Time-Dependent Surface Properties Of Asphalt Friction Courses: Earlier Experiments By A New Accelerated Test

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Synopsis

Pavement Management Systems need to estimate schedule and costs; as a result, it becomes more and more important the evaluation of friction and texture reduction in time for different conditions of traffic and weather.
This can be done by suitable provisional models in order to analyse factors affecting wearing and their influence on surface performance.
Full-scale experiments (often consistent and effective but expensive) or accelerated friction testing (often reliable, less expensive, with well-controlled boundary conditions) are so needed.
This paper deals with the design and the carrying out of an experimental plan in order to realize low-cost information on friction and texture decrease as an effect of traffic.
An apposite device has been recently designed and constructed at the DIIV Laboratory (Palermo University - Department of Road Infrastructures), by modifying a Wheel Track Machine for rutting tests.
Authors present the results of the earlier experiments on friction reduction; time-friction and time-texture curves are analysed and interpreted. Friction is estimated in terms of British Pendulum Number while both micro- and macro-texture components are measured by a laser device.

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MODEL DEVELOPMENT

It is well known that, as regards bituminous pavements, surface properties have an outstanding importance due to the necessity to guarantee sufficient friction [Dupont P. at Al. (1993), Andresen A. et Al. (1999), Gothiè M. at Al. (2001)], which can't be ruled without controlling surface texture.
Both friction and texture are importantly affected by some negative effects and actions (tribological, etc.) in time domain.
These risky effects on road pavements depend on many factors (below called causes):

- Tyre-road interaction;
- Weather, amount of rainfall, environmental factors;
- Aging;
- Chemical and physical attacks and contaminants, such as rubber debris, etc.
- Others.

Tyre road interaction depends on tyre features (tread pattern, compound, degree of tyre wear, inflation pressure, vertical load, horizontal speed, tyre/pavement sleep ratio, etc.) and pavement characteristics (mix composition and, in particular grading, bitumen content, aggregate mineralogical quality, shape, micro- and macrotexture, etc.). Boundary conditions at the interface can greatly affect horizontal stresses.
By explicitly referring to tyre-pavement interaction, friction loss corresponds to chemical, physical and geometric modifications.
These alterations origin from tyre-pavement dynamic, cyclic contact and slip and, at the same time, they generate the overall effects of friction, wearing and rolling resistance.
The above-mentioned changes are caused by a given quantity of energy which is a part of the energy provided by the engine and which is lost in rolling resistance.
This misplaced energy depends on two main factors: deformation (mainly of tyre) and adhesion. Both of them depend on contact patch area, then, for unit of transverse dimension, on the major axis d_i of the footprint.
Inflation P_g of the tyre (which is different but often similar to the actual contact pressure), weight P_i on the tyre, tyre compound and geometry (in particular the transverse "axis" b_i in contact patch) and other minor components affect d_i:

$$d_i \cong P_i \cdot (\pi \cdot b_i \cdot P_g)^{-1}$$

If one assumes that the transverse axis b_i of the contact patch (figured as elliptic, oval shaped or rectangular) is quite constant, when the load P_i increases or/and the pressure P_g decreases then d_i increases.
If one considers a given small area $\delta x \cdot b_i$ in the contact patch (where δx is taken in the direction of motion, see the figure), as d_i increases, one load passage causes much more contact time for pavement in the above mentioned small area; all other factors being constant, this can origin more surface wearing.
Importantly, at the same time, one must remark that decreasing P_g reduces wearing, being P_g related to the actual stresses.

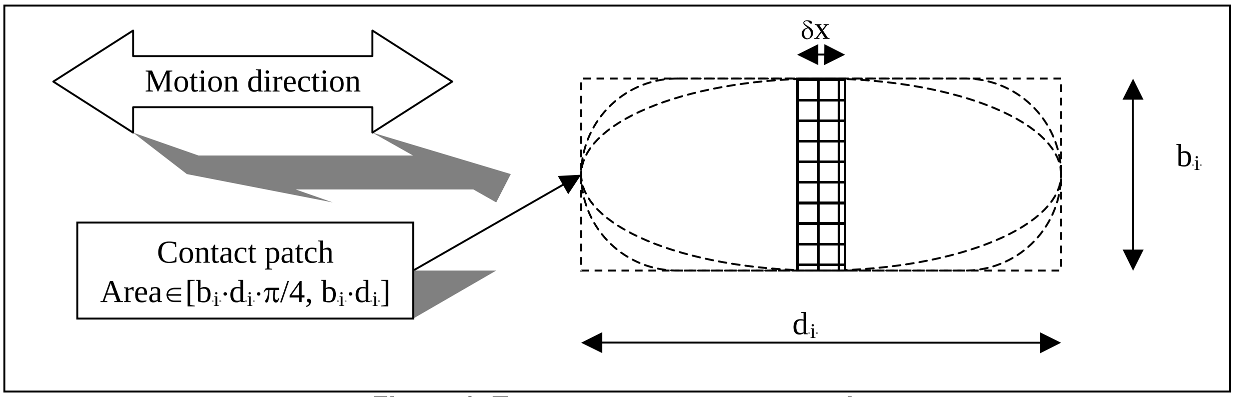


Figure 1: Tyre-pavement contact patch

In the light of what said above, in this paper, let C be the causes (traffic, etc), E the effects (texture and friction variations, etc.) and F a suitable application:

$E=F(C)$ (1)

Let us hypothyse that:

$C=\sum_i N_i \cdot d_i \cdot c_i + \sum_j p_j$ (2)

Where:

- N_i is the number of repetitions for the i-th component of traffic spectrum;
- d_i is the i-th contact diameter (with reference to the longitudinal axis in contact patch ellipse);
- c_i is a correction coefficient due to contact pressure, axle load, transverse distribution of loads, tyre and road characteristics, etc.;
- p_j refers to the j-th remaining (secondary) factors, such as weather, debris (included rubber debris), aging, tester-pavement interference, thermal effects, etc. They can vary over the time.

The Effects E may be analyzed in terms of friction indicators or texture indicators [Boscaino G. at Al. (2001)], being surface geometry strictly related to surface performance [Gothiè M. at Al. (2001)].

If causes are simulated in laboratory by wheels on slabs as in accelerated loading tests, the following expression can be derived:

$E=F(\sum_i N_i \cdot d_i \cdot c_i + \sum_j p_j)= F(n \cdot d \cdot c+ \sum_j p_j)=F(f \cdot t \cdot d \cdot c+ \sum_j p_j)$, (3)

where n stands for the number of passages, f refers to loading frequency and t is the testing time.

If the goal of the experiment is confined to the in-lab analysis of traffic influence, it becomes necessary to detach the remaining factors.

A strategy may be to evaluate the effects E_{CS} (where CS stands for "Check Sample") on a pavement sample not interested by traffic loading but anyway interested by all the remaining j-type factors:

$E_{CS}= F(\sum_j p_j)$. (4)

In this case, if F may be considered as a linear application, for a given time t one can obtain a decomposition into two simple factors:

$E= F(n \cdot d \cdot c)+ F(\sum_j p_j)$; (5)

So, it results:

$E-E_{CS}= F(n \cdot d \cdot c)$ (6)

One must remark that there are two main sets of effects, that is to say Texture effects ^{T}E and Friction effects ^{F}E.

