Economic feasibility of SACC production for use in asphalt concrete

Viabilidade Econômica da Produção do ASAC para uso no concreto asfáltico

Viabilidad económica de la producción de ASAC para su uso en hormigón asfáltico

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Abstract
The Amazon region lacks surface raw material to obtain stone aggregates used in civil construction, more precisely in paving. Many studies have been conducted in order to identify an alternative material that can replace the use of rolled pebble and crushed stone in the production of asphalt concrete, due to the high cost of these raw materials as well as the worrying environmental impact arising from the extraction of rolled pebble from riverbeds. Among many alternative materials studied, the Sintered Aggregate of Calcined Clay (SACC) stands out as a replacement for these coarse aggregates, since there is a large reserve of clay in the State of Amazonas. The viability of this material has already been proven technically and environmentally. What is proposed in the study is the proof of the economic viability of SACC as a replacement for rolled pebble in the production of Hot Mix Asphalt (HMA) Concrete in the paving of highways in our region, especially in places far from Manaus.
Keywords: Sintered aggregate of calcined clay; Clay; Coarse aggregate.

Resumo
A região Amazônica é carente de matéria prima superficial para obtenção de agregados pétreos usados na construção civil, mais precisamente em pavimentação. Muitos estudos têm sido realizados a fim de identificar um material alternativo que possa substituir a utilização do seixo rolado e da brita na produção do concreto asfáltico, em virtude do alto custo destas matérias primas, bem como o preocupante impacto ambiental oriundo da extração do seixo rolado dos leitos dos rios. Dentre tantos materiais alternativos estudados destaca-se o Agregado Sinterizado de Argila Calcinada (ASAC) na substituição desses agregados graúdos, visto que a argila se apresenta com uma grande reserva no Estado do Amazonas. A viabilidade desse material já teve sua comprovação técnica e ambiental. O que se propõe no estudo é a comprovação da viabilidade econômica do ASAC em substituição ao seixo rolado na produção do Concreto Betuminoso Usinado a Quente (CBUQ) na pavimentação de rodovias de nossa região, especialmente em locais distantes de Manaus.
Palavras-chave: Agregado sinterizado de argila calcinada; Argila; Agregado graúdo.

Resumen
La región amazónica carece de materia prima superficial para la obtención de áridos pétreos utilizados en la construcción civil, más precisamente en pavimentación. Se han realizado numerosos estudios con el fin de identificar un material alternativo que pueda reemplazar el uso de grava y grava en la producción de hormigón asfáltico, debido al alto costo de estas materias primas, así como al preocupante impacto ambiental derivado de la extracción. de grava. de cauces. Entre muchos materiales alternativos estudiados, el Agregado de Arcilla Calcinada Sinterizada (ASAC) se destaca como reemplazo de estos agregados gruesos, ya que la arcilla tiene una gran reserva en el Estado de Amazonas. La viabilidad de este material ya ha tenido su prueba técnica y medioambiental. Lo que se propone en el estudio es la prueba de la viabilidad económica de ASAC como reemplazo del canto rodado en la producción de Hormigón Bituminoso Mecanizado en Caliente (CBUQ) en la pavimentación de carreteras de nuestra región, especialmente en lugares alejados de Manaus.
Palabras clave: Agregado de arcilla calcinada sinterizada; Arcilla; Gran agregado.

1 Introduction

The Amazon Region, due to its geological formation, lacks superficial raw material for obtaining stone aggregates used in civil construction, mainly in the paving of urban roads and highways. Rolled pebble is a natural option, however, as it causes a great environmental impact, it becomes unfeasible and increasingly difficult, considering the progressively stricter environmental legislation. To solve this situation, since the 1980s, studies have been carried out with the objective of developing artificial aggregates, which can replace the materials used today (Erol, 2007).

