

CYPRUS UNIVERSITY OF TECHNOLOGY  
DEPARTMENT OF CIVIL ENGINEERING AND GEOMATICS



## **Postgraduate Thesis**

ASPHALT TRANSPORT PAVEMENTS: CAUSES OF DETERIORATION,  
METHODS OF MAINTENANCE AND SUGGESTIONS /GUIDELINES FOR  
NEW SMART METHODS.

**SOTIRIADIS GEORGIOS**

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# **APPROVAL FORM**

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The approval of the thesis from the Department of Civil Engineering and Geomatics of the Cyprus University of Technology does not necessarily imply acceptance of the opinions of the author, on behalf of the Department.

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## **Abstract**

The pavements have developed in recent decades, as studies have introduced new materials in their construction, such as types of asphalt, new standard sizing and new requirements for the surface characteristics. The surface characteristics, namely the critical contact surface with vehicle tires, is able to deliver higher quality, speed and travel comfort without compromising the integrity of mobile vehicles and their passengers.

The pavement, as a construction element, is inextricably linked with the road transport systems, since essentially the supporting structure, which is responsible for the movement of vehicles. Modern technology has brought great improvement to the durability, quality and safety of road surfaces with the use of new materials and construction techniques

The provision of permanent deformation is necessary both during the design phase and construction and during the operation phase of a pavement. It explores the impact of factors affecting development and can provide valuable information on the behavior of road against traffic loads. This allows the better management of the road network.

The study presents the types of deformation found in asphalt pavements, as well as a number of types of maintenance, along with new ideas and suggested solutions from abroad.

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## **1. Introduction**

Over the centuries, the roads and pavements have evolved to be able to meet the needs of humans to move themselves and the products they produce. The pavements are the surface on which the movement of vehicles and people takes place, and the characteristics of these are the most critical for how to make a move for a particular vehicle. Speed, safety, comfort, quality is some of the parameters that traditionally have preoccupied people who drive and move in the cities. Nowadays these parameters are a requirement (El-Basyouny & Witzcak 2005).

The pavements have developed in recent decades, as studies have introduced new materials in their construction (eg. Asphalt), new standard sizing and new requirements for the surface characteristics. The surface characteristics, namely the critical contact surface with vehicle tires, is able to deliver higher quality, speed and travel comfort without compromising the integrity of mobile vehicles and their passengers (Marwan et.al 1993).

The asphalt (bitumen) is defined as a viscous liquid or solid, consisting essentially of hydrocarbons and their derivatives, which is soluble in trichloroethylene, is essentially non-volatile and softens gradually when heated. It is black or brown in color and has insulating properties and adhesive properties. It is obtained from the refining of crude oil and is also found as a natural reserve or as a component of natural bitumen, which coexists with mineral materials (El-Basyouny & Witzcak 2005). The asphalt is generally used as a sealant or adhesive material in a wide range of applications which are subject mainly of civil engineering (road construction, building construction, insulation dams and reservoirs, varnishes production etc.) and is picked either from natural resources (natural asphalt) or as derived fractional distillation of crude oil (oil asphalt). The most widely spread is the oil bitumen mainly for economic reasons since collecting the natural asphalt is quite expensive and difficult. Its main use is in the manufacture of road surfaces, as a binder between the graded aggregate for its production (Goktepe, 2005).

Nevertheless, each new pavement from the time delivered begins inevitably be subject to a devastating influence of external factors, such as vehicles, weather conditions etc

For this reason, there is an effort of several decades for the inspection and measurement of surface characteristics with the creation of appropriate instruments and measurement systems. Traditional measurement instruments are those used in most roads, while the last decades there is an attempt of such development. The development of technology, the past three decades, enabled, initially, the academic institutions, to try to create modern methods of measuring and recording the surface characteristics or to incorporate cutting-edge technology to the existing technology (Acikgoz, and Rauf, 2010).

One consequence of the deterioration of pavements is the development of residual deformations, which according to the design principles of the pavement due to the failure-deformability of the soil. However permanent deformation can be developed due to the deformation of asphalt layers. Generally, the permanent deformation caused by the dynamic load on the road, reduced quality of the materials of the layers and the influence of climatic conditions (Dawson, and Kolisoja, 2004). It leads to the degradation on the one hand of the pavement characteristics and secondly the level of convenience to the users of the road. Therefore, in order to reduce the likelihood of occurrence, especially in the first pavement service intervals, it is necessary to investigate their behavior towards the factors affecting its structural state. As part of this investigation includes the need to provide the residual deformation

The provision of permanent deformation is necessary both during the design phase and construction and during the operation phase of a pavement. It explores the impact of factors affecting development and can provide valuable information on the behavior of road against traffic loads. This allows the better management of the road network. The systematic and timely maintenance of road surfaces is a basic tool of the management systems. Their continued monitoring and determination of two suitable response time prolong their life and restores functionality to the appropriate service levels (Loizos, 2008).

The prediction of the residual deformation can be accomplished through the statistical, empirical or engineering standards. The first require long-term monitoring of data relating to a road surface and is limited while the empirical models based on empirical functions and relations, arising from information measured or observed.

Therefore, in order to properly investigate the behavior of a pavement and to provide for the permanent deformation we should take into account the mechanical properties of materials, utilizing appropriate mechanical standards (Skok, 2008)..

In the following chapters an attempt is made to overview the characteristics of asphalt surface and traditional instruments to measure them.

## **1.1 The research questions**

The research questions of this study can be summarized as follows:

- What are the characteristics of asphalt pavements?
- What are the causes of deterioration?
- What methods of maintenance could be used?

## **1.2 The Structure of the Study**

This study, including the present, consists of four chapters. Here is a summary of the chapter structure. Chapter one is the introduction to the topic and also includes the research questions and goals of the study.

Chapter 2 contains the general information on the asphalt and its profile, as well as the main reasons for the asphalt fatigue, and the causes of deterioration.

Chapter 3 describes in detail the potential measures and methods of maintenance of asphalt. Specifically, a review is performed on the theoretical underpinnings of dynamic stiffness measures and describes methods for determining by laboratory testing and prediction algorithms in order to be able to make suggestions and the presentation of new smart methods.

Finally, Chapter 4 develops extensively the findings regarding the subject of this thesis, as well as suggestions for further investigation.

## **2. Types of pavement**

the pavement, as a construction element, is inextricably linked with the road transport systems, since essentially the supporting structure, which is responsible for the movement of vehicles. Modern technology has brought great improvement to the durability, quality and safety of road surfaces with the use of new materials and construction techniques. The basic distinction however is between flexible and rigid pavements.

Flexible pavements consist of successive layers of natural soil and crushed soil material is usually covered by the asphalt surface. The substantially rigid pavements whose main structural element a concrete slab are used as the basis and traffic surface, and as an under-base is used the natural or crushed gravel.

Often there are intermediate types mentioned as types of pavements and roadways intermediate type: ➤ The semi-rigid, ie bituminous pavements with stabilized base (aggregates and hydraulic cement) and ➤ Composite, carrying traffic on asphalt concrete slab. During the road operation phase there is a two-way relationship between the road surface and traffic flow which determines to a very large extent, the design, management, wear and maintenance of roads. The change of traffic characteristics that are growing creates the need for improvement of the geometric characteristics of roads and surface characteristics of pavements at design level and then increase spending on construction and maintenance due to increasing damage shown in use (Garba, 2002)

### **2.1 The Asphalt**

The use of asphalt as a building material dates back to 3,800 BC 3,000 BC when the surface of natural bitumen leaks was used as raw material for waterproofing masonry works in the valleys of the Euphrates and the Indus. [Peters et al, 2005). Herodotus also makes reference to the use of like the ancient Egyptians used it for waterproofing tanks and finally the Persians where they built roads with asphalt. It should be noted that the asphalt is used as the end of the 19th century was a natural product, and then followed by a turn to the petroleum asphalt.

Asphalt is the residue of the distillation of crude oil after further distillation under pressure. The preparation of the crude oil contains a number of distillation processes, and if necessary further processes including the mixing and oxidation processes. The refining of crude oil starts with atmospheric fractional distillation to separate the gas oil, kerosene, naphtha, gasoline, gas oil and residue that forms a complex fraction of higher molecular weight. The residue was then passed through a second distillation, wherein the distillation column is now prevailing temperatures 350 ° C - 400 ° C and vacuum conditions (10 - 100 mmHg). So we get different types of paving asphalt, they can be used both in roads and in airport projects. The residue of the second distillation may be further modified by blending processes or either oxidation or emulsifying the production of bitumen of different properties and cohesion (Skok, 2008).

Today the types of asphalts available commercially are divided into two major categories according to their use: 1. pavement asphalts, 2. asphalts of industrial use. The asphalt used in road construction is separated primarily by a function of degree of penetration, i.e., how much is the penetration for certain load, at 25 C and for a time of 5 seconds. Specifically, the softer bitumen has greater penetration is and respectively the hardest has less. Unit of measurement of the degree penetration is the 'pen', where 1pen = 0,1mm. Asphalts widely used in pavement are of

- 40/50 pen
- 60/70 pen
- 80/100 pen
- 120/150 pen
- 200/300 pen

Of course depending on the country and the needs other kinds of asphalts are also produced. However, each bitumen type is characterized by other functional properties such as the ductility, the flash point etc. which are taken into account upon use (Franco, et al 2009).