In order to divide the analyses of surface geometry from that of friction performance the following expressions can be provided:

$^{T}E-{}^{T}E_{CS}= F_T (n \cdot d \cdot c)$ (7)

and

$^{F}E-{}^{F}E_{CS}= F_F (n \cdot d \cdot c)$. (8)

Moreover, in this case it is possible to analyze both correlations texture-friction of the type $F_T(n \cdot d \cdot c)$ versus $F_F(n \cdot d \cdot c)$ and of the type ^{T}E versus ^{F}E.

The first ones relate only to the effects of traffic (that is to say the device wheel, rolling on its wheel track), while the second ones concern all the effects.

Importantly, the effects ^{T}E versus ^{F}E (or $F_T(n \cdot d \cdot c)$ versus $F_F(n \cdot d \cdot c)$) being correlated, it can results:

$^{F}E=F_{FT}(^{T}E)$ or $F_F(n \cdot d \cdot c)=F'_{FT}[F_T(n \cdot d \cdot c)]$, where F_{FT} and F'_{FT} stand for suitable functions relating the effects of wearing on friction to that suffered by surface geometry.

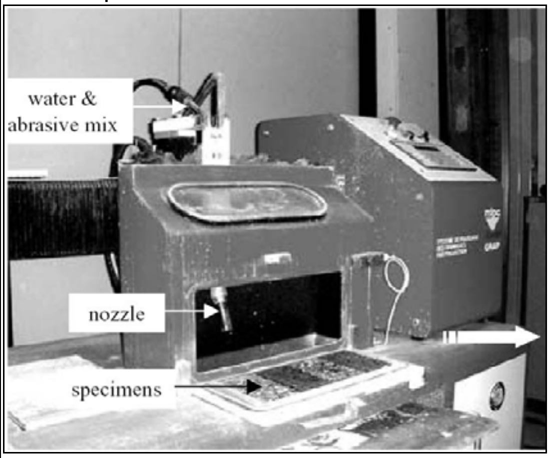
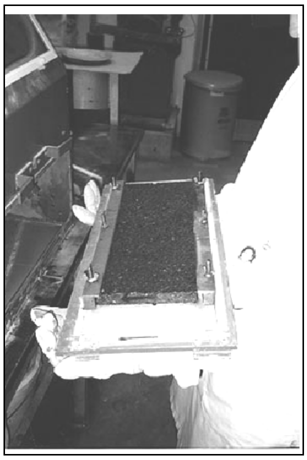
LITERATURE REVIEW

An inventory is here proposed concerning the main devices worldwide used in order to test surface performance reduction with time, both for bituminous surface courses and aggregates.

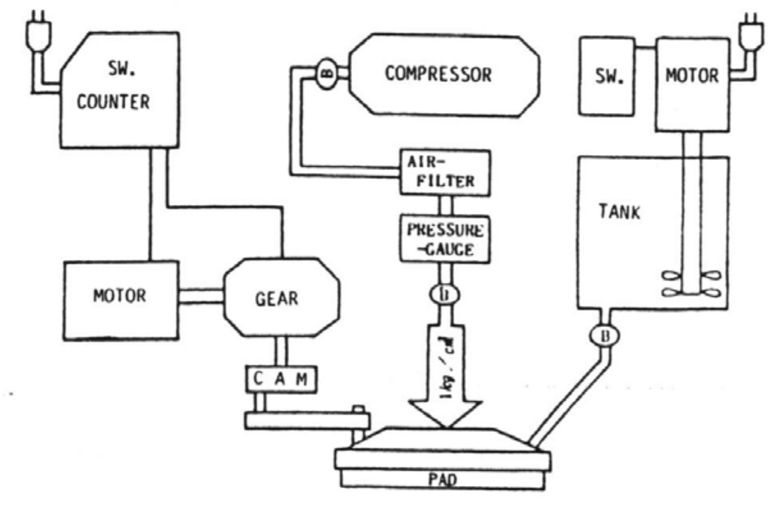
The following topics are summarized (see, Tab 1a, 1b and 1c):

- Wearing method;
- Tested specimen (Hot Mix Asphalt or aggregates);
- Abrasive characteristics (if used);
- Friction test.

Tab 1a: Main devices for accelerated polishing of aggregates and bituminous mixes

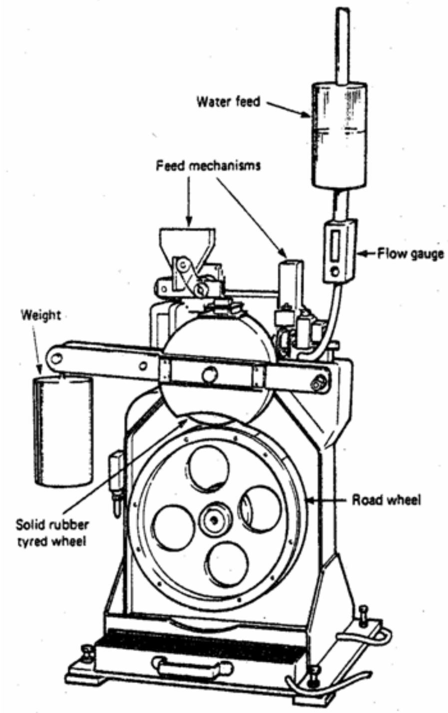
Technique or Device: **GRAP**	References
 	Delalande G. (1992) Janoo V.C. et Al. (1999) ASTM E303-93 (2003) Khoudeir M. et Al. (2004)

Simulation	Projection of water and fine abrasive mix under a pressure of 10 MPa. Incidence angle from vertical axle = 50°÷60°. ProjectionTime/Specimen = 11 min
Specimen	<u>Typology</u>: Aggregates 6/10mm or asphalt concrete <u>Form</u>: Plain and rectangular 100x150mm
Use of Abrasive	Dimension << 63μm. Flow rate = 500g/min
Friction measure	British Pendulum Number

Technique or Device: **Penn State reciprocating polishing machine**	References
	Nitta N. et Al. (1990) ASTM E1393 (1996) McDaniel R. et Al (2003) ASTM E303-93 (2003)

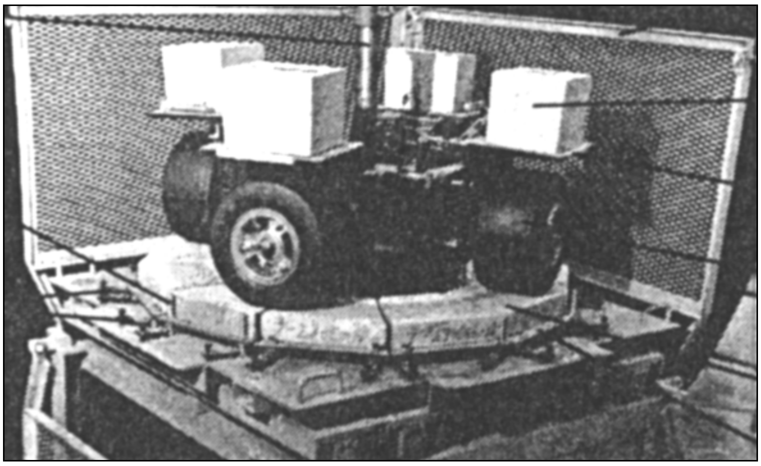
Simulation	The device reciprocates the rubber pad under a contact pressure of 0,98bar. Specimens are polished by 5000 rubber pad passages (2 cycles/sec).
Specimen	<u>Typology</u>: Aggregates 6/10mm or asphalt concrete <u>Form</u>: Plain and rectangular, minimum size 100x165mm
Use of Abrasive	Slurry of 1/10 allumina (35μm) to water ratio by volume. Flow rate=200cc/min
Friction measure	British Pendulum Number