It is noteworthy that the most common asphalt coatings in Brazil and in the State of Amazonas are Hot Mix Asphalt (HMA or AC) and Sand Asphalt Hot Mix (SAHM) (Singh, 2015). Comparing these two compositions, the SAHM formulation has a lower technical performance compared to the CA, as it does not contain coarse aggregate, such as the crushed stone or the pebble (Manual De Asfalto, 2002). Despite this, there is a greater use of SAHM as compared to HMA, which is justified for economic (the distance to be covered for obtainment of asphalt concrete raw material implies a high transport cost) and environmental (the impact arising from the extraction of rolled pebble from riverbeds) reasons (Bernucci, 2002).

Facing this reality, in the last 20 years the Geotechnics Group (GEOTEC) of Universidade Federal do Amazonas (UFAM) has been conducting researches on alternative materials, in order to find substitutes for traditional materials from nature, as well as to contribute with solutions to the historic problem of regional pavements. Among them, there is the Sintered Aggregate of Calcined Clay (SACC), whose raw material, clay, is present in a large reserve in the Amazon (BACCI, 2006).

Such alternative material has been demonstrated in numerous studies as technically feasible for the construction of pavement coatings and sublayers (Valença Et Al., 2012; Silva Et Al., 2008; Silva, 2009; Silva, 2010; Silva, 2006; Silva Et Al., 2013; Cunha, 2004; Spínola et al., 2019), especially at high temperatures, in contrast to mixtures made with rolled pebble and stone aggregates. Despite this finding, up to the present moment, the SACC has not been commercialized yet.

In this context, the main objective of this article is to analyze economically the production of the HMA, comparing a reference mixture with rolled pebble to an alternative composition, with the presence of SACC.

2. Materials e Methods

This research is quantitative and qualitative and was supported by the work of Silva (2008) to carry out the study, the reference used was the paving of a side road located at the branch of the Purupuru headwater, km 22 of the BR-319 road, with 8.7 km in length, in the Municipality of Careiro, Amazonas. The execution period is of 210 days (Vasudevan, 2013).

To prepare the cash flow, the financial schedule suggested by SEINFRA (Secretariat of Infrastructure and Metropolitan Region of Manaus) was used as a basis, with a BDI of 15% and a profit of 7.5% (Table 1).

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Table 1: Financial schedule.

Description	30 days	60 days	90 days	120 days
	Cost	Cost	Cost	Cost
Work administration	92,848.82	227,219.35	213,661.24	210,998.04
Supply, transport and mobilization Manaus/Careiro (km 22 BR-319)	0.00	1,345,443.37	1,312,279.80	207,974.21
Paving of the Purupuru headwater branch, located at km 22 of the BR-319 road in the Municipality of Careiro, Amazonas	0.00	2,648,552.13	3,216,041.11	3,123,599.48
	92,848.82	**4,221,214.85**	**4,741,982.15**	**3,542,571.73**
	92,848.82	**4,314,063.67**	**9,056,045.82**	**12,598,617.55**

Description	150 days	180 days	210 days
	Cost	Cost	Cost
Work administration	162,092.02	151,923.43	151,802.38
Supply, transport and mobilization Manaus/Careiro (km 22 BR-319)	0.00	0.00	89,327.71
Paving of the Purupuru headwater branch, located at km 22 of the BR-319 road in the Municipality of Careiro, Amazonas	1,102,555.12	50,715.99	159,962.75
	1,264,647.14	**202,639.42**	**401,092.84**
	13,863,264.69	**14,065,904.11**	**14,466,996.95**

Source: SEINFRA (2020).

The reference used was the composition SICRO3 6416078, in which the crushed stone, part of the original formulation, was replaced by rolled pebble and SACC for comparison purposes. The analysis performed consisted of calculating the market price of the production of HMA with the aforementioned materials, making an economic comparison (VILCHES, 2002). To this end, spreadsheets with the composition of unit costs were prepared, arising from research in local commerce and official pricing systems such as SINAPI (National Research System of Civil Construction Costs and Indexes) and SICRO (System of Referential Costs for Works) (Yang, 2013).

