AAUQ Asphalt Mixtures Using Carbide Lime for Low Traffic Paths in Manaus – AM

Herbert Pereira Tomé
hptcomercio@hotmail.com
Centro Universitário FAMETRO – Amazonas - Brasil

Joilson Rocha de Almeida
joilson_juruti@hotmail.com
Centro Universitário FAMETRO – Amazonas – Brasil

Livia da Silva Oliveira
oliveira.livia@gmail.com
Centro Universitário FAMETRO – Amazonas - Brasil

David Barbosa de Alencar (Corresponding author)
david002870@hotmail.com
Instituto de Tecnologia e Educação Galileo da Amazônia (ITEGAM) - Brasil

Camily Murrieta Vasconcelos Oliveira Bezerra
camilymv@hotmail.com
Instituto de Tecnologia e Educação Galileo da Amazônia - ITEGAM

Abstract

The asphalt pavements of the residential streets and outskirts of Manaus city are usually made of Hot Machined Asphalt Sand (AAUQ), which is ideal for low traffic roads, not only for the flow of vehicles and use of materials, but also for the economic viability of the project. In this research we used the waste originated from acetylene gas production in factories of the Industrial District, Cal de Carbureto in the composition of asphalt mixtures of type AAUQ, replacing the usual filler, Portland cement. These mixtures were mechanically evaluated with respect to the Diametral Compression Tensile Strength, Resilience Module and Fatigue Life tests, and it was found that the alternative filler presents superior results when compared to the usual used in the asphalt plants of the City.

Keywords: asphalt mixture; paving; traffic volume;

1. Introduction

In Manaus, capital of the State of Amazonas, there is limited availability of materials for asphalt paving, implying the need for research related to new natural and recycled materials. The studied solutions should propose the optimization of the financial resources, aiming at the viability of the project, showing that the paving of the roads in general, especially to the coating, must be carefully studied in order to result in the highest possible cost-benefit, thus fitting in. current investment limitations of the responsible agencies. With regard to low traffic volume (BVT) routes, the importance of the costs of alternative proposals is increased, assuming lower accuracy and, consequently, minimum budget percentages. BVT roads are essentially residential, where there may occasionally be truck and bus crossings of no more than 20 per day per lane, characterized by a typical "N" number of 105 standard single axle requests (80kN) for the 10 year project period [1]. In this context are the most peripheral streets and avenues of the municipality Manauara with little load request of the pavements of this region, despite the high population growth [2].

Among the solutions commonly used in Manaus for the BVT roads is the Hot Machined Asphalt Sand (AAUQ) asphalt coating, which causes early structural failure shortly after its construction, especially due to the excessive accumulation of permanent deformations in the layer. surface, caused by the absence of coarse aggregates in these mixtures, in addition to the small size of the sandy aggregates, resulting in a large surface to be covered by the asphalt binder, thus requiring a high binder content for the asphalt mixtures [3]. The early deterioration of these asphaltic pavements may cause, in addition to the aforementioned pathology, fatigue cracking, a phenomenon allusive to both the viscoelastic behavior of asphalt binders and the stress concentration at the aggregate-binder interface [2].

Aiming to overcome these regional difficulties, new technologies have been researched, among them the use of acetylene gas (Carbide Cal) residue from Manaus industrial park, as a filler in asphalt composites, through the analysis of the mechanical behavior to various temperatures. The technical literature has presented the technical viability regarding its use in asphalt composites [4] [5] [6].

Based on the above, the objective of this project is to present Carbide Lime material as a technical alternative, as it is a material to replace the usual filler (Portland cement) in asphalt mixtures, and to provide an environmental alternative for waste. industrial solids, thus avoiding disposal in landfills or wastelands, as well as minimizing the extraction of natural resources, aiming at low traffic asphalt pavement in the State of Amazonas.

2. Theoretical Referential

2.1 Asphalt Coating - Hot Machined Asphalt Sand

Also called asphalt mortar, this coating is used, especially in places where there is a shortage of coarse stone aggregates, generally consisting of sand, asphalt binder (PAC) and filler.

2.2 Tensile Strength by Diametral Compression

In the Tensile Strength (RT) test the specimens are tested in a computerized press with graphical interface, where a displacement rate of 0.8 mm / s was applied until their rupture. By obtaining this load, tensile strength by diametral compression was calculated.

2.3 Resilience Module

The Resilience Module (MR) determined by indirect loading with repeated loading in asphalt mixtures, is the relationship between the tensile stress applied repeatedly in the vertical diametric plane of the sample and the specific recoverable strain corresponding to the tension applied at a given temperature and for a given temperature. load application frequency.

The application of the theory of elasticity to asphalt mixtures and diametral compression tests is only permissible at low tensile stress levels (40% or less of the tensile strength of the RT test) and at temperatures below 40 ° C [7]. Several works have applied loads to reproduce tensions in the order of 10 to 20% of RT and it is recommended to apply the lowest load.

2.4 Fatigue Life

Fatigue is a process of structural deterioration that undergoes a material when subjected to a state of repeated stress and strain, and may not reach the ultimate strength of the material, resulting in cracking after a sufficient number of loading repetitions. That is, fatigue is the loss of resistance that a material suffers when repeatedly bending or pulling [8] [9].