Tab 1b: Main devices for accelerated polishing of aggregates and bituminous mixes

<table>
<tr><td colspan="2">Technique or Device: British polishing Wheel


</td><td>References
CNR B.U. n°140 (1992)
ASTM D3319 (2000)</td></tr>
<tr><td>Simulation</td><td colspan="2">Solid rubber tyred wheel, 200mm in diameter and 38mm in width; the wheel is free rolling on the specimen.
Applied load =725N; Speed = 320cycles/min
Specimens are polished by 57600x2 passages</td></tr>
<tr><td>Specimen</td><td colspan="2"><u>Typology</u>: Aggregates 6/10mm
<u>Form</u>: Curved and rectangular, 45x98mm</td></tr>
<tr><td>Use of Abrasive</td><td colspan="2">For three hours, water and corundum powder (0,25÷0,63mm) mix, with flow rate=27g/min; After, for other three hours, water and corundum powder (<0,063mm) mix, with flow rate = 3g/min</td></tr>
<tr><td>Friction measure</td><td colspan="2">Polish Stone Value (British Pendulum Number modified)</td></tr>
<tr><td colspan="2">Technique or Device: Wehner Schulze
</td><td>References
Dames J. (1990)
Huschek S. (2004)</td></tr>
<tr><td>Simulation</td><td colspan="2">Three conical rubber rollers roll on test surface with a speed of 17 km/h; average contact pressure is $0,4N/mm^2$; slip is 0,6%</td></tr>
<tr><td>Specimen</td><td colspan="2"><u>Typology</u>: Aggregates, asphalt concrete
<u>Form</u>: Circular with a 225mm diameter</td></tr>
<tr><td>Use of Abrasive</td><td colspan="2">Water and quartz powder (<0,06mm) mix</td></tr>
<tr><td>Friction measure</td><td colspan="2">PWS (Polish Wehner Schulze) skid measurement in wet condition by three rubber sliders; Interface Area=$3x4cm^2$; wheels are placed in a circular frame; average contact pressure is $0,2N/mm^2$; Speed = 60km/h</td></tr>
</table>

Tab 1c: Main devices for accelerated polishing of aggregates and bituminous mixes

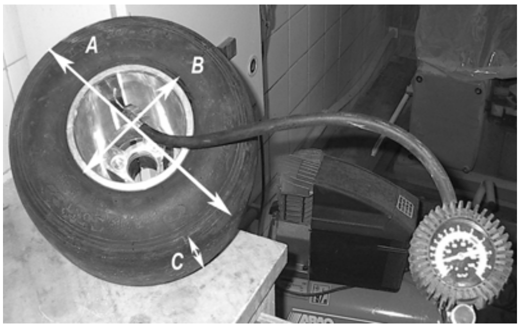
Technique or Device: **Small-wheel circular track polishing machine**		References
		ASTM E660 (2002) McDaniel R. et Al (2003) ASTM E303-93 (2003) ASTM E707-90 (2003)
Simulation	Four wheels are attached to the central pivot; they free roll on a circular track of 914mm in diameter. Tyres are 27.9x15.2x12.7 cm; smooth tyres are used. Tyre pressure = 140KPa; Wheel loading = 320N. Speed = 7200 wheel passes for hour. Exposure Time = 8hours.	
Specimen	Typology: Asphalt concrete or Cement concrete. Form: Circular (diameter =152mm); trapezoidal moulds.	
Use of Abrasive	NO	
Friction measure	British Pendulum Number and/or Variable Speed Friction Tester	

Technique or Device: **NCAT polishing machine**		References
		McDaniel R. et Al (2003) ASTM E303-93 (2003)
Simulation	Three wheels are attached to the central pivot; they free roll on a circular track of 500mm^2. Tyres are 20.3 cm in diameter; smooth tyres are used; Wheel loading = 667N; Exposure Time = 100.000 revolution at 40rpm (41.7hours);	
Specimen	Typology: Asphalt concrete Form: nominal 500cm^2 slab	
Use of Abrasive	NO. Water is used to wash abraded rubber particles from the surface during polishing.	
Friction measure	British Pendulum Number	

DESIGNING AND CONSTRUCTING A NEW POLISHING MACHINE

In order to evaluate the influence of traffic loading on friction and texture reduction, a specific experimental plan was designed and performed at the DIIV Laboratory (Palermo University - Department of Road Infrastructures), by modifying a Wheel Track Machine (WTM) for rutting tests. In what follows, device design and preliminary tests are discussed.
In the new arrangement, the modified WTM (here called PWTM - Polishing Wheel Track Machine) was designed in order to make it possible to control tyre inflation pressure, load, test temperature (both for air and slab, by a specific box with two thermocouples and a default temperature of 20°C ± 2°C) and Slip ratio (by a particular braking system, with two brake shoes, see figure 3b).
Tyre characteristics are listed in table 2. One can observe that tyre features partially meet the standard [ASTM E660 (2002)]. As Starting configuration the free rolling was chosen.
Two different load configurations LW1 and LW2 (where W stands for Wheel and L for Load) were considered (see tables 2 and 3). Load scheme for reaction analysis is there reported (table 3). Importantly, the entire frame of the machine was modified in order to provide that the centre of gravity was positioned on the wheel axis.

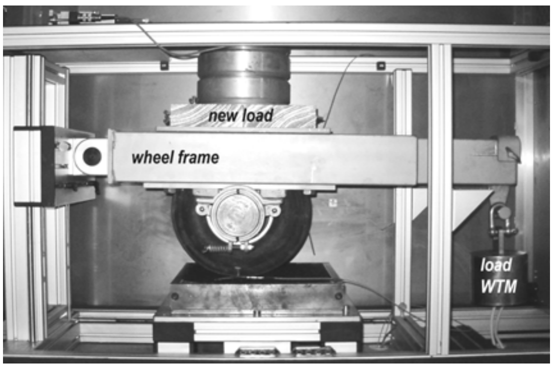
Tab 2: Polishing Wheel Track Machine (PWTM)- Tyre characteristics



Tyre Typology	AxCxB = 27.9x18.3x12.7cm smooth tyres.
Max tyre pressure	400 KPa
LW1 Tyre Pressure	350 KPa
LW2 Tyre pressure	250 KPa
Rolling type	Free
Use of abrasive	NO

