

# Rehabilitation of Airport Pavements: The Experience of Linate Airport

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**ABSTRACT:** At Linate Airport (Milano – Italy) in August 2002 the rehabilitation of the runway pavements was carried out. The works concerned both the asphalt pavements of the runway and the concrete slabs of the 36R Threshold Area. For both the pavements the works were characterized by preliminary studies and experimental research (started in 2001), by a very severe control activity during the works, by many measures after the works to verify the results. Many constraints, especially the need to complete all the works in only 20 days of August, forced to study solutions (in some cases completely innovative such as the new wide slabs 10,0 x 15,00 m) which were able to optimize design and building. The present paper discusses the experience carried out and the results obtained, with the aim to allow other Airport Authorities and technicians to find solutions when facing with similar problems and needs.

**KEY WORDS:** Airports, Runway, Rehabilitation, Asphalt Concrete Pavement, Rigid Pavement.

## 1 INTRODUCTION

In 2001, the runway flexible pavement and the 36R Threshold Area rigid pavement of Linate Airports (Fig. 1) showed structural distresses (extended wide cracks) at a severity level considered no more acceptable for safe operations. Need of rehabilitation was therefore considered. Many operating constraints brought to postpone the rehabilitation works to August 2002, when the airport would have been closed for some days, transferring all flights to Malpensa and Orio Al Serio Airports, some kilometres far from Milano. For safety purposes, a “light” maintenance activity was carried out in the autumn of 2001, eliminating any possible risk for operation up to the planned period for rehabilitation works (August 2002). A thickness of 4 cm of the existing pavement and the laying of the same thickness of a very high performance modified asphalt concrete was carried out in October 2001. At the same time, the studies concerning the pavement rehabilitation started. In particular the rehabilitation of pavements was characterized by preliminary studies and experimental research, by a very severe control activity during the works, by many measures after the works to verify the results. Many constraints, especially due to the need to complete all the works within 20 days of August (without any possible delay) forced to study solutions (in some cases completely innovative such as the new wide slabs 10,0 x 15,00 m) which were able to optimize design and building. The present paper discusses the experience carried out and the results obtained, with the aim to allow other Airport Authorities and technicians to find solutions when facing with similar problems and needs.

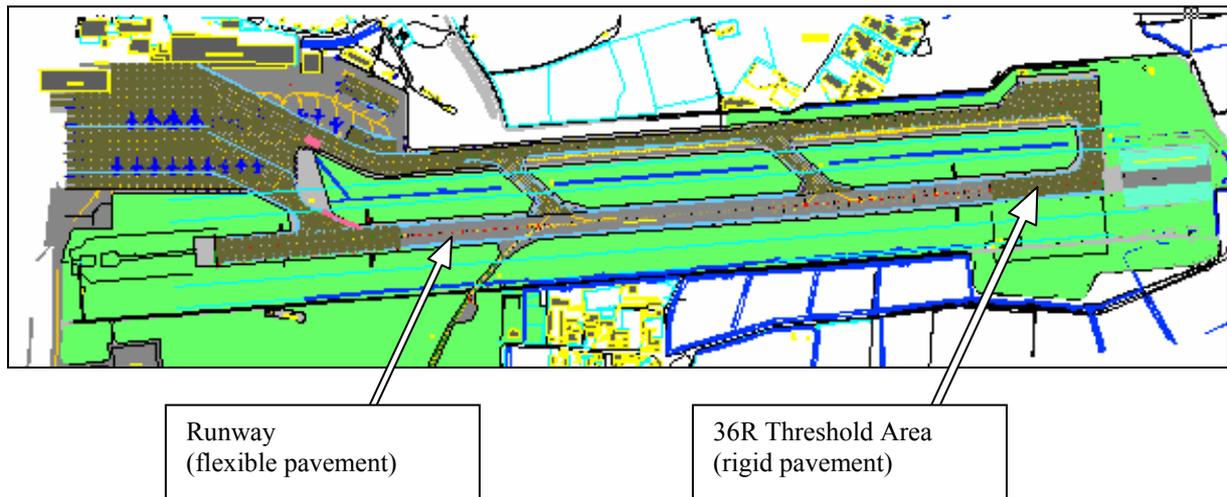


Figure 1: Plant of Linate Airport

## 2 THE REHABILITATION OF THE RUNWAY PAVEMENT

By a preliminary visual inspection carried out in 2001 it was found that the runway pavement was characterized by the following distresses (fig. 2):

- the pavement of the central area, (16,0 meters wide: +/- 8,0 meters from the center line) showed severe cracks especially in the Touch Down Zone due to the high traffic of airplanes;
- the pavement of the lateral area, (22,0 meters wide: from +/- 8,0 to +/- 30 meters for both sides from the center line) showed only surface distresses (wearing, ravelling, etc.).