Laboratory equipment for repeated load testing allows the application of cyclic loading to the material under stress (TC) and controlled deformation (DC) regime. Thus, the great separation that can be made between the different experiments is in the mode of request. In both tests there is a reduction of the initial stiffness of the material to a level that can be pre-set in order to define the end of the test [10].

In the controlled stress test, the fatigue criterion is associated with the fracture of the sample. Therefore, Fatigue Life (N) is defined as the total number of applications of a load required for the complete fracture of the sample [10]. In the controlled strain experiment, Fatigue Life will be the number of load repetitions capable of reducing the initial performance or stiffness of the sample to a predetermined level. Some consider that a 50% reduction in Stiffness or Resilience Module defines the end of the test, ie Fatigue Life..

3. Methodology

3.1 Asphalt Binder Characterization

As binder was used asphalt oil cement - CAP 50/70, donated by the Manaus Isaac Sabbá Refinery (UN-Reman) to the present study. It was characterized by rheological analysis in the specifications of the Superior Performance Asphalt Pavements - Superpave, suggested by the Strategic Highway Research Program (SHRP) [11].

3.2 Asphalt Binder Characterization

As a small aggregate, the Sand Manaus (Areia Mao), usually used in the engineering works of the homonymous city, was selected for the composition of the asphalt mixtures. It was characterized for particle size (ASTM C 136.1995) according to ASTM C 128 (1988), which determined the Actual Specific Mass (Gsa), Apparent Specific Mass (Gsb) and Absorption [12]. According to [13], the (Rodded Unit Weight).

Portland cement, widely used for this purpose (reference material), and carbide lime for the composition of the asphalt mixtures under study, were chosen as filler material. They were characterized according to the actual specific mass - DNER ME 085 (1994) and according to particle size for acceptance or rejection as filler according to DNER specification EM 367 (1997) [14]. The researched alternative material - carbide lime, is a residue of acetylene gas production, the present research being supplied by a Manaus Industrial Pole factory (PIM).

3.3. Characterization of Asphalt Mixtures

Hot Machined Asphalt Sand (AAUQ) asphalt mixtures were classified in Band A of the National Department of Transport Infrastructure (DNIT), through the service specification DNIT ES 032 (2005). The project content was determined by DNIT's 3rd Federal Highway District (3rd DRF) method, which is based on the Void Volume (Vv) and Bitumen-Void Ratio (RBV) values, and according to the specification of the Marshall method of dosing DNER ME 043 (1995), which is 3% to 5% Vv and 75% to 82% RBV.
In order to simulate the short-term conditioning effect, the mixtures were, before compaction, two hours in a greenhouse and at a temperature of 10 ° C above the compaction temperature (AASHTO PP-2). The Marshall DNER ME 043 (1995) Method, with 75 strokes per face, was adopted in the compaction of the specimens. Based on Test Method DNER ME 004 (1994), the preparation and compacting temperatures of the mixtures were defined. The Rice Test (ASTM D 2041) was used to calculate the Maximum Specific Density (Gmm), and binder levels were determined for Superpave (SHRP 1994a, 1994b).

3.4. Mechanical Characterization

In order to evaluate the effect of temperature, as prescribed in standard and field, the tests were performed at temperatures from 25 to 60 ºC, varying from 5 to 5 degrees. It is noteworthy that the high temperatures employed aimed to simulate the environmental conditions of the Amazon region. Figure 1 shows the specimen prepared for performing the RT test on the Universal Testing Machine (UTM 14).

Figure 1 - Performing the RT Assay
Source: Author

The MR test was performed according to the test method [14], which consists of the application of diametric compression loads on cylindrical samples, inducing in the specimen vertical and horizontal tensile stresses. Vertical loading is applied by means of a curved strip and horizontal displacement is measured by Linear Variable Differential Transducer (LVDT). Resilience Module tests were performed with loads corresponding to 5, 10, 20 and 30% of the rupture load determined in the RT test, according to the temperature range of 25 to 60 ºC, varying every 5 ºC. The frequency used was 1.0 Hz, with a load application time of 0.1 seconds and a rest time of 0.9 seconds. Figure 2 shows the specimen in the MR assay, and the graphical interface of the program used.

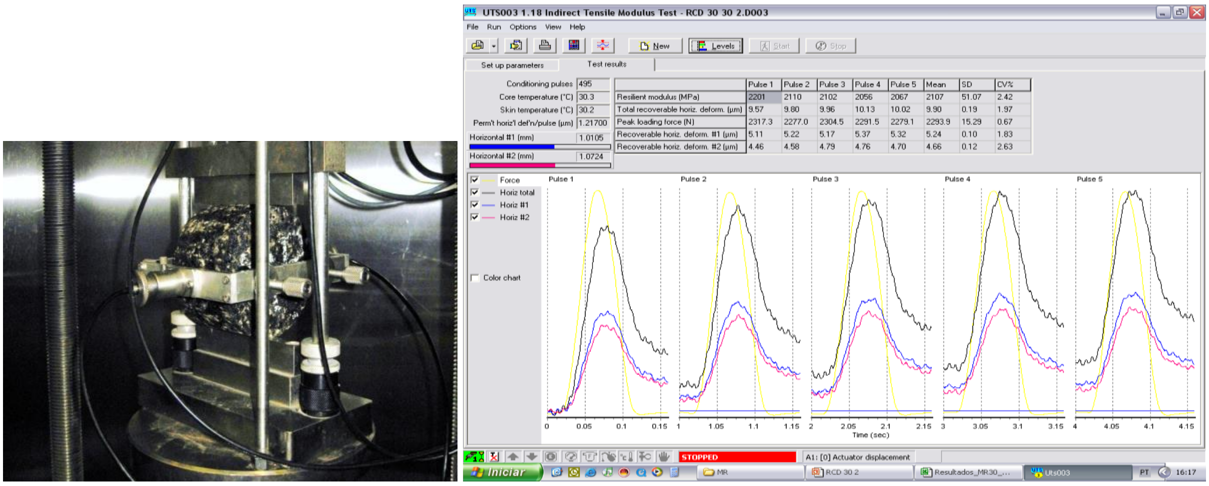

Figure 2 - UTM specimen press with MR assay graphical interface.

