COMBINATION OF POLYMER MODIFIED BITUMEN TECHNOLOGIES FOR PAVING PRESERVATION.

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ABSTRACT

Trends to improve the characteristics of bitumen as part of the pavement have been focused on the rheological and mechanical properties (G */sin δ for Superpave, Force Ductility, MSCR, etc.). When this improved bitumen is used to rehabilitate pavements, they may offer additional benefits by the combination of different application technologies. This paper presents the rehabilitation results for a pavement concrete with abundant cracking, where a crack sealer formulated with polymer SEBS was applied, also a tack coat made with a linear SBS polymer was applied to create an impermeable moisture barrier, decreasing the spread of cracks and have a high adherent interlayer binder; and finally, a SMA membrane (Stone Mastic Asphalt) made with a radial SBS as ingredient of a PG 76-22 asphalt grade. This modified SMA membrane presented Marshall stability values of 12 kN, which in term of 1.5 years of monitoring has no reflection of the cracks into the rehabilitated pavement, while in the same period of time with a SMA membrane formulated with unmodified bitumen and 8 kN of Marshall stability without tack coat application, this pavement showed premature bitumen raveling and holes.

Keywords: Polymer modified asphalt, SMA, HMA, Crack sealer

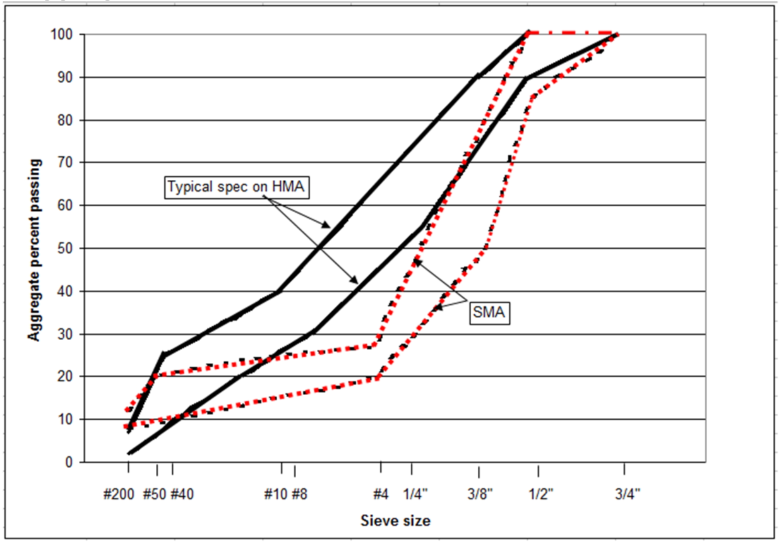
BACKGROUND.

Pavement construction has been affected by different variables related with worldwide economy and environment trends as high increments in cost of raw materials, high construction cost itself as well as pollution reduction. All these variables[1,2] have promoted to look for the use of more efficient and cheap materials as well as recycled products (for instance, RAP "Reclaimed Asphalt Pavement" and polymer modified bitumen emulsions), all in order to reduce the energetic consumption and making easier the road manufacture and decrease the environmental damage.

Besides of new road construction, rehabilitation and preservation of existence pavements is getting high importance. In most of these treatments the use of bitumen emulsions[3] is very helpful not only as surface coating, but also as binder between the base and new bitumen layer and innovative ways to create membranes to repair and reuse the original pavement.

Bitumen emulsion technology has permitted the use of recycled materials (as RAP or RAS "Reclaimed Asphalt Pavement" and "Reclaimed Asphalt Shingles") to create low cost but high resistance materials for pavement treatment. Also a combination of bitumen emulsion with traditional materials like Hot Mix Asphalts (HMA) permits to have synergistic effects for having durable materials, and also to open the possibility of combining nontraditional materials as SMA formulations (Stone Mastic Asphalt), which is the formulation of a special Hot Mix Asphalt in combination with a discontinuous particle size distribution in aggregate and fibers as figure 1 shows. This work will show a combination of alternatives using polymer modified bitumen in crack sealant, polymer modified bitumen emulsion and SMA[4] membrane to rehabilitate a concrete pavement with abundant cracking.