With reference to the chemical composition of the asphalt, it is a complex mixture of organic molecules that differ significantly in composition. These molecules are

predominantly hydrocarbons having a small percentage of heterocyclic compounds containing sulfur atoms (S), nitrogen (N), and oxygen (O). It also contains traces of metal nickel (Ni), magnesium (Mg), iron (Fe), vanadium (V) and calcium (Ca) in the form of inorganic salts and oxides (Buckley 2012).

It should be noted that the exact composition of asphalt both depends on the source of the oil and the amendment made by the fractional distillation of this, and from the upcoming "aging" of the asphalt. However, the knowledge of the molecular structure of the asphalt is important for the fundamental understanding of how the composition affects the physical properties and its chemical activity (Franco, et al 2009).. Yet throughout the complexity of the chemical composition of the asphalt, we can separate the two larger chemical groups and to obtain useful information about the physical properties that directly affect the behavior of various applications such as in road construction. These two groups are the asphaltenes and maltenes (Geiger, 2005).

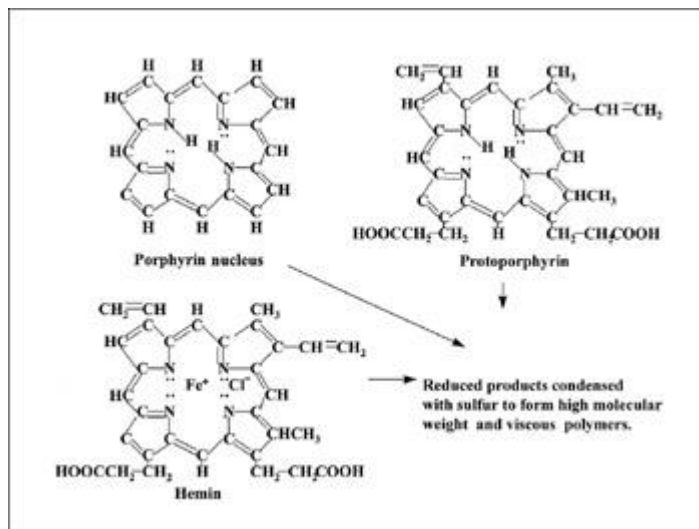


Figure 1: asphaltene origins

The maltenes can be subdivided into saturated hydrocarbons, aromatic and resins. briefly mention some influences of the change in the content of these molecular groups on the physical properties of asphalt:

- Increasing the percentage of asphaltenes reduces the degree of penetration and increase the softening point and therefore the final product has a high viscosity. Their proportion ranges from 5% to 28%.
- The resins determine the type of bitumen behavior sol or gelatin.
- These substances are the principal steps dispersant of asphaltenes and are in a ratio of 40% to 65%.
- The saturated substances affect largely with asphaltenes viscosity and temperature sensitivity of asphalt (hardness).

Of course, the asphalt can be classified as a thermoplastic material that exhibits similar behavior to that of glass, which is elastic and brittle in charge at temperatures under zero and behaves like a liquid at temperatures above 60 ° C [4]. In the intermediate temperature interval between 0 ° C and 60 ° C the bitumen exhibits both elastic properties and viscous (viscoelastic behavior). Obviously depending on the temperature and charging more prevails one of the two properties without however does not appear at all the other. This is the fundamental rheological property of the bitumen, which characterizes it and makes it a versatile binder (Geiger, 2005).

It is however very difficult to describe all the physical properties of the asphalt as influenced all the production, loading, temperature, time, etc. The two main physical properties are given emphasis for roads the hardness and viscoelastic behavior. Summarizing the characteristics of the bitumen:

- a composite material,
- exhibits viscoelastic properties,
- its "behavior" is temperature dependent,
- the properties are dependent on time or production, either charging or oxidation,
- behaves like an elastic solid at low temperatures and / or high charge rates



- behaves as a viscous fluid at high temperatures and / or low frequencies charging,
- combination of both at intermediate temperatures (Johnson, 2000).

## 2.2 Asphalt layers

The asphalt layers of a flexible pavement are the upper layers rooted in layers of loose gravel (base and sub-base). The asphalt layers are divided into: Leveling layer and wearing course (Yoder & Witczak 1975).

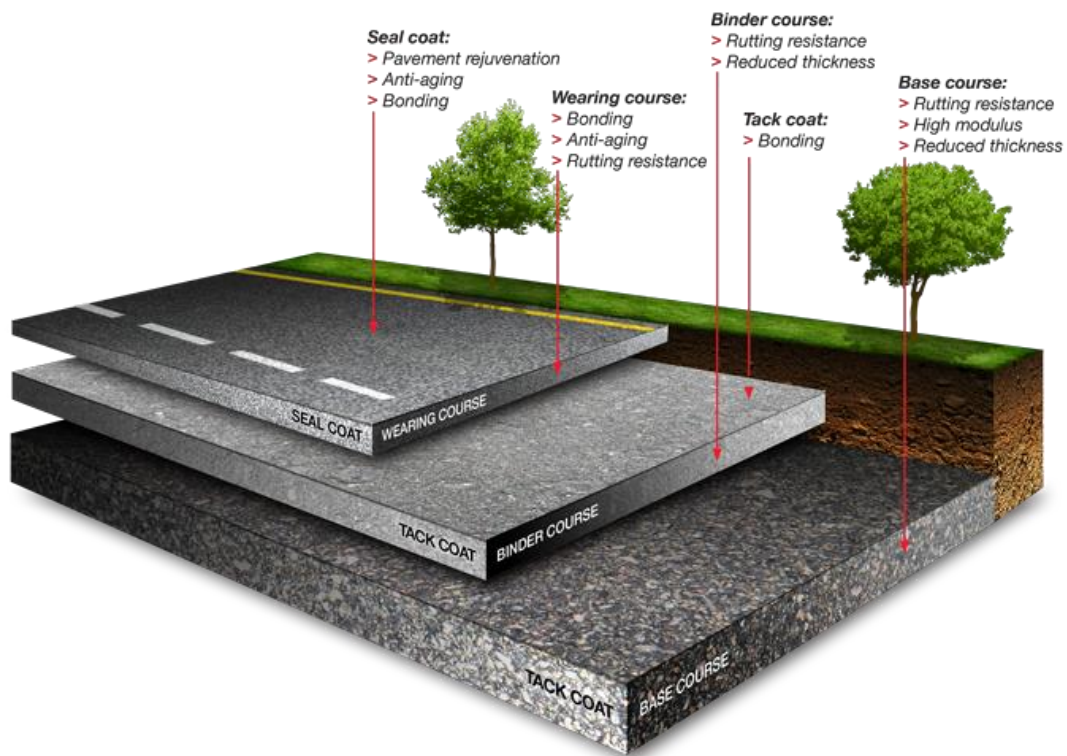


Image 1: Asphalt Layers

The leveling layer is mounted on the base layer of loose material. It provides the desired gradients while receives and distributes the traffic load on the underlying layers. Since the critical positions failure of one track is the bottom of the bituminous layers due to fatigue of the asphalt mix and the top of the bearing layer due to the vertical compressive strain, the leveling layer should have high fatigue strength, high rigidity and resist to deformation (Peshkin, 2011).

The release layer which is usually non-slip should provide comfort and safety to the road user. As it is in direct contact with the vehicle wheels should have a resistance to permanent deformation and cracking, and is characterized by high stability and water tightness. The thickness of this layer ranges from 2 to 4 cm depending on the type of the asphalt mix.

The percentage of bitumen in the asphalt mix is an important parameter both in the mix design of the mixture and in the context of the road behavior. Asphalt low rates results to the detachment of the aggregates and reduces the cohesion and high levels of lead in wheel tracking phenomena, emergence of asphalt and reduced levels of slip - resistant capacity.

The largest percentage of asphalt is composed of inert materials which make up the structural frame of asphalt giving strength and coherence. Depending on their origin aggregates categorized into crushed and collectors. The fragments used for the synthesis of asphalt because of their very good mechanical characteristics while the panels are mainly used for the subbase layer. Depending on the size of the aggregates are divided into the following categories: coarse, which are retained by the sieve No. 10, the fines which are retained by the sieve No. 200 and the filler that passes through the sieve No. 200 (Morian, 2011). The key feature of all of the mixtures is the grading curve of the mixture of aggregate which may be continuous or discontinuous i.e. are all fractions of aggregates at a rate corresponding or some aggregate fractions to be missing or be present in very small quantity. Depending on the amount of each fraction of aggregates mixtures classified as open, semi-open or closed type. Hence they have high or low levels of air gaps.

### **2.3 Asphalt Gaps**

By asphalt gaps we refer to the air sacs situated between the coated asphalt aggregates a compressed asphalt. Spaces are divided into the following categories: the gaps between the aggregate (VMA: Voids in the Mineral Aggregate), the gaps which are filled with asphalt (VFA: Voids Filled with Asphalt) and the compressed asphalt gaps that are inflated (PAV: Percentage of Air Voids). The percentage of gaps between the aggregate (VMA) is the available space between the aggregates that receives the

active volume of the contained asphalt (i.e., the total volume of the bitumen, reduced by the volume which is absorbed by the aggregates) and the volume of voids air necessary for the asphalt.

