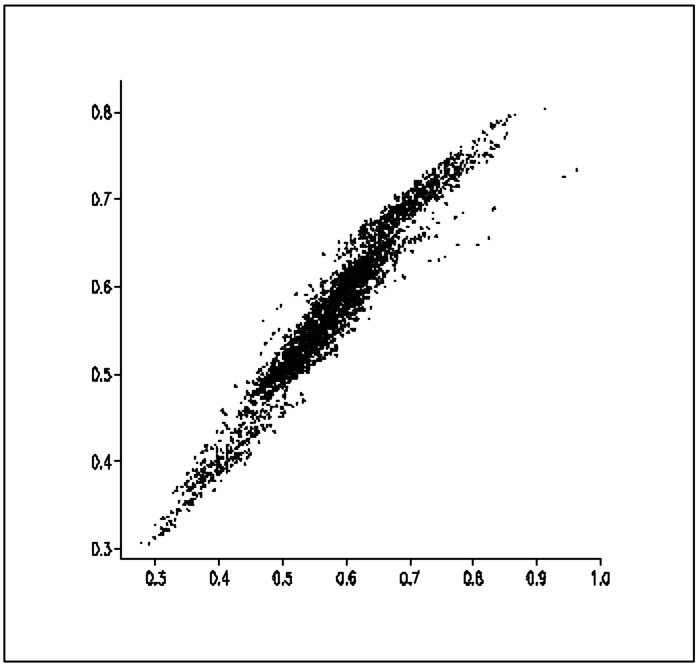


Figure 4 - Measured skid resistance plotted against fitted values from a model with surface-type specific corrections for temperature, hardness of tyre, and speed; R=1.127.

3.1.2. Explanatory factors: rubber hardness and surface macrotexture

For that model tyre type has been replaced with hardness, and surface type has been replaced with texture.

$$F = A_i + (\delta_0 + \delta_1 mpd^* + \delta_2 mpd^{2*}) H^* + (\alpha_0 + \alpha_h H^* + \alpha_1 mpd^* + \alpha_2 mpd^{2*})(v - 53.43) + (\beta_0 + \beta_h H^* + \beta_1 mpd^* + \beta_2 mpd^{2*})(T - 12.94)$$

with $H^* = H - 64.28$, $mpd^* = mpd - 0.8004$, and $mpd^{2*} = mpd^2 - 0.7673$
Parameters are given in the report (SCHOEN, 2001).

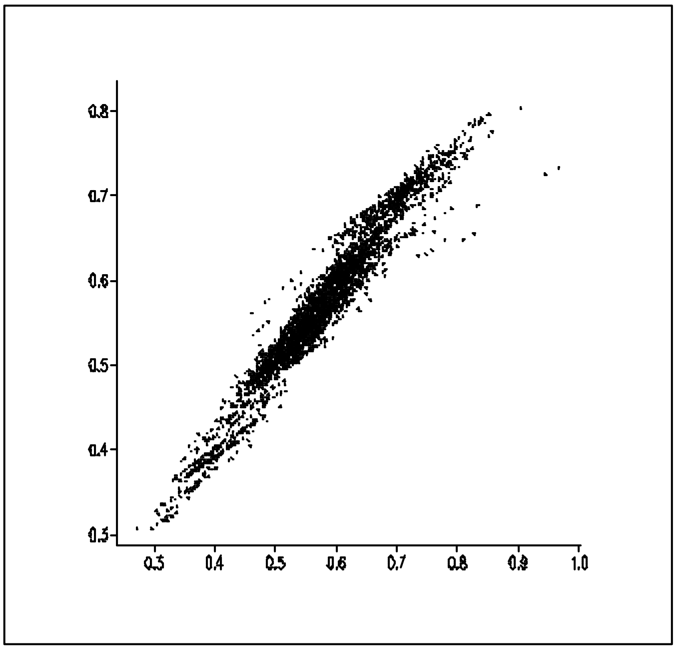


Figure 5 - Measured skid resistance plotted against fitted values from a model with texture-specific corrections for temperature,hardness of tyre, and speed; R=1.126.

Overall these 4 models seem statistically interesting but they give a reproducibility value rather important, especially when on a particular roadwork.

