Italian Roads in the 20th Century
FROM *RUPTA* TO HIGH-QUALITY ROAD AND MOBILITY MANAGER
A century-long process

GABRIELE CAMOMILLA
Terotechnologist expert in maintenance and road management
ANAS Consultant
g.camomilla@stradeanas.it

ABSTRACT

One hundred years of road construction in Italy represented a long process coming from a remote past. Firstly, the origins of the Roman roads are outlined, with etymology, and words used in many European countries. The first Italian (and European) road was called "rupta" - broken - in Latin language - (route, rue, road, ruta). Then a jump is made to the early 20th c. - when PIARC was established - to find out that roads were not much different than in Roman age, to get to the 1920s, when the **motorways** was invented. Soon after, the road system was organised in Italy by AASS, established in 1926, then ANAS, that would manage the successive road development process. After WWII, the second generation of motorways introduced the pay-toll system. This allowed to build thousands of miles of modern roads. The Autostrada del sole or Autosole (Sun Motorway) pioneered this new approach, supplemented by maintenance science or Terotechncology which involved the concept of Quality Management with Performance Indicators. These ones are at the grounds of Global Services also.

Another innovation generator is the great deal of care devoted to environment with specific technical solutions to reduce noise. Euphonic pavements are the most advanced breakthrough. The state of the art is represented by air pollutant reduction techniques.
The development process of the road system is now evolving towards mobility management. This is the last challenge because roads in the future have to be safe, comfortable, with advanced services, environmental-friendly, and …smooth for travel time.

1. THE ITALIAN[*] AND EUROPEAN ROAD CULTURE

1.1. ROADS SPEAK LATIN

The history of modern roads dates back to a remote past. Roads derive from facilities built, initially, by the Ancient Romans for military reason. They later provided fast and safe communications throughout the extensive Roman Empire. From a technical viewpoint, these roads already had many characteristics of modern roads. In the last century only, road-construction techniques could outdo the ancient precursors, also from a design viewpoint. In Roman roads, layout geometry is very accurate according to the purpose why the road had been built; bridges, viaducts and tunnels were the best solution to overcome natural barriers, which impeded a straight-lined road layout. Pavements were designed based on the subgrade bearing capacity. They were specialized, based on materials and functions of layers.

[*] The phrase "Italian culture" is used because modern roads were born in the Latium area when Sublicius built the first road bridge (700 B.C. approx.) to ford on the Tiber (RUMA in Etruscan language). Later, the Romans disseminated their skills throughout the Empire. Also Europe set a great store by their experience.

Fig. 1 The maximum spread of the Roman Roads

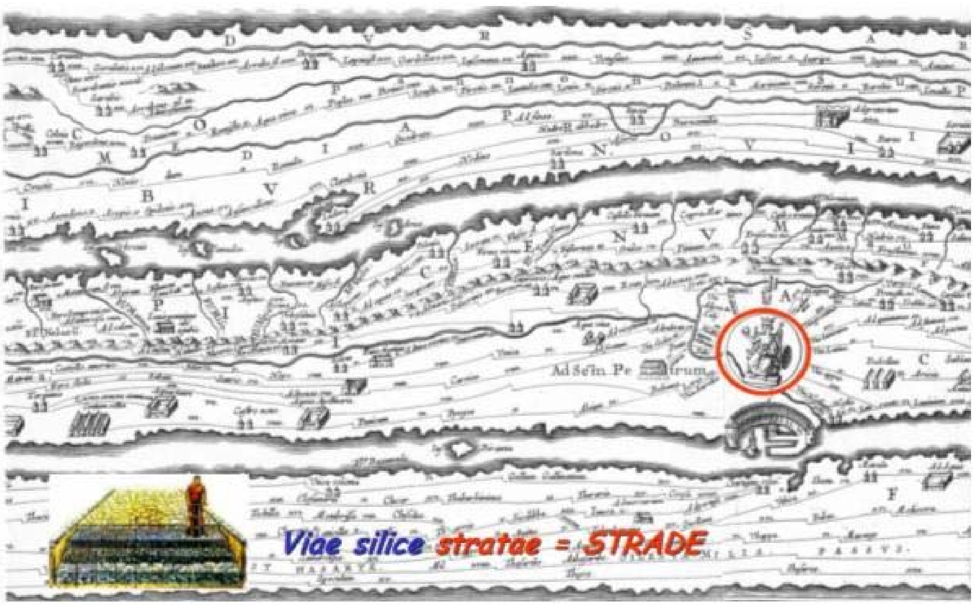


Fig. 2 PEUTINGERIAN TABLES from 1235 Edition: see Italy with Rome (center), Illiria over and Iberia bottom

However, the wonder is due to centuries-long operation lifetime. Even after the fall of the Roman Empire, Roman roads continued to perform their task. Later, although heavily deteriorated, they continued to show the route to travellers.

Etymology describes this feature of roads. As a matter of fact, the Italian word for road, *strada*, derives from the Latin phrase *via silice strata* i.e. "street covered with stone" (Indo-European word to indicate the place where goods transit). Only the last word of the phrase remained which became *street* in English and *Strasse* in German.

Later, due to deterioration caused by centuries of neglect, the street became "*rupta*", i.e. broken; but pilgrims and traders continued to "follow the route", as it says in Italian in sailor's jargon, and as it is commonly said for "road" in French, Spanish and English with "route"-"rue", "ruta" and "road" respectively.

Fig. 3 The most followed "rupta" by pilgrims in the Middle Ages: the Francigenena to Rome and the Ruta de Santiago de Compostela

1.2. THE ROAD "CURSE"

However, this is also the curse of the road: is the only construction job which always works, even if broken, to justify poor construction and maintenance provided today also, despite high construction, maintenance and operation standards have been reached, which may make road the paramount of human construction jobs.
As a matter of fact, the greatest wonders of modern world constructions are roads, both for they way they are constructed (with the poorest materials available) and because they represent a carrier of civilisation and mutual knowledge among populations, next to the most advanced type of existing road today, i.e. the Web.

Fig. 4 Via "rupta" still operating

2. THE BIRTH OF MODERN ROADS – THE "INVENTION" OF THE MOTORWAYS

2.1. Roads in the early 20th c.

Let's go back to 1907, the year when PIARC was founded. What did the roads of the Kingdom of Italy looked like?

The turn of the 20th c. until WWI may be defined as the years of road making up against railways. Despite the 19th century has been, for road transport, the century of great innovation in construction techniques, the period 1900 – 1920 has undoubtedly been characterised by the implementation of modern technologies in order to simplify and automatise road construction and maintenance works. Over these years, new machinery were developed to crush stone material. New paving systems were tested. Finally, transport means improve.