The higher the value the more VMA space between aggregates to extract the bitumen. Through the VFA is determined whether a sufficient proportion gaps filled with asphalt and indirectly determine the necessary amount of bitumen in the mix. The appropriate percentage of VFA helps prevent weakness of the mixture due to the thin coating of aggregates with asphalt (Reena et al, 2012).

The percentage of air gaps will depend largely on the concentration method of the asphalt mix during the laying and the gradation of aggregate in the mix. The final percentage of air gaps is associated with the behavior of the pavement. Low percentage of air gaps results in the wheel tracking appearance as the asphalt cannot enter and fill the aggregate, resulting in observed declines in the wheel tracks upon the enforcement of traffic loads. Higher percentages of air gaps allow air entering the asphalt causing oxidation of the bitumen and thus premature aging of the mixture by reducing the resistance to permanent deformation. The volumetric composition of asphalt and the characteristics of the materials that make up the asphalt determine the stiffness measure (Reena et al, 2012)

## **2.4 Permanent deformation**

Ensuring comfort and safety of a road user is the main concern for the design of pavements. A road constructed in order to secure the transfer of traffic loads to the subsoil and avoid damage creativity, critical for its functionality. So, proper planning, proper construction and proper management are three key components that contribute to the good operation and the prolongation of its life. Defining the factors which determine the bearing capacity of an asphalt pavement, and the study of the structural stress of requiring particular attention in order to achieve the possibility of transferring the traffic loads for which it was designed. The determination of the critical position of an asphalt pavement is the first step to assess the behavior and structural situation over the imposed loads (Reena et al, 2012).

In Greece flexible pavements are used primarily. In flexible pavements two critical locations are identified. The first corresponds to the bottom of the bituminous layers where problems arise relating to the resistance to cracking due to fatigue of the asphalt, while the second layer to the bearing surface; we have a failure - of deformability. Similarly, critical intensively sizes of these positions are the tensile stress and deformation and vertical stress and deformation.

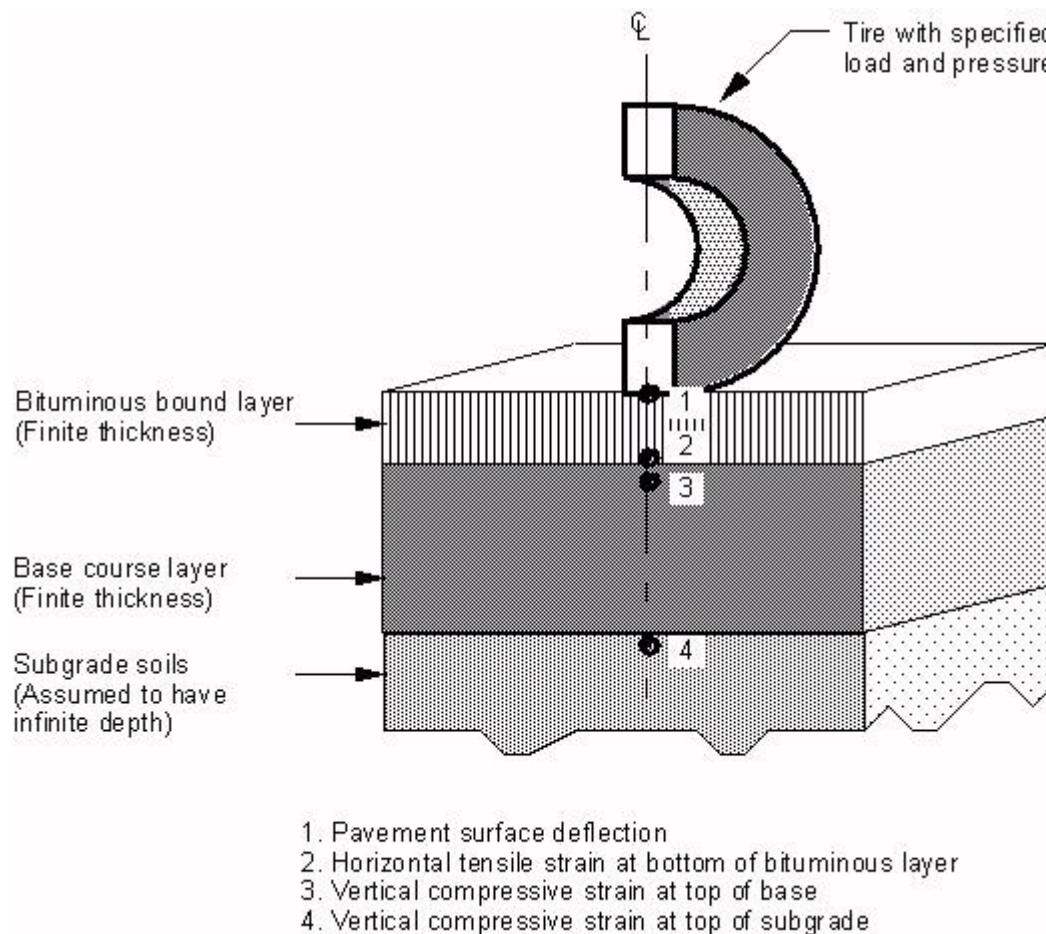


Figure 2: Critical analysis locations in a pavement structure.

The deformation of a road surface may be flexible (cracks) or residual. The development of permanent deformation is a critical condition for the road lurking dangers for road users. According to the design principles of road surfaces caused by the failure of the bearing layer and the overrun of the compressive strength. However, the development of residual deformations may be due to deformation of asphalt

layers. Accordingly, the Permanent deformation of great interest and is a fundamental chapter in the scientific area of road surfaces (Yoon et al, 2009).

In the manufacture of flexible pavements used various types of asphalt mixtures depending on the project requirements. A key ingredient is the binder, ie the bitumen oil. Therefore, the properties of asphalt affect the lifetime of a pavement. Feature size of asphalt is the viscosity, which is an expression of cohesion and decreases with increasing temperature (Yoon et al, 2009).. The viscosity with the penetration and the softening temperature affect the rheological properties and asphalt stiffness meter. In the last effect and ductility, i.e. the asphalt tensile strength, and the temperature increase which result in increased deformability (Loizos, 2008).

Gross bulk density, the percentage of air gaps, the percentage of gaps in the skeleton of the aggregates and the volumetric percentage aggregate-asphalt ratios are still some factors affecting the condition of the pavement structure (Loizos, 2008).

Additionally, the layers of a flexible pavement, i.e. the asphalt layers, the base-sub-base and the bearing layer is characterized by the elastic modulus  $E$ , the ratio Poisson  $\nu$  and  $G$  shear modulus, quantities which reflect the behavior of the materials of each layer. Furthermore, the setting of each layer thickness is particularly important for the evaluation of the pavement strength in the appearance of residual deformation (Yoon et al, 2009)..

The stresses on the asphalt pavements by traffic loads is another important factor that contributes to the development of permanent deformation. Therefore, driving conditions affect the size and rate of accumulation of residual deformation. A flexible pavement, then, is primarily dynamic stress from repeated loads of traffic. During the passage of a wheel from a point of road contact surface changed from a minimum value to a maximum and then again to a minimum. This phenomenon is due to the dynamic loading of the pavement to a maximum value, the discharging and the emergence of horizontal, vertical (compressive) and shear stress (Yoon et al, 2009).

The imposed time of the loads is proportional to the speed of the vehicle while form of the charging is approximately sinusoidal with a period of 0.1 seconds for the

surface layer and higher in the subsurface (0.4 seconds). Thus, the frequency of the load, as well as the size, variety and arrangement of the imposed loads determine the stress and the structural condition of the pavement. Furthermore, with regard to traffic loads, especially important is the pressure, the type of tire (eg studded tires damage the bituminous material) and the transverse position of the wheels. Thus the movement of vehicles causes damage to the roadway and eventually degrades its functionality (Huebner et al., 2001).

the vertical and horizontal voltages vary in a similar manner except that the charging wave of the horizontal stresses are greater at a lower intensity than the waves of the vertical stress (and usually exhibits tensile stresses at the bottom of the rigid layers). Also, the shear stress shows a reversal sign (compression-tension) to the point where the wheel passes over the spot.

Individual parameters that affect the development of residual deformation is the existing cracking, the cross section of the road (if located in embankment or tunnel), the percentage of humidity and direct sunlight. With regard to stress, due to fatigue of the asphalt layer due to repeated traffic loads, the principle of generating the observed on the bottom of the bituminous layers which have the highest tensile stresses and deformations. Examples of such cracks are longitudinal cracks, transverse cracks, alligator cracks, the cracks rectangular block type and reflective cracks in the joints. Due to the occurrence of such cracks decreases the elastic modulus of the asphalt layer and the bearing capability against the movement of loads, thereby greater stresses are transferred on the weakest areas of the base and subbase (Akikgoz and Rauf, 2010).

If the section of the route is in the trench, if the water level due to the excavation closer to the surface then the base and sub-base showing a high moisture content and decreases the extent of elasticity. Thus the existence of trenches affects the permanent deformation (Acikgoz and Rauf, 2010). Thereafter, the increased water content results in a higher permanent deformation due to excess pore pressure that lowers the stiffness of the materials. Instead, sufficient water has a positive effect on endurance and stress state of unrelated materials (Acikgoz and Rauf, 2010).

