Assessment of Alternative Pavement Options for Local Roads in Guimaras, Philippines

Nelson DOROY [a], Alexis FILLONE [b], Ramilo VILLASIS [c], Evan ARIAS [d], Reynaldo ASUNCION [e]

[a] *School of Urban and Regional Planning, University of the Philippines, Quezon City, Philippines; E-mail: nelsondoroy@gmail.com*
[b] *College of Engineering, De La Salle University, Manila, Philippines; E-mail: amfillone@gmail.com*
[c] *Provincial Government of Guimaras, Jordan, Guimaras, Philippines; Email: ramil_villasis@yahoo.com*
[d] *College of Public Administration, Central Philippines University, Iloilo City, Philippines; E-mail: Evan_Arias@prmf.org.ph*
[e] *College of Engineering, University of San Agustin Gen. Luna St., Iloilo City; E-mail: rmasuncion2000@gmail.com*

Abstract: The road network in the Philippines is integral to the country's over-all transportation infrastructure. The National Government through the Department of Public Works and Highways (DPWH) develops and manages the national roads, while the local government units (LGUs) have jurisdiction over local roads. Due to local fiscal constraints, most provincial governments have difficulty ensuring their provincial roads provide the necessary accessibility and mobility for people and goods under their jurisdiction. Provincial governments do not have the luxury of resources that can be used to fully pave its entire provincial road network. This research will assess appropriate pavement options for local roads in Guimaras Province. The research will undertake a comparative assessment of recommended pavements including its performance against local conditions. The research will estimate life-cycle costs for the assessed pavements and will recommend to Guimaras appropriate alternative pavements that are best suited to local conditions and availability of pavement materials.

Key words**:** local roads, alternative pavements, life-cycle cost, pavement performance

1. INTRODUCTION

1.1. Overview

Local roads are key components of the road network in the Philippines. They support the local movement of people and goods amongst communities, production areas and markets. The development and management of local roads have been the mandate of local government units (LGUs) by virtue of the implementation of the Local Government Code of 1991. Local road management is thus a critical function of the LGUs as they provide public services and goods.

The road network in the Philippines is an integral component of the country's transportation infrastructure. Roads are classified as either national or local roads. The National Government (NG) through the Department of Public Works and Highways (DPWH) develops and manages the national roads while the local government units (LGUs) have jurisdiction over local roads. The local roads are further stratified as provincial, city, municipal and barangay roads, which correspond to the level of local government having administrative jurisdiction over it (i.e., provincial governments over provincial roads, city and municipal governments over city and municipal roads, and barangay councils for barangay roads). The Department of the Interior and Local Government (DILG) provides technical support and assistance to LGUs in the area of local road management.

In 2012, the country has 31,597.68 km of national roads as listed by DPWH in its road atlas. In terms of pavement, 80.52% of the national roads are paved, while 19.48% are unpaved. For the same year, there are 7,928 national bridges with an aggregate length of 348,574 linear meters. On the other hand, in terms of data for local roads that DILG is managing, there are 31,620.213 km of provincial roads in 2013, for which 32.737% are paved and 66.778% are unpaved. Likewise, city roads have an aggregate length of 15,247.390 km with 61.984% of these roads being paved and 35.313% being unpaved.

The Province of Guimaras has a total road length of 761.320 kilometers. National roads in Guimaras account for 16.94% (128.962 km), provincial roads account for 15.87% (120.81 km) while municipal/barangay roads account for 67.19% (511.55 km).

Due to local fiscal constraints, most provincial governments have difficulty ensuring their provincial roads provide the necessary accessibility and mobility for people and goods under their jurisdiction. Provincial governments do not have the luxury of resources that can be used to fully pave its entire provincial road network. The over-all strategy to address this situation is to maximize the value for money in the selection and investment of pavements for local roads that is appropriate for the traffic volume and other local environmental conditions of the site. The national government and the local government units should avoid the default and common misconception of using concrete pavements for roads that have very low volume but will provide greater political mileage for the incumbents. Cement-stabilization and the use of alternative aggregate materials could be better alternatives and could provide higher value for money for provincial governments. It is in this context that the research will assess appropriate pavement options for local roads with the Province of Guimaras as the case study. The research will then undertake a comparative assessment and monitoring of recommended pavements including its performance against local traffic and site conditions. The research will estimate life-cycle costs for the assessed pavements and will recommend to the provincial government appropriate alternative pavements that are best suited to local conditions and availability of pavement materials.