Fig. 5 Unpaved roads in the early 20th c.

3

In the late 19th c., the first attempts were made to mechanise horse-carriages in order to avoid using horses (or velocipedes for short distance) and to replace them with mechanical-powered systems.

Since at that time there were neither cars nor trucks, traffic was essentially made up of animal-driven carriages which had not changed over centuries.

The road network had not changed very much since the Ancient Romans. However, many good works had been done, especially in some mountains roads. Pavements had been reinforced. At the time, they were all made in water macadam, with the technique imported from Scotland, the homeland of the homonymous engineer who had paved the industrial roads of Scotland and of the United Kingdom in the 19th c.

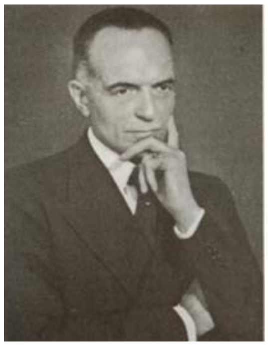
Fig. 6-Carts used in the early 20th c.

The largest Italian car-manufacturing factories were already born and WWI was to give a thrust to truck, airplane engine and, of course, to car manufacturing. Engine-propelled vehicles spread over quickly with the ensuing need to upgrade roads.

In the second decade of the 20th c., this need resulted in two fundamental actions, not only for Italy:

- The "invention" and construction of motorways;
- The establishment of a national company for the road construction and operation (AASS to become later ANAS)

2.2. The birth of **motorways**: an Italian idea [1]



In 1923, an Italian engineer, Piero Puricelli, devised and designed a road with no grade junctions with other roads, only for fast-riding traffic of engine-powered cars and vehicles, to be banned to any other kind of vehicle, with a toll to be paid to cover construction and operation expenses. It was a really pioneering idea, because there were very few cars circulating at the time. In 1923, there were 84,687 vehicles riding in Italy, broken down into 57,000 cars, 25,000 trucks and 2,685 buses.

In 1921 already, Piero Puricelli, an important entrepreneur in the field of road and industrial constructions, had been issued the authorisations to have his designs declared as "public utility", and then to start construction works. With the acknowledgement of "public utility" it was possible to expropriate land to build new roads. Then *Società Anonima Autostrade* was established, a concessionary company with public ownership, strongly wanted by the Minister of Public Works, Carnazza, and funded with 50 million of start up capital. This one may be considered among the first administrative deeds of the Mussolini government, established on Dec. 1st, 1922[*].

Construction works to build the Milano-Varese motorway had a cost of £it. 90 mil. On the inauguration day, the inauguration ribbon was cut by the King's car (Victor Emanuel III) followed by the guests' cars. The new road had one lane only per traffic direction. This was more than enough for the few dozens of cars riding over every day. There was not a real pay-toll station, but toll was paid at the service area where it was obligatory to stop.

Less than one year later, on June 28, 1925, the road section between Lainate and Como was inaugurated, a 24 km. long stretch. Its cost was £it. 57 m. In 1925, again, the Gallarate-Sesto Calende stretch was built, 11 km. long.

On Sept. 1924, in Lainate, the first section of the Milan to Varese motorway stretch was inaugurated; it was to become the *Autostrada dei Laghi*. It was to be the first pay-toll motorway ever made world-wide.

Fig. 8 The autostrada dei Laghi one two-lane carriage-way

From 1924, technical experts began to come to Lainate from various foreign countries to study and copy this new fast-riding pay-toll road. Therefore, the "mother" of all the pay-toll roads was born, that would spread over world-wide.
Actually, the primacy of Italy in this sector was such that, in many European languages, to name the motorways, the word used for motorway is the exact transposition of the Italian word *autostrada*: i.e. the German *Autobahn*, the French *autoroute* and the Spanish *autopista*.

Therefore, while Rome is the mother of the Road, Milan can claim paternity for motorways.

Actually, in that same period, U.S. Route 66 or Route 66 one of the first US Federal Highways was built in the USA. However, this one was not a motorway like the new Italian or German motorways, which would come soon after. US 66 was endorsed by Cyrus Avery, a native from Oklahoma, in 1923 when a debate on a national road system started. It was open on Nov. 11, 1926, even if until the year after many road signs still had to be installed. Pavement was finished in 1938 only. Like all the other highways, Route 66 had a hard-ground for pavement subgrade. Thanks to the efforts of the Route 66 association, it became the first fully paved road in 1938.

[*] In 1933 only, the State of Italy issued a legislation by Royal Decree no. 1740 to define the new motorways as roads exclusively reserved to vehicle traffic. In the meantime, quite many kilometres of these new roads had been built: the Milano-Laghi motorway (as already mentioned), 84 km.; Milano-Bergamo (1927), 50 km.; Napoli-Pompei (1929) 23 km.; Brescia-Bergamo (1931), 48 km.; Milano-Torino (1932), a long motorway 127 km. Additionally, always in 1933, Firenze-Mare (81 km.) was completed and Padova-Mestre (25 km) also. For the construction of these motorways, and of the *camionabili* which came later (the first of them was the Milano-Genova inaugurated in 1935), road designers used the technique of the high-resistance reinforced concrete slabs with an average thickness of 20 cm.

5

Not only did Puricelli built the first motorways with his company by using the newly-engineered machinery and technologies for pavement and other constructions; but also, when he became a Senator of the Kingdom, he designed the motorway network he considered as necessary to the country as an alternative or to supplement the railways network. These projects were developed in the after-war period, as we'll see later. After the first motorway whose layout essentially run in the valley area, many other motorways were built later whose layout stretched over hills and mountains. They included a number of bold technical solutions like viaducts and tunnels. These ones were used essentially in the Milano - Genova "camionale" which was built in two years only through the Liguria mountains of the Giovi pass, to connect the Port of Genoa to the industrial core of the Country located in Northern Italy at the time.

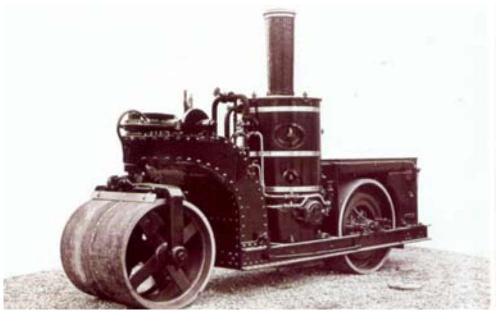


Fig. 10 A steam roller used by Puricelli SA.