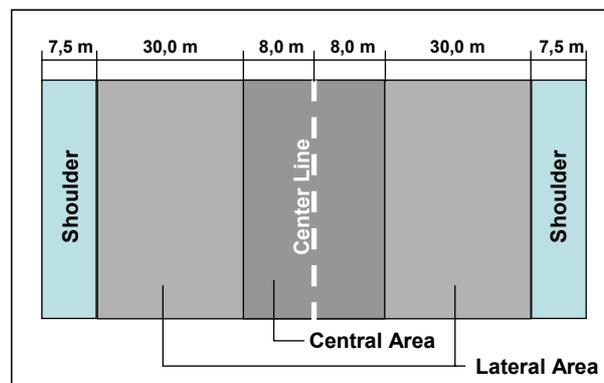


Figure 2: Particular of the runway areas

For these reasons two different kinds of rehabilitations were needed for the runway. In the central area a deep rehabilitation was designed (fig. 3). A thickness of 16 cm was removed by cold milling machines, then 2 cm of new asphalt concrete were laid to support a fiber glass geogrid, which was placed in order to reduce crack reflection.

Then 8 cm of new base course made of High Modulus asphalt concrete were then laid. This layer is very important in the pavement structure because its high modulus allow to increase the bearing capacity without modifying the total thickness of the pavement (Anderton, 1991). The top layer is a 6 cm Wearing Course with modified asphalt concrete (fig. 3).

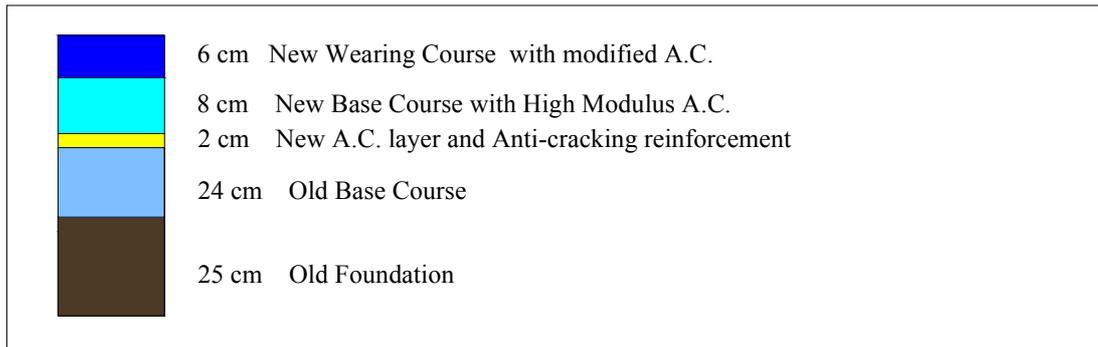


Figure 3: Scheme of the rehabilitation of the runway pavement in the central area (+/- 8,0 m across the center line)

In the lateral area (fig. 4), instead, only 6 cm were removed and 6 cm Wearing Course with modified asphalt concrete were placed in.

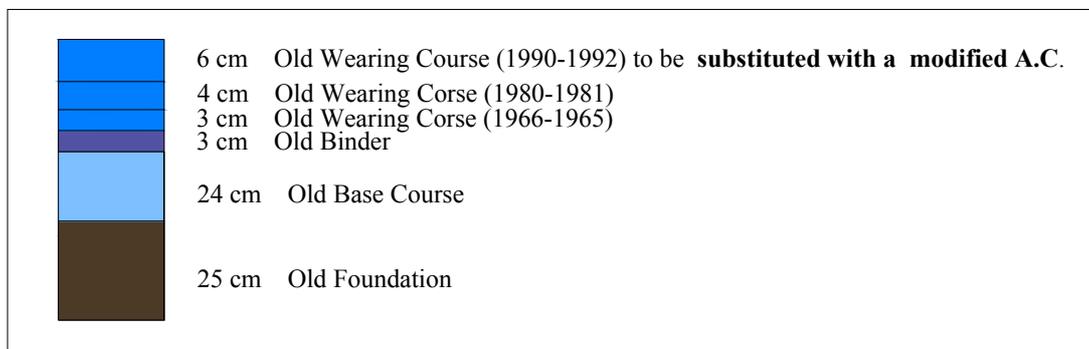


Figure 4: Scheme of the old pavement of the runway and its maintenance in the lateral areas (from 8,0 to 30,0 m, from the center line, for both sides)