Source: Author

Fatigue life tests were performed at temperatures of 25, 30, 40, 50 and 60 ºC using the diametrical compression test on cylindrical specimens and at controlled stress levels of 30, 40 and 50%. the tensile strength of the RT test. The 1Hz load frequency was used, according to the load application time of 0.1 seconds and rest time of 0.9 seconds. Fatigue Life was defined as the total number of applications required for complete fracture of the sample.

4. Analysis and Discussion of Results

4.1 Asphalt Binder Characterization

The asphalt material experiments classified petroleum asphalt cement (CAP 50/70) according to Superpave criteria as PG 64-22. Therefore, such a binder may only be used for the construction of floors where its working temperature is not below 22 ° C or above 64 ° C.

4.2 Granular Material Characterization

Figure 3 shows the particle size curve for the fine aggregate (Areia Mao), where it can be observed, according to the ABNT NBR 6502 (1995), that it shows average predominance (fraction between 0.2 and 0.6 mm). . Table 2 shows the results of the characterization assays, concerning the small aggregate under study. Manaus Sand presents specific mass results according to the theoretically expected values for such material (quartz mineral).

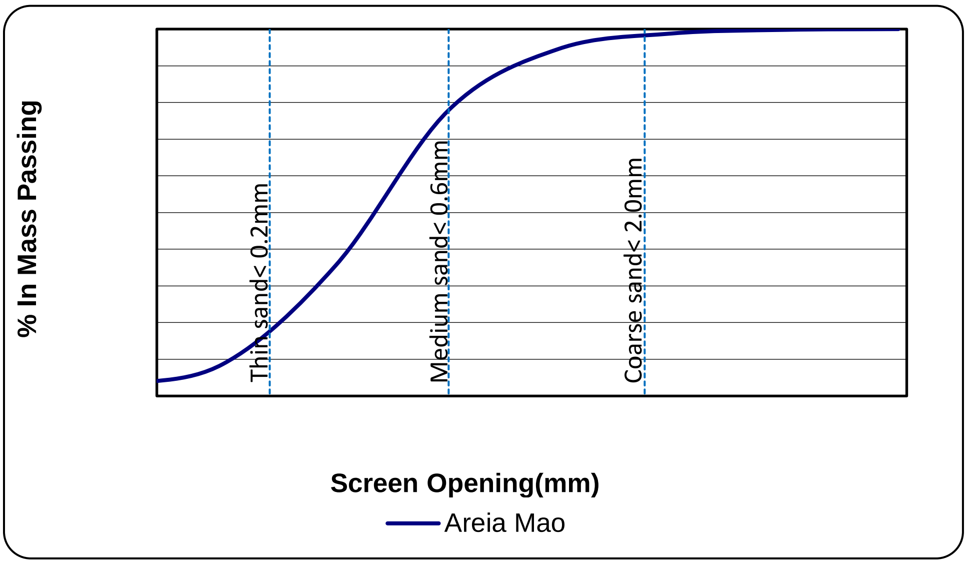

Figure 3 - Particle size curves of small aggregates.

Source: Author

Table 2. Household characterization.

Sample	Manaus sand
Gsb (g/cm³)	2,632
Gsb SSS (g/cm³)	2,692
Absorption (%)	0,00
Density (kg/m³)	1675,90

Source: Author

Figure 4 shows the particle size curve of the filler materials - Portland Cement and Carbide Lime. Regarding their actual specific masses, the values presented were 3.15 g / cm³ and 2.20 g / cm³ for the standard and alternative fillers, respectively. The results also indicated that Portland Cement passed entirely in the 0.075 mm sieve, while Carbide Lime showed only 58% passing in that sieve, outside the limits of the established specification. However, as shown in this paper, the residue from acetylene gas production has already been used in other research, proving its effectiveness technologically.