In that same period (1927), upon suggestion of Piero Puricelli, the German motorway network was devised and designed. It had a reinforced concrete pavement. It was to be built by Fritz Todt between 1933 and 1939 who was general inspector of the roads under the Third Reich, and the creator of the motorway network built by the regime.

Only after WWII, Gen. Eisenhawer, mindful of the German *autobahan* built to make military vehicle move fast, devised the US motorways network and dismissed old highways and the historical route 66.

However, all these motorways have a common ancestor, the *Autostrada dei laghi* made by Puricelli.

3. AN ORGANISATION SPECIALISED ON ROADS: THE BIRTH OF AASS

3.1. Road reorganisation

On Nov. 15, the Royal decree no. 2506, also called Carnazza Law, provided new rules to classify roads in Italy (excluding local roads).

Roads were broken down into five classes: class one included roads that formed the heavy traffic road network, and cross-border roads; class two included roads that connected the province capitals, or province capital to harbours or alpine passes. The other three classes included local and hinterland roads.

Accountability for road maintenance varied according to the class of the road. For military class five roads accountability was assigned to the military administration – except for the stretches that fell under the municipal administrations crossed by these roads – for the other classes, administrative accountability was as follows:

6

3.2. The birth of AASS

The spread of these communication roads is linked to the set up in 1928 of the **Azienda Autonoma Statale della Strada**, or **AASS,** by the Carnazza Law mentioned above. This company was required to operate class one road network. However, also two and three class were assigned to AASS.

In the first year of operation, AASS could count on about a £it. 320 m. budget, £it. 180 m. came from governmental contributions, and £it. 95 m. from automobile circulation taxes. This financial base, although relevant, was far from being adequate if one considers that out of 20,000 km. assigned to AASS for operation, 463 only were in viable conditions. In such a situation, ordinary maintenance only accounted to AASS for almost all the budget available.

As a matter of fact, roads in 1928, were almost all built based on MacAdam indications: an obsolete system at that moment, and unsuitable for the development of a modern road network. The solution adopted in the mid-Thirties, in full ***autarchic*** period, was to replace macadam roadbed with a new one which used the technique of asphalt sand cut back with bitumen in order to give a better cohesion to roadbeds built on the MacAdam method.

Actually, the Thirties were very important to test new construction methods, essentially thanks to the tireless research by the AASS engineers.
In particular, many mixtures of surface asphalts were tested, as artificial asphalt derived from bituminous and tar concrete, up to modified conglomerates derived from the treatment of tires dust (*poudrette*).

But this is not all; the establishment of an independent Company specialising in roads made a number of number of maintenance and operation activities to be set up which gave a modern definition to these road operation systems.

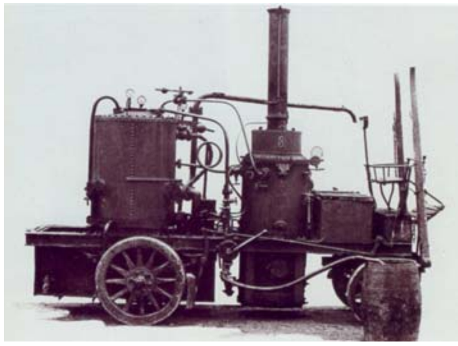


Fig. 11 Bitumen spreading machine

Roads were broken down into stretches under the supervision of a head-roadman who operated in local premises that hosted material warehousing and roadman houses. The layout was scattered with material and warehouses premises for normal and winter maintenance (in places where these activities were probable, mountain passes, northerner region roads, etc).

Fig. 12 and 13 AASS roadmen are re-plotting road on the mountain pass before re-opening it with rotary-type snow plough (1932)

7

Roads were constantly patrolled by roadmen who developed a number of efficient tools for their works and for snow removal. Sometimes they were surprisingly modern.

3.3. Intuitive road signing

Another early requirement was to regulate private road transport by creating norms and regulations to protect both the driver and those who were exposed to the new dangers involved with the spreading of cars.

In the early 20th c., no road signing was regulated by norms and regulations in force, with the only exception of some norms dating back to Napoleon era which concerned the obligation to lay milestones along the main roads.

The new dangers involved in vehicle traffic growth made soon the old road signing obsolete and insufficient. Then, as early as in 1912, the *Touring Club Italiano* did everything possible in those years to promote international rules for road signing and norms to regulate traffic. TCI required a road signing system to be adopted so that drivers could immediately understand where level crossings, sharp and dangerous bends were placed, and also dangers for landslides from surrounding hills, passes on instable or provisional bridges.

Based on the Touring Club project, road signing was also supposed to regulate vehicle speed. A fully-completed road traffic regulation only came in 1928, when the Royal Decree no. 3179 dated Dec. 2, integrated the previous regulations.

Then the Road Police corps was established (*militia*) tasked to control road safety norms and to fine any breach of law.

The Road Law dates back to 1933 (Royal Decree dated Dec. 8, 1933, no. 1740) which integrated and modified the previous regulations, and would remain in force until 1959.

AASS provided for road signing through a series of measures since 1933. These included also horizontal road signing regulations formed by fender lines and direction arrows painted on the pavement to provide circulation signing. Official norms, from the Ministry for Public works and the Ministry of Communications were issued in 1936 only: an inter-ministerial decree issued on Nov. 5 that same year, eventually provided homogeneous regulation all over Italy for vertical road signing (but not horizontal yet), and for traffic lights. Horizontal road signing legislation was issued in 1959, only.

4. POST WAR RECOVERY – MODERN MOTORWAY CONCESSIONS

4.1. Reconstruction after WWII – ANAS role [1]

At the end of WWII, infrastructures in Italy were on the verge of collapse: while maintenance had been discontinued, ravage caused by air-bombing and heavy artillery had turned both road and railways transport systems unusable.

To have an idea of damages endured by Italy during war, only on national roads, over 1,400 bridges and more than 14,700 km. of roads had been destroyed.

8

Reconstruction was almost totally implemented between 1945 and 1950. It was financed by the US-funded reconstruction plan: the ERP plan (European Recovery Plan) better known after the name of the promoter, Marshall plan.

As from 1950, reconstruction became the so-called economic boom: the fastest economic development ever witnessed before, a skyrocketing industrial production growth and mass consumption.


STRADA STATALE ANNI 50

This strong expansion of the Italian economy was undoubtedly fostered also by a sensible infrastructural development policy which lead the transportation system in Italy from a backward situation, to the optimal levels of market economy development.

To manage the reconstruction of the motorway system and its growth to fit to international standards, it was necessary to establish again AASS, that a lieutenant decree dated Sept. 29, 1944 had dismissed to favour the direct operation of the motorway system by the Ministry of Public Works.