Finally, the sunlight raises the temperature of the bitumen, reducing, thus, the elastic modulus  $E$ . By extension transferred greater stresses in the layers of loose materials (Acikgoz and Rauf, 2010). This problem is particularly acute in countries with high temperatures and high rates of sunshine, as during the summer months they have large solar radiation rates.

Zhou and Scullion (2002) investigate the three possible stages of residual deformation

First stage: It is the initial stage where a permanent deformation takes place rapidly and is at the stage of pre-compression. Change in the volume of material is observed and the material is permanently deformed so as to increase the resistance to further deformation.

Second stage: At this stage the rate of permanent deformation is slow and stable, with an increase in shear deformation at the same rate.

Third stage: The last step corresponds to high levels of residual deformation, which is associated with the plastic deformation. In the third stage there is no volumetric change. At the end of the second stage a threshold voltage is observed, which increases again the rate of residual deformation. This limit is called the Plastic Limit Adjustment (Acikgoz and Rauf, 2010).

## **2.5 Forms of residual deformation**

### **2.5.1 Wheel tracking**

One form of residual deformation is the wheel tracking. The wheel tracking due to permanent deformation of some or all of the pavement layers or subsoil and is caused by the relative movement of the material due to the traffic load. This form of the residual deformation is associated with the transverse distribution (profile) of the road surface (Loizos, 2008). The wheel tracking gradually grows under the influence of repeated loadings and typically depicted in the form of deformations along the wheel tracks, accompanied by small rearrangements at the ends. Two causes that contribute to wheel tracking is the compression and shear deformation (Sousa et al., 1991). Its appearance may occur at various times during the life of a pavement.

According to a research done by the AASHO Road Test (American Association of State Highway and Transportation Officials, the shear deformation is crucial in the wheel tracking mechanism with condensation (ie reducing the volume and thus increase the density) have secondary role. Eisenmann and Chilmer (1987), illustrated the effect of the number of times the wheel passes to the surface profile of a plate of the laboratory. the specific authors came to the following conclusion

In the initial phase, the compression due to the traffic load is the primary growth mechanism of residual deformation. After the initial stage but the bulk of the compression due to the traffic conditions has been completed, further wheel tracking caused by the shear deformation. Therefore, the shear deformation is considered the main cause of wheel tracking growth in most of the life of a pavement.

Hofstra and Klomp (1972) found that the deformation of asphalt layers was greater in loading enforcement surface and gradually reduced depending on the depth. This is because the wheel tracking is a permanent deformation and thus increasing the depth increases the resistance and shear stresses are reduced. Also, Uge and van de Loo (1974) concluded that a further increase of the asphalt layer thickness beyond a limit does not entail a further increase of deformation within them. The above show that for materials having normal stiffness, the wheel tracking limited to asphalt layers (Sousa et al., 1991). Asphalt with low shear strength, essential for resistance to repetitive loads of traffic, have intense display wheel tracking problem. The problem is more acute especially during the summer months, as high temperatures are observed on the roadway (Garba, 2002).

The appearance of the wheel tracking a road helps create the phenomenon of aquaplaning wheel. This phenomenon, i.e. the accumulation of water in the grooves of the surface of a road surface thus losing the tire tread and the road surface, making it dangerous to drive.

### **2.5.2 Lack of smoothness**

The lack of smoothness along the surface of a road is another form of residual deformation. Typically, Ullidtz (1998) investigating the effect of the absence of



normality in a roadway, explaining how this is a result of fluctuations in extended length. These variations are related to the thickness of the layers, the elastic modulus, the asphalt content of the dynamic stress etc. The lack of smoothness represents an estimate of the variation of the residual deformation along the roadway (Kenis et al., 1982).

Specifically, as a lack of smoothness is defined all along the road deviations from the true flat surface, with characteristic dimensions that affect the dynamic behavior of the vehicles, the dynamic loadings of road surfaces and ride quality (Loizos, 2008). The longitudinal lack smoothness described by the undulations of the road surface. Great waves length is due primarily to the underlying layers, while small ripples length associated with the surface layer.

Any initial lack of normality, which may be due to manufacturing errors or material quality and equipment failure, usually intensifies with the passage of time. The downgrade was due to factors affecting permanent deformation, such as traffic loads and environmental conditions (Loizos, 2008). The absence of normality seriously impacts the comfort of the users of a road and vehicle maintenance costs. Moreover, greater lack of normality involves more numerous and large changes of the vertical forces, and also created lateral forces between the tire and the road surface (Loizos, 2008).

## **2.6 Measure of asphalt stiffness**

The asphalt as mentioned consists of two materials with different behavior, the asphalt with viscoelastic behavior under normal load conditions and concentrated inert elastic behavior fundamentally. The viscoelastic behavior of asphalt prevails and therefore the asphalt behaves this as viscoelastic material (Loizos and Plati 2013). Therefore, the asphalt cannot be characterized by the fundamental characteristic of the elastic material that is expressed by the modulus of elasticity (E). If the asphalt is used the term stiffening measure. The characteristic and essential that capacity depends, in contrast to the elastic modulus wherein the deformation depends only on the applied load, and the temperature (T) and the charging time (t). The stiffness of the asphalt measure is calculated by the following fundamental equation :  $S_m = (p/e)T, t$  Where

p: positive trend

e: reduced distortion

t: Charging time

T: asphalt temperature

The stiffness is a measure of the asphalt resistance to deformation in imposing load. High price of stiffness measure on asphalt layers leads to relief of the underlying base layer and subbase while there is also a phenomenon of early occurrence of cracks in the repeated loading of such asphalt. so the increase in charging time, and the temperature increase, impact negatively on measure of rigidity, resulting in a reduction of the price, often with adverse effects on the roadway, if the changes are not taken into account.

The identification of the measure stiffness of asphalt can be achieved either by appropriate laboratory tests on specimens or pavement cores, either on the spot where the existing pavement with non-destructive testing systems (NDT: Non Destructive Test methods), or through algorithms.

Laboratory determination of the measure of stiffness of an asphalt mixture may be effected by various devices such as direct tensile-compressive test (direct tension-compression test on cylindrical specimens: DTC-CY), the triaxial test, compressive test, and more. The measure of stiffness resulting from these tests differ primarily due to the different test device and the different ways of enforcing the loads. On how the imposition of loads can be pulsed (compressive load for a short time, followed by short rest period) or harmonic (sinusoidal charging where necessary compressive and tensile load without resting period). In the test configuration differences are identified in the mounting specimens to cargo exercise axes so that the imposition of charging take place either along the vertical diameter of the specimen or on the horizontal plane of the specimen. In any event, the extent of stiffness resulting from the ratio of applied voltage to the resultant distortion.

For the in situ determination of the measure stiffness bituminous existing pavements various systems of non-destructive testing have been developed (Non Destructive Testing: NDT) which are divided into two main categories depending on how they have implemented the load on the pavement and the measurement methodology of recording (Marwan et.al 1993).

In the first type belong the systems that require static load to the road surface and record the maximum standard drop, which occurs on the roadway. Measurements of concessions is point and at specific distances along the road and made using strain gauge. The size of the elastic regression is an indication of the soil's ability to bear the applied load. System of this class is the Benkelman Beam and Deflectograph device.

In the second type belong the systems imposed by force (shock) load to the road surface and record the elastic retreat, taking place in the roadway. Measurements of concessions tires are usually made at distances of 20-40 meters. A representative and widely used system in this category is the Falling Weight Deflectometer (FWD). the FWD requires dynamic load on the surface of such intensity and duration pavement with actual traffic loads. Through special measuring systems which are arranged at fixed distances from the point of application, the elastic retreats recorded immediately after the imposition of the load. Then, through an appropriate processing and data analysis, calculated measure stiffness of asphalt layer with the inverse method (back analysis) (Loizos 2013). Systems belonging to this category is also the Dynaflect and Road Rater.

## **2.7 Effects of residual deformation**

The permanent deformation of a road surface lowers the level of functionality and adversely affect their safety and comfort of a road user. The reduction of the quality and the rolling speed, increasing the operating costs of a vehicle, wear of suspension and tire, and the increase in fuel consumption are some of the consequences of the occurrence of residual deformation. Particularly, in the case of extensive damage there is a risk of the vehicle loss of control that may be fatal to the user. Another effect of the residual deformation is aquaplaning which can be dangerous for the user. In addition, the emergence and spread of permanent deformations in the pavement

bring large maintenance and repair costs for the Lord or the manager of a roadway. Finally, the creation of permanent deformation conducive to the further dynamic stresses and wear of the pavement. This reduces the life of the pavement and eventually fail. It should also be noted that the prolonged appearance of permanent deformations may help in failure due to fatigue of the pavement due to tensile deformation on the surface (Barksdale, 2011).

Hence, then, as indicated above, the prediction of residual deformation becomes imperative. The growth and diversification of the axle loads, the development of technologies that affect the way a construction asphalt and load repetitions strain on a roadway, require development of investigative methods and models predicting permanent deformations. Apart from the use of the residual deformation prediction models is essential and on-site visual inspection for a fuller assessment of a road.

Additionally, through a variety of methods of measurement of permanent deformation arises a set of information that can be used as part of a maintenance management system of road surfaces.