1.2. Objectives

The broad objective of this study is to assess pavement options that are appropriate for local roads in the Province of Guimaras. In this context, the specific objectives of the research are:

a. To test locally-sourced aggregate materials that will comply with the standard specifications for pavements of local roads;
b. To design an optimum mix of pavement materials for cement-stabilized aggregate base (CSAB) that can be used by the Provincial Government for its local roads;
c. To construct and monitor a test section of CSAB to determine its performance against local traffic volume; and
d. To compare the performance of CSAB against typical pavements used for the local roads in the Province.

1.3. Study Area

Guimaras is a fourth class island province of the Philippines located in the Western Visayas region (Figure 1). Among the smallest provinces, its capital is Jordan. The island is located in the Panay Gulf, between the islands of Panay and Negros. To the northwest is the province of

Iloilo and to the southeast is Negros Occidental. The Province has five municipalities with Jordan as the capital town. Guimaras has a total land area of 604.57 sq. km. with a total population of 162,943 as of 2010. In the 2008 land use data, built-up areas account only for less than one percent of the total provincial land area. About 44.19 percent of the province is allocated to other land uses such as the naval reserve, open spaces, areas for pastures, ravines and shrubs which account for the biggest share in the provincial land use.

Guimaras has 120.8 km of provincial roads, for which majority (52%) are earth or gravel pavement. More than half (58%) of the total length of provincial roads are in poor condition, 5% in bad condition, 31% in fair condition, and 5% in good condition (refer to Figure 2). Concrete provincial roads account for about 27% of the total length, asphalt surface covers roughly 2%, and the asphalt surface treatment accounts for around 19% of the total provincial road length (see Figure 3).