The Story of AASS started again in the full reconstruction era by D.L.P. no. 38 dated June 27 1946, the year when *ANAS, Azienda Nazionale Autonoma delle Strade* was established. ANAS was assigned the task to restructure, modernize and upgrade the road and motorway network: an objective the agency met in 1954, when it was disclosed that the reconstruction works had been completed.

Overall, in the first decade of operations, ANAS could claim not only to have finalised reconstruction, but also to have given a thrust to a program targeted to improve and upgrade the national road network. In that same decade, however, vehicle traffic had grown under many aspects: it had become heavier, faster, and thicker. For these reason, huge investments were necessary in order to respond to the new challenge posed by road traffic, and to the threat for Italy to be excluded from the international economic context.

To this end, in these same years, the works for the large alpine road tunnels began, as for the **Great San Bernard** and the **Mont Blanc.** They would be opened in the Sixties. They contributed to solve the problem of road links with Switzerland and France in winter periods.

These tunnels were the first in Europe, preceded only by the **Caldecott tunnel** in Oakland, California, a 2 bores 1,100 m. –long tunnel built in 1937 (a third bore was added in 1964). Another road tunnel longer than 1 km. is the less famous **Salang tunnel**, 2.6 km. Construction works began in 1955 and finished in 1964. It was built by the Soviet Union and Afghanistan to reach Kaboul.

4.2. Motorways under concession: an *ante litteram* ***Project financing***

The true step forward in the reorganisation and development of the national road network took place only in the late Fifties with the decision to launch a plan for the construction of the so-called “second generation motorways”. As stated before, the road network situation in the post-war period was far from being adequate: a little bit more than 300 km. were viable vs. over 6,000 provided by the Puricelli* Plan passed in 1934.

After the end of reconstruction, it became necessary to develop a long-term plan to provide a far-reaching development of the motorway network, both by the direct action of the government to support the operation as well as through the newly re-established institution of Motorway concession which implemented its first memorable action with the construction of the Sun Motorway later called by its acronym A1.

The true "power force" of the project was Fedele Cova, engineer, a curious but ingenious man - whose name nobody recalls today. However, he was the inventor of Eternit – asbestos-concrete - which allowed thousands of low-cost constructions in the booming after-war period. He also reinvented motorways. In the sense the invented the underlying mechanisms: the modern concession system i.e. an anticipation of today's Project Financing. In practice, in exchange for a 30-year concession (from the government), for managing motorways, IRI was committed to built them at their own expenses. Funds were collected on the market through bonds issued by IRI. No particular funding was provided by the Government, except for the levying of some taxes and a duty. However, ***autostrade*** cp. (established expressly for the construction of these roads) renounced to these duties in order not to delay the works.

Construction works by 40% by with specialised companies of the IRI group, (Italstrade – a controlled company of Puricelli SA) and by 60% by contractors; costs resulted out from public tenders (also for road sections built by IRI)

The sun motorway construction works started on May 19, 1956 from San Donato Milanese, and about two years later, it had already reached Parma. In early October 1964 it was completed down to Naples. It immediately had a huge success. It must be noted here that the Sun Motorway was for sure the symbol of IRI and Italian enterprises technical capability. About eight years were necessary to construct 755 km of motorway, including the very complex Apennine section with many tunnels, bridges and on a soil subject to landslides.

A complex debate concerned the Rome to Naples stretch: according to various economists, there was no traffic, and therefore it was useless to make it. Cova could overcome objections supporting that the motorway itself would generate traffic, he built it and was a good prophet.

After being built, the Sun Motorway became something more than a mere communication road. It became a fast link which opened the South of Italy to many people living in the North of Italy and in Europe. Somehow, some people state that the Sun Motorway was one of the "powerful" phenomena which speeded up the unification of Italy.

Another effect was the establishment of scattered industrial areas: earlier, industrial production was concentrated essentially in the North of Italy. After making the sun

* In the meantime, Puricelli SA had been acquired by ITALSTRADE S.p.A. of the IRI group. The IRI group would then establish Società ***autostrade*** spa .

Motorway (and the other motorways built later with the same formula) many new industrial areas were set up all over. A new manufacturing process came out, with semi-finished products transported from a manufacturing point to another.

But the force of the system, beyond the construction of the Italian network, was the development of a maintenance and operation method which created successive road innovations linked to customers' satisfaction and continuous upgrade of roads.

From a technical viewpoint, the Sun Motorway was the origin of many construction systems: only in the Apennine, from 1961 to 1964, more than 80 bridges were built with many different technologies: arches and continuous beams and simple supported beam, reinforced concrete was used, the first elements of pre-stressed concrete, the mixed steel-concrete technique and network-shaped beams in welded steel pipes: for tunnels, multiple perforating devices, and rotating cutters in addition to explosives. Soil subject to landslides were stabilised; they required effective drainage and the preventive improvement of slopes, in addition to tree planting used a very first environmental-friendly solution: just think about the planting of weed-controlling and self-limited growth trees. Motorways built later, where larger green areas were provided in the neighbouring areas, as in the Adriatica Motorway, from Bologna to Taranto, were provided in the 1970s, with standardised bridges which were essentially made in prefabricated beams, to reduce construction deadlines (bridges built as a "manufacturing chain").

It was a time when construction speed was the keyword and this made maintenance problems to arise in the following decade.

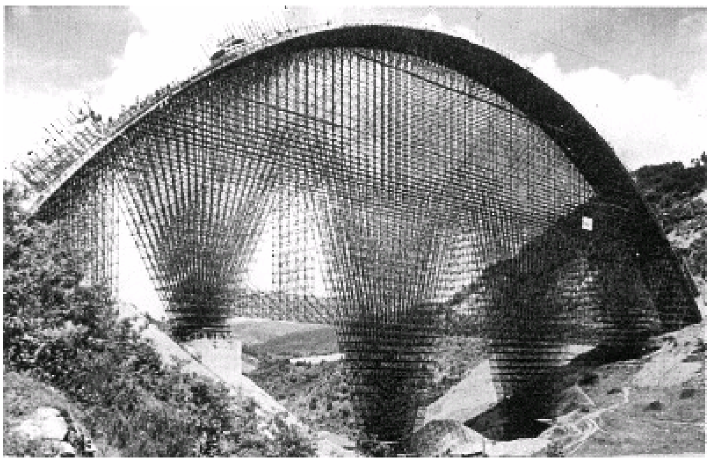


Fig.14 Construction of the arch of the Aglio viaduct (R.Morandi)

5. 1982, BIRTH OF ROAD TEROTECHNOLOGY

autostrade Co. established a sector specialised in study and innovation to manage maintenance in a more and more heavily truck-trafficked road and to find construction solutions which would minimise in time the requirement to repair roads. The target was: *It is not enough to build, it is necessary to last and make maintenance easy, to be anyway prevention-oriented and with techniques supplying added value to maintenance work.*

Road Terotechnology was built**.**

Terotechnology is the science of Maintenance, start from planned maintenance was the product of the awareness acquired at the end of the 1970s [2] that maintenance work could not be done in the same manner as that for new construction.