## **2.8 Structural strength (carrying capacity) of the pavement**

As structural strength is defined the ability of the pavement to bring loads of traffic and transfer them reduced to the ground. When the roadway is given in circulation, factors such as traffic volume and the axial extension of traffic passes, as well as the environment, reduce the carrying capacity of the pavement resulting in the appearance of damage. The traffic load cause stresses in the pavement, resulting in cracks, grooves, slides, etc. Environmental factors such as temperature changes also cause tensile stress and aging of the bituminous material, resulting in failure of cracking. As structural strength (efficiency) of a road surface is defined the remaining life expressed in either equivalent crossings, either in years, taking into account their respective future traffic volumes the design or the time of the pavement life, provided by the design (Zander 2000).

Audits of structural strength are made with special schemes of nondestructive measurements and by spot checks. The spot non-destructive measurements with

specific systems consist of impact force (static or dynamic) to the road surface and measuring the sinking, which occurred in all layers including the subsoil. The total immersion is the resultant of dips of the individual layers.

The measurement systems of structural strength of the road divided into two main categories, depending on the resistance measurement methodology, ie how to impose the load on the pavement and the measurement recording methodology.

The first category includes systems that require static load road surface and record the maximum standard immersion, which occurs on the roadway (photo 18). Measurements of dips is point and at specific distances along the road and measured means strain gauge. Representative systems of this class is the Deflectograph (France), the Dynaflect (USA) The Road Rater (USA), Deflectograph La Croix, Curviameter, the Benkelman Beam etc (Ruan et al, 2003).

In the second category belong the systems that require dynamic (shock) load to the road surface and record the sinking, occurring on the carriageway. The treatment of immersion data / retreat by skilled analysts using appropriate software makes possible the determination of other parameters such as the modulus of elasticity of the layers, possible cracks in stiff mainly roadways etc. The measurements of the depressions are at distances of 20-40 meters using geophones. Representative and widely used machine in this category is the Falling Weight Deflectometer (FWD), which was first made in Denmark (Ruan et al, 2003).

In addition to the measurements, the overall assessment of the structural condition of the pavement requires sufficient historical data and data such as layer thicknesses, materials, equivalent transits and reliable analytical models predict traffic volumes. Measurements of the structural condition of the pavement as a guide for evaluating the condition of the road and in some cases. They must be accompanied by random checks and spot investigations. In these studies, also the recording of the pavement layers' thickness throughout the length of the road is included, using a radar system (Ground Penetrated Radar, GPR picture 20), which inter alia supports the analysis of data collection with the FWD, as reduce the need for taking cores (Masad et al ,2007).

Moreover, to support the analysis process of data collection with the FWD and determining the structural strength of road surfaces, it is recommended to systematically collect traffic data to calculate equivalent axle passes. Examples include direct recording systems and analysis of equivalent passes (Weight In Motion (WIM) Systems). Measurements of the structural strength of the pavement will be made in selected parts of the highway, when deemed necessary by the management body, taking into account road conditions as resulting from the evaluation of surface characteristics of the road surface (eg smoothness, surface damage, etc.), the existence or non-available data of the pavement structure, the time of the motorway construction, available resources, etc.. In each case a roadway rehabilitation program, the structural strength measurements are a valuable tool for taking decisions for the recovery of damages or strengthening the roadway (Tashman, et al, 2004).

As for skid resistance, evenness and surface texture, in the case of the structural strength down there are also maximum permitted warning and intervention limits. The structural strength limits and measurement frequencies, after three years will be determined by a similar process, which refers to the limits and frequencies of slip resistance coefficient of smoothness index and index of the surface texture.

Ensuring a sufficient level of normalcy in the streets and roads preoccupied man already from the first pavement construction. Immediate smoothness correlation with the level of comfort onboard, was quickly understood, long before the development of vehicles. The measurement methods were originally developed was simple both in its conception and implementation. The first instruments were manually and so, they rendered the measuring process very time consuming. Progress in this area has continued with the development of other organs, some from which were deemed effective and therefore established, while others were abandoned as unreliable or uneconomic. The steady growth of traffic figures raised the issue of maintenance of road surfaces in the spotlight, while the increased road networks functionality requirements, the need for security, quality and speed requires the adoption of methods which will promote and contribute to tightening, higher quality and more efficient methods of measuring evenness of pavement.

A first general distinction of basic normality measurement methods are: i. Subjective methods of normality ii valuation. The objective methods of valuation normality

In the subjective methods is classified the valuation of normality by scoring groups (panel rating), ie has subjective nature and generally express the functionality of the road. On objective methods are all instruments used to measure the smoothness. These instruments are broken down into categories depending on how the reference level is set and how it is measured and how are the results recorded (White et al, 2002).

### **3. Restoration of pavements**

The manner, timing and extent of recovery of lesions on the pavement carriageway and the methods to be used depend on the one hand by the indicators of measuring the characteristics of the road surface and between the association, the results of surface inspection, the structural strength measurements of the pavement and on the other by traffic volumes, the climatic conditions, the available resources (manpower, equipment) and materials and especially financial resources.

The developer can choose how and when the pavement rehabilitation of the motorway or parts of it will take place with the help of Pavement Management System (PMS). As a Pavement Management System is composed of the tools or methods that assist in finding the best financial strategy for the maintenance of road surfaces, achieving an acceptable level of service for the user. A PMS operates on two levels, the "Network Layer" and "Project Level" (Robbins et al, 2011).

The management at the network level is designed to implement conservation strategies decided by management of maintenance organizations and relate to the whole motorway. So, at this level, the PMS gives information about extended service plans, rehabilitation or construction of new pavements. The aim is to optimize the return on invested capital for all the pavement of the highway(Robbins et al, 2011).. The decisions taken by management, based on the comparison of alternative strategies maintenance programs, with the ultimate aim of identifying the maintenance program, which will have the greatest benefit / cost ratio, in a certain time period analyzed. A prerequisite for the proper and efficient functioning of a PMS is being powered with all the necessary data (roads, materials, climatic conditions, work costs, traffic volumes, etc.) and development of models predicting the behavior of pavements. So the collection of road data, as provided in this Directive, an operating condition of a PMS for the rational management of the maintenance and execution of appropriate analytical models / prediction models of the evolution of damage to road surfaces (Robbins et al, 2011)..



### **3.1 Management of Pavements**

In developed countries, the construction of highways and motorways is essentially complete and the interest of road operators has passed the stage of operation and maintenance management, ie to improve the quality of roads in line with the functional criteria (comfort, safety, cost, environment) of transportation projects and to maintain a high level of functionality through the planned technical operations.

Public investment in roads is therefore for each country a national capital of great value, which should be used and maintained to a high degree of efficiency for the longest possible time, which is mainly achieved by upgrading and maintenance. The road maintenance done by services that are responsible for different geographical areas. Moreover, in the same geographic area and according to the type of roads, the jurisdiction belongs to different services (Witczak et al, 2002).

Decisions are made with little or no cooperation between services based on subjective criteria taking into account local characteristics. Furthermore, the resources allocated are adequate only for a small percentage of the actual needs and available services based on simple rules (eg road network rate) without a systematic analysis of the actual needs. Thus, it is obvious that neither the pavements are adequately maintained nor the resources are efficiently allocated. The existence of limited resources for maintenance of the transport network infrastructure require optimal and cost-effective management of available resources. The decisions relating to the maintenance of the road network is the product of compensation of the maintenance costs, the cost affects the users because of the situation in which it is located and the environmental cost (Witczak et al, 2002).

The engineers at companies, agencies, state agencies often lack the necessary training and experience as well as the time required Basic concepts in pavement management data 12 to take the best decisions for the maintenance of road surfaces. However, they are responsible for the 75% of national highways. The Pavement Management tries to solve the above problem addressed in road operators who want to have full details of the situation of the pavement of the road network to be able to intervene directly and at reduced cost to maintain in good condition.

The Pavement Management is a process that helps in making decisions concerning the maintenance of the road network at an adequate level of service, functionality and security with the least cost to the technical services and for users. To satisfy these requirements are necessary correct and sufficient information to take the decisions on the principles of engineering and management. The problem of Pavement Management lies in the large number and variety of parameters and the difficulty of establishing correlations between them. (Witczak et al, 2002).

Generally, the Pavement Management consists of three elements: pavement life cycle: includes information on the construction of pavements, the change in their status over time and how these processes can be affected by various forms of maintenance or reconstruction. Costs related to the pavement life cycle: it includes the cost of initial construction, maintenance costs, determining the remaining final value and to determine the cost of users. Management systems Pavements: include all systems for determining the timing for road maintenance at a satisfactory level of service at minimum cost. (Loizos, 2008).

### **3.2 Management systems of Pavements**

The road network is one of the major factors contributing to the economic, social and cultural development of each country. In recent years, the number of vehicles that run on it, and the user requirements for an adequate level of network functionality are increasing. It is therefore an urgent need for the systematic and effective road maintenance. Bearing in mind also that the funds available from public funds for road maintenance are usually smallest of needs, these resources must be used in the most efficient manner. In this direction they are designed and implemented in many countries systems for optimal management of resource maintenance of the road network to ensure safety, comfort and economy travel with the lowest possible maintenance costs (Karlaftis and Golias 2002),

The major benefits that can arise from the use of pavement management system are: Knowledge of the current state of road surfaces by creating data analytical base with information such as road conditions, the traffic volumes, manufacturing data and records of maintenance and rehabilitation interventions which have preceded.