Tab 3: PWTM - Load scheme (loads in KN)

$P_1 = P_{1a} + P_{1b}$	P_{1a} = frame weight		0.35
	P_{1b} = new load	Load type 1=LW1	0.61
		Load type 2=LW2	0.36
P_2 = Load of the WTM			0.12
P_3 = Reaction on the hinge			0.21
P_4 = Contact patch reaction		Wheel Load 1=LW1	1.29
		Wheel Load 2=LW2	1.03
l_1 = 31cm		l_2 =53cm	



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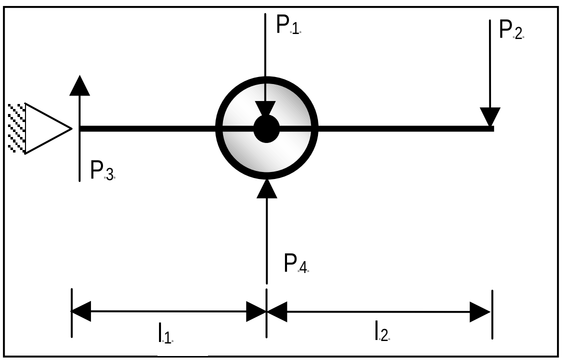


b

Figure 2 deals with the experimental correlations among reaction P_4, tyre inflation pressure, and footprint area. One can observe that, for a given inflation pressure (350 KPa), as P_4 increases the contact patch area increases; moreover, for a given load P_4 (1.03 KN) if the inflation pressure increases then contact area decreases. LW1 load type has an inflation pressure of 350 KPa and a contact area of about 90cm^2. Load type LW2, by an inflation pressure equal to 250 KPa, has the same contact area.
Specimen were produced following WTM standards, see [Vaiana et Al. (2003)].

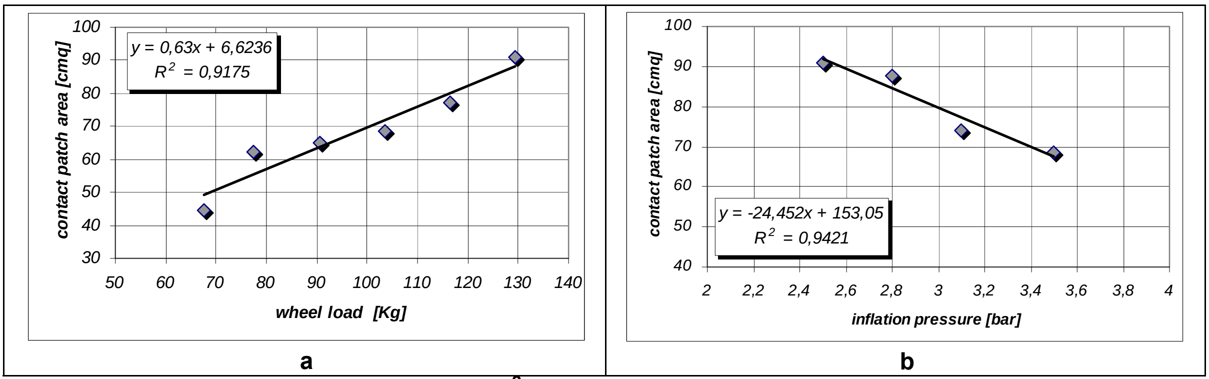


Figure 2: (a) Contact patch area (cm^2) versus wheel load (inflation pressure =350 KPa); (b) Contact patch area (cm^2) versus inflation pressure (wheel load ≈1.03 KN)

Figure 3: PWTM: Construction details

Preliminary tests were performed in order to choose a proper testing duration.
Due the first experiments results, eight load cycles were established, each one lasting eight hours. In fact, at about 56 hours, both for texture and friction indicators (see figure 4), a clear tendency to steady was observed; so, for this reason, tests were ended at 64 hours.
In the PWTM, the asphalt slab has a horizontal alternate motion for a displacement of 24 cm; it makes about 24 cm in 46^{-1} minutes. Therefore, for each slab, 64x60x46=176640 passages took place.

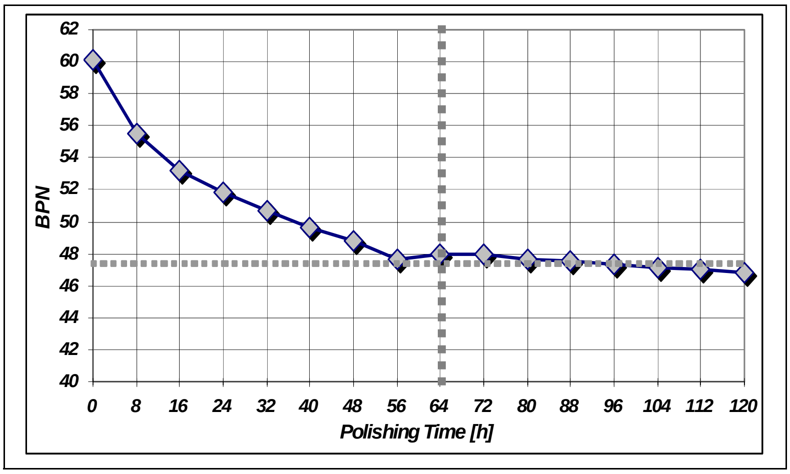
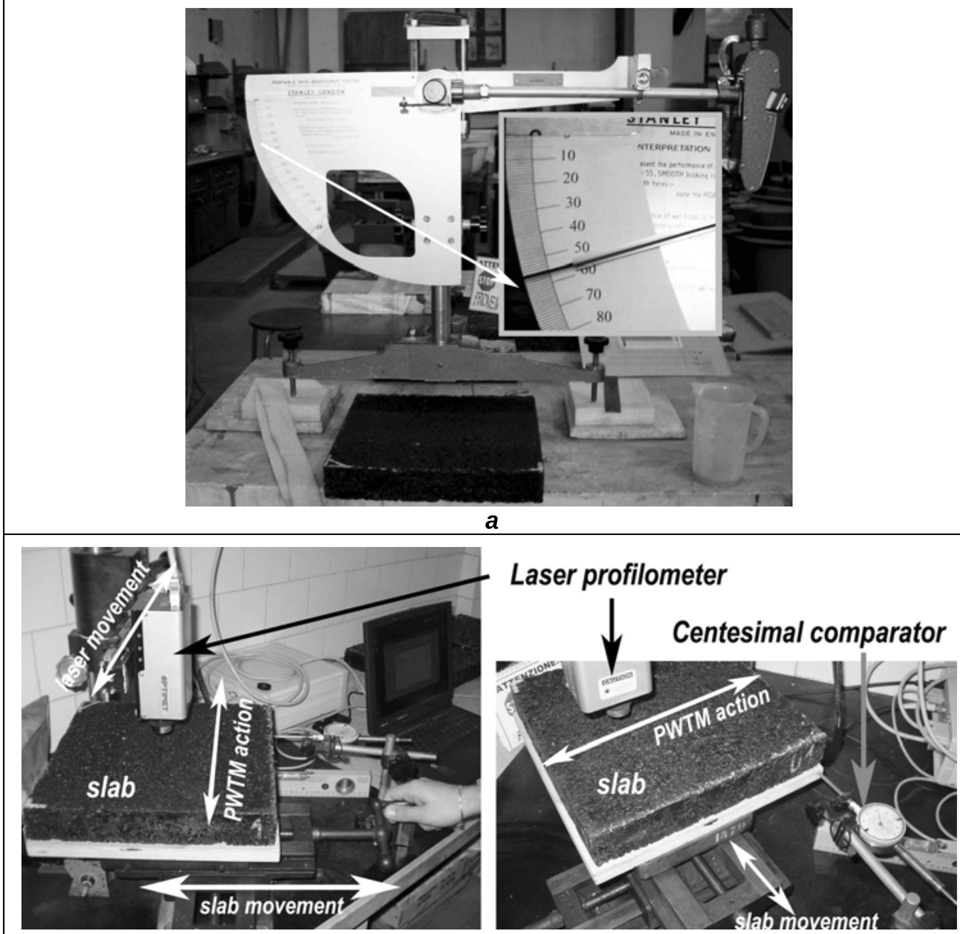