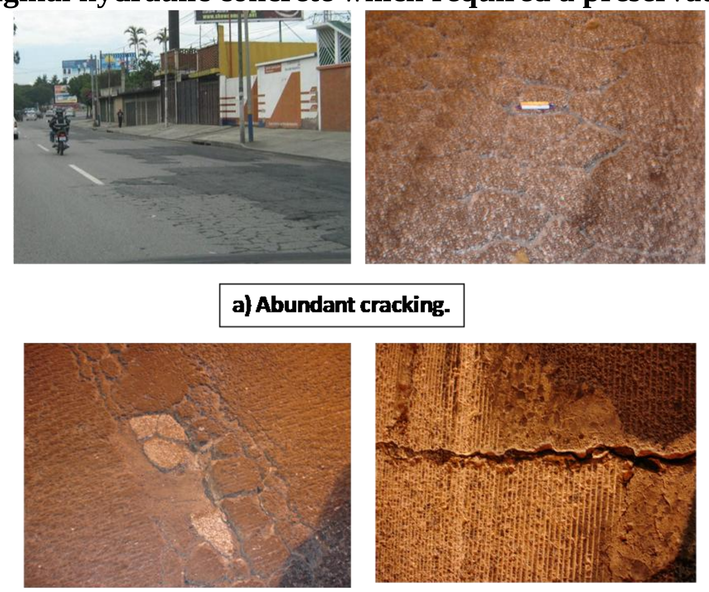
Figure 1.- Aggregate size distribution comparison between HMA and SMA.



PROBLEM DESCRIPTION.

Main goal on this work was a proposal of preservation treatment for a hydraulic concrete with abundant cracking as well as longitudinal and transversal cracks, as figure 2 shows. This pavement is considered main artery with high transit as more than 30,000,000 ESAL´s (Equivalent Single Axe Load considered as 80 kN or 18,000 lbf).

Figure 2.- Original hydraulic concrete which required a preservation treatment.



a) Abundant cracking.

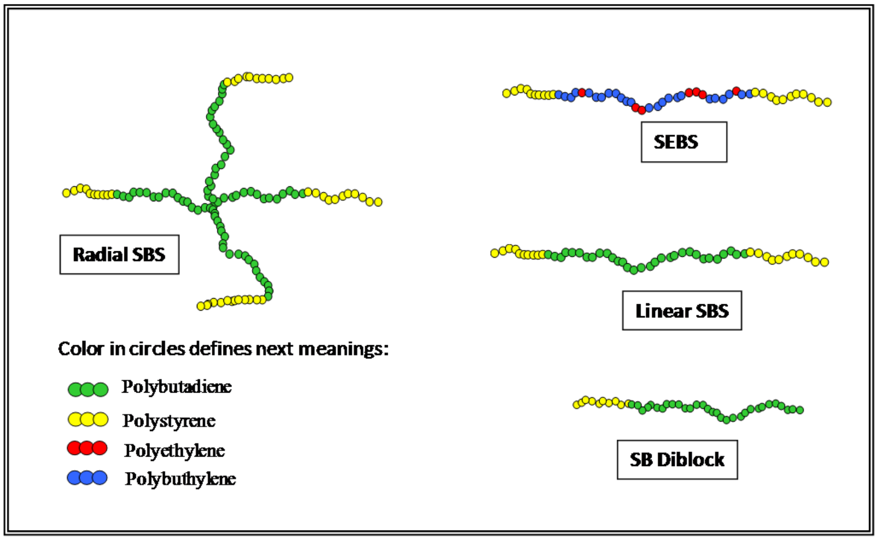
b) Holes

c) Longitudinal and transversal cracks.

APPLICATION RESULTS.

Different Styrene-Butadiene copolymers were proposed in different modified bitumen products to give the pavement treatment for injured pavement mentioned. Main polymer structures and configuration chains are showed in figure 3.

Figure 3.- Main polymer structures used in different modified bitumen products.