Coordinated planning interventions and new asphaltting, through specific intervention programs based on specific maintenance budgets and because of the continuous monitoring and recording of maintenance and recovery on all roads (Karlaftis and Golias 2002). The economic and rational management of resources by allowing modeling of predicting the future state of pavements and presentation of alternative maintenance strategies, depending on the funds available and those required to improve their situation. Reducing the material and social costs resulting from traffic accidents, due to the improvement of the situation of road surfaces, which entails raising the level of safety on the roads. A Pavement Management System handles the procedures for finding a solution that will satisfy the user requirements, but is not able to take final decisions. However, it can provide the basis for understanding the potential consequences of alternative decisions (Karlaftis and Golias 2002).

### **3.2.1 Structure of Pavement Management Systems**

The Pavement Management Systems were developed in the last three decades and are used mainly for strategic planning of maintenance of the road network to make optimum use of available resources by achieving safety, comfort and economy for network users. The Pavement Management includes two decision levels, the macroscopic strategic planning at the network level and scheduling maintenance activities and rehabilitation at the project level. At a network level pavement management system provides general inference information over the network and addresses the following: The size of the network, the current road conditions, the extent of damage and the history of wear and tampering. The current assets of the pavement as travel times and traffic accidents (Ochieng et al, 2010). The annual budgeted maintenance costs and available resources. The regular decisions and optimal resource allocation to maintenance works. The quality of road infrastructure strategy: control and intervention levels. Identify parts with similar features. Defining the characteristics of road surfaces to be measured, the measurement methods, the required equipment and the prescribed measuring frequency. Forecasts for future needs and costs of interventions (Ochieng et al, 2010).

### 3.2.2 Pavement Condition Index, PCI

The Pavement Condition Index enables the assessment of the condition of the roadway based on damage observed on the surface and has been endorsed by the ASTM standards for evaluating the condition of pavements airports. It provides a subjective basis for determining maintenance needs and priorities assessment. The indicator does not measure the structural failure of the pavement or provide immediate assessment of flatness or slip. The index takes into account 16 species damages for flexible pavements and its value ranges from 0 (unacceptable situation) to 100 (excellent condition). Extracting Road Conditions Index is a specific mathematical algorithm based on the percentage of the area and the level of severity of any damage and weighting factors for each type and wear severity level (Mokwa, and Peebles, 2005).

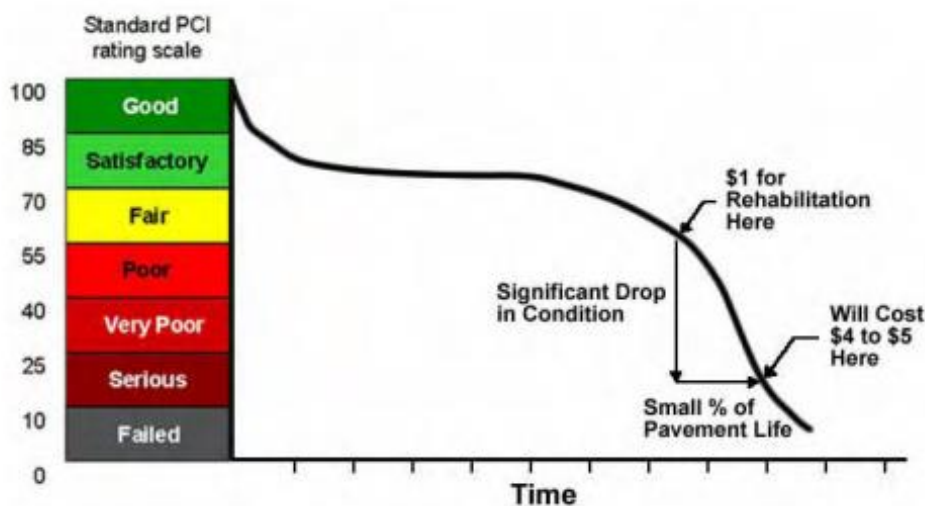


Figure 3: pavement condition curve based on index PCI

Roughness Index for Driving Expenditure, RIDE aims to link the vehicle operating costs by state of the road in terms of flatness. The index measures the vertical acceleration of the vehicle due to road surface irregularities on the basis of analysis of frequency of road profile. The index can be measured using a suitable accelerometer mounted in a moving vehicle. The index is measured in  $\text{mm} / \text{sec}^2$  and takes values between 150 (approximately) on roads without incident and 1500 (approximately) on roads with significant abnormalities.

Riding Comfort Index, RCI also known Present Performance Rating, derived from the rating of driving quality made empirically by an expert group for roadways various situations with export condition scores average. It was developed in the late 50s and early 60s in Canada. The RCI indicator proposed in order to describe the overall condition of the road surface, but goes to a measure of the flatness of the road surface (Trzebiatowski, 2005).

### **3.2.3 Pavement Condition Rating, PCR**

The method is based on recording and scoring of all damages that occur to the road. The rating of all wear takes values from 0 (no damage) to a maximum value of 5 or 10 (corresponding to a portion with high wear). The algebraic sum of scoring all damage dealt, represents the state of the road surface and ranges from 0 (perfect condition without damage) to 100 (significant damage). The PCR index is calculated by subtracting the value of the algebraic sum of the value of 100 (Toivonen 2007),

Present Serviceability Index, PSI connects the functional state of the road driving quality. This is the result of the experience obtained in the context of road experiment AASHO and based on objective measurements of certain physical parameters of the road surface as the variation of camber, the cracks (percentage cracked surface), the tread depth and the surface area ratio with local repairs. The index takes values from 0 (unacceptable driving quality) to 5 (excellent ride quality). In the US, the PSI value for new roadways must have a value between 4.2 to 4.7, depending on the quality. The index value gradually decreases with time. (Toivonen 2007), The value of 2.5 is usually considered as a warning level for rehabilitation of pavement. When the index value is less than 2.0, the road surface is considered in poor condition and requires immediate restoration. (Toivonen 2007),

PSI indicator may be calculated for flexible pavements by the equation [28]:  $PSI = 5,03 - \log(1 + SV) - 1,38 RD^2 - 0,01(C + P) 0,5$  where SV is the average fluctuation value camber to both the wheel tracks, RD is the average groove depth (a in) measured in both the wheel tracks with 4 ft long rod, C is the percentage of cracked surface (along cracks in ft / 1000 ft<sup>2</sup>) and P is the percentage of the patches (ft<sup>2</sup> / 1000 ft<sup>2</sup>). The flatness is expressed by the average slope value (SV), contributes very

substantially to the PSI value (approximately 95%), while only 5% related to the influence of other factors such as the surface damage. Very patient, for example, the contribution of the grooves as a result of association of this functionality index situ observations on roads.

### 3.3 Interventions for pavement maintenance

The restoration of damage to road surfaces can be done with various maintenance techniques. Technical maintenance is an activity that takes place on the road surface to restore a better state. The technique selected each time depends on the type, extent and severity of damage, but also from the expertise, the available materials, etc. Some wear, maintenance techniques are unique, while other alternatives are followed where appropriate. Each maintenance action is a set of maintenance techniques that each of them is best applied to a specific type of wear (Toivonen 2007),. Simply put, any deterioration of the pavement are the corresponding maintenance interventions that will improve the situation. Also, to determine the most suitable maintenance-treatment of damage is better defined precisely the main cause of the deterioration. Table 1 shows the main maintenance operations implemented in recent years.

Code	MAINTENANCE OPERATIONS
1	No interference.
2	Local spreading hot or cold mix, preceded by adhesive
3	Local consolidation without squaring and laying of hot or cold asphalt mix preceded by adhesive
4	Local consolidation with squaring and spreading hot or cold asphalt mix, preceded by adhesive.
5	Local consolidation without squaring and laying of hot or cold asphalt mix, preceded by adhesive and then Leveling layer of 4-5 cm.
6	Local consolidation with squaring and spreading hot or cold asphalt mix, preceded by adhesive and then Leveling layer 4-5 cm
7	Local spreading of hot or cold mix, preceded by adhesive and then Leveling layer 4-5 cm.
8	Local consolidation with squaring and spreading hot or cold mix,

	preceded by adhesive and then Leveling layer 4-5 cm and then non-slip mat.
9	Milling in layers and leveling screed carpeting 4-5 cm
10	Milling in layers and leveling screed carpeting 4-5 cm and then construction non-slip mat.

### **3.4 Interventions for pavement maintenance**

The following paragraphs include interventions for pavement maintenance, depending on the type of problem.

#### **3.4.1 Interventions for cracks maintenance**

The types of surface crack of the pavement and vary due to various causes. In many cases simple early filling of the crack or cracks are more correct and efficient maintenance. In other cases, it is necessary local reorganization of the area affected. The sealing / filling of cracks in all cases is a thick material that is specific modified asphalt. The modified bitumen (elastomeric) should fulfill the requirements of specification ASTM 1190 or BS 2499. For the implementation of the modified asphalt to seal cracks requires the use of special hardware, such as (a) heating the elastomer asphalt machine capable of heating up and 200 ° C and capable of supplying the hot asphalt material over the crack and (b) a burner (propane) which ejects superheated air (not flame) for heating and fixing the crack before the diffusion of the modified asphalt (Toivonen 2007).