The figure of the user (not yet a customer) also played a role in this phase: the work needed to repair motorway damage, then as now, caused inconveniences, queues and accidents. In those years, it had just been discovered that also a motorway even if perfectly built, had a finite duration in terms of structural capacity, and that the obsolesce of some of its parts made maintenance necessary.

However, this aspect, to tell the truth, was also recognised by the founding fathers of the institute of the motorway concession, who right from the start had proposed, for example, to immediately repair the damage procured by an accident, to carry out relevant cleaning activities, winter operations and also to take care of the shrubbery and vegetation on the pavements, etc).

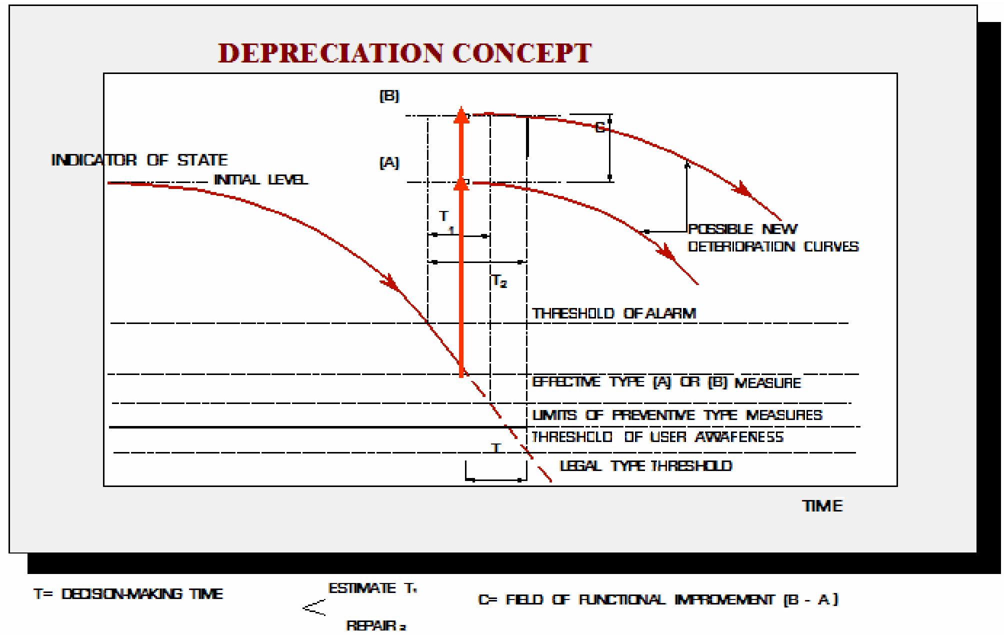


Fig. 15 - Deterioration curve of the indicator (parameter) of state and the choice criteria for preventive maintenance

The novelty of planned maintenance lay in the global management method applied to these various operations; and which on account of their interference with traffic flow were considered complex. The lack of the definition of the useful or working life of a structure is the main difficult to overcome when planning maintenance operations*. It has been possible to overcome this difficulty by applying a series of measures over time referring to parameters of deterioration, in such a way as to keep - without exceeding appropriate thresholds - the phenomenon of the failure of the elements and/ or their non-operation - under control.

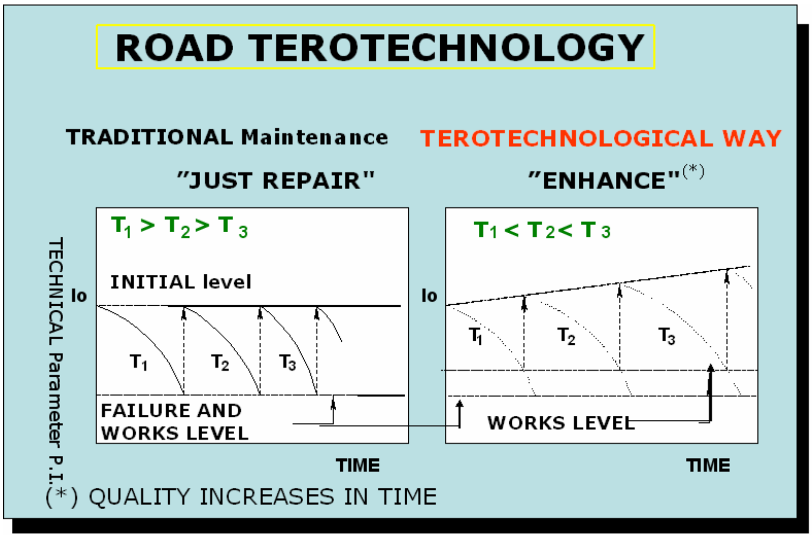
This manner of proceeding makes it possible, inter alia **to choose the place and the time of the maintenance work**, which is all preventive in nature, thus reducing the inconvenience caused to traffic by multiple roadworks.

*In this field the operator is always at an advantage with respect to the public organisation as it can always use the concession time as its reference, and will, at the onset, give it one of the right approaches to managing the durability of an infrastructure

12

For this reason every effort has always been taken to **avoid reaching <u>serious levels</u> of deterioration (figure 15) and wherever possible the repair work has always been of an ameliorative nature with respect to the initial condition of the infrastructure** (fig.15 e 16) **- at the right moment** (before the facility stops working - preventive maintenance) - **to obtain an improvement in the facility** upon which to take action, with respect to the initial level (functional maintenance) – something that mainly took place in the period when profits of the company were capped by state decree (up until 1992).

The performance in question has led to maintenance management that makes it possible to prolong the time (T_i) between maintenance work ($T_1<T_2<T_3$) and an improvement in the facility repaired, as set out in box II of figure16. Box I, instead, illustrates traditional maintenance, that is, acting after the failure of a facility and where ($T_1>T_2>T_3$). Box 1 - Traditional Maintenance Box II- Preventive and functional maintenance used by Autostrade up until 1993. Therefore a terotechnologist understands the causes of deterioration, as regards road wear and knows how to measure it



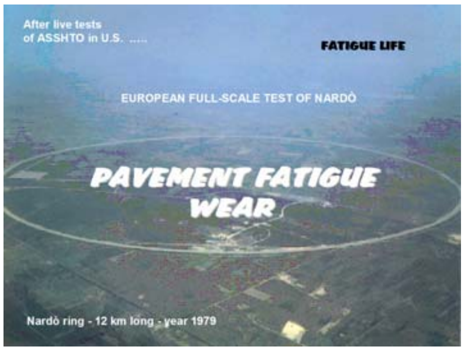


Fig. 16 - Maintenance philosophies

The first surveys of this type were focused on pavement degradation. They led in the 1970s, to the Nardò trial to measure pavement fatigue and the different level of aggressiveness of the various types of axles of heavy loads. This survey caused a great deal of interest, because common rules had to be found to chose less aggressive freight transport vehicles to ride on the roads of the "unified" Europe.