3.1. Study done by French

From numerous measurements, grouping together Dutch measurements and French measurements carried out with ADHERA (measuring a longitudinal friction coefficient with blocked wheel) French people state the following points:

- Linear correlation established between various tyres, confirm the differences previously noticed between the series 1990 and 1998, and improve, when we go from a tyre of the 1998 series to a tyre of the 1998 series artificially aged at 5 years, and more to a tyre of the 1998 series aged at 10 years and when using only one device for the FC measurements,
- The Shore A hardness of tyres is difficult to measure on roadwork and shows very important dispersion. This factor can be replaced by some other explanatory factors (microtexture, macrotexture) without important modification of the determination coefficient value R^2,
- Microtexture and macrotexture level of the tested surfaces seem to be explanatory factors for the differences noted between the two tyres series. In order to avoid complementary measurements, microtexture was assessed by a friction coefficient measurement at low speed (40km/h), and macrotexture was assessed by a calculation of the FC decrease slope measured between 40 and 90 km/h.

From these elements, it was suggested in France:

- to keep in the short term the 1998 tyre (not artificially aged),
- to keep the obtained results with this tyre,
- to modify the reference envelope used in France by technique and for the whole wearing courses, in using the model established from the measurements made by the ADHERA device, with as explanatory factors:
  - the FC measurement at low speed (40km/h)
  - the calculation of the FC decrease slope according to the test speed of 40 to 90 km/h.

For the ADHERA device, the two laws (1) and (2) built to pass from a BFC measured with a 1998 tyre series to a BFC measured with a 1990 tyre series and vice versa are given bellow:

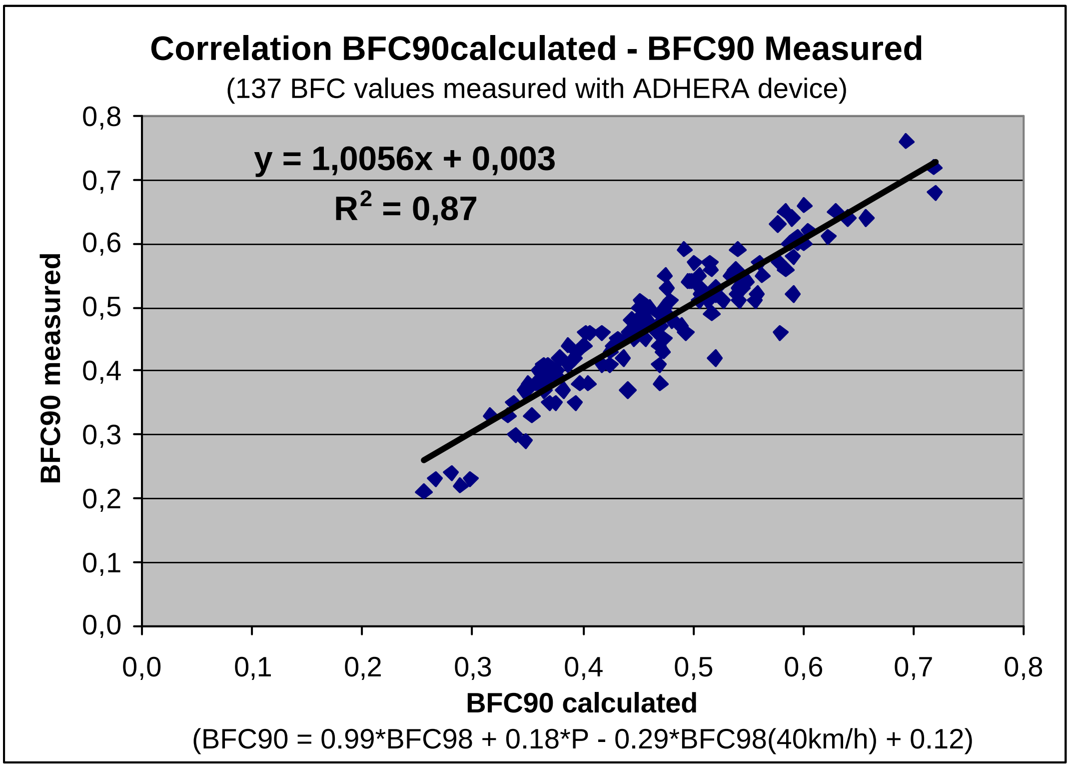
$$CFL98 = 0{,}92.CFL90 – 0{,}14.P + 0{,}13.CFL90(40\ km/h) – 0{,}02$$