The total area rehabilitated is 120.000 m<sup>2</sup> (1640 meters long and 60 meters wide: 8,0 m + 8,0 m as “central area”, 22,0 + 22,0 m as “lateral area”, 7,5 m of shoulder for each side).

Laboratory research was carried out to study the materials performances and characteristics, according to the rehabilitation design hypothesis. After characterizing the bitumen and the aggregates, the mix design was carried out basing on gyratory press method and dynamic test results (stiffness modulus).

The stiffness modulus of the two materials measured by indirect tensile test, is presented in table 1.

Table 1: Stiffness Modulus (Indirect Tensile Test) at 10 Hz

	<i>High Modulus A.C. for the Base</i>	<i>Modified A.C. for the Wearing Course</i>
Modulus at 40°C [MPa]	1133-1534	2082-2817
Modulus at 25°C [MPa]	4342-5874	4508-6099
Modulus at 10°C [MPa]	10630-14382	10748-14542

The paving activity was monitored through the measure of the asphalt concrete temperature and the collection of material specimens taken behind the paver during all the works. By laboratory tests it was found that the modified wearing course had an average of bitumen content equal to 5,63 % and a 3 % average of Marshall voids, according to mix design.

The high modulus asphalt concrete for the base had an average of bitumen content equal to 4,72 % and a 3,2 % average of Marshall voids, also in this case according to mix design.

The paving was concluded the 20<sup>th</sup> of August. Six days later a falling weight deflectometer test was made on the runway. The test was conducted on seven different alignments parallel to the center line. In particular a test was carried out every 50 m along the center line, and at 3,0 and 10,0 meters alignments from the center line; the test was instead carried out every 100 meters along the alignment 20 meters on the left and on the right side of the center line. In table 2 the deflections under the center of the load plate are presented.

Table 2: Results from FWD Tests under the center of the load plate

Location	Deflection at 1400 kPa
	Mean Values [mm*10 <sup>-3</sup> ]
Center Line	586
Axis +3m	677
Axis +10m	475
Axis +20m	547
Axis -3m	637
Axis -10m	460
Axis -20m	458

The results presented above show a good and homogeneous bearing capacity of the flexible pavement both on the central and on the lateral areas.

### 3 THE REHABILITATION OF THE RIGID PAVEMENT: THE SLAB DESIGN

#### 3.1 Foreword

The design of the new slabs was based on the results of a preliminary wide experimental study whose most important issues mainly concerned:

- characteristics of the concrete, whereas a very high resistance (not less than 35 MPa) had to be required just after 3 days from the end of the works (to reduce the no-operating time of the runway);
- effects of the shrinkage, using a very high resistance concrete;
- length and wideness of the new slabs, to be increased as much as possible to reduce the number of joints;
- the structural adequacy of the existing under slab layers.

It was decided, therefore, to support the rehabilitation design by full scale tests. They were aimed at monitoring the temperatures and the stresses inside the test concrete slab due to shrinkages effects (Weiss and Shah, 1997) and also due to moving loads (see Figures from 6 to 10). The test were also aimed at evaluating different types of concretes, to verify first of all which resistance values were reached after only three days and also to verify the homogeneity and the workability of the mix (Meininger and Nelson, 1997).

At the end of the first experimental phase, on May 2002, the final characteristics of the slab were defined and a rectangular shape 10,0 m long and 15,0 m wide for each slab was finally assumed. Such dimensions resulted among the biggest ever assumed for airport runway slabs (Guo and Rice, 1997). Due to such dimensions and to the particularly resistant concrete, a particular steel reinforcement of the slab was studied not to have cracks due to the concrete shrinkage or to other mechanical phenomena.