Results were found: the ***tandem effect*** measurement led to identify the less aggressive type of vehicle (the 18 double tandem 18 wheels) [4]

The validity of the measurement criteria was confirmed by successive measurements conducted simultaneously from 7 OECD countries [4] [5].

Other detailed confirmations were obtained with the "manege". Full scale tests were conducted at Nantes (F), Crowthorne(UK) and Zurich SW

13

Fig. 17 Italian and European publications after the Nardò experience

In the following picture are represented the cover of principal proceedings on Nardo experiment and subsequent check of methodology, in Italy and in other European country The most important outcome was to confirm reliability of the rational methodology

"ε ***METHOD***"

Not so much for the data on the aggressiveness of vehicles on the two pavements (flexible and rigid type) but for the verification of the validity of the approach to the rational calculation of vehicle aggression. After Nardò it was possible to forecast the duration of the maintenance work using also new untested materials. It was sufficient to measure their fatigue curve and calculate their duration [6].

The terotechnological approach fostered a number of innovations also on bridges. For example, **seismic retrofitting** transformed bridges lying on the major motor-roads into fully safe bridges against earthquake for the next 500 years. Reversible dissipators were used to this purpose. They spread worldwide, in high earthquake-risk countries, like Italy. Other innovations occurred in the Bridge Management Systems as in the renovation of engineering structures as the urban cables stayed viaduct in Valpolcevera at Genova whose stay cables were replaced without traffic flow break.[8]

Fig.18 Vision of Polcevera Viaduct with new cables (right)

5.1. High performance machines for road data collection

Terotechnology makes a measurement of the road to be operated, that has to be identified with the high-yield systems, i.e. automatic systems which do not obstruct traffic flow and can be repeated to check out the positive outcome of maintenance works.

Italy has been among the first countries to introduce systematically the use of this equipment in the current road management operations. The most reliable machines world-wide are used and sometimes they are assembled directly by road operators.

14

The measurement must be taken with objective methods and criteria and make use of automatic equipment calibrated on the basis of predefined methodologies that measure parameters on a repeatable basis according to defined indicators of quality.

It is important to keep in mind the **peculiarity of the measurements of the state** of roads.

The measurement of the parameters of state and the consequent indicators are not deterministic type measurements such as those associated with the evaluation of purely physical-technical phenomena. Instead they are probability measurements that involve phenomena related to human behaviour, and more importantly, the changing nature of the evaluated characteristics of materials and the type of measurement needed to survey the parameters, referred to as high performance measurement.

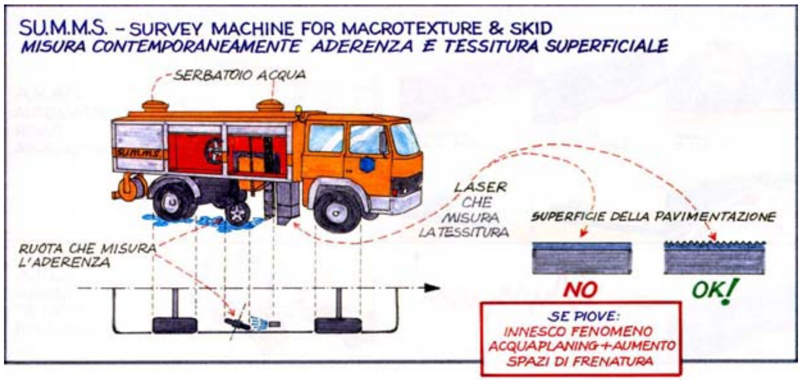


Fig. 19 MachineH.P. to measure pavement skid and texture

Such measurements are normally made by machines that by surveying a very high number of values achieve validity for their measurements in terms of the statistical value provided by the large amount of data surveyed rather than by referring to a precise value measured at a single point, which could differ (but without changing the average condition of the characteristics) from one machine to another and which by itself could not provide an exhaustive description of the phenomenon in question.

And also a High Performance Measurer licence are issued to public and private bodies that file an application in order to promote a new form of road professionalism made up of various fields of expertise: pavements, motorway/road structures, hydraulic and geo-technical works and complementary works such as road signs, safety structures and land cultivation work (green areas). In this way is possible to control the work of **Global Services**, the new way for exploiting roads.

The terotechnologic "*modus operandi*" has generated in the Italian motorway network the first **Measured Quality System** to make control on the operation of new private owners of these infrastructures. The tolls are connected to the results of levels of measured quality for 4 Performance Indicators (P.I.) that every five year must change. However, the greatest innovation is not only P.I. but also their variety: they are no longer linked to road efficiency, but also to the way road is operated, to get to the concept of intrinsic safety and environmental impact measurement.

In addition to the first 4 P.I. there are 10 more being measured and then controlled.

Details of this method are in the proceedings of Durban PIARC World Road Congress[14].

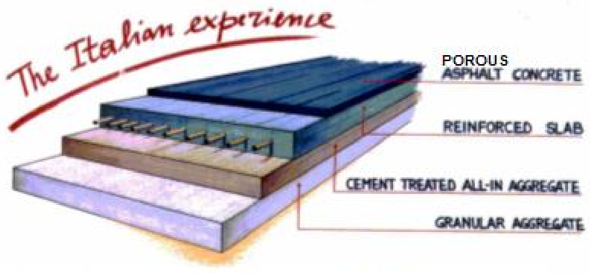
5.2. Technological innovations generated by terotechnology

In the choice of actions to be implemented to restore road original conditions, terotechnolgy has to consider:

- Road users' expectations

15

- Technological know-how at the moment of maintenance works. This may determine more effective and durable roadworks compared to maintenance operations provided with standard procedures.



Polifunctional Composite Pavement

This procedure led to a number of innovations, all made or perfected in Italy, after taking inspiration from other Countries.

