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Application of White-topping Technology in a Section of the Road: South Circuit - Topes De Collantes

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Abstract: The objective of this work is to transmit the experience acquired during the rehabilitation of the road: South Circuit - Topes de Collantes, from 9.0 to 10.5 km, in the province of Sancti Spíritus, through the use of white topping. This rural road is located in a mountainous terrain, there are large slopes and steep slopes, presenting in some sections the need for reconstruction using technologies that extend the useful life and decrease the total construction and conservation costs. The work consisted of the construction of a concrete slab made with Portland Cement P-35 on the existing deteriorated asphalt pavement. It was designed considering the elastic modulus of the old pavement and ensuring a strong bond between the two layers, to minimize the thickness of the slab, in this case executed in "alternate cloths". The application of white-topping technology has allowed extending the life of the pavement, improving the safety of road traffic and the total costs of these tasks, as it has been seen during the commissioning of the section of rehabilitated road.

Key words: conservation; paving technology; white topping

1. Introduction

In recent years, Cuba has experienced a significant increase in the average annual number of automobiles, creating a need not only for the construction of new roads but also for their maintenance: maintenance, repair, reconstruction, and rehabilitation. Pavements are prone to damage caused by repeated vehicular traffic loads, as well as the effects of weathering, particularly temperature, rainfall, and other environmental factors.

Paved road surfaces, whether constructed with flexible or rigid pavements, must withstand the axle loads of moving vehicles without causing stresses and deformations in the paved road surface and underlying layers. These loads are repetitive in nature and, over an extended period, cause fatigue damage to the pavement structure. Climate changes cause temperature variations throughout the depth of the pavement, as well as the induction of internal stresses.

White-topping (WT) technology is a relatively new development. It consists of the application of a hydraulic concrete slab made with Portland cement P-35, generally ranging from 50 mm (thin WT and ultra-thin WT) to 200-250 mm thick, superimposed on top of the existing asphalt pavement.

Experience with its use shows that the life cycle or useful life is much shorter for surface layers made with hot asphalt concrete, since the level of service (structural deterioration and roughness) decreases rapidly. However, by using the white-topping alternative, a good level of service can be maintained for a much longer period, which leads to reduced total costs (construction + maintenance) by extending the inter-repair cycles by up to two or three times as long.

2. Development

In Cuba, the rehabilitation of flexible pavements is usually carried out by resurfacing the surface layer of the existing flexible pavements, mainly on the national highway network. Quality issues arise, shortening the useful life of these works and unjustifiably increasing costs.

Among the various asphalt pavement rehabilitation technologies, there is one known as "white topping", whose classification depends on the thickness of the hydraulic concrete layer of the slab, in addition to whether or not it assumes adhesion between the two layers (See Table 1). Initially, it had an original classification: conventional and ultra-thin, depending on whether or not it exceeded 10 cm in thickness. This classification was later expanded to include an intermediate term, incorporating the term "thin white topping".

Table 1. White-topping classification according to concrete thickness and adhesion

White topping	Concrete thickness	Observations
Conventional (CW)	≥ 20 cm	No adhesion to asphalt layer is assumed
Thin (TWT)	Between 10 and 20 cm	Adhesion may or may not be assumed
Ultra-Thin (UTW)	Between 5 and 10 cm	Adhesion to the asphalt layer is assumed

Note: CW: Conventional White Topping; TWT: Thin White Topping; UTH: Ultra-Thin White Topping

White topping involves placing a hydraulic concrete overlay or slab on top of existing pavement, thereby increasing the structure's useful life. It is a technology that has been developed and used in several developed countries and allows for the rapid and low-cost restoration of road serviceability.

This technology uses existing road surfaces as a foundation, thereby utilizing the strength of standard concrete. This is known as Conventional White Topping (WC). When high-strength concrete reinforced with steel mesh is used, it is called Ultra-Thin White Topping (UTW), and its thickness is much thinner than the previous method.

Its use does not require excavation or other earthworks. Generally, the surface layer of the asphalt pavement is patched and cleaned, then milled if necessary, and finally, the concrete slab designed over it is constructed.

For road rehabilitation using the white-topping technique to be viable, it must meet certain conditions:

- The deterioration of the existing asphalt layer must be superficial, meaning that it must not have an obvious impact on the rest of its structure.
- The thickness of the existing asphalt after milling must be greater than 7.5 cm.

Advantages of white-topping technology:

- It can be applied to asphalt pavements with any level of surface deterioration, from those requiring minimal repairs such as patching, to those requiring complete removal of the surface course prior to the construction of the concrete slab.
- Hydraulic concrete provides a stronger and more durable surface that will not rut or bulge under heavy loads and will maintain a high level of friction between the vehicle and the pavement, preventing dangerous slippage that can cause accidents.
- It improves drainage by eliminating defects in flexible pavements that tend to accumulate water and cause dangerous "backspray", producing a safer surface for road traffic.