### 3.2 The Test Slab

Basing on a preliminary design phase, it was decided for the new slabs to increase the thickness to 35 cm respect to the existing slabs thickness of 25 cm (fig. 5).



Figure 5: Stratigraphy of the old and the new rigid pavement

To verify theoretical hypothesis concerning the designed slab, it was decided to build an experimental pavement. It was built in the airplane stop area of the airport where the slab subgrade (made of a cement bounded layer, of a granular foundation layer, and of a soil subgrade) was identical to that of the 36R Threshold Area, where the slabs had to be actually built.

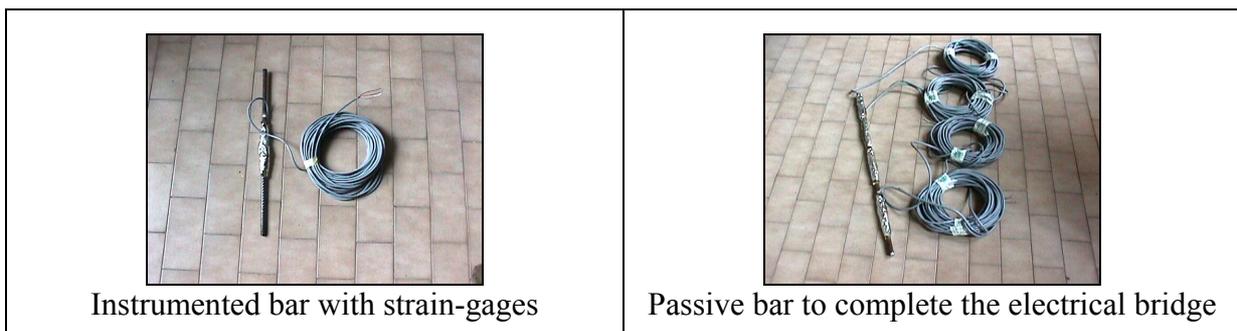
The main goal of the experimental pavement was to evaluate stress/strain in the slabs both due to the shrinkage phenomena and to the airplane loads, thus verifying:

- the correct use of the reinforcing steel bars respect to the risk of shrinkage cracking;
- the correct thickness of the slab, also respect to the under slab layer, made of bound cement soil, which was the existing one.

For the purpose, instrumented bars with thermocouples and strain-gages (to be inserted into the experimental slab) were made (Huhtala and Pihlajamaki, 1992). At same time the concrete to be used for the slab was tested through slump and compression tests.

The instrumentation for the experimental slab was in particular made as follows:

- n. 4 steel bars, ( $\Phi$  12 mm) 50 cm long, where the “active” strain gages were applied, able to log the strains of the reinforcing bars of the slab. The steel of the bar supporting the strain-gages was of the same type of the slab reinforcing bars;
- n. 1 steel bar ( $\Phi$  16 mm) 80 cm long, to complete the electrical bridge of the measuring bar;
- n. 3 steel bars ( $\Phi$  10 mm), 30 cm long, supporting 17 thermocouples to sample the temperatures along the thickness of the slab and 1 thermocouple to monitor the temperature outside the slab (air temperature).