I am referring to management systems for pavement surfaces, continually monitored to check their adherence and regularity from the first years of the 1980s and for which the points with the lowest values were eliminated; to the draining surfaces[*] especially fitted for road traffic, developed in that period. The best results also for fatigue durability are obtained when this superficial layer is posed on continuous concrete slab; this solution is the P.C.P Polyfunctional Composite Pavement to the new safety barriers "moveables" for bridges and median strips designed to provide total prevention against driving off bridges or onto the opposite carriageway; to the improvement in bridge joints to eliminate the noise and inconvenience hitherto associated with them; to the reversible seismic devices checks that dissipate energy designed for bridges to protect them against the earthquakes; to measures for road utilisation (ever safer and prompter winter operations despite ever higher traffic levels) and road aesthetics which regard motorway vegetation and phytotechnological measures.

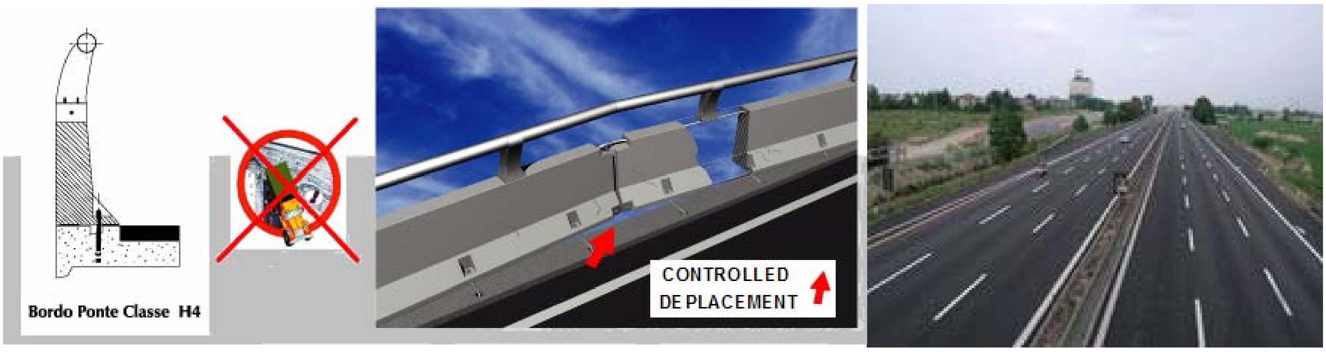


Fig. 20 and 21 "Moveable" barriers for bridges and median strip; in the bridges the energy of choc broke ductile anchorages without transmission to the bridge deck; the vehicle is redirected and the roll over avoided

6. ENVIRONMENTAL PROTECTION BECOMES A MAJOR PLAYER

In the 1990s, the great deal of care addressed to the environmental impact of roads becomes increasingly important. The Italian choice to solve these issues is focused from the beginning on supplementing the standard road component solutions and materials to reduce the effects on environment or mitigate them as far as possible.

The first problem to be faced is **traffic noise**. A number of solutions do already exist, essentially anti-noise barriers. An innovative solution developed in Italy is the **euphonic pavement** developed within the Si.R.U.Us project:

[*] In Italy the development of this type of road surfaces is 65 million of square meter at the end of 2005

16

These pavements are made up of surface porous material layers (anti noise draining mixes). The lower layers contain large cavities to reduce low-frequency sounds (caused by trucks), which are easily transmitted by ground. The problem of resistance to traffic load has been smartly solved. Two types of pavement are used: one for motorways, and one for urban roads. Additionally, it is possible to check pollutant solid materials leaking from vehicles and cavities hold dangerous liquid.

This kind of pavements was implemented in 2002. A very high load of traffic has been riding over these pavements for four years now.

Usually, the old pavement is replaced, the upper layers are removed and recycled with foamed bitumen for subgrade, to provide load-bearing capacity. Then a continuous-reinforced slab with cavities made with pipes having a varying diameter is laid (to absorb the various frequency ranges). Surface layer is made with porous bituminous mixes Urban road pavement is similar, however its structure is simplified due to lighter loads travelling onto it

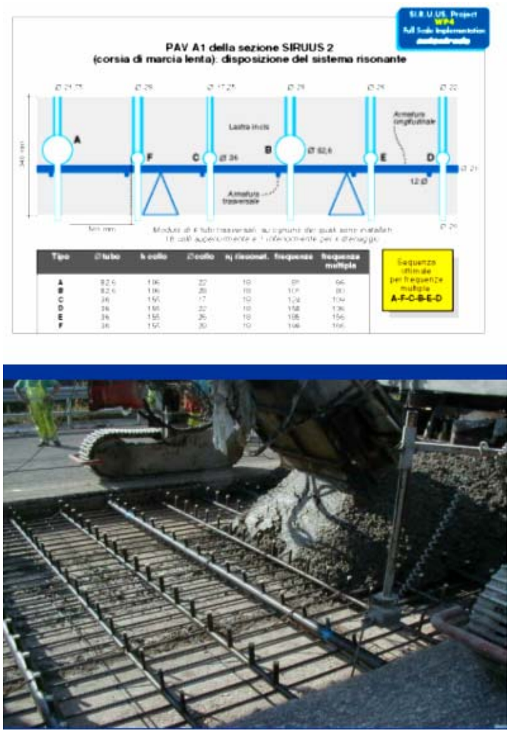


Fig 22 Eufonic Pavement with "canne d'organo" resonators

6.1. Emission-controlling road structures . PM10 elimination.

A new road structure, developed to protect environment, is the "false" cutting which led to develop environment protections devices. In addition to anti-noise barriers, which supplement euphonic pavements, devices which intake polluted air form traffic (including PM10), process them inside units called "artificial rain storm" which expel 100% purified air after processing it with a high-. performance catalysers

These devices are currently investigated by the European NR2C research, they may be placed also at tunnel entrance to purify air.