- Its total cost is lower than rehabilitation with asphalt concrete, considering the full life cycle (construction plus maintenance), although the initial investment is higher.
- The pavement's useful life is increased by 15 to 20 years, with virtually no maintenance costs.
- Pavement visibility is increased in adverse conditions, even leading to a reduction in nighttime lighting costs.
- Concrete slabs are better able to withstand typical design traffic loads, with wide safety margins, should they increase.
- The rigidity of these pavements and their resistance to fuels and lubricants make them especially reliable for maintaining a road surface in proper condition throughout the road's operational life.
- It is an ideal solution for toll areas, interchange ramps, signalized intersections, bus stops, parking areas, and the ends of airport runways, in cargo areas at ports, generally in areas where traffic starts and stops frequently and where heavy vehicles are parked for long hours, thus avoiding undulations and other undesirable deformations.
- After heavy rainfall, it is possible to construct a concrete pavement using this technology, which is not feasible using traditional paving procedures using hot-mix asphalt concrete (HAC).
- It is a technique that can be completed more quickly than the traditional method.

Main application areas (The main areas of use or application areas of white-topping technology are):

- Roads, both rural and urban;
- Intersections, at intersections of all types where road users experience inconvenience due to deterioration of the existing pavement;
- Parking Areas, primarily in commercial, industrial, and port parking areas, and bus parking areas;
- At Airports, it is used to build or repair airport parking areas for small aircraft, such as crop dusters and passenger aircraft; at the ends of runways and takeoffs, in taxiways, etc.

The construction equipment and tools for manual and/or mechanized execution are the following: pavement milling machine, hydraulic concrete batching plant, concrete mixer trucks, dump trucks, metal and wooden formwork, vibratory rollers or smooth-tire vibratory cylinders, slipform paver, vibratory screeds, immersion vibrators, scrubbers, texturizer, metal rakes or combs, water sprinklers, pavement cutter, jointer.

The use of these machines and tools will depend primarily on the type of white topping to be performed and the available resources. These can be seen below in a sequence of photos illustrating the repair of a section of road using the Ultra-Thin White-Topping technique. This technique used a semi-mechanized "alternating-panel" technique due to the lack of slipform pavers.

2.1 Ideal technique for WC and UTW construction

Before using WT technology, the first aspect to define is the thickness of the hydraulic concrete slab to be poured (for WC, it ranges between 10 and 20 cm, and for UTW, between 8 and 10 cm). Another aspect is the type of concrete to be produced (for UTW, the concrete is reinforced, while for WC, it is massive). Another aspect to be specified is the degree of mechanization to be employed in both technological variants: whether they are mechanized, semi-mechanized, or manual. This will all depend on the equipment available for their execution; they should preferably be carried out using highly mechanized techniques.

For the section to be rehabilitated on the road to Topes de Collantes, a semi-mechanized variant called "Alternating Panels" is proposed. This is the most commonly used option in Cuba, given the equipment and other resources available in the country and in the province of Sancti Spíritus.

Semi-mechanized construction technique for conventional white topping (WC):

(1) Preliminary activities (layout of the area or section to be repaired, cleaning, etc.);

(2) Treatment or patching of the pavement surface to be repaired;

(3) Layout and placement of forms;

(4) Concrete production at the plant, with the strength specified in the mix design;

(5) Transportation and placement of concrete in the "A" sections of the section using concrete trucks;

(6) Compaction of the concrete in the "A" sections with immersion vibrators;

(7) Finishing the pavement surface of the "A" sections;

(8) Curing the concrete for 7 days;

(9) Placement, compaction, surface finishing, and curing of the "B" sections;

(10) Stripping of the formwork;

(11) Execution of longitudinal and transverse joints;

(12) Sealing of joints;

(13) Reconstruction of gutters, cross gutters, side walks, and slopes, if necessary;

(14) Cleaning of the completed area or section;

(15) Replacement of horizontal and vertical signage;

(16) Opening to traffic.

The following table shows the different types of deterioration that can occur in pavements and the operations that must be performed before implementing hydraulic concrete reinforcements on asphalt concrete pavements.

Table 2. Repairs to be carried out according to the type of damage

Types of deterioration	Repair to be carried out	Factors to consider
Rodras (> 5 cm)	Milling of the leveling layer	Transverse drainage or pumping
Ripples	Milling	Remaining thickness
Disintegration	Surface sealing and primer application	Surface sweeping
Crocodile skin	Crack sealing	---
Thick cracking In mesh	Crack sealing or section reconstruction	Existence of an unstable area in the subgrade ("toads")
Transverse cracking	Crack sealing	Non-stick treatment
Cracks (< 5 cm)	Crack sealing	---
Deep cracks	They must be filled with granular material, with SCC or FCC	---
Large potholes	Filling with selected, well-compacted rock material	If the base is affected

2.2 Construction technique for using Ultra-Thin White Topping (UTW)

In UTW, the connection between the wearing course of the flexible or asphalt pavement and the reinforcing hydraulic concrete slab is considered a system composed of a thin layer of hydraulic concrete reinforced with a steel mesh, which is placed on the surface of the deteriorated pavement. It is important to note that both layers form an integral structure; they do not behave as independent layers. This reduces critical stresses by lowering the neutral axis to the center of the new pavement structure, with the maximum critical stress occurring in the asphalt and not at the bottom of the concrete slab. The close joint spacing allows UTW to act as a block pavement, thereby reducing buckling stresses in the concrete slab, according to studies.