For alligator type cracks when they appear in a small area, the full removal of all bituminous layers is suggested, and layers with unbound inert and part of the foundation soil; these are the appropriate measures for reducing the level of the aquifer and the reconstruction of all the layers' new suitable materials. When the extent of alligator type crack is large, treatment is only restoring the carpet, ie an additional bituminous layer similar state of the road thick. If the fractured carpet cannot be removed, leveling the layer screed is recommended, before laying the new

carpet. The same maintenance procedure should be followed for reflection cracks, apply to cracks between paving lanes or widening in shrinkage cracks and helical cracks (Wang et al, 2008).

For cracks in the pavement ends, the filling of the cracks with suitable modified asphalt after careful cleaning is recommended. If precipitation occurs, then the filling is made with cold or hot asphalt. Cold Slurry-rating formula III or IV, cast when the precipitation is less than 25 mm, otherwise used hot asphalt. On reflection cracks with opening less than 3 mm and a small area the maintenance is done by sealing / filling with modified asphalt. (Wang et al, 2008). When the opening is smaller than 3 mm, to a large extent, the maintenance becomes simple with asphalt coating. When the opening is larger than 3-5 mm and the size is small, cracks are opened with a special cutter to a depth of about 10-15 mm, are cleaned with compressed air, are dried and heated to a specific burner superheated air (Wang et al, 2008)..

Sufficient compaction with vibratory or roller is required. Longitudinal cracks when due solely to seasonal reduction of the bearing capacity of the subsoil, the maintenance is done as in the cracks of reflection while setting the level of the water table (drainage works). In all other cases the roadway needs strengthening, which is achieved by laying a new asphalt layer. For transverse cracks the same maintenance procedure with longitudinal cracks should be followed. (Wang et al, 2008).

### **3.4.2 Interventions for deformations maintenance**

Deformations or distortions of the road surface are, in general, those deteriorations that characterize the pavement as non-planar. Generally, the maintenance of deformations may consist of simply filling them with hot or cold asphalt mix to the complete removal of the affected area and replacing it with new material. Rutting wheel tracks, the maintenance is done by filling the groove with a suitable hot or cold asphalt Slurry-rating formula II or III, after being sprayed adhesive coating with a cationic emulsion in an amount of 0.25 up 0,5 lt / m<sup>2</sup>. If the deformation of the asphalt mix is high, certainly requires the removal of the particular asphalt layer and then the re-laying thereof with another suitable asphalt.



The removal of the strip is made by milling to a depth 40-50 mm, or depending on the thickness of the mat to be dismantled. Before laying required adhesive coating with cationic emulsion in amounts of about 0,25-0,35 lt / m<sup>2</sup>. For widthwise grooves requires milling of the surface to a depth of 20-50 mm or analog of the layer thickness and the new carpet laying by hot asphalt mix, after having sprayed adhesive coating with a cationic emulsion. If the maintenance decides to proceed only with milling, then the surface must be sealed with sealant carpet of type rating Slurry- III or simple bitumen coating. When the road surface is composed of a single layer of asphalt 40-50 mm thickness and the basis of loose aggregates (3a) the maintenance can be done by breaking the carpet with a special machine, the scraping thereof and part of the base, the addition of a small amount of bitumen emulsion and finally forming and rolling the mixture (fragments, aggregates base and binder) (Witczak, 2004).

In local subsidence maintenance takes place either by the hot asphalt laying or laying cold carpet of Slurry formula depending on the depth of immersion. When the depth of the settling is greater than 25 mm is maintained with a suitable hot asphalt after sprayed adhesive coating with a cationic emulsion in an amount of 0.25 up 0,5 lt / m<sup>2</sup>. The asphalt is laid and suitably concentrated, so as not to create contoured to the old surface (Witczak, 2004).. When the maximum immersion depth of less than 20-30 mm, local precipitation filled with cold asphalt sealer formula Slurry-grade III in one, two or three layers as the area previously cleaned and sprayed with adhesive. In other cases, the hot asphalt is used which suitably cast so as not to create tooth.

Finally, a sufficient concentration to steamroller 6-8 ton. For local bulges maintenance shall be the same as the maintenance of alligator type cracks for local performances (Witczak, 2004)..

### **3.4.3 Interventions of weathering maintenance**

Repairing damage detachment aggregates is done by laying the cold asphalt mix type Slurry seal-grade II or III or with surface coats. When road conditions are very bad and examined the case of additional asphalt layer. For potholes maintenance can be temporary or permanent. When temporary becomes simple cleaning puddle and filled with suitable hot or cold asphalt or ready packaged cold asphalt. When maintenance is

definitively cutting and squaring puddle so as to have a healthy lateral layer material, thorough cleaning, spraying the walls and the surface with a cationic emulsion, filling it with a suitable hot or cold asphalt and finally appropriate calendaring (Witczak, 2004)..

#### **3.4.4 Interventions tread grinding maintenance**

Local asphalt emergence usually restored by dispersion and fine aggregate hot rolling, or hot air jets. If dispersion hot aggregates are recommended to work the hottest days of the year. When the emergence of asphalt is to a great extent and especially when it is severe, it is recommended to be dismantled across the layer and restored with new asphalt. When the road surface presents grinding aggregate maintenance and restoration of Slip resistant capacity of this is done with the following methods:

- Laying of a new carpet suitable hot asphalt with hard aggregates.
- Laying porous mat.
- Method of Pre-anointed chip.
- Construction of cold Slip-minute Slurry type carpet.
- Chipseal (single or dual layer).
- Construction of hot carpet.
- Scraping the surface with a special cutter.

In all the above methods except the last, necessary prerequisite is the use of suitable hard aggregates, not limestone. (Witczak, 2004).

#### **3.5 Application of stabilization with foamed bitumen**

For many years the cement has been used for modification and stabilization of road surfaces. It has been recently carried out an extensive research and several successful test to investigate the role of lime in the subsoil stabilization with very high plasticity. Hundreds of kilometers of roadways have been stabilized using mixtures of lime / fly ash in conjunction with this research. Recently, there have been some problems of cracking in pavements stabilized using combinations of cement / lime and fly ash (Yoo, et al, 2006)..

It is believed that this is due to the cracking sensitivity of cement-linked pavement by overcharging of vehicles where there is a poor substrate support. The test facility accelerated load indicate that a power relation holds in the twelfth to wear a stiff connected roadways because of overload while for flexible pavements applies a force relative to the fourth. For example, 20% overload represents nine times almost wear on rigid pavements, compared to just over twice the wear on granular pavement (i.e.  $1.24 = 2.1$  for flexible pavements granular compared to  $1212 = 8.9$  for rigid pavements). (Yoo, et al, 2006).

The quantification of fatigue relationship for roadways stabilized with foamed bitumen is useful for predicting the length of the pavement design life. At this time, it is believed that the bituminous binder facilitates an increased resistance to fatigue. the TTD currently conducting a survey using bending beams to extract quantitative relationships fatigue (Yoo, et al, 2006)... On the side of the fatigue properties of the stabilized pavement low substrate support, - the stabilizing bitumen has been investigated in order to utilize the flexibility of the asphalt properties.

This cold treated material produced with foamed bitumen (without cement addition) can be stored for very long periods. The storage properties depend on the water content. If the water content in the cold treated material kept near the optimal value through appropriate measures, such as protection from the sun and wind, can be stored more or less indefinitely. The minor moisture losses can be replenished by adding a corresponding amount of water and homogenizing the cold treated material once, for example at a mixing facility (Yoo, et al, 2006)...

Material treated with foamed bitumen can, for a prolonged period, also be placed under adverse weather conditions. The asphalt is not washed out of the inert. A particular advantage of the road rehabilitation work areas is the fact that the cold treated material can be attributed to the movement immediately after the condensation. The obstacles to the movement caused by the execution of field work can thus be kept to an absolute minimum. The fact that the foamed bitumen may be produced by conventional asphalt grade penetration by adding only small amounts of water, resulting in economic benefits because of the reduced cost for use as a binding

agent and with respect to the transmission facilities. Ecological aspects also speak for the application of foamed bitumen in road construction technology

### **3.6 MODERN TECHNIQUES**

Below we will refer to some of the modern techniques of construction and pavement maintenance products and the respective companies that produce them.

#### **3.6.1 Ratchet**

The **Ratchet** method was invented in America and allows it to repair roads in inconceivably short time and under any weather conditions as far as the citizens' demands have increased, not sufficient to fully build a technical project and the quick recovery of the road and the performance in circulation. For 15 years, the maintenance of roads in America was using the **Ratchet**, a method which meets the most stringent in the world, American quality and durability standards. Modern technology combined with high-quality materials enables to heal bumps, irregularities and problems to disappear asphalt pavements and to protect roads from alligator cracks which otherwise would evolve into new potholes (FHWA, 2004)

#### **3.6.2 ROAD TECH**

A breakthrough is the ROAD TECH technology. ROAD TECH 2000 is a stabilizing product based on a microbe "non-pathogenic to plants and animals." This makes the technology ROAD TECH 2000 environmentally friendly both in the design and implementation. Designed for use in all types of clay, guarantees excellent road stabilization and dust suppression, requires no specialized equipment and can reduce the cost and secondary road construction and maintenance of the existing road. It offers not only higher stability and low maintenance, but can substantially reduce erosion. Unlike other products, technology ROAD TECH 2000 has reduced the total cost of living increase on-site road bearing strength, and can be customized to specific programs or directly applied to all varieties of stabilization or dust suppression applications (Elliot, et al, 2012).