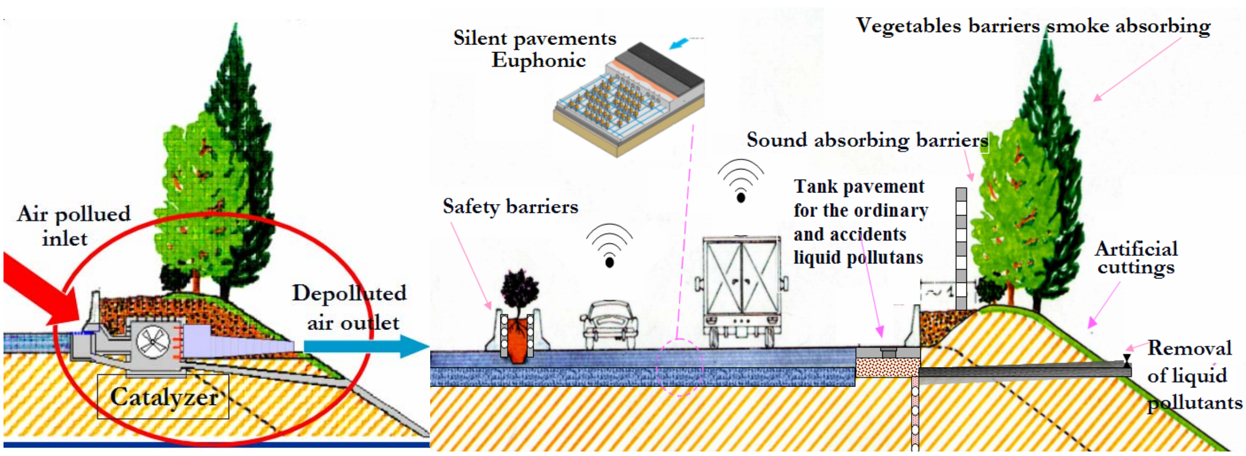
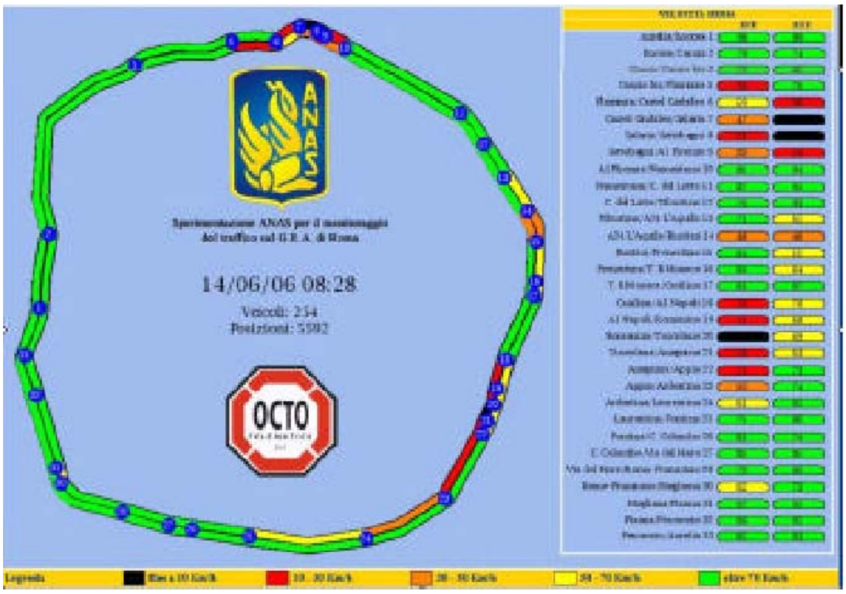


Fig 23- False cutting; Fig. 24 False cutting with devices for the "synthetic rain storm" to reduce PM10 by 95%.

7. 2007 – IMMATERIAL DATA COLLECTION AND THE MOBILITY MANAGER

New progresses were made over the last few years. However many findings still remain to be implemented. A mention should be made to traffic control equipment which will allow over the next few years to get to an individual interaction between road operators and users. These ones will receive in real time all information required. Therefore, a new type of road technical expertise will be established: the Mobility Manager. This one will operate on the base of accurate information provided by sensors. In the future, nano-sensors will be placed in the pavement, and will collect "immaterial" data, i.e. data that do not require specific equipment on the road itself. Research is currently made on these devices.

7.1. "Immaterial" data collection



Today, vehicles are equipped with positioning sensors and sometimes with acceleration-gauges to identify from remote distance the relevance of any accident.

Or the driver and/or the riders hold and use cell phones which may be identified. Vehicles riding along pay-toll motorways normally have on board a "telepass".

Devices used by the pay-toll motorway companies is called "telepass*". It allows to make the same assessments.

Fig. 25 - Web image to show traffic on the Ring Road of Rome detected by GPS sensors fitted by the insurance company on vehicles: the average speed of each ring road segment is visible on screen.

REFERENCES

1. Da Rios G et alteres- La strada in Italia dall'unità ad oggi 1861-1987 – ANAS Pubblication
2. Camomilla G.. La manutenzione programmata Dove Quando e Come intervenire..- Proceedings ASECAP Meeting, Innsbruk 1982 - Autostrade Magazine December 1983
3. Camomilla G et alter _ Measurement of the aggressiveness of good traffic on road pavements Autostrade Magazine 1979

* Telepass was developed in the 1980s by *Autostrade Co*. It was the first and widest used payment instrument with no need to stop at pay toll station. The device automatically computes the vehicle class and toll due. Today, since it is fitted on millions of vehicles, it is possible to compute travel time on the road sections where detection stations are laid.

18

4. OECD –Full Scale Pavement Test – Recherche routiere 1982
5. OECD – Strain Measurements in bituminous layers Recherche routiere 1983
6. Camomilla G.- Road wear due to heavy vehicles -Tenth meeting of the ACEA Scientific Advisory Group Meeting in Bruxelles June 23 2005
7. Camomilla G. - Performance Measurement System for High Capacity Toll Roads –World Bank Meeting Washington December 1999
8. Camomilla G., Feroci V., Malgarini M., Bruschi S. - I nuovi parapetti da ponte ad ancoraggi duttili: la problematica applicativa su viadotti esistenti "L'Industria Italiana del Cemento" n. 460 Marzo 1990
9. Camomilla G,Pisani F.Martinez y Cabrera F,Marioni A. – Repair of stay cables of the Polcevera Viaduct in Genova, Italy - IABSE Symposium Report San Francisco 1995
10. OECD Road noise Controll -Abbattimento dei rumore lungo le strade - Recherche routiere1996
11. Luminari M Camomilla G, Road Innovation Concepts, Studies and Full Scale Experiments on Autostrade motorway network - PIARC XXII World Road Congress, Durban oct.2003
12. Camomilla G. Fornaci M. - LA GESTIONE IN QUALITÁ DELLA VIABILITÁ STRADALE "strade" in qualitá totale: percepita ed intrinseca, durevole ed economica per struttura,servizi ed ambiente Giornate ASECAP 2000 Roma 6 6 2000
13. Camomilla G Pereira P.-Framework of Performance Indicators- Technical Committee C6: Road Management Proceeding Durban PIARC 2003
14. Camomilla G. Luminari M - THE SIRUUS PROJECT -The anti-noise pavements of the Si.R.U.Us. research ASECAP 2000 Meeting Roma 6 6 2000
15. Camomilla G. Developments and management of porous pavements, water draining, noise and pollution reducing.- Asphalt and Innovation SITEB Italia 2004

19