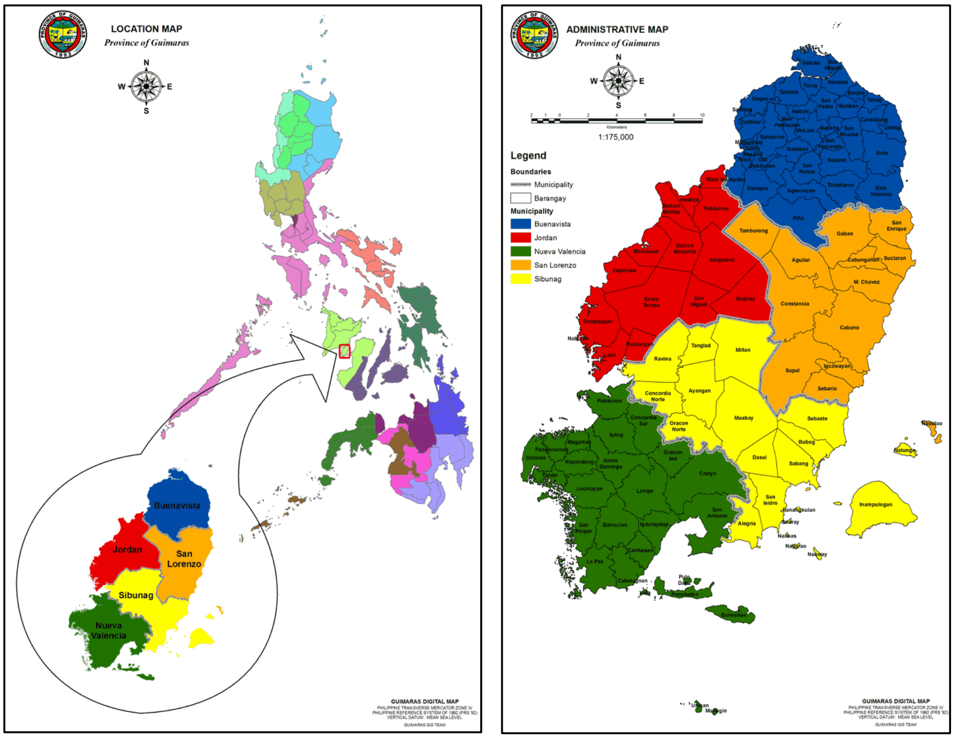


Figure 1. Map of the Province of Guimaras

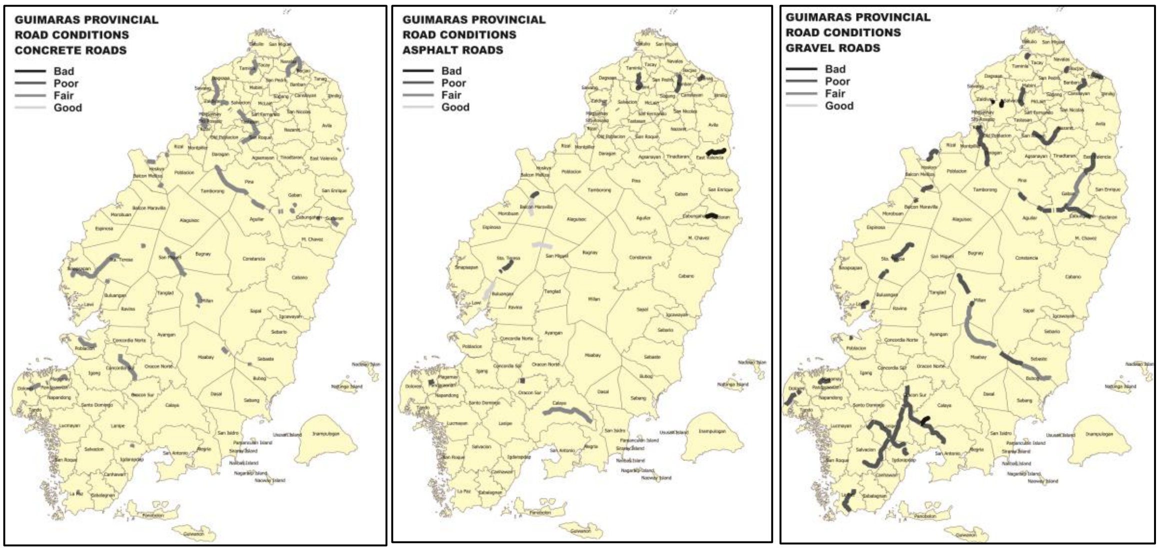


Figure 2. Pavement Conditions of Provincial Roads of Guimaras

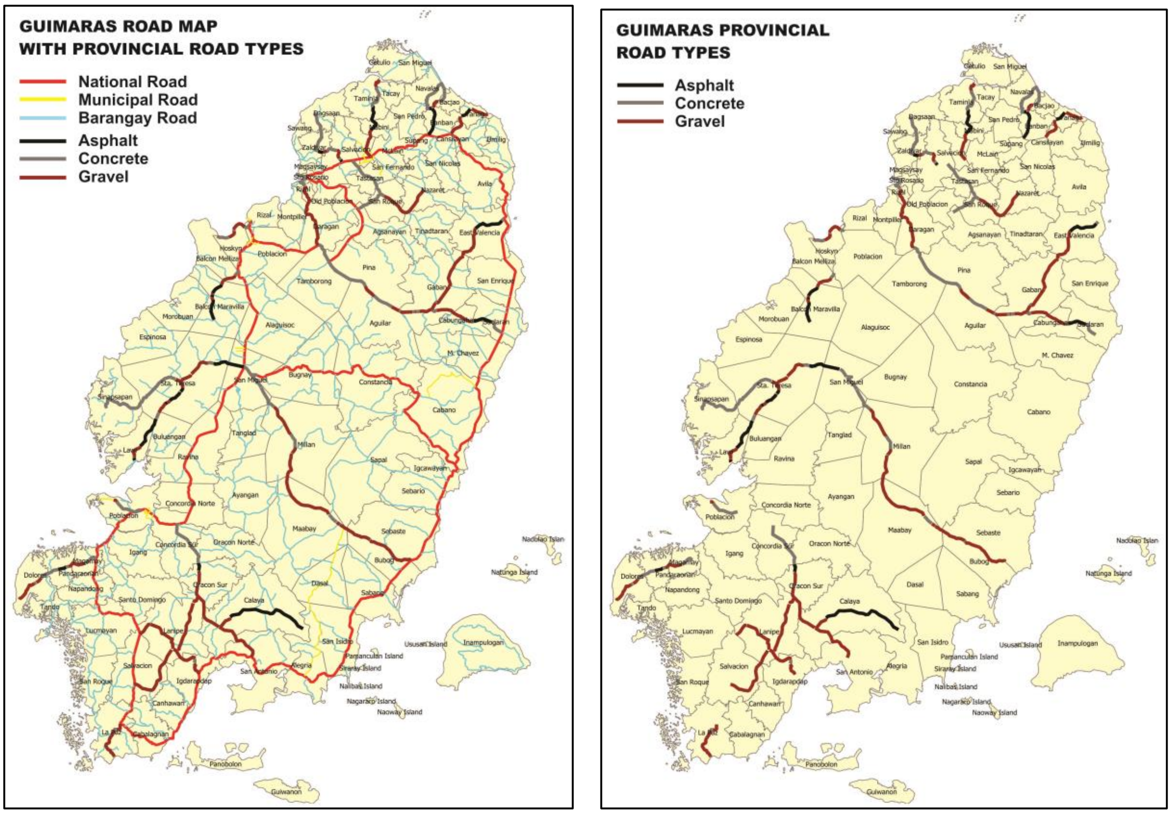


Figure 3. Pavement Types of Provincial Roads of Guimaras

2. REVIEW OF RELATED LITERATURE

Pavement researches in the country are normally undertaken by the National Government (e.g. Department of Public Works and Highways [DPWH]) or by official development assistance (ODAs) as part of their development programs. The methodologies for sampling, testing and design for pavements are typically adopted from the American Society for Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO). To the extent possible, this study shall adopt the pavement standards and related methodologies prescribed by the DPWH and the recently launched Local Road Management Manual of the DILG.

The Department of Public Works and Highways (DPWH) issued in 2013 its latest “Standard Specifications for Public Works and Highways”. Cement stabilized aggregate base (CSAB) are officially categorized by the DPWH as Item 204 (Portland Cement Stabilized Road Mix Base Course). This Item shall consist of a foundation for surface source composed of soil-aggregate, Portland Cement and water in proper proportions, road-mixed and constructed on a prepared subgrade/subbase in accordance with this. The said reference mandates CBR Test for Gravelly Soils. The mixture passing the 19 mm (3/4 inch) sieve shall have a minimum soaked CBR-value of 100% tested according to AASHTO T 193. The CBR-value shall be obtained at the maximum dry density determined according to AASHTO T 180, Method D. The same reference also requires Unconfined Compression Test for Finer Textured Soils. The 7-day compressive strength of laboratory specimen molded and compacted in accordance with ASTM D 1632 to a density of 100% of maximum dry density determined according to AASHTO T 134, Method B, shall not be less than 2.1 MPa (300 psi) when tested in accordance with ASTM D 1633. This study follows this reference from the DPWH.

The University of Canterbury of New Zealand had a study on the application of low-volume road maintenance management systems in the Philippines (Bangasan 2006). Most of the local roads in the country are gravel roads, which are technically termed as unsealed low-volume roads. The study reviewed and compared the maintenance management systems between New Zealand and Philippines. The research proposed performance-based specifications for sealed (paved) and unsealed (gravel) roads. The study concluded that performance-based specifications result to a more efficient and effective system of maintenance especially for unsealed low-volume roads such as the case of local gravel roads in the Philippines.