Figure 4: Polishing time: choosing test time

For t=0h, and at the end of each cycle, friction and texture were monitored (see figure 5).
Friction was measured by the British Pendulum [CNR – B.U. n°105 (1985)]; a supplementary label was used in order to appreciate BPN values until half a point (see the zoom in figure 5.a).
Texture surveys were carried out by a Laser profilometer, based on conoscopic olography, for the characterization of pavement texture on the basis of surface profiles z(x). Post-processing of profile-signal was performed and developed by a specific dedicated software. In order to detect the same profile position

(always parallel to wheel rolling direction) the micro-displacements of the slab were controlled with an accuracy of ±0,01mm see fig.5.b.



a b c

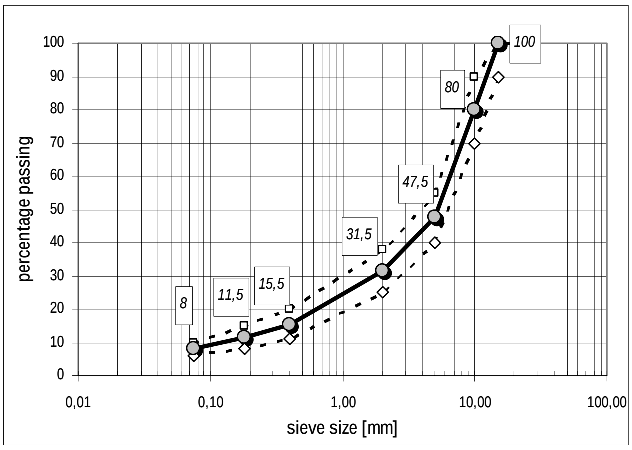
Figure 5: Devices utilized in the experimental plan - (a) British Pendulum; (b)(c) setting out laser position in order to analyse the same slab track

DESIGN OF EXPERIMENTS

The tests were designed by considering:

- one type of wearing course (traditional, dense-graded wearing course), with a given mix composition (see table 4);

Tab 4: In-lab mix composition



Binder characteristics	
Penetration	64dmm
B&R softening temp.	47°C
Aggregates characteristics	
Crushed Limestone	
L.A.	20,7%
Micro Deval	9%
P.S.V.	0,39
Asphalt characteristics	
Binder content	5,0%
Voids %	4,3%
Density	2,48g/cm^3

- six identical slabs, see tab. 5;

Tab 5: Load configurations

Slab	A1	A2	A3	A4	B1	B2
Load Configuration	LW1				LW2	
Inflation pressure	350 KPa				250 KPa	

- for each slab subjected to the accelerated friction test, three sectors were identified: two "check surfaces" marked with (SX) and (DX) (outside the wheel track, then without wheel passages) and one central sector marked with (C) (inside the wheel track, with wheel passages) see fig. 6;

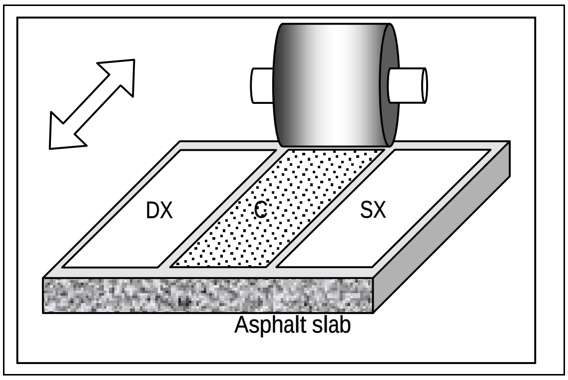


Figure 6: Dividing each slab into three parts: two check surfaces (DX and SX) and one central sector (C)

- for all the sectors (C), (SX) and (DX), the polishing effects were evaluated in terms of texture indicators (see table 6 - laser profilometer survey - n°7 profiles for each sector), and British Pendulum Number (see Boscaino G. et Al. (2001) and (2004)).

Tab 6: Surveyed texture indicators

ID	***Unit***	***Definition***
MPD_{iso}	[mm]	Mean Profile Depth measured according to ISO algorithm
RMS	[mm]	$\approx \sigma \approx [\Sigma(z-z_{mean})^2 p(z)]^{0.5}$; Standard Root-mean-square roughness; p(z) is the probability function
AAH_e	[mm]	$(\Sigma h_i/n)$ Average *micro* Asperity Height, estimated on the part of the profile above the Mean Profile Depth; h_i= microasperity height; n=microasperity number.
ASF_e	-	$(\Sigma h_i/L)$ Average *micro* Shape Factor, estimated on the part of the profile above the Mean Profile Depth; h_i=microasperity height; L=baseline profile length.

RESULTS AND DISCUSSION

This section deals with the earlier results obtained on the slabs compacted and analyzed at the DIIV Laboratory at the Palermo University.

Figures 7 to13 show texture and BPN variations in time.

If one analyses the effects in time, that is to say how the effects (texture and friction variations) depend on the causes (number of passages of the wheel on the slab), it is possible to observe that:

- in all the surfaces texture and friction often decrease, apart from considering only the wheel action on the contact patch (see figure 7); in fact, also in the surfaces type "DX&SX average", not rolled by the wheel, RMS has a slight decrease and BPN (obviously determined according to the standard [CNR – B.U. n°105 (1985)] and so by considering temperature correction) is affected by an appreciable reduction;
- the surfaces type C (where C stands for central, that is to say just on the wheel track) have often more reduction in time (see figure 7); this happens both for some texture indicators (herein RMS is reported) and friction (BPN values); this evidence can be definitely related to wheel action (that is to say traffic simulation) prevalence in time.

- medium-pressure actions (slabs B1 and B2, pressure=250 KPa, load=1.03 KN, see figure 7) have a specific effect on friction properties; for them, BPN reduction results lesser important than for the others (slabs A1, A2, A3, A4, pressure=350 KPa; load=1.29 KN);
- the inner variance of texture (dishomogeneity, test variance, etc.) seems to partly cover the influence of all the induced actions; on the contrary, by observing derivative behaviour, the influence of the induced actions may be considered quite clear.