3 Results and discussion

In the comparison of the two scenarios, some parameters were considered, such as:

1. To calculate the annual depreciation of the equipment used in scenario 2, the value of 10% of the investment was used;
2. Sales tax was considered at a rate of 21.25%;
3. From the composition of the B.D.I. provided by the contracting agency the percentage of profit was obtained, which is 7.5%;
4. For the Social Contribution on Net Profits (CSLL [Contribuição Social sobre o Lucro Líquido]) the percentage of 24% was used.

The costs of the inputs corresponding to medium sand, stone dust, Petroleum Asphalt Cement (CAP [Cimento Asfáltico de Petróleo)] and pebble, collected from the SINAPI price list of the State of Amazonas, with base date in June 2020 (Table 2). It is noteworthy that these values do not consider the transport of materials (Wang, 2020).

Table 2: Unit value, in BRL, of asphalt mix materials commonly used in the region, based on SINAPI/Amazonas, in 07/2020.

Materials	Unit	Unit Value (BRL)
Medium sand	m^3	75.00
Stone dust	m^3	89.12
CAP	T	2,658.96
Pebble	m^3	119.45

Source: The author.

The unit value of SACC was obtained based on its production for consumption in the work, that is, its direct cost will not consist of the installments referring to Administration/Sales, Taxes and Profitability. The quantities were based on Silva and Frota (2013), and the unit value updated based on July 2020. Thus, the result was equal to BRL 112.88/t, per ton (Table 3).

Table 3: Unit value of production per ton of SACC, for own consumption.

Description	Unit	Quantity	Unit Value (BRL)	Total Value (BRL)
Raw material	m^3	0.83	12.71	10.54
Homogenization	T	1.25	11.39	14.23
Calcination	T	1	87.3	87.3
Facilities	T	1.25	0.65	0.81
			Total Cost	**BRL 112.88**

Source: The author.

In this scenario, taking into account that the bulk density in the loose state is 1,062 kg/m³ (Silva; Frota, 2013), the value obtained for the cubic meter of SACC is 119.88/m³, according to the equation below:

$$BRL\ 112.88/t\ x\ 1.062\,\frac{t}{m^3} = \ BRL\ 119.88/m^3 \quad (5)$$

The reference composition by SICRO3 6416078, which describes the Machining of Asphalt Concrete – Type C – Commercial Sand and Crushed Stone (Table 4), was adapted to a formulation containing Pebble (Table 5). The aforementioned constitution was selected, considering that it is used for contracting works in the State of Amazonas. The base date taken was July 2020, as it represented the most recent during the development of the work. It is noteworthy that machining costs of asphalt mixture containing crushed stone and pebble are of BRL 268.00 and BRL 268.17, respectively (TOZZI, 2017).

Table 4: Machining of Asphalt Concrete containing Crushed Stone in its composition (SICRO 6416078)

A	Equipment	Quantity	Use		Operational Cost		Hourly Cost
			Operative	Unproductive	Operative	Unproductive	
E9559	Thermal fluid heater – 12kW	1.00000	1.00	0.00	40.2357	18.2777	40.2357
E9584	Wheel loader with capacity of 1.53m³ - 106 kW	1.00000	0.57	0.43	139.1054	56.6834	103.6639
E9021	Generator group – 456 kVA	1.00000	1.00	0.00	219.8686	11.2388	219.8686
E9558	Asphalt storage tank with capacity of 30,000 L	2.00000	1.00	0.00	23.9645	16.3325	47.9290
E9689	Gravimetric hot mix asphalt plant with capacity of 100/140 t/h – 260 kW	1.00000	1.00	0.00	771.5101	410.6134	771.5101
						Hourly cost of equipment	1,183.2073
B	**Workforce**	**Quantity**	**Unit**	**Hourly Cost**			**Hourly Cost**
P9824	Servant			16.4322			131.4576
						Total hourly cost of workforce	**131.4576**
						Total hourly cost of execution	**1,314.6649**
						Unit Cost of Execution	**15.8393**
						Rainfall Influence Factor - FIC	
C	**Material**	**Quantity**	**Unit**	**Unit Cost**			**Hourly Cost**
M0028	Medium sand	0.32704	m²	57.6100			18.8408
M0005	Crushed stone 0	0.12579	m²	118.0600			14.8508
M0345	Hydrated lime	56.60377	kg	0.5262			29.7849
M1943	Asphalt cement CAP 50/70	0.05660	t	2658.96			150.4971
M1103	Gravel	0.13836	m²	109.13			15.0992
M1941	Fuel oil 1A	8.00000	l	2.6126			20.9008
						Total unit cost of material	**249,9736**