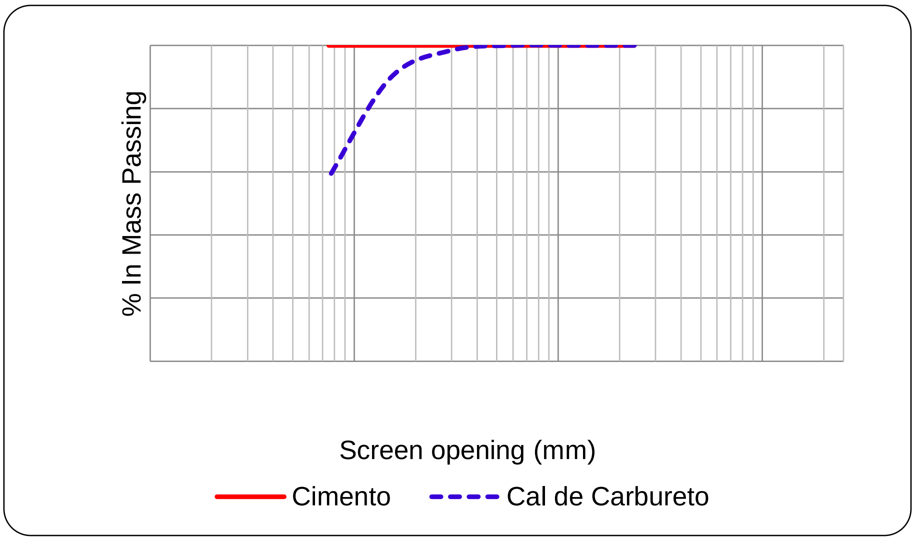

Figure 4. Particle size curves of filler materials.

Source: Author

4.3 Characterization of Asphalt Mixtures

Table 3 shows the compositions of the AAUQ asphalt mixtures, whose particle size curves were in DNIT Strip A. In order to better compare the results achieved with the mechanical tests, the mixtures were made with the same fractions of materials, changing only the filler.

Table 3. Composition of type mixtures AAUQ.

Components	Asphalt mix	
	AAUQ - Cement	AAUQ - Cal
Mao sand	95,0%	95,0%
Portland cement	5,0%	-
Carbide Lime	-	5,0%

Figure 5 shows the calculated values for T1, T2, T3 and T4, respectively 11.68%, 9.68%, 8.89% and 10.94%, with the arithmetic mean of the two central values (T2 and T4) defined the project content "T" of the AAUQ-Cement Mix, which resulted in a value of 10.3%. According to Figure 6 we have the values for T1, T2, T3 and T4, respectively equal to 11.06%, 9.11%, 8.57% and 10.51%, being the arithmetic mean of the two central values (T2 and T4). Also shown is the optimal design grade "T" of the AAUQ-Cal Mix as 9.8%.

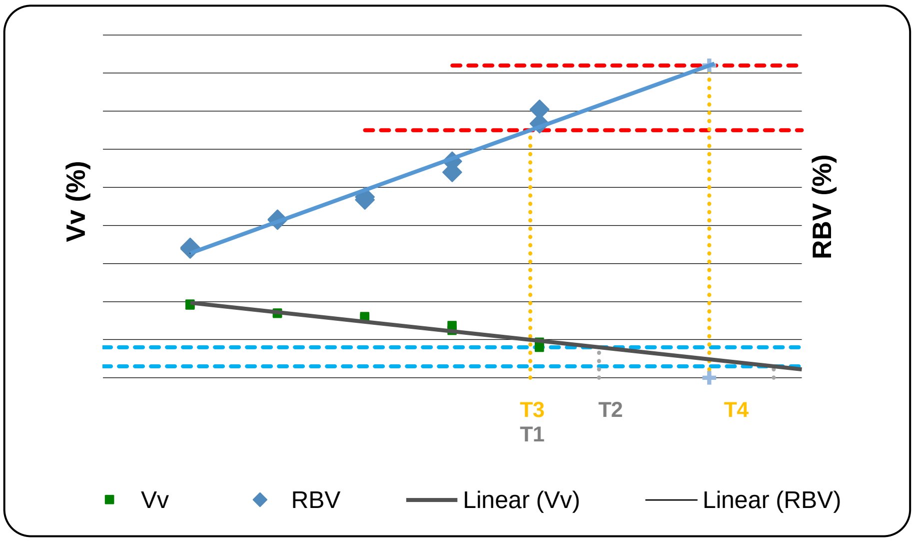

Figure 5 - Binder content of AAUQ-Cement Mix by the 3rd DRF.

Source: Author

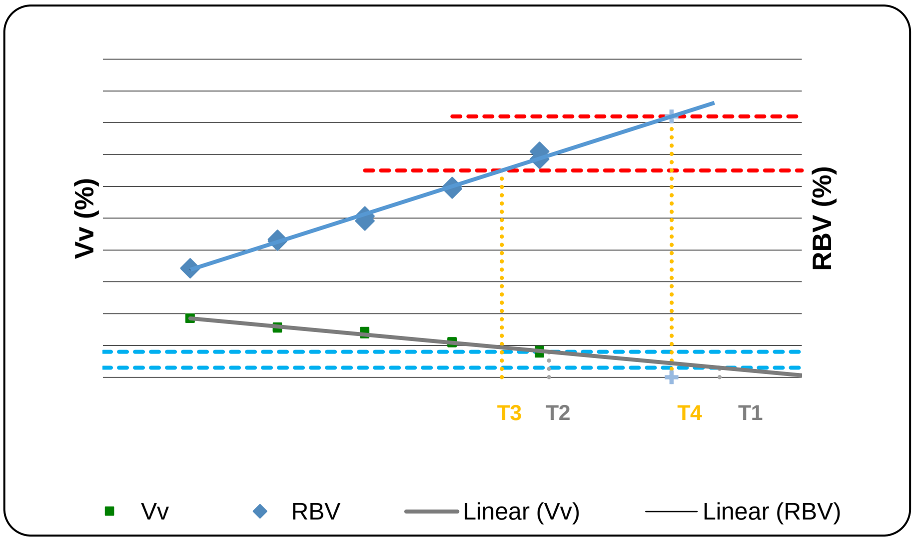

Figure 6. Binder Content of AAUQ-Cal Mix by 3rd DRF.
Source: Author

4.4 Mechanical Characterization

Tensile Strength values for all mixtures surveyed at 25 ° C indicated results greater than 0.65 MPa, as recommended by the Brazilian specification (DNIT 031/2004-ES). Particularly, the AAUQ – Cal Mix, even consuming a different portion of binder, provided satisfactory results due to the cementing properties of that residue. It is also observed that the AAUQ - Cement Mixture presented lower resistances, relative to the composites with the alternative filler, as the temperature increased (Figure 7).