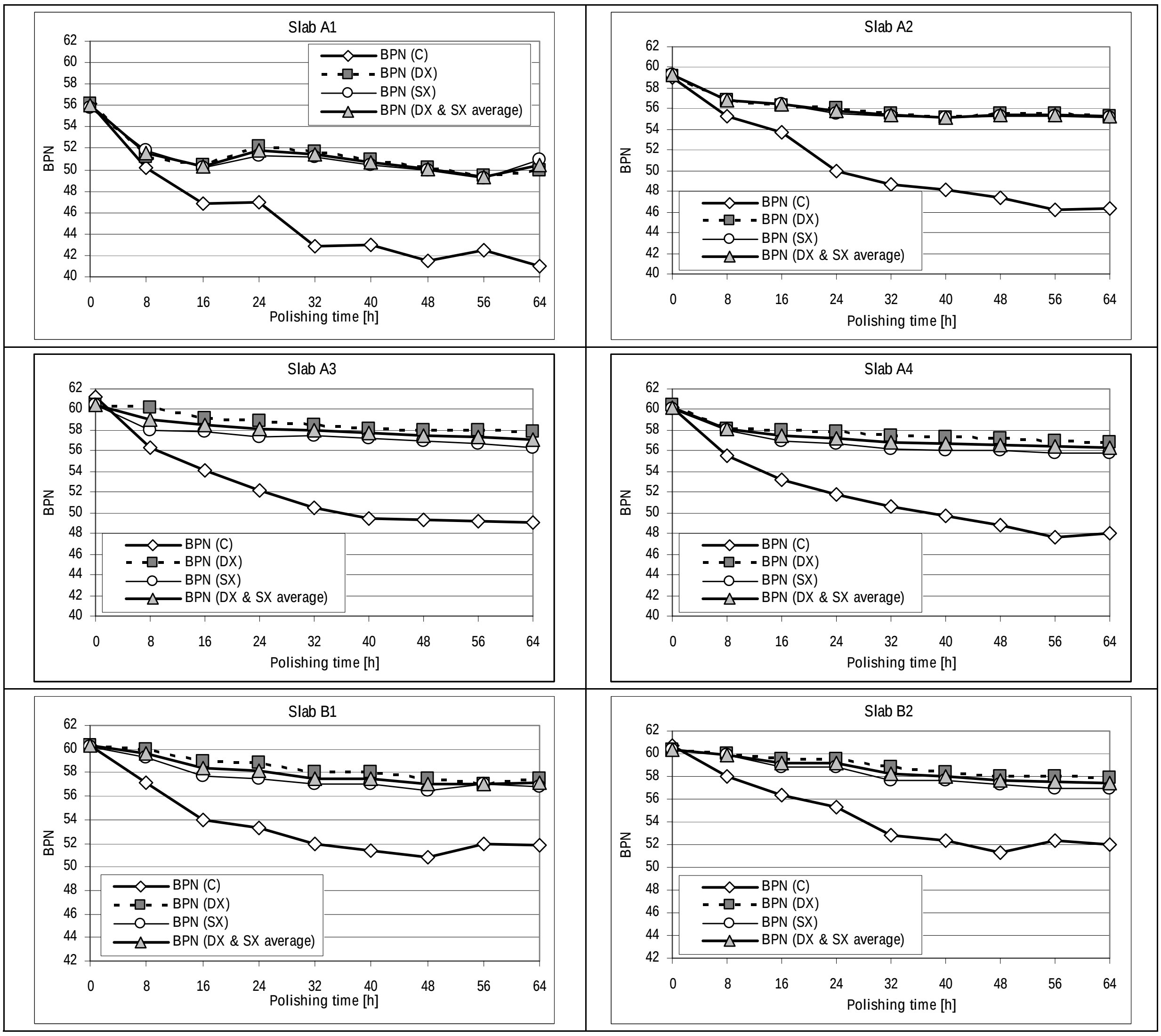


Figure 7: BPN vs Polishing time for all the sectors of each slab

In analysing these results, which were obtained by using a particular device, the following considerations must be taken into account.

- *Absence of an early increasing for BPN*.
  It is well known that, once opened to the traffic, a *real* surface course has often a slight BPN increase; this early behaviour, though common, is successively overcome by consistent wearing and friction reduction [Giannattasio P. At Al. (2002)]; this opening phenomenon probably origins from aggregate stripping, because, in footprint, slip takes place. In the case of the used device, the wheel is quite free of rolling while the slab has an alternate motion; in these conditions slip ratio in slab-tyre interface is probably less than in the real case; this can reduce stripping phenomenon and, therefore, the above-mentioned earlier rising in friction results somewhat totally bypassed;
- *Earlier (friction) reduction in lateral surfaces*.
  In the first 8-16 hours a reduction in friction of about 5% can be observed just in lateral surfaces outside the wheel track (SX and DX); this phenomenon can, for example, derive from the increasing of temperatures in that area, though device box is maintained at constant temperature and the estimated BPNs take into account surface temperature as in the standard

[CNR – B.U. n°105 (1985)]; this reduction in friction can't be interpreted as a direct consequence of the action of the rolling wheel;

- o *Detaching minor causes.*
In the light of the consideration of the above-mentioned two minor phenomena (that is to say unlikely earlier reduction both in wheel track and outside), the following main consequences can be drown: a) the designed new device can reproduce a particular type of wearing; b) there is the need for detaching minor causes, as previously provided in the model development. Therefore, both for friction and texture effects, the indicators are below computed in terms of differences of wheel track behaviour from lateral surfaces (DX and SX average); hence, following the theoretical approach above described, a specific analysis was made on the k-th standard texture or friction indicator at the time t. For example, in order to upgrade the effectiveness in describing the actual causal relationships, the following operators "detached from minor causes" were obtained:
    - $BPN_D=BPN_C-E[BPN_{SX}, BPN_{DX}]$
    - $\Delta\%BPN_D= 100\cdot[BPN_D- BPN_D(t=0)]/[BPN_D(t=0)]$
    - $RMS_D= RMS_C-E[RMS_{SX}, RMS_{DX}]$.
    - $\Delta\%RMS_D= 100\cdot[RMS_D- RMS_D(t=0)] /[RMS_D(t=0)]$

  where the subscript D stands for detached, C stands for central, SX and DX for left and right surfaces outside the wheel track and E [ ] stands for the expected value estimated from that on left (SX) and right (DX) areas.

Figures 8 to 13 show friction and texture (macro and micro domains) behaviour in time. Figures 8 to 10 deal with the load condition LW1 (high pressure); figures 12 to 13 concern LW2 case, while in figure 11 both LW1 and LW2 (medium pressure) load conditions are given.