E	Fixed times	Quantity	Unit	Unit Cost	Hourly Cost
M0028 - 5914647	Medium sand - Loading, maneuvering and unloading sand, crushed stone, hand rock or soil in a 10m² dump truck - loading with loader (excluded) and free unloading	0.49056	T	1.0100	0.50
M0005 - 5914647	Crushed stone 0 - Loading, maneuvering and unloading sand, crushed stone, hand rock or soil in a 10m² dump truck - loading with loader (excluded) and free unloading	0.18869	t	1.0100	0.19
M0345 - 5914655	Hydrated lime - Loading, maneuvering and unloading various materials in a 15t truck body - manual loading and unloading	0.5660	t	22.8500	1.29
M1103 - 5914647	Gravel - Loading, maneuvering and unloading sand, crushed stone, hand rock or soil in a 10m² dump truck - loading with loader (excluded) and free unloading	0.20754	t	1.0100	0.21
				Total cost of fixed times	**2.1890**
				Total Direct Unit Cost	**268.00**

Source: DNIT, 2020.

Table 5: Machining of Asphalt Concrete containing Pebble in its composition.

A	Equipment	Quantity	Use		Operational Cost		Hourly Cost
			Operative	**Unproductive**	**Operative**	**Unproductive**	
E9559	Thermal fluid heater – 12kW	1.00000	1.00	0.00	40.2357	18.2777	40.2357
E9584	Wheel loader with capacity of 1.53m³ - 106	1.00000	0.57	0.43	139.1054	56.6834	103.6639

	kW						
E9021	Generator group – 456 kVA	1.00000	1.00	0.00	219.8686	11.2388	219.8686
E9558	Asphalt storage tank with capacity of 30,000 L	2.00000	1.00	0.00	23.9645	16.3325	47.9290
E9689	Gravimetric hot mix asphalt plant with capacity of 100/140 t/h – 260 kW	1.00000	1.00	0.00	771.5101	410.6134	771.5101
Hourly cost of equipment							1,183.2073
B	**Workforce**	**Quantity**	**Unit**	**Hourly Cost**			**Hourly Cost**
P9824	Servant			16.4322			131.4576
Total hourly cost of workforce							**131.4576**
Total hourly cost of execution							**1,314.6649**
Unit Cost of Execution							**15.8393**
Rainfall Influence Factor - FIC							
C	**Material**	**Quantity**	**Unit**	**Unit Cost**			**Hourly Cost**
M0028	Medium sand	0.32704	m²	57.6100			18.8408
OWN INPUT	Pebble	0.12579	m²	119.45			15.0256
M0345	Hydrated lime	56.60377	kg	0.5262			29.7849
M1943	Asphalt cement CAP 50/70	0.05660	t	2658.96			150.4971
M1103	Gravel	0.13836	m²	109.13			15.0992
M1941	Fuel oil 1A	8.00000	l	2.6126			20.9008
Total unit cost of material							**249.9736**
E	**Fixed times**	**Quantity**	**Unit**	**Unit Cost**			**Hourly Cost**
M0028 - 5914647	Medium sand - Loading, maneuvering and unloading sand, crushed stone, hand rock or soil in a 10m² dump truck - loading with loader (excluded) and free unloading	0.49056	T	1.0100			0.50