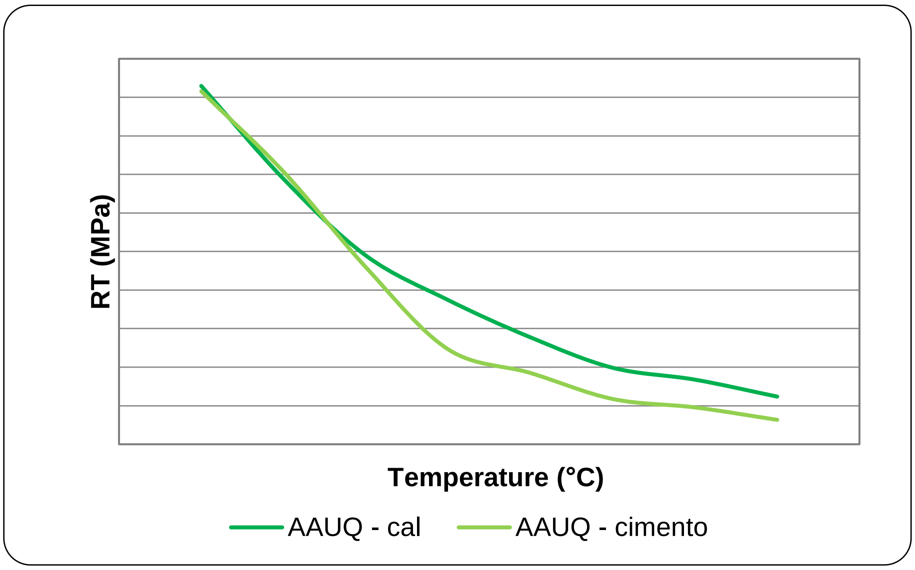

Figure 7. Tensile Strength x Mixture Temperature.
Source: Author

Concerning the Resilience Module the results are presented in Figures 8 and 9, and Table 5. It is noteworthy that although RM tests above 40 ° C have been performed, it is known from the literature that the elastic regime is no longer representative.

Regarding the behavior of the AAUQ-Cal Mix, shown in Figure 8, it is observed that: a) the MR has a significant variation with the voltage level applied at 25 ° C, around 1400 MPa, for voltages corresponding to 5% and 10% Tensile Strength. However, increasing the load to 20% and 30% of RT causes a sudden decrease of this parameter; b) from 30 ° C, result in modules with slight variations related to changes in the percentage of RT, except for the temperature of 50 ° C outside the elastic regime; c) it was not possible to test this mixture with voltages corresponding to 5% RT at 55 ° C, because the small load values were smaller than the equipment full scale (100N); d) the highest values are indicated for the temperature of 25 ° C; e) as temperature increases, MR values decrease.