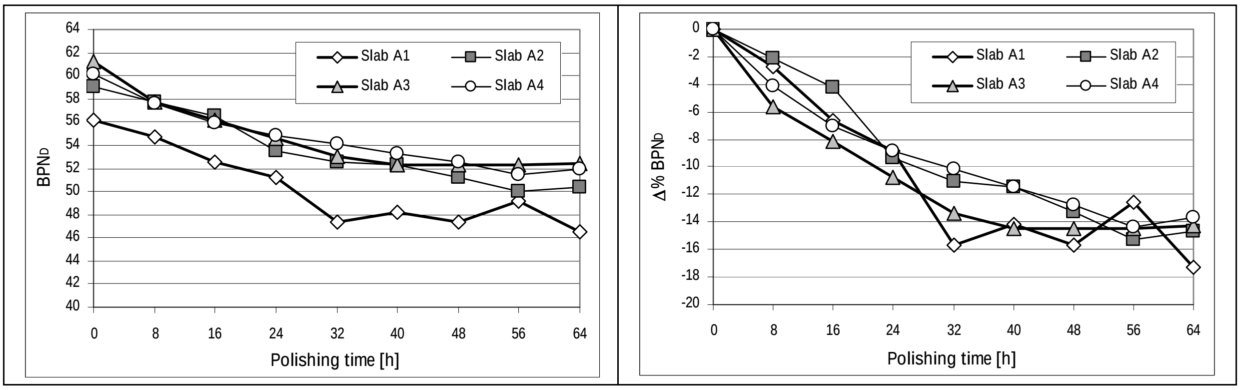


Figure 8: Time behaviour of BPN_D and $\Delta\%BPN_D$ (load condition LW1: inflation pressure=350KPa; load=1.29 KN)

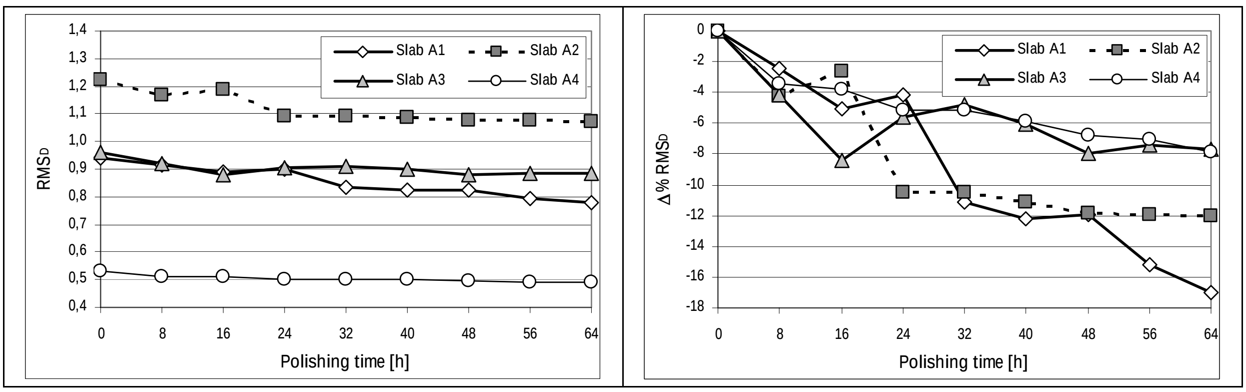


Figure 9: Time behaviour of RMS_D and $\Delta\%RMS_D$ (LW1)

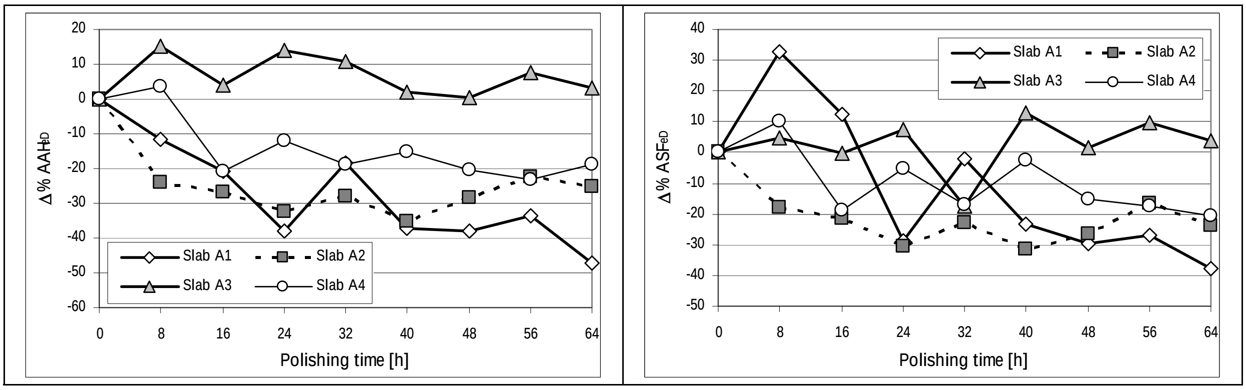


Figure 10: Time behaviour of $\Delta\%AAH_D$ and $\Delta\%ASF_D$ (LW1)

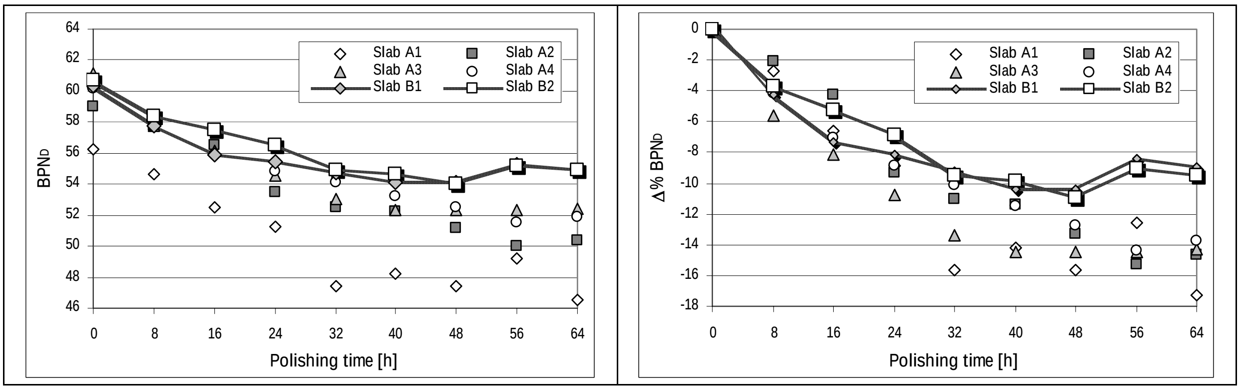


Figure 11: Time behaviour of BPN_D and $\Delta\%BPN_D$ for both LW1 (A_i slabs) and LW2 (B_i slabs) load conditions; load condition LW1: inflation pressure=350KPa; load=1.29 KN; load condition LW2: inflation pressure=250KPa; load=1.03 KN)