M0005 - 5914647	Crushed stone 0 - Loading, maneuvering and unloading sand, crushed stone, hand rock or soil in a 10m² dump truck - loading with loader (excluded) and free unloading	0.18869	t	1.0100	0.19
M0345 - 5914655	Hydrated lime - Loading, maneuvering and unloading various materials in a 15t truck body - manual loading and unloading	0.5660	t	22.8500	1.29
M1103 - 5914647	Gravel - Loading, maneuvering and unloading sand, crushed stone, hand rock or soil in a 10m² dump truck - loading with loader (excluded) and free unloading	0.20754	t	1.0100	0.21
				Total cost of fixed times	**2.1890**
				Total Direct Unit Cost	**268.17**

Source: DNIT (2020).

It should be noted that the cost of machining with the asphalt formulation containing crushed stone is BRL 268.00, and with pebble it is around BRL 268.17.

Subsequently, a new adaptation was carried out, considering now the clay aggregate (SACC), which resulted in the value of BRL 268.23 (Table 6).

Table 6: Machining of Asphalt Concrete containing SACC in its composition.

A	**Equipment**	**Quantity**	**Use**		**Operational Cost**		**Hourly Cost**
			Operative	**Unproductive**	**Operative**	**Unproductive**	
E9559	Thermal fluid heater – 12kW	1.00000	1.00	0.00	40.2357	18.2777	40.2357
E9584	Wheel loader with capacity of 1.53m³ - 106 kW	1.00000	0.57	0.43	139.1054	56.6834	103.6639
E9021	Generator group – 456 kVA	1.00000	1.00	0.00	219.8686	11.2388	219.8686

E9558	Asphalt storage tank with capacity of 30,000 L	2.00000	1.00	0.00	23.9645	16.3325	47.9290
E9689	Gravimetric hot mix asphalt plant with capacity of 100/140 t/h – 260 kW	1.00000	1.00	0.00	771.5101	410.6134	771.5101
						Hourly cost of equipment	1,183.2073
B	**Workforce**	**Quantity**	**Unit**	**Hourly Cost**			**Hourly Cost**
P9824	Servant			16.4322			131.4576
						Total hourly cost of workforce	**131.4576**
						Total hourly cost of execution	**1,314.6649**
						Unit Cost of Execution	**15.8393**
						Rainfall Influence Factor - FIC	
C	**Material**	**Quantity**	**Unit**	**Unit Cost**			**Hourly Cost**
M0028	Medium sand	0.32704	m²	57.6100			18.8408
OWN INPUT	SACC	0.12579	m²	119.88			15.0797
M0345	Hydrated lime	56.60377	kg	0.5262			29.7849
M1943	Asphalt cement CAP 50/70	0.05660	t	2658.96			150.4971
M1103	Gravel	0.13836	m²	109.13			15.0992
M1941	Fuel oil 1A	8.00000	l	2.6126			20.9008
						Total unit cost of material	**250.2025**
E	**Fixed times**	**Quantity**	**Unit**	**Unit Cost**			**Hourly Cost**
M0028 - 5914647	Medium sand - Loading, maneuvering and unloading sand, crushed stone, hand rock or soil in a 10m² dump truck - loading with loader (excluded) and free unloading	0.49056	T	1.0100			0.50
M0005 - 5914647	Crushed stone 0 - Loading, maneuvering and unloading sand, crushed stone, hand rock or soil in a 10m² dump	0.18869	t	1.0100			0.19

	truck - loading with loader (excluded) and free unloading				
M0345 - 5914655	Hydrated lime - Loading, maneuvering and unloading various materials in a 15t truck body - manual loading and unloading	0.5660	t	22.8500	1.29
M1103 - 5914647	Gravel - Loading, maneuvering and unloading sand, crushed stone, hand rock or soil in a 10m² dump truck - loading with loader (excluded) and free unloading	0.20754	t	1.0100	0.21
				Total cost of fixed times	**2.1890**
				Total Direct Unit Cost	**268.23**

Source: DNIT (2020).