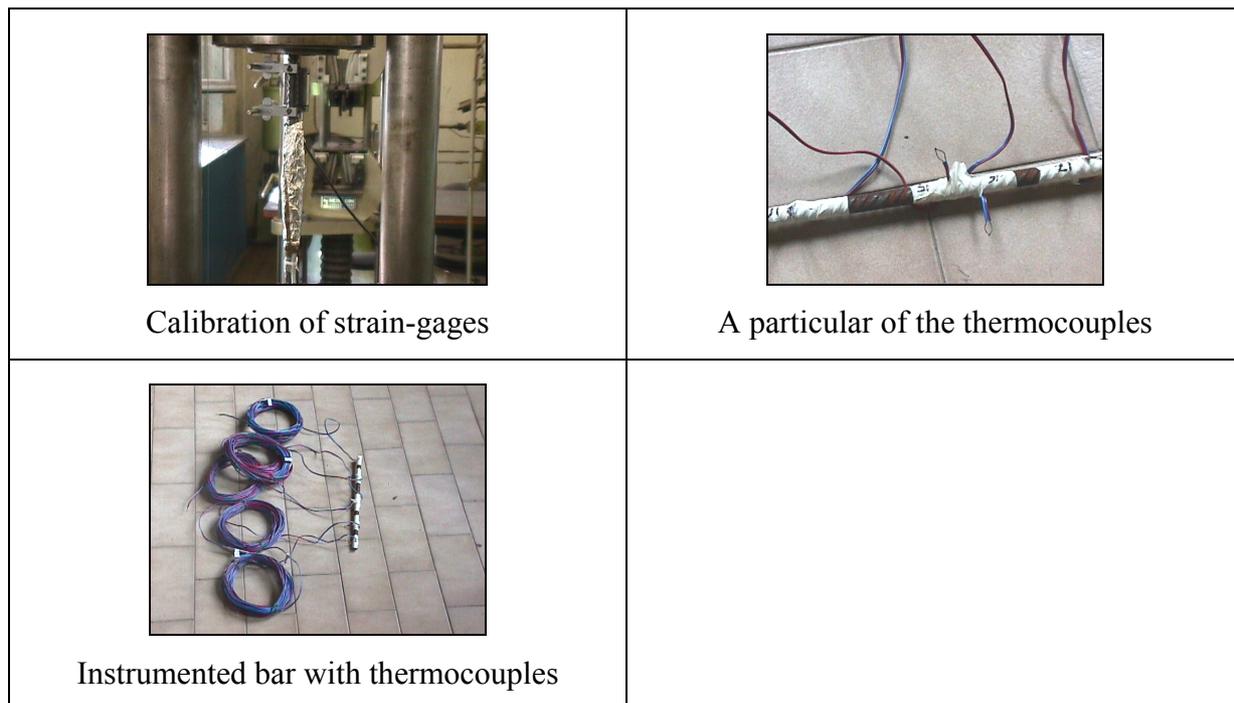


Figure 6: Preparation and calibration of strain-gages and thermocouples

The instrumentation was preliminary calibrated in laboratory. The figures 6 and 7 show some phases of calibration and positioning of the instrumented bars.

The instrumentation was positioned at the most representative position inside the slab (fig. 7):

- strain-gage A: positioned at the center of the main side of the slab, along the main side direction, at the bottom of the slab;
- strain-gage B: positioned at the corner of the slab, along the short side direction, on the fifth bar ( $\phi$  12) from the side, at the top of the slab;
- strain-gage C: positioned at the corner of the slab, along the main side direction, on the fifth bar ( $\phi$  12) from the side, at the top of the slab;
- strain-gage D: positioned at the centre of the main side of the slab, along the short side direction, at the top of the slab.

The thermocouples were positioned as follows:

- from 1 to 6 (from the top to the bottom) vertically in the centre of the slab;
- from 7 a 12 (from the top to the bottom) vertically in the same corner of the slab were strain B and C were positioned;
- from 13 to 18 (from the top to the bottom) at the mean point of the main side of the slab, close to the strains A and C; the thermocouple 16 is positioned outside the slab to monitor the air temperature.