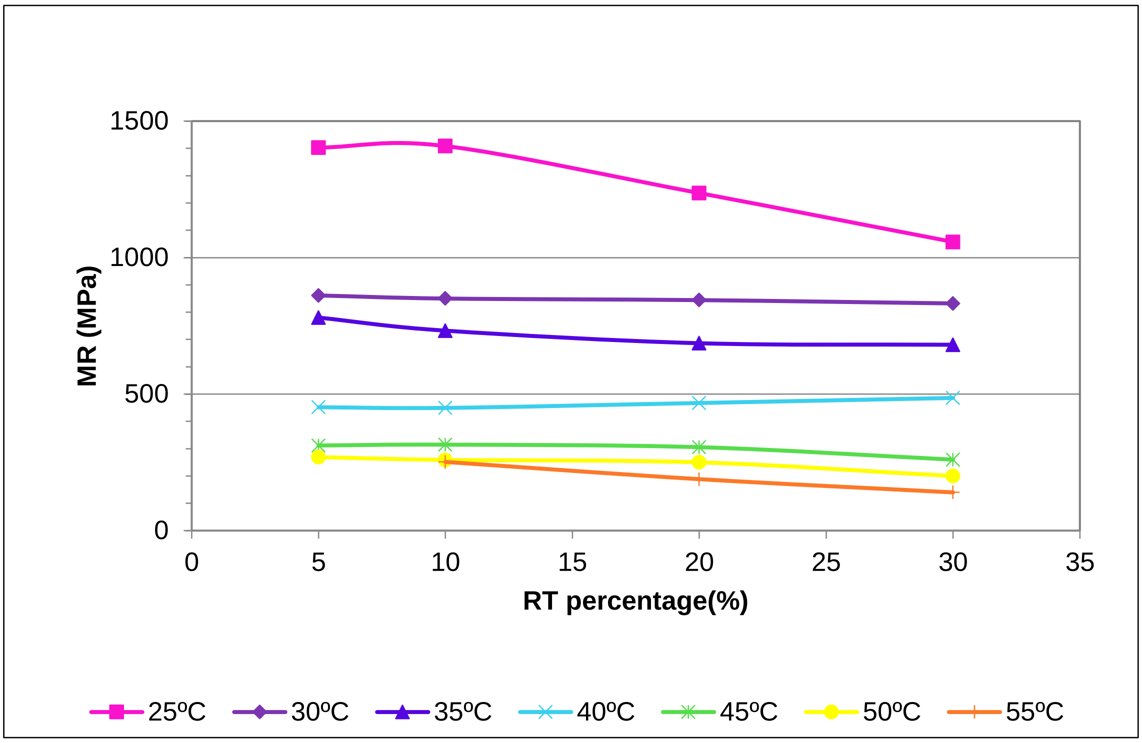

Figure 8. AAUQ-Cal Mix Resilience Modules

Source: Author

Concerning the AAUQ-Cement Mix there are: a) slight variations of the modulus values under all tested stresses and temperatures; (b) the impossibility of testing this mixture at voltages corresponding to 5% RT from 45 ° C and at voltages corresponding to 10% RT at 55 ° C because the small load values are lower than the background. equipment scale (100N); c) higher MR values for the temperature of 25 ° C; and d) as temperature increases, MR values decrease.

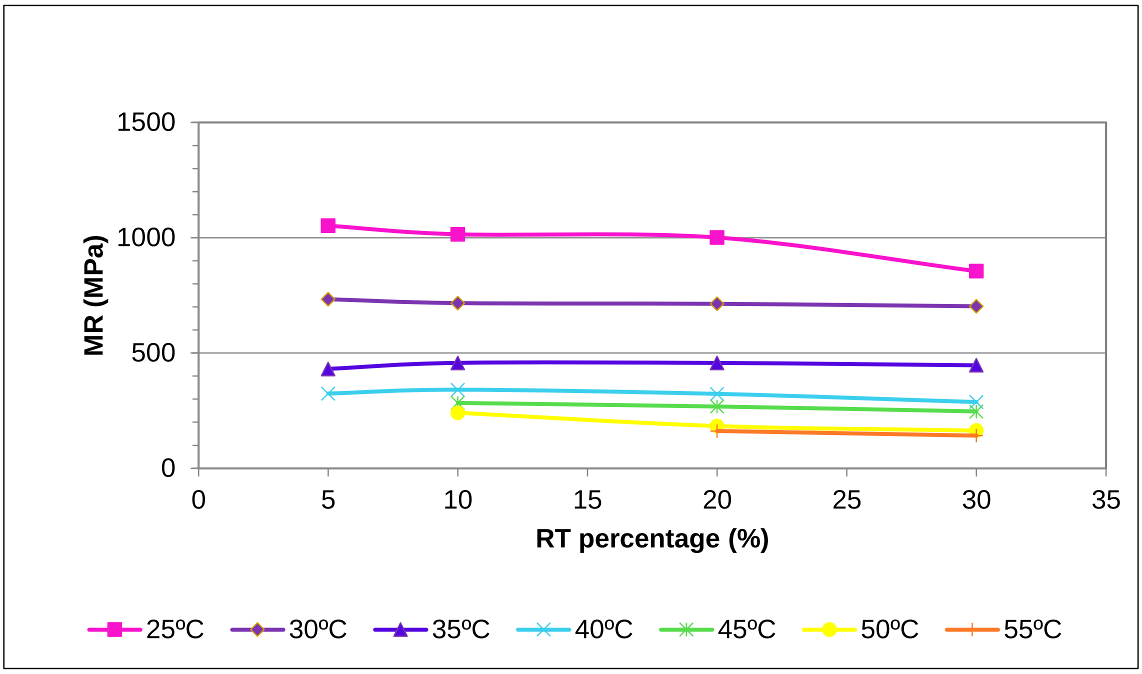

Figure 9. AAUQ – Cement Mix Resilience Modules.

Source: Author

Thus, as recommended by DNER ME 133 (1994) [14], the lowest load value was adopted, capable of generating measurable records for the determination of the Mix Resilience Module, corresponding to the load at 10% of RT. Exception AAUQ-Cement Mix tested at a temperature of 55 ° C, whose percentage of RT corresponded to a very small load (less than 100N), below the relative value of the equipment's full scale. For this mixture and for this temperature, the MR calculated for 20% of RT was adopted. Table 5 lists the MR values for the AAUQ-Cal and AAUQ-Cement Mixtures.

Table 5 - Mixture Resilience Module.

Temperature	AAUQ-Cal	AAUQ- Cement
25°C	1409	1015
30°C	850	717
35°C	732	457
40°C	449	341
45°C	315	284
50°C	259	242
55°C	252	162

In the Fatigue Life study, the number N, obtained from the predicted traffic, is related to the N determined in this test by a Field Laboratory Factor (FLC). However, due to the difficulties of considering real field conditions in the laboratory tests and in the calculation of the stresses generated in the specimens, it is common to use the results of the experiments only to compare the mixtures. Figures 10 and 11 show the Fatigue Life Curves of mixtures submitted to different temperatures, where it can be noted: a) for all composites studied, as the temperature increases, a smaller number of load repetitions is necessary to occur. rupture under a certain stress level; b) that the Fatigue Life Curve in tests performed at 60 ° C does not follow the trend of those representing lower temperatures. This result is due to the loss of elastic properties of mixtures at high temperatures, also observed in previous tests.