According to SEBRAE (2019), the cost to implement a pottery varies between BRL 466,340.00 and BRL 759,050.00. In this research, the average value of BRL 612,695.00 was adopted for a plant with a monthly production of 200 thousand/month, production sufficient to supply the work on screen. Table 7 shows the cash flow from road construction using HMA containing pebble and Table 8 shows the cash flow with the mixture containing SACC (Hall, 2007).

Table 7: Cash flow from highway construction using HMA with pebble.

Description	**0 year**	**30 days**	**60 days**	**90 days**	**120 days**	**150 days**	**180 days**	**210 days**
Gross Revenue (BRL)	-	92,848.82	4,221,214.85	4,741,982.15	3,542,571.73	1,264,647.14	202,639.42	401,092.84
(-) Prop. Tax on Sales (BRL)	-	19,730.37	897,008.16	1,007,671.21	752,796.49	268,737.52	43,060.88	85,232.23
(=) Net Revenue (BRL)	-	73,118.45	3,324,206.69	3,734,310.94	2,789,775.24	995,909.62	159,578.54	315,860.61
(-) Fixed and Variable Production Costs (BRL)	-	66,433.33	3,020,279.23	3,392,888.23	2,534,710.07	904,855.03	144,988.51	286,981.93
(=) Gross Profit (BRL)	-	6,685.12	303,927.47	341,422.71	255,065.16	91,054.59	14,590.04	28,878.68
(-) Variable General Expenses	-	-	-	- -	-	-	-	-
(-) Fixed General Expenses	-	-	-	- -	-	-	-	-

(-) Financial Expenses	-	-	-	- -	-	-	-	-
(=) Net Income before Income Tax (BRL)	-	6,685.12	303,927.47	341,422.71	255,065.16	91,054.59	14,590.04	28,878.68
(-) Depreciation (BRL)	-	-	-	- -	-	-	-	-
(=) Operating Profit (BRL)	-	6,685.12	303,927.47	341,422.71	255,065.16	91,054.59	14,590.04	28,878.68
(+) Active sales result	-	-	-	- -	-	-	-	-
(=) Taxable Income (BRL)	-	6,685.12	303,927.47	341,422.71	255,065.16	91,054.59	14,590.04	28,878.68
Income Tax / Social Contribution on Net Profits (BRL)	-	1,604.43	72,942.59	81,941.45	61,215.64	21,853.10	3,501.61	6,930.88
Net Income after Income Tax (BRL)	-	5,080.69	230,984.88	259,481.26	193,849.53	69,201.49	11,088.43	21,947.80
(-) Amortization	-	-	-	- -	-	-	-	
(-) Investments (BRL)	0.00	-	-	- -	-	-	-	-
(+) Release Financing	-	-	-	- -	-	-	-	-
(+) Residual Value	-	-	-	- -	-	-	-	-
Enterprise Cash Flow (BRL)	0.00	5,080.69	230,984.88	259,481.26	193,849.53	69,201.49	11,088.43	21,947.80
Internal Rate of Return	-	-	Minimum Attractiveness Rate	6.50%				
Expected Rate of Return	10%		Income Tax / Social Contribution on Net Profits	24%				
Net Present Value	BRL 583,359.85		Residual Value	-				
Payback	0		-	-				
Days for investment return	0		-	-				

Source: The author.

Table 8: Cash flow from highway construction using HMA with SACC.