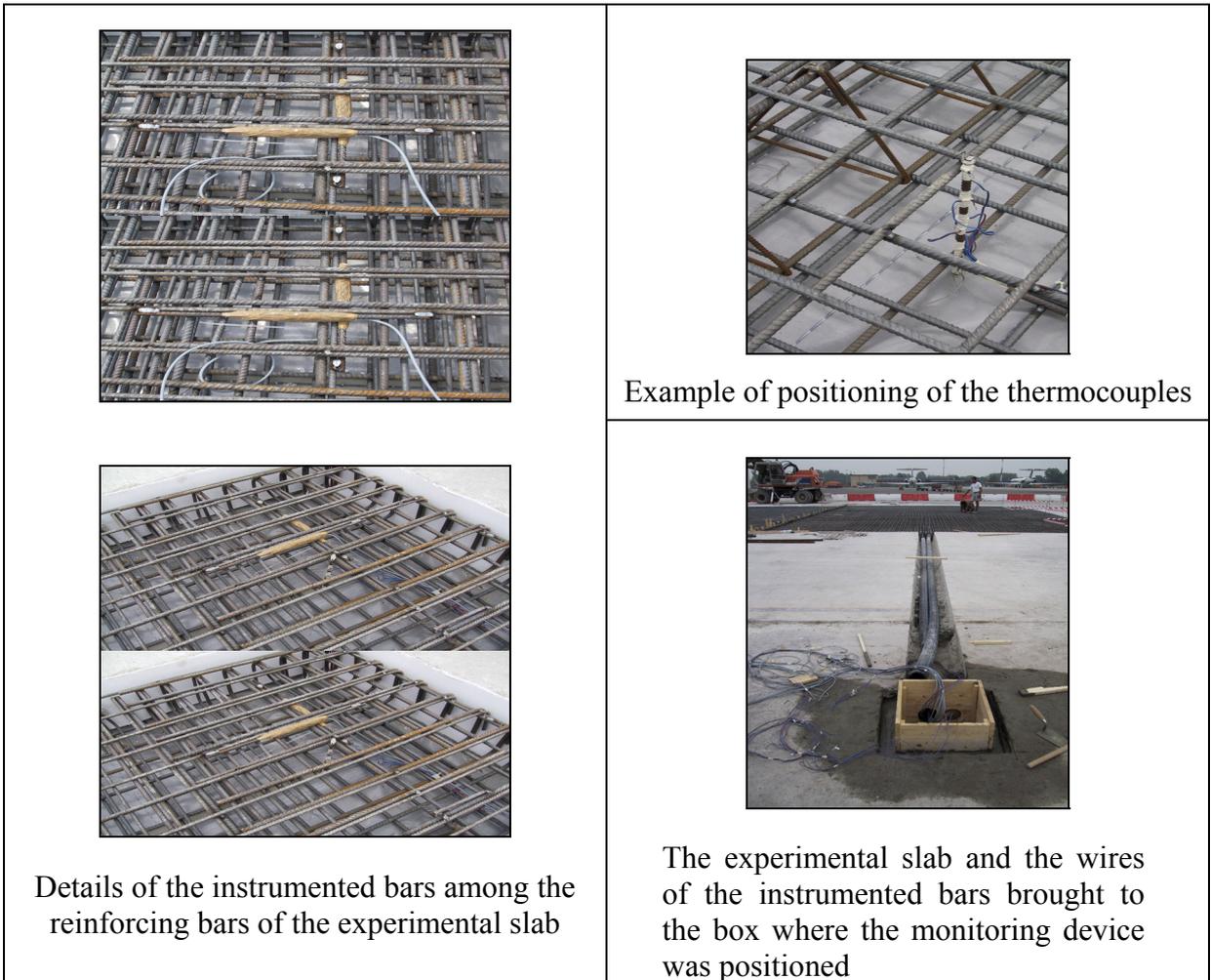


Figure 7: Details of the instrumentation inserted into the concrete test slab

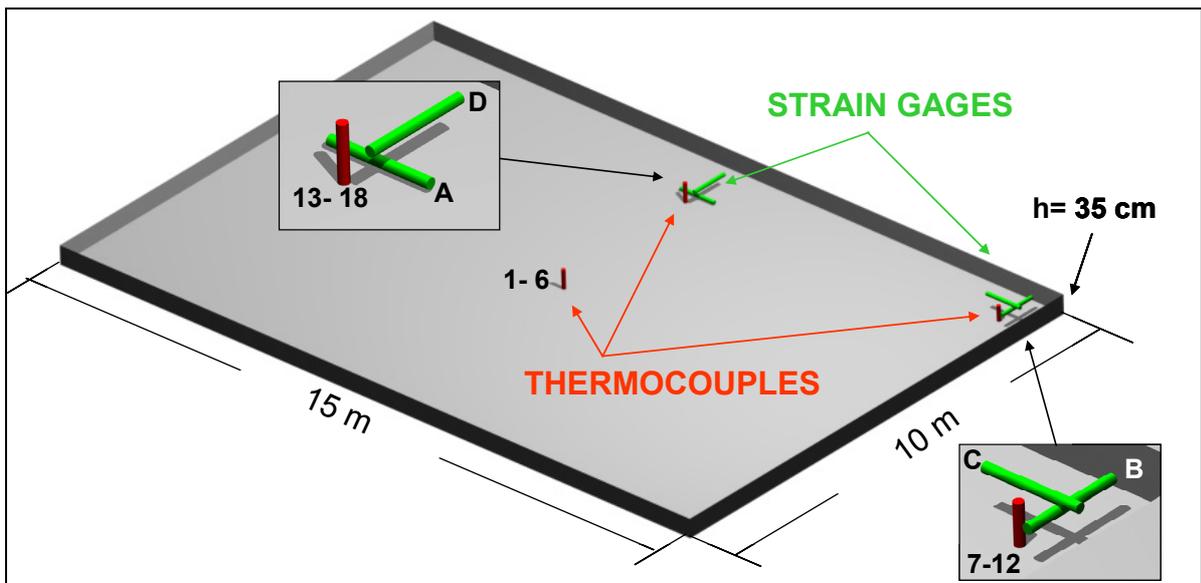


Figure 7: Position of strain-gages and thermocouples into the concrete test slab

### 3.3 Data monitoring and analysis

As concerns the temperatures, they were monitored starting just from the building of the slab. The results are showed in figure 8, where the graph of the temperatures is showed for the first 6 days, the most representative ones for what concerns the concrete curing phenomena. It can be observed that just the day after the casting of concrete the temperatures reached a peak of about 47 °C. In that moment the equilibrium between produced