Technology ROAD TECH 2000 is a unique blend of natural microbes that exploits clay granules, producing a polymer that replaces water between the clay granules, significantly reducing the ability of the clay to reabsorb moisture. The ROAD TECH 2000 technology has been proven in years of use that the maintenance costs are reduced dramatically. One of the important benefits of ROAD TECH 2000 was the increase in road life (Elliot, et al, 2012)

### 3.6.3 Gilsonite

The gilsonite a natural hydrocarbon modifying the asphalt so that one part does not "soften" the asphalt, and is deformed at the high temperatures of the environment and to increase the resistance to low temperatures (maintaining its elasticity).



Image 2: Type of Gilsonite

General Characteristics of Gilsonite.

- ✓ Natural hydrocarbon.
- ✓ Fine solid .
- ✓ Not carcinogenic.
- ✓ Fully compatible with the asphalt. High asphalt content.
- ✓ High nitrogen content (3%).
- ✓ Essentially no sulfur (0.3%).
- ✓ 99% pure in its natural state (Woods et al, 2012)

Nontoxic Key Advantages of Gilsonite asphalt.

- ✓ Radical increase in strength of the asphalt and thus the apron.
- ✓ Substantial reduction of wear and destruction of the apron.

- ✓ Reducing the temperature effects of the environment on the tarmac without distortion.
- ✓ Fold increase in resistance to water corrosion.
- ✓ Significant increase in heavy traffic resistance capacity (softening asphalt) without distortion (Masooleh et al, 2010).

### **3.6.4 STREET PRINT**

The Street Print is a solid paving solution that combines the cement strength with elasticity of asphalt through technology and a variety of colors. The Street Print delivers the most robust and elegant solution to the existing market with better final results and low maintenance costs. The Street Print Standard Formula is a unique, fully colored, acrylic polymer product cemented data coating which specifically constructed for use on asphalt has been engraved. It has excellent adhesion characteristics, resilience and resistance to scratching, as well as color stability, and resistance to chemicals and abrasion. The combination of features that are required to meet the Street Print applications are very demanding and Street Rint Standard Formula is manufactured in such a way as to meet these requirements.



Image 3: Image of street print

### **3.6.5 Trends for smart monitoring of pavements**

Modern roadways must be monitored continuously so as to prevent failures allowed in the underlying asphalt layers and chiefly in the layer bearing and thus on geotechnical infrastructure. Any failures should be limited as much as possible to the inelastic layer traffic.

As part of ensuring the performativity of road surfaces in depth the operation time, the problem is twofold. First there must be a credible process of assessing the status of a road and on the other, should this evaluation be linked to the behavior of the pavement, in depth uptime. Regarding the first part of the problem, the definition of an informed process required for monitoring and evaluation of the road surface characteristics, in order both to improve the original design, and the management of maintenance. Regarding the second part of the problem, evaluation of pavement behavior is by assessing the progress of individual characteristics, over time. In this case, the key element is the possibility to predict the evolution of the pavement characteristics to prevent, through the implementation of required actions or actions that are required to address foreseeable failures of a pavement. Thus, it is possible to realize an optimal pavement protection strategy in each stage of operation, which leads to the preservation of the performativity [Loizos, 2008].

Monitoring and recording of the above characteristics is carried out with high-tech non-destructive testing systems (Non Destructive Testing: NDT), including geophysical systems. The use of non-destructive testing allows the rapid and reliable data collection plurality without damaging the road surface. Also, due to the high speed at which usually move, it is not necessary to exclude the road and thus not causing nuisance traffic.

Through visual inspection surface road surface wear are identified, which are taken into account in assessing the carrying capacity of the road for the completion of construction of the evaluation. The damage may be due to reduced strength of the pavement and thus have a structural nature, but may not be related to the carrying capacity and therefore be operational. The evaluation of the results of visual inspection will be carried out with particular attention, whereas the visual inspection

is a supportive tool in the status evaluation of pavement and in any case cannot replace or set aside the control and recording with high systems technology. This is because the visual inspection only provides information on the surface state of the road surface. Therefore, on the one hand through it cannot be detected faults may be present in the underlying layers and secondly when the failures evolve to the higher layers (eg bottom up cracking) and show on the road surface, wear it is already at an advanced stage.

Micro-Electromechanical Systems (MEMS) are a recent solution which aims to offer real time, and continuous monitoring of pavement systems. The MEMS consist of micro-sensors, which are made with the use of micro-fabrication techniques (MEMSnet, 2014). These sensors can detect the changes on the surface and overall environment of the pavement ( Phares et al., 2005).

Another smart type is the wireless system, which is structured using three common topologies for civil infrastructures: star, peer-to-peer, and multi-tier (Lynch and Loh, 2006). This type of system is designed to communicate with a designated server.

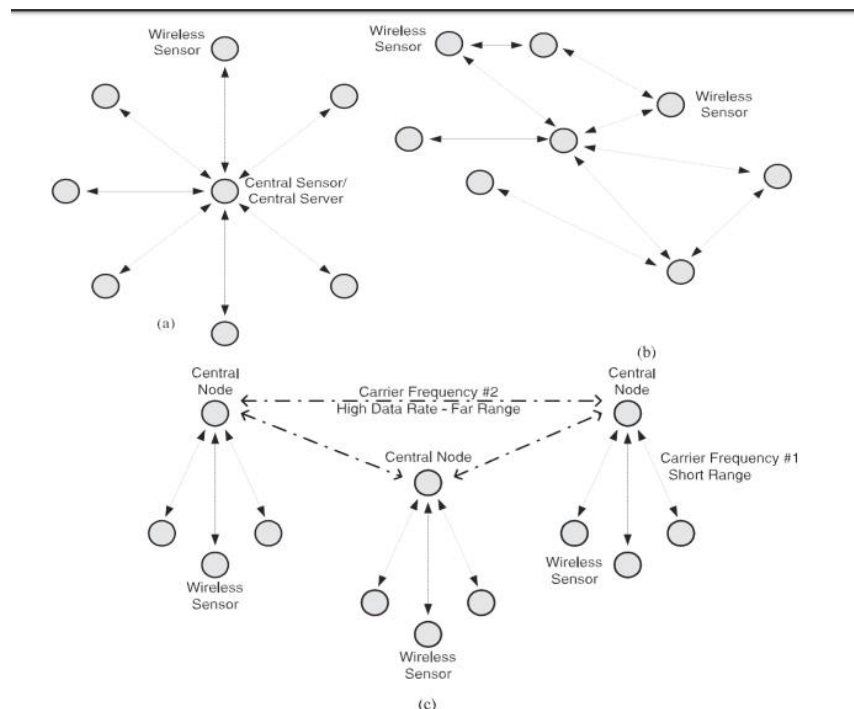


Image 4: Wireless network topologies: (a) star; (b) peer-to-peer; (c) multi-tier network topologies (Lynch and Loh, 2006).



In addition, there are the Radio Frequency Identification system, which makes use of radio waves in order to identify objects, and write the available data to the tag (Ruan, et al., 2011). The Radio Frequency Identification system consists of both a reader and a tag, and can be divided into active and passive sensor systems.

One of the most popular methods used today is the high speed profilometer Laser Profiler (LP), which can yield an estimate of the transverse deformation (Loizos, 2008.) It is one of the most technologically advanced and widely used systems. The LP record the characteristics of the distributions of the road surface at high speeds. For recording, an accelerometer and one or more sensors (laser) are used, which measure the vertical distance traveled. The high speed profilometer has as a basic unit a beam in which electronic sensors incorporated. The beam is adjusted at the back of suitably shaped vehicle (Loizos et al, 2005).

The LP counts and records during vehicle movement the following parameters:

- The vertical displacement of the beam from the road surface.
- The vertical acceleration of the beam.
- The time and distance recorded the two aforementioned parameters (via the speedometer)

## 4. Conclusions

The transportation projects and particularly road infrastructure is very essential to the proper functioning of a society. The road maintenance is important both to ensure the safe and unimpeded traffic and the other for efficient traffic management and provide the necessary services to users. For this reason, the roads and especially roadways should be in good condition to allow proper operation of the road network. The pavement management through complex decision-making processes undertakes to maintain the desired state of the roadway with better resource allocation. The pavement management systems are tools used in pavement management. In recent years the pavement management systems use artificial intelligence technologies for finding the optimal solution for road management. This is because classical optimization methods seem inefficient to complex problems.

The limitation and the proper handling of potential problems caused by the development and dissemination of residual deformations makes it imperative provision of permanent deformation. This need led to the development of mechanical prediction models, in which however the international literature responding is limited. This is due mainly because there are different views on the mechanics and thus the development of standards must be based on internationally accepted endorsements.

To enrich the provision and further exploration of the permanent deformation is proposed the calibration of the parameters based on laboratory tests on samples of materials in situ. Additionally, the expansion of provision can be accomplished including increasing the number of experimental pavements, diversification of the section and pavement materials, increasing the time of prediction, etc. Thus, pending the development of complex and advanced models for predicting residual deformations can perform an adequate assessment of their development.

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