Description	0 year	30 days	60 days	90 days	120 days	150 days	180 days	210 days
Gross Revenue (BRL)	-	92,848.82	4,221,214.85	4,741,982.15	3,542,571.73	1,264,647.14	202,639.42	401,092.84
(-) Prop. Tax on Sales (BRL)	-	19,730.37	897,008.16	1,007,671.21	752,796.49	268,737.52	43,060.88	85,232.23
(=) Net Revenue (BRL)	-	73,118.45	3,324,206.69	3,734,310.94	2,789,775.24	995,909.62	159,578.54	315,860.61
(-) Fixed and Variable Production Costs (BRL)	-	66,209.57	3,010,106.10	3,381,460.05	2,526,172.47	901,807.23	144,500.14	286,015.29
(=) Gross Profit (BRL)	-	6,908.88	314,100.60	352,850.89	263,602.76	94,102.39	15,078.40	29,845.32
(-) Variable General Expenses	-	-	-	-	-	-	-	-
(-) Fixed General Expenses	-	-	-	-	-	-	-	-
(-) Financial Expenses	-	-	-	-	-	-	-	-
(=) Net Income before Income Tax (BRL)	-	6,908.88	314,100.60	352,850.89	263,602.76	94,102.39	15,078.40	29,845.32
(-) Depreciation (BRL)	-	-	-	-	-	-	-	-
(=) Operating Profit (BRL)	-	6,908.88	314,100.60	352,850.89	263,602.76	94,102.39	15,078.40	29,845.32
(+) Active sales result	-	-	-	-	-	-	-	-
(=) Taxable Income (BRL)	-	6,908.88	314,100.60	352,850.89	263,602.76	94,102.39	15,078.40	29,845.32
Income Tax / Social Contribution on Net Profits (BRL)	-	1,658.13	75,384.14	84,684.21	63,264.66	22,584.57	3,618.82	7,162.88
Net Income after Income Tax (BRL)	-	5,250.75	238,716.45	268,166.68	200,338.10	71,517.82	11,459.58	22,682.44
(-) Amortization	-	-	-	-	-	-	-	-
(-) Investments (BRL)	612,695.00	-	-	-	-	-	-	-
(+) Release Financing	-	-	-	-	-	-	-	-
(+) Residual Value	576,956.50	-	-	-	-	-	-	-
Enterprise Cash Flow (BRL)	-35,738.50	5,250.75	238,716.45	268,166.68	200,338.10	71,517.82	11,459.58	22,682.44

Internal Rate of Return	218%	-	Minimum Attractiveness Rate	6.50%
Expected Rate of Return	10%		Income Tax / Social Contribution on Net Profits	24%
Net Present Value	BRL 567,147.70		Residual Value	94.17%

Payback	0.305781401		-	-
Days for investment return	111.6102113		-	-

Source: The author.

4 Conclusion

The results found in the comparative study regarding the production of asphalt concrete in the paving of the side road, located at km 22 of the BR-319 road, demonstrate that the use of the SACC showed only a slight increase replacing the rolled pebble in the unit cost of the HMA, around 0.063%.

It is worth mentioning that in the economic feasibility study two scenarios were analyzed. The first, considering the traditional materials in which the NPV was BRL 583,359.85 (five hundred and eighty-three thousand, three hundred and fifty-nine reais and eighty-five cents), with no amount being calculated for IRR and PAYBACK, since there is no initial investment in this option. In the second, using the alternative material, SACC, the IRR value was 218%, with a PAYBACK of 111.61 days and a NPV of BRL 567.147,70 (five hundred and sixty-seven thousand, one hundred and forty-seven reais and seventy cents).

Comparing the two scenarios, it is ratified that the use of SACC replacing traditional aggregates in the paving of highways in the North Region is fully economically viable, especially in locations far from Manaus, notably in the southwest region of the State of Amazonas, an area lacking in stone material. It is recommended as future works the realization of a study considering stretches of 30 km, 40 km and 50 km of road, as well as with different periods of execution.

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