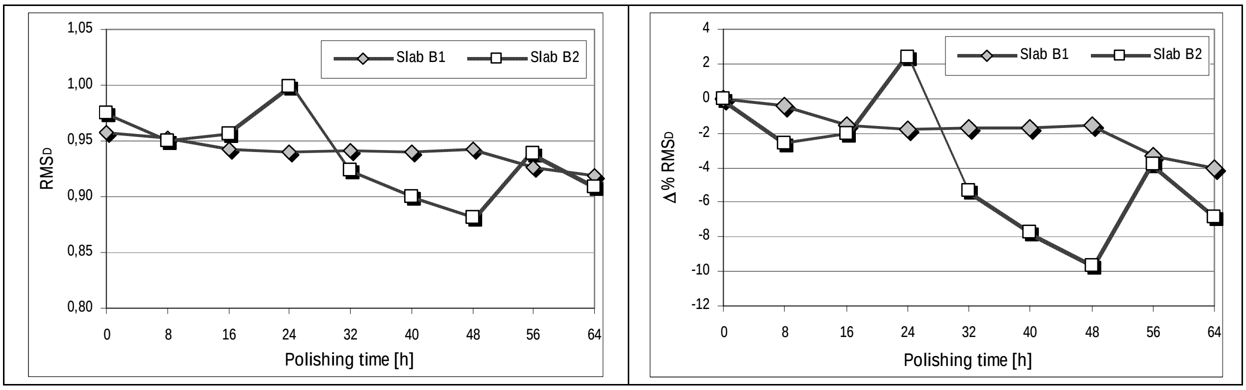


Figure 12: Time behaviour of RMS_D and $\Delta\%RMS_D$ for B_i slabs; load condition LW2: inflation pressure=250KPa; load=1.03 KN)

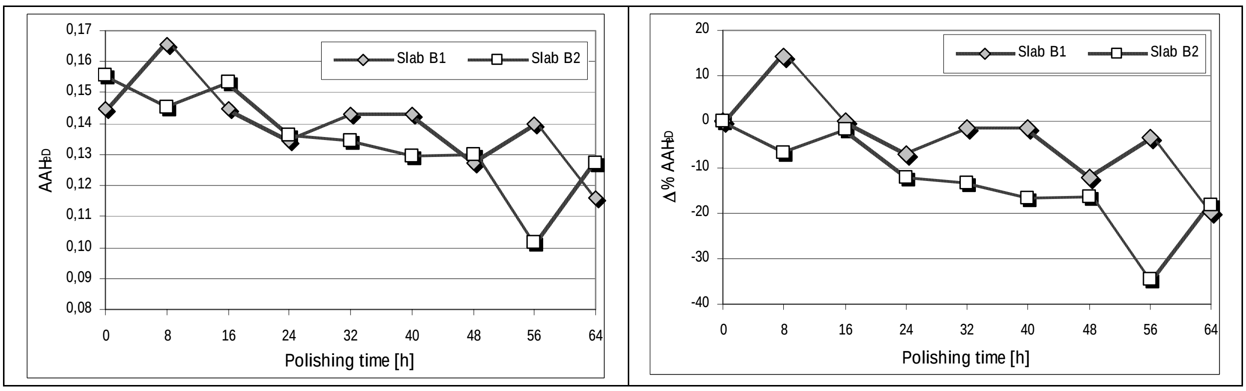


Figure 13: Time behaviour of $\Delta\%AAH_{eD}$ and $\Delta\%ASF_{eD}$ for B_i slabs; load condition LW2: inflation pressure=250KPa; load=1.03 KN)

By referring just to the action of the wheel on the slabs (simulating traffic loads on pavement, see equations (7) and (8) and figures 8 to 13, it is interesting to observe what follows:

- the effects of the wheel actions on friction properties seem to be quite relevant both for high- and medium inflation pressures (see figures 8 and 11); the behaviour of the slab A1 results quite interesting in that part concerning a somewhat sinusoid performance in time - while probably asymptotically decreasing towards a limit value (see figure 8).
- the wearing caused by the rolling wheel has a consistent effect on macrotexture; for both LW1 and LW2 load conditions a reduction of about 4-18% is obtained (see figures 9 and 12);
- surface dishomogeneity and other effects seem sometimes to partly cover the tribological effects of the rolling wheel on microtexture for the different slabs (see figures 10 and 13); This seems to be appropriate for both high and medium pressures; at the same time one must notice that the slab A3 has a quite singular behaviour and definitely influences the above observation; moreover, at times, in the early hours, the slabs A1, A3 and B1 present a noteworthy microtexture increase.

Table 7 resumes R-square coefficients. All the effects are considered.

Tab 7: R-square coefficients (Texture versus BPN) - all the actions

Slab	A1	A2	A3	A4	B1	B2
Configuration	LW1				LW2	
MPDiso	0.74	0.92	0.53	0.58	0.39	0.67
RMS	0.75	0.94	0.63	0.97	0.51	0.55
AAH_e	0.70	0.46	0.03\	0.68	0.32	0.59
ASF_e	0.38	0.48	0.02\	0.43	0.14	0.62
Note: \ stands for negative correlation; in the remaining cases there is a positive correlation; the subscript ISO stands for calculated according to ISO standard [ISO 13473-1 (1997)]; e stands for effective.						

Table 8 lists the R-square coefficients estimated according to the procedure above detailed in order to detach undesirable causes.

Importantly, in this case, both for texture indicators and BPN, only traffic actions were taken into account (by operating on the single values according to equations (7) and (8)).

Tab 8: R-square coefficients (Texture versus BPN) only traffic actions

Slab	A1	A2	A3	A4	B1	B2
Configuration	LW1				LW2	
MPD_{isoD}	0.63	0.90	0.51	0.56	0.37	0.70
RMS_D	0.76	0.92	0.60	0.96	0.45	0.53
AAH_{eD}	0.65	0.32	0.03\	0.70	0.25	0.52
ASF_{eD}	0.50	0.36	0.01\	0.45	0.10	0.56
Note: \ stands for negative correlation; in the remaining cases there is a positive correlation; the subscript ISO stands for calculated according to ISO standard [ISO 13473-1 (1997)], while e stands for effective as above specified, and D stands for estimated by detaching minor causes (as above specified).						

By observing tables 7 and 8, the following observations can be drown:

- MPD_{ISO} and RMS are well-correlated to BPN values; R-square coefficients are definitely noteworthy;
- The parameter AAH_e (in which only the part of he profile effectively enveloped by the friction tester is considered) is often well correlated with BPN;
- Slabs A3 and B1 have a quite different behaviour in terms of texture-friction relationship;
- No apparent distinction between high pressure and medium pressure cases can be here straightforwardly detected in terms of correlations.

CONCLUSIONS

In the light of the above the main conclusions can be outlined as follows:

i) the designed and constructed device appears able to simulate some of the consequences of wearing rate by traffic loads and can separate “contact” actions in the wheel track from the remaining effects;

ii) though interesting results and high R-square correlation coefficients obtained, more research is needed; a specific campaign of experiments is in progress on a rural road in order to validate and optimize the above stated theoretical correspondence between in-lab number of passages and in-place traffic flow, for a given traffic spectrum;

iii) tribological actions cause a reduction in friction properties and a related modification in texture indicators;

iv) the relationship between friction and texture variations results very strong and effective for some of the selected indicators, such as the Root Mean Square of macro amplitudes (RMS); very noteworthy R-square coefficients were *here* obtained by the Authors (>0.90);

v) traffic action and friction-texture effects, for the analysed domain, are related by a decreasing function that seems asymptotically approaching a zero derivative condition; further investigation is necessary indeed.

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