First action was making two millimeter stripes on the concrete surface by the use of a milling machine and clean all surface by air and sweeping. After this, a second action was taken on longitudinal and transversal crack with more than one inch of thickness as well as big holes and damage. For these items a bitumen crack sealant was proposed. This sealant was formulated with a blend of SBS radial and SEBS with a total polymer content of 4% weight/weight in a polymer ratio of 50/50 % weight/weight. Main properties of crack sealant are showed in table 1.

Table 1.- Properties of Bitumen Crack Sealant used as first preservation treatment.

PARAMETER	TEST METHOD	ORIGINAL BITUMEN	BITUMEN CRACK SEALANT BASED ON RADIAL SBS + SEBS
Softening point temperature, °C	ASTM D36	51	115
Penetration (100g, 10s, 25°C), 1/10mm	ASTM D5	80	25
Torsion elastic recovery, %	N-CMT-405-002/06 (Mexican method)	6	62
Brookfield viscosity at 160°C, cP	ASTM D4402	167	2967

A second treatment was used by the application of a polymer modified bitumen emulsion with a tack coat function formulated as cationic rapid set type CRS-2P using a linear SBS polymer as modifier. This emulsion had two preservation functions. On one side, it permits to seal the rest of minor cracks; and on the other side, it will be a binder to link a new bitumen surface course based on SMA formulation. Table 2 shows main characteristics of bitumen tack coat emulsion.

Table 2.- Tack coat emulsion.

INGREDIENT	UNIT	VALUES
TENSOACTIVE DISSOLUTION		
Water	L	4700

Diamine emulsifier	Kg	49
Clorhidric acid at 37% volume (pH=2 in soap dissolution)	L	36
POLYMER MODIFIED BITUMEN		
AC-20 Perenco Guatemala original bitumen	% weight/weight	93.7
Linear SBS	% weight/weight	2.4
Aromatic flux agent	% weight/weight	3.9
MODIFIED BITUMEN EMULSION PROPERTIES		
Bitumen emulsion residual	% weight/weight	66
Residuals retained by sieve number 20	% weight/weight	0.03
Saybolt Furor viscosity at 50°C	s	103
Size particle diameter in emulsion droplets	micron	7

Finally, a decision for a bitumen surface course was taken. In this sense, a SMA (Stone Mastic Asphalt) formulation was used to improve reinforcement and resistance for cracking propagation. The aggregate used in SMA had 12.5 millimeter as maximum nominal size within limits defined in figure 1 and graduation is showed in table 3.

Table 3.-Nominal maximum aggregate size (12.5 mm) on SMA formulation.

Sieve size	**% passing**
1"	100
¾"	97.5
½"	70.4
3/8"	57.2
No. 4	27.2
No. 8	22.6
No. 16	19.0
No. 30	16.4
No. 50	14.0
No. 200	9.7
Aggregate apparent specific gravity (G_{sb})	2.715

There was also used a polymer modified bitumen with a radial SBS for PG 76-22 and different formulation designs varying the polymer modified bitumen content in SMA blend. A proposal[3,4] for fatigue life of 5000 cycles (measure by AASHTO T321 at 10 Hz and 20°C) and a resilient modulus of 17.2 x 10^3 MPa were set to estimate the polymer modified bitumen content around 12% in volume according to algorithm[5] proposed in equation number one (Muniandy, etal, 2001).

$$\Phi = -0.337 + 3.568\,\alpha + 0.828\,\lambda - 0.129\,\nu \qquad \text{............ Equation (1)}$$

Where:

Φ = Log (fatigue life in unit of cycle).

α = Log (Bitumen content in percentage of volume).
λ = Log (Resilient modulus in MPa).
ν = Log (strain x 10^{-6}, %).

Table 4 shows the properties from polymer modified bitumen using AC-20 virgin bitumen in combination with radial SBS, the polymer modified bitumen was prepared using a tank provided with agitation and high shear mill, mixing SBS polymer in bitumen for three hours at 185 $\pm$ 5°C and after polymer dispersion a powder sulphur was used as crosslinlink agent, maintaining same agitation conditions for additional one hour. Different test specimens were prepared for fatigue life test (cycles by AASHTO T321) varying the bitumen content, aggregate samples from same source and void percentage, in order to chose the better formulation to get the resilient modulus set as showed in figure 4.