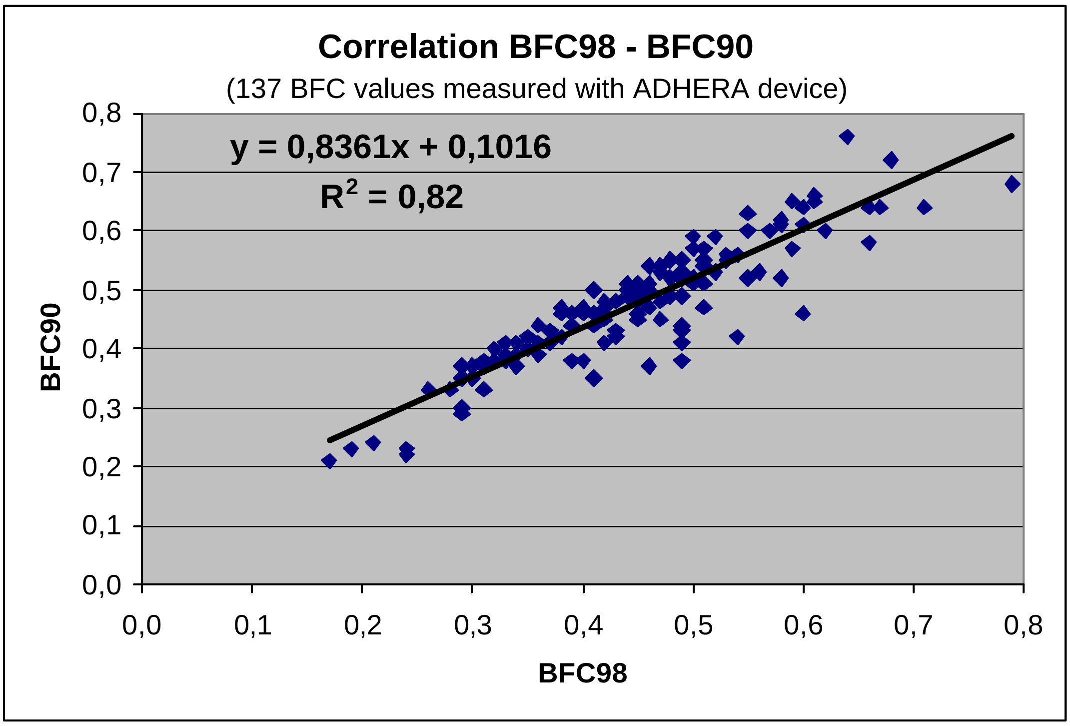
(Determination coefficient = 0 .84 ; Quadratic mean deviation = 0.044)
P/ BFC decrease slope function of the speed:
P = (BFC98(40) – BFC98(90))/50
BFC98 : BFC measured with the PIARC tyre series 1998
BFC98(40) : BFC measured with the PIARC tyre series 1998 at 40 km/h
BFC98(90) : BFC measured with the PIARC tyre series 1998 at 90 km/h
BFC90 : BFC measured with the PIARC tyre series 1990
BFC90(40 km/h) : BFC measured with the PIARC tyre series 1990 at 40 km/h

$$CFL90 = 0{,}99.CFL98 + 0{,}18.P – 0{,}29.CFL90(40\ km/h) + 0{,}12$$

(Determination coefficient = 0 .87; Quadratic mean deviation = 0.037)

P/ BFC decrease slope function of the speed:
P = (BFC90(40) – BFC90(90))/50
BFC98 : BFC measured with the PIARC tyre series 1998
BFC98(40 km/h) : BFC measured with the PIARC tyre series 1998 at 40 km/h
BFC90 : BFC measured with the PIARC tyre series 1990
BFC90(40) : BFC measured with the PIARC tyre series 1990 at 40 km/h
BFC90(90) : BFC measured with the PIARC tyre series 1990 at 90 km/h





Figures n° 1 and 2 – Improvement bring in the correspondence law by using macrotexture and microtexture as explanatory factors

4. PROPOSALS DONE TO USERS

After these various tests, choice was given to the users of AICPR tyre:

- not to use AICPR 1998 tyres any more
- to use them with full knowledge of the facts in establishing their own correction rules.