and dissipated heat caused by the curing phase is reached. The temperature peak depends on the relationship between the area of the slab and its volume. In the following days the temperatures progressively reduced, reaching a mean value of about 23 °C, with a night/day excursion of about 8°C.

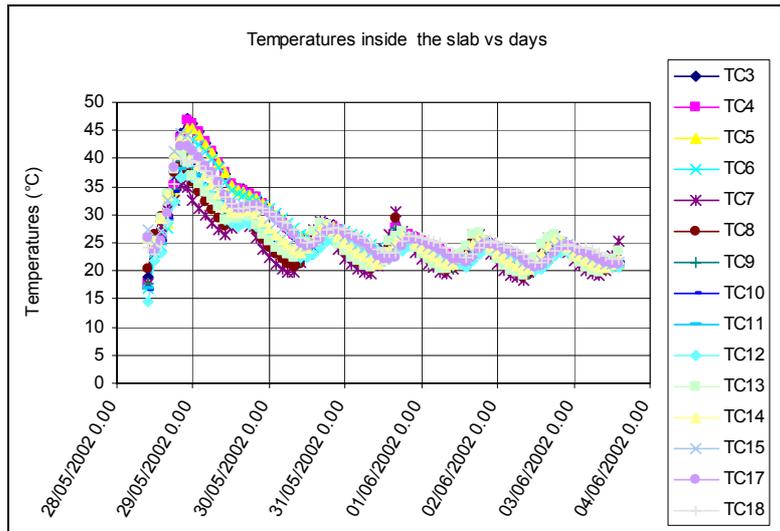


Figure 8: Temperature inside the slab during the first 6 days after the casting of concrete

The corresponding strains are depicted in figure 9.

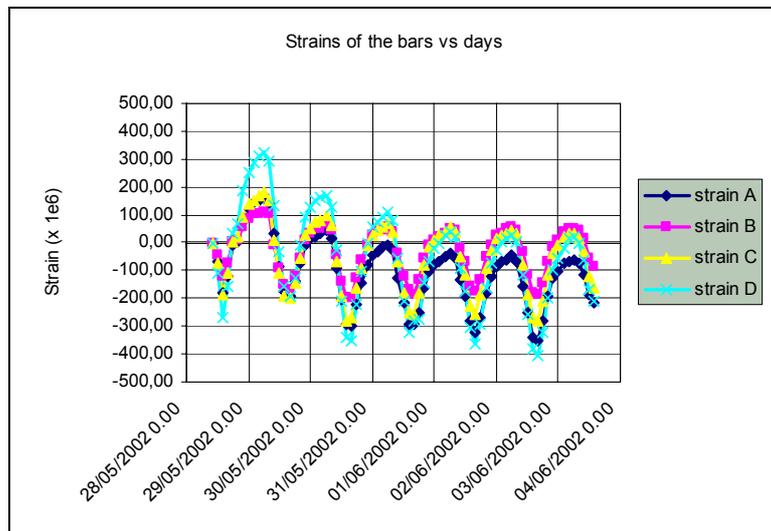


Figure 9: Strains of the bars in the first 6 days after the casting of concrete

It can be observed that the mean value of strain reduced itself for the phenomenon of shrinkage into the concrete slab.