Table 4.- Properties of PG 76-22 polymer modified bitumen.

INGREDIENT	METHOD	CONTENT, %weight/weight
AC-20 Guatemala bitumen of Perenco refinery	Gravimetric	97.8
Radial SBS	Gravimetric	2
Powder Sulphur (99.9% purity as neat sulphur)	Gravimetric (based on polymer weight used in formulation)	1.5
MODIFIED BITUMEN PROPERTIES.		
Softening point temperature, °C	ASTM D36	60
Penetration (100g, 5s, 25°C), 1/10mm	ASTM D5	55
Brookfield viscosity at 135°C, cP	ASTM D4402	1200
Torsion elastic recovery, %	NCMT-4-05-002/06	65
Ductility (5 cm/min, 4°C, after RTFO), cm	AASHTO T51	28
Rheological shear rate (G* / sen d) a 76°C, kPa	AASHTO T240	3.02
Phase angle at 76°C, grade	AASHTO TP5	74
Negative PG grade (BBR), °C	AASHTO T240	-22
MSCR recovery at 100 Pa and 76°C, %	AASHTO TP 70	46.27
MSCR recovery at 3200 Pa and 76°C, %		31.82
MSCR % Drop (Maximum 75%)		31.2

Best SMA formulation at lab scale was characterized according with properties described in table 5 and use as reference for production scaling up. Both samples were compared against a typical data reported in technical literature[4]. Production was made in a discontinuous Barber Green hot mix asphalt plant with a capacity of 250 MT/hour. The surface course was made with a thickness of six centimeter.

Figure 4.- Fatigue life moving bitumen content on SMA test specimen.

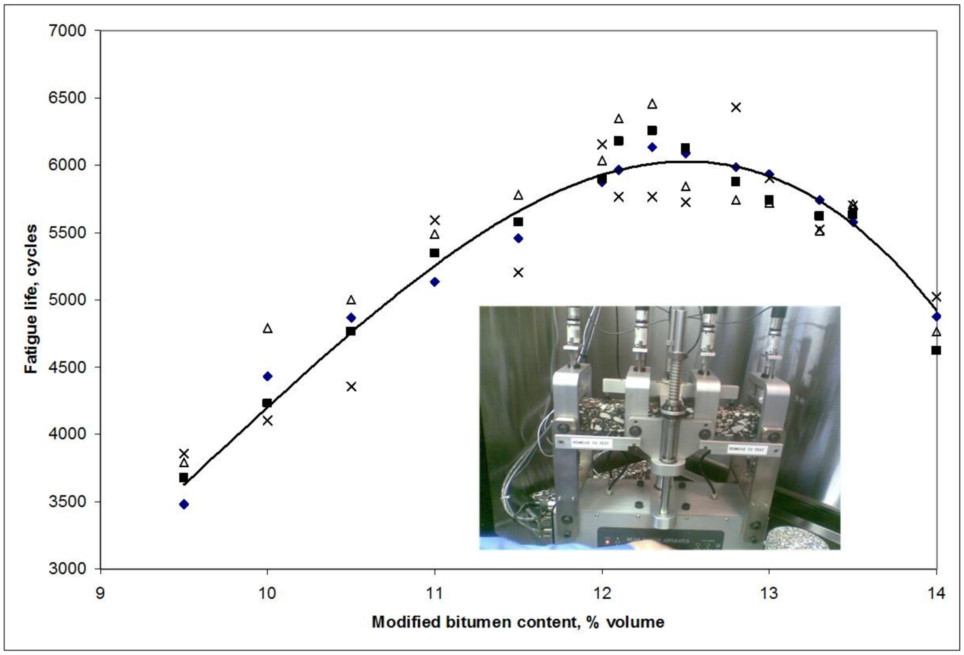


Figure 5 shows a comparative image were tack coat residual and surface course were taken.