Slabs created with UTW must have an adequate thickness, ranging from 7 to 10 cm. Fatigue failures can be common in pavement slabs made with UTW, so appropriate measures must be taken to address them.

Advantages:

- It is a new, much more durable and faster option for repairing pavement surfaces.
- It is cost-competitive compared to conventional WT and traditional flexible pavement, although its initial cost is obviously higher than that of WC.
- Maintenance is reduced.
- The smaller boards are ideal for maintenance.
- It does not reduce drainage capacity.
- Light reflection is good day and night, as with all rigid pavements, compared to flexible pavements.
- The pavement surface is resistant to aging and the effects of fuels.
- It is a more durable surface compared to flexible pavements.
- It can be completed quickly, making it suitable for use in critical areas or points on roads.

2.3 Construction technique for pavement repair using UTW:

The following construction technique is specified:

(1) Mark the boundaries of the repair and carry out all necessary preliminary activities to ensure the required quality of the work.

(2) Demolish the area to be repaired to assess the depth of the asphalt pavement layer to be repaired.

① For small areas, use manual breaker hammers and wagons to remove waste material.

② For large areas, in addition to using self-propelled breaker hammers, mini front-end loaders can be used to remove pieces of old pavement, placing them on the sides or on dump trucks for disposal at distant landfills.

(3) Thoroughly examine the area to be repaired to take any additional measures before continuing the work.

(4) Clean the surface with an air or sand spreader.

(5) Place the metal forms in the area to be repaired, securing them properly.

(6) Place the reinforcing steel mesh in the molds and position it properly.

(7) Production or preparation of hydraulic concrete in a fixed or mobile plant according to the mix design.

(8) Transport to the construction site in concrete trucks and pour into the molds.

(9) Compact the concrete in the mold using vibratory screeds.

(10) Finish the pavement surface of the repaired area or section.

(11) Curing the concrete.

(12) Stripping the formwork in accordance with the concrete used.

(13) Marking the joints.

(14) Making joints.

(15) Cleaning the construction site or repaired area.

(16) Installing traffic signs.

(17) Opening to traffic.

2.4 Application of Conventional White Topping (WC) on the reference road

This rehabilitation technique is being applied to the road to Topes de Collantes in the municipality of Trinidad. This road is 28.0 km long and 6.0 m wide. It has a profile layout with gradients of up to 18% and curves with very small turning radii. Due to these conditions, the road suffered various deteriorations, such as ruts and undulations in the flexible pavement, which made vehicular traffic difficult and dangerous. The construction process followed the steps outlined in the semi-mechanized construction technique for conventional white topping. The demolition of the road section (9.0 to 10.5 km) was carried out with pneumatic hammers, eliminating existing irregularities. Drill holes were made in different parts or areas of the road section to allow for better adhesion of the conventional mass concrete (WC) slab to the existing pavement. The concrete slab layer thickness was 20 cm according to the project, and metal forms were used to allow for concreting using the alternating panel technique of 4 × 3 m. Dowels with corrugated steel bars were used in the transverse joints, and tongue-and-groove joints were used in the longitudinal joints.

The 30 MPa concrete was produced at a centralized batching and mixing plant in Trinidad and transported to the site using 6 m^3 concrete trucks and placed manually using channels. The compaction process was carried out with immersion vibrators. Curing took a week, involving manual watering with hoses. The slab's tread surface was marked with metal rakes or combs to prevent vehicle slippage and skidding, thus ensuring adequate road safety. The sidewalks were then reconstructed and the horizontal and vertical signage of the repaired 1,500 m were replaced.

Images of the execution of the rehabilitation of the section:

Figure 1. Casting alternating sections on the track.

Figure 2. Sampling and quality control. Tread surface treatment.

Figure 3. Sections of the rehabilitated road.

3. Conclusions

- Adequate quality of execution was achieved for the various works using conventional WC technology on the rehabilitated 1.5 km section of road.
- Total costs were reduced by significantly increasing the pavement's useful life by 15 to 20 years and increasing the repair cycle, compared to the commonly used flexible pavement resurfacing technique.
- Increased road safety was achieved on the rehabilitated section by improving the pavement's surface smoothness, constructing sidewalks, and using retaining barriers.
- Greater load-bearing capacity was achieved in the pavement structure, resulting in a stronger and more durable surface.

4. Recommendations

Expand the application of white-topping technology to sections of roads with similar characteristics to the one described.

Conduct a study of existing Cuban roads in deteriorated mountainous areas that recommend the application of this technology.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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