These rules directly depend on their measurement device characteristics (longitudinal or side measurement, slip ratio percentage, speed etc.) in this latter case users were invited to establish correction rules with the possible help of M de WITT and GOTHIÉ. Also in this latter case users were invited to note that it was necessary to respect some tyre storage and use conditions, defined with the manufacturer.

In order to make easy communication between users of test tyres, and to investigate together what would be the best solutions to avoid similar problems in future, a meeting was organised in Delft on September 2002, where all known users of these tyres were invited. Were also invited to this meeting a representative from VREDESTEIN and KOAC/WMD companies respectively current tyre manufacturer and distributor.

At the end of the meeting, several proposals were submitted to AIPCR C1 committee. These proposal were supported by the following elements:

A) The test tyre is only a means to appreciate a surface wearing course skid-resistance in standard conditions.

B) There is by no means obligation do have a tyre which reflect all the evolutions of trade tyres, but,

C) If the modifications made on these tyres (size, blend composition) lead to modify the wearing-courses classification between themselves, we have to think about modifying the test tyre in order be in conditions nearer to those met by the road users.

D) The presentation of VREDESTEIN society inform us about two current evolutions that could modify our classification:

- width increase which will increase the measurement sensitivity to water depth,
- presence of silica in the blends used instead of black of carbon, which lead to an improvement of the results obtained on wet pavement with an ABS system, but deteriorate the results obtained with a blocked wheel.

E) It is advisable to be cautious in the size modification of tyres in order to be able to mount them in the current measurement devices.

5. COMMITTEE C1 RECOMMENDATIONS

These elements led workgroup D to do the following recommendations to C1 committee:

5.1. Short-term recommendations (within 6 months)

5.1.1**.** It is possible to use the 1998 series tyres with some precautions in order to ensure the results continuation (make a correlation rule with the measurements carried out with the 1990 series tyre).

5.1.2. Very soon the C1 committee will write, with VREDESTEIN society (which make the tyre) as a partner, a document grouping together very precisely the current characteristics of the AIPCR tyre and the storage and use conditions.

5.2. Medium term recommendations (6 months to 1 year)

5.2.1. Group together our knowledge about the compared performances of the AIPCR tyres and the trade tyres.
5.2.2. Group together the results obtained on tests conducted after the 1992 experiment between the AIPCR standard tyre of 1990 series and the special tyre manufactured by the American society "Specialty tyres" with the AIPCR tyre mould and the rubber blend of the ASTM E and E 524 tyres.

5.3. Long term recommendations (1 to 2 years)

5.3.1. Carry out comparative measurements between the reference tyres now available and of size close to those of AIPCR tyre (especially the ASTM 1136 tyre).
5.3.2. Carry out comparative measurements between the AIPCR tyre and current trade tyres made with silica instead of black of carbon. These measurements should be conducted with devices permitting longitudinal coefficient measurements between 0 and 100% slip ratio, and possibly side coefficient measurements. These measurements should permit to assess the silica effect on the performances of the various wearing-course surfaces used and to see if the classifications of these surfaces are, or not, kept when this component is used in the test tyre.

6. CONCLUSION

All these points might allow the C1 committee to have the elements in order to decide if it is necessary to foresee an important evolution of the current AIPCR tyre (size, composition…). This decision could be made before a new fabrication of AIPCR tyre was launched, when the series 1998 is run out.

REFERENCES

SCHOEN, E.D. ((2001) Correction of Skid Resistance Measurements Obtained under Non-Standard Conditions (Revised Version) TNO-report

GOTHIÉ, M. (2001) Appareil ADHÉRA pneus AIPCR séries 1990 et 1998 (L, M et H) ; LCPC; Comité C « Infrastructure et sécurité routière » Opération de recherche : ADHÉRENCE.