Figure 5.- Tack coat emulsion and SMA during construction works.

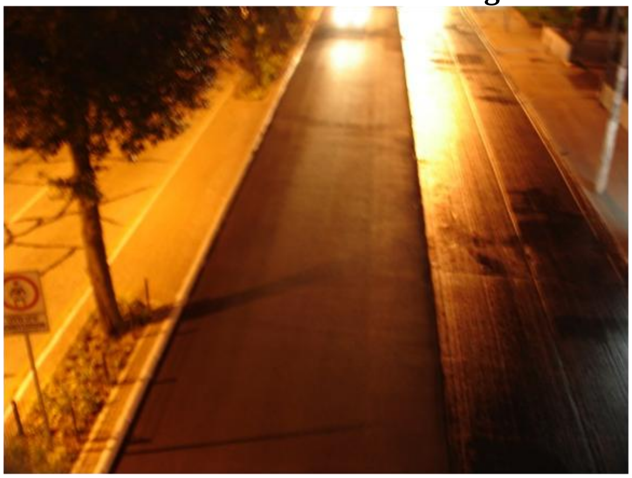


Table 5.- SMA formulation and final design parameter for bitumen mix.

PARAMETER	DESIGN VALUE		REFERENCE
	LAB SCALE	PRODUCTION SCALE UP	
Number of knocks	2 x 75	2 x 75	2 x 75
Total content in AC-20 bitumen (original bitumen), % weight/weight	6.5	6.4	6.2
Content of cellulose fiber additive, % weight/weight	0.03	0.03	0.03
Radial SBS content, % weight/weight	2	2	2
Maximum aggregate density, g/cm^3	2.787	2.788	2.688
Bulk density, g/cm^3	2.6869	2.6869	2.359
Maximum mix density, g/cm^3	2.433	2.452	2.441
Voids content, % volume	3.90	3.76	3.40
Voids filled with asphalt, %	78.45	79.90	80.8
Polymer modified asphalt, % volume	12.60	14.34	14.30
Marshall stability (AASHTO T245), kN	11.0	12.1	12.5
Marshall flow, mm	3.04	3.93	4.5
Temperature of Marshall compaction, °C	145	145	145
Modified Lottman (AASHTO T283) indirect tensile strength, Kg/cm^2	25.4	27.3	More than 12
Lottman tensile retained strength (TSR), %	70	72	More than 70

CONCLUSION.

New technological trends in rehabilitation and preservation of pavements had been developed. Particularly, the use of polymers and additives permits to give different properties to bitumen as binder in the bitumen mix. In this work, a preservation of a concrete pavement was done in order to give more life time to road and save money avoiding demolition and re-building of a new pavement. Preservation techniques proposed permits to repair the pavement in hours and open the traffic fast and safe.

Approaching that some polymers permits to improve thermal stability to bitumen, in this work the use of SEBS in combination with a radial SBS permitted to obtain a crack sealant applied using a torch in a melted state. This treatment permits to seal big cracks and holes.

Secondly, a cationic rapid set polymeric emulsion was used to seal the rest of cracks in concrete pavement, improve the IRI and serves as link for a new bitumen membrane. This emulsion permits to create an elastic film in the concrete surface with low energy and fast cure time for obtaining the bitumen residual. The linear SBS used for bitumen modification permits to give elastic recovery and adherence to bitumen residual.

Finally, a surface course made of Stone Mastic Asphalt (SMA) formulation was put after the emulsion cured. Besides of the SMA characteristics, a polymer modified bitumen with a radial SBS improve the resilient modulus in the SMA formulation.

In order to verify the polymer performance and superior properties from bitumen in different applications, there were made a similar treatment in one part of pavement with the use of a crack sealant with virgin bitumen, the application of a cationic bitumen emulsion as tack coat (without the previous bitumen modification) and a SMA formulation without polymer modified bitumen. The monitoring of physical status of both treatments (since February 2009) shows evidence of crack propagation, rutting and raveling in area without bitumen modification treatment, while in the other area with bitumen modification treatment there is not presence of cracking, neither raveling or rutting.

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