The experimental slab was also used to verify its structural adequacy (position and area of reinforcing bars, slab thickness, structural adequacy of the existing under slab layer, etc.). For that purpose, two three-axes trucks were used to pass on the experimental slab, while the

corresponding strains were measured. In figure 10 the results of the test are reported. Considering a modulus for the steel of 210.000 MPa, the tension were also calculated.

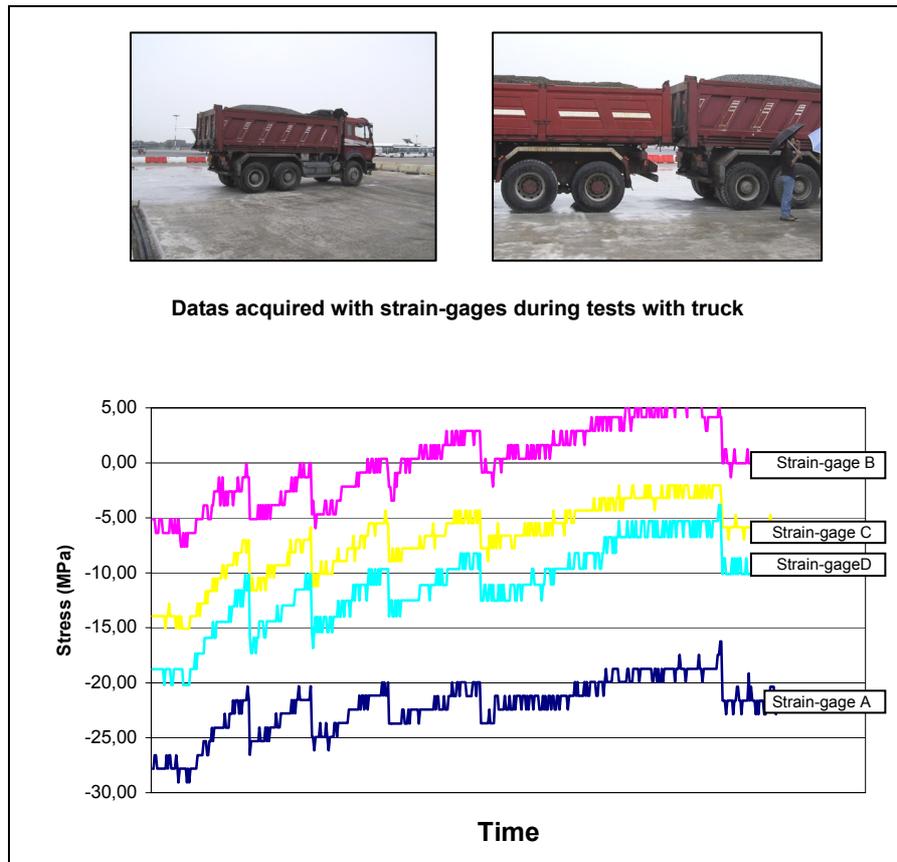


Figure 10: Stresses in the slab due to the test made with two full-load trucks

It can be seen that during the test, the full-load trucks produced a stress of 10-15 MPa on the monitored steel bars into the slab. The low stress levels show that the concrete slab should not be affected by cracking during traffic operations.

### 3.4 The works and the results

The pavement rehabilitation works (for about 64 slabs of the 36R Threshold Area) took only 20 days during August 2002. During the works many control tests were carried out (bearing capacity of the subgrade, of the foundation, material qualities and performances, etc.). At the end of the works the bearing capacity of the pavement was evaluated through falling weight deflectometer. A deflection mean value of  $161 \cdot 10^{-3}$  mm at the centre of load plate was measured. From August 2002 up to December 2004 the pavement was continuously monitored through visual inspections without finding any structural crack over the 64 new slabs.

## 4 CONCLUSIONS

The experience carried out with Linate pavement rehabilitation has showed, once more, that with a deep preliminary research and study activity very interesting results may be reached, finding innovative solutions and completing all the work in only 20 days, without unexpected events. A very important aspect it is to support rehabilitation design with results coming from in situ and laboratory tests.

In this case, as concerns the flexible pavement rehabilitation high performance asphalt concretes were designed through laboratory tests, whereas for the rigid pavement a very high resistance concrete (with a very high curing speed) and wide slabs were designed, basing on the results of a deep experimental activity which allowed to measure strains and temperatures in a test slab during curing time and under moving loads.

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