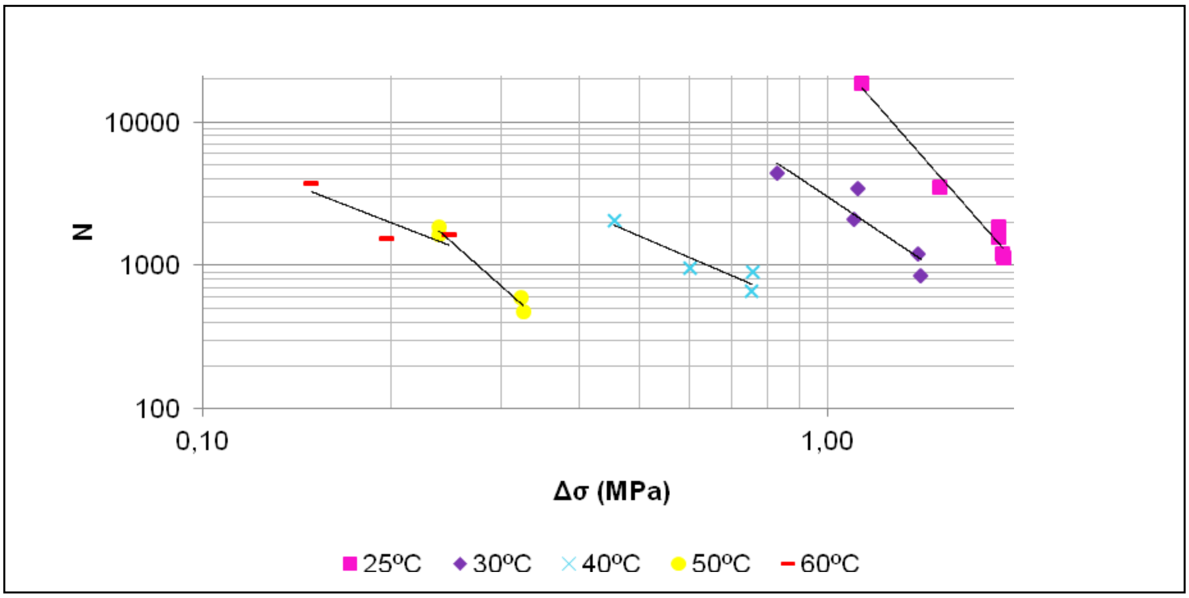

Figure 10. Fatigue Life for AAUQ-Cal Mix.
Source: Author

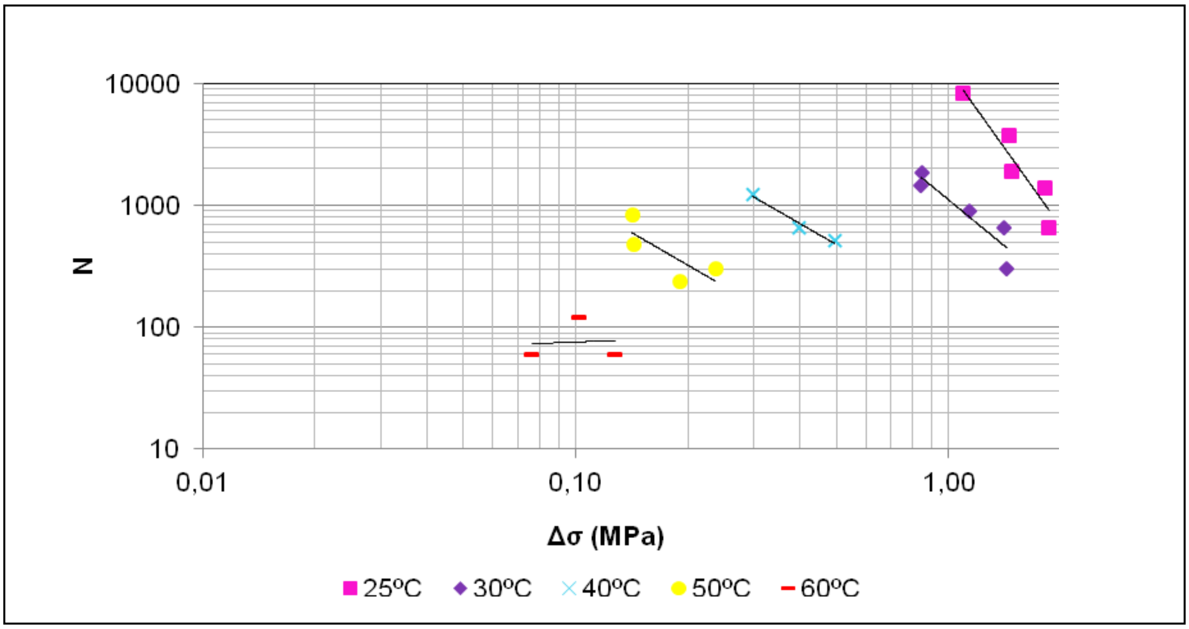

Figure 11. Fatigue Life for AAUQ-Cement Mix.
Source: Author

5. Conclusion

The analysis of the results allowed some conclusions to be drawn about this study:

Mechanical properties of asphalt mixtures (Tensile Strength, Resilience Module and Fatigue Life) have been shown to influence high temperatures (field).;

The Resilience Module generally did not vary with increasing applied stress if it remains within the elastic limit.;

- Loads according to tensions from 10% to 20% of RT are recommended for the calculation of the Mixture Resilience Module, as they presented good deformation readings and remained within the elastic regime in almost all studied mixtures;
- As the temperature increased, fewer charge repetitions were required for the mixtures to rupture under a certain stress level;
- As temperature increased, RT and MR values decreased;
- AAUQ type mixtures made from acetylene gas (carbide lime) manufacturing residue showed superior results when compared to composites usually made with portland cement as a filer;

From the above, it is concluded that the alternative filler (Carbide lime) can satisfactorily replace the traditional filler (Portland cement), reducing the thermal susceptibility of asphalt mixtures made with such material, showing as a solution to high temperature regions. - Manaus case.

6. References

[1] SANT'ANA, W.C. *Soluções de Pavimentos Urbanos para Baixo Volume de Tráfego e Cidades Pequenas.* 18ª Reunião de Pavimentação Urbana. São Luís, MA, 2012.

[2] CAVALCANTE, D.G., CRISÓSTOMO, P.H.S., SILVA, L.C.P., SOUZA, R.J.Q., GUIMARÃES, D.M.D., FROTA, C.A. *Levantamento Visual das Patologias na cidade de Manaus-AM.* Revista Teoria e Prática da Engenharia Civil, Brasil. 2012.

[3] IBP – INSTITUTO BRASILEIRO DE PETRÓLEO. *Informações básicas sobre materiais asfálticos.* Rio de Janeiro: IBP, 1999.

[4] FROTA, C. A., NUNES, F. R. G., e SILVA, C. L. "*Estudo da Substituição do Seixo por Agregados Sintéticos de Argila Calcinada*." 12ª Reunião de Pavimentação Urbana. Aracaju, SE, 2003.

[5] FROTA, C.A., SILVA, C.L., SANTOS, M.G.R., SILVA, R.V.P. "*Caracterização de Solos para Obtenção de Agregados Sintéticos de argila calcinada*." 35ª Reunião Anual de Pavimentação. Rio de Janeiro, RJ, 2004.

[6] CARDOSO, F.A.; FERNANDES, H.C.; PILEGGI, R.G.; JOHN, V.M. *Cal de carbureto como material de construção civil: caracterização.* 17º CBECIMAT - Congresso Brasileiro de Engenharia e Ciência dos Materiais. Foz do Iguaçu, PR, Brasil. 2006.

[7] MEDINA, J., e MOTTA, L.M.G. *Mecânica dos Pavimentos.* 2a. Rio de Janeiro: Imagemaker Interactive, 2005.

[8] PINTO, S. e MOTTA. L.M.G da. *Catálogo de Curvas de Fadiga*. Boletim Técnico nº 16 da ABPv, 1995.

[9] SANTOS, M.G.R. "*Estudo do Comportamento de Agregados Sintéticos de Argila Calcinada para Uso em Revestimentos Asfálticos para Manaus.*" Dissertação de Mestrado, Programa de Mestrado em Geotecnia, Universidade de Brasília - UnB, Brasília, DF, Brasil, 2007.

[10] PINTO, S., e PREUSSLER, E.S. *Pavimentação rodoviária – conceitos fundamentais sobre pavimentos flexíveis*. Rio de Janeiro,RJ.: Copiarte, Copiadora e Artes Gráficas., 2002.

[11] SHRP. "*Superior Performance Asphalt Pavements (Superpave). The Product of SHRP Asphalt Research Program. Superpave Series N°. 2*." Strategic Highway Research Program. 1994b.

[12] ASTM - American Society for Testing and Materials. "ASTM C 127-88: *Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate.*" American Society for Testing and Materials. Philadelphia, Pennsylvania, 1988.

—. "ASTM C 128-93: *Standard Test Method for Specific Gravity and Absorption of Fine Aggregate*." American Association of State Highway and Transportation Officials. Philadelphia, Pennsylvania, 1993.

—. "C 131-96: *Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine*." American Association of State Highway and Transportation Officials. Philadelphia, Pennsylvania, 1995..

—. "C 136-95: *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*." American Association of State Highway and Transportation Officials. Philadelphia, Pennsylvania, 1995.

—. "D 2041-00: *Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures*." American Association of State Highway and Transportation Officials. Philadelphia, Pennsylvania, 2000.

[13] AASHTO - American Association of State Highway and Transportation Officials. "AASHTO T 19-93: *Standard Test Method for Unit Weight and Voids in Aggregate*." USA, 1997.

[14] DNER - Departamento Nacional de Infra-Estrutura de Transportes. "DNER ME 043/95: *Misturas betuminosas a quente - Ensaio Marshall.*" Rio de Janeiro, 1995.

—. "EM 367/97: *Material de enchimento para misturas betuminosas*." Rio de Janeiro, 1997.

—. "ME 004/94: *Material Betuminoso: determinação da viscosidade Saybolt-Furol a alta temperatura método da película delgada*." Rio de Janeiro, 1994.

—. "ME 085/94: *Material finamente pulverizado: Determinação da massa específica real.*" Rio de Janeiro, 1994.

—. "ME 138/94: *Misturas betuminosas - determinação da resistência à tração.*" Rio de Janeiro, 1994.