The University of the Philippines also had a research on the adoption of a pavement management system (PMS) for local governments (Domingo 2002). The study developed a simple PMS that can be implemented by LGUs, which includes a knowledge-base expert system application software for data storage and analysis of pavement distress. A pavement condition index rating system was also used to ascertain the pavement condition. These software applications were validated through actual road condition surveys. The results proved to be consistent with standard practices of road maintenance treatments for varying pavement conditions.

Cement stabilized aggregate base (CSAB) courses provide an alternative for the conventional concrete or gravel roads. According to Abdo (2009) of the Portland Cement Association (PCA), a cement-treated base course is an intimate mixture of native and/or manufactured aggregates with measured amounts of Portland cement (and possibly other cementitious materials) and water that hardens after compaction and curing to form a strong durable paving material. The use of CSAB as an alternative pavement material is seldom used in the country and has not been tested for low-volume local roads.

There is therefore a general lack of research endeavour in the Philippines towards the assessment of alternative pavement materials for local roads particularly the use of cement-stabilized aggregate base. It is in this light that this study seeks to address the gap of the body of literature in the country concerning alternative pavements for low volume local roads.

3. METHODOLOGICAL FRAMEWORK

The study is a research and innovation project under the Provincial Road Management Facility (PRMF) that is funded by the Australian Government and that is implemented through the DILG and ten partner provinces in Visayas and Mindanao. The study thus follows the approach of engagement and partnership with local institutions. In this case, PRMF partnered with the Provincial Government of Guimaras and the University of San Agustin, which is one of the major universities in Iloilo and Region VI.

The study follows the typical design methodology for road pavements as illustrated in Figure 4. The input variables are carefully collected to ascertain the ambient conditions of the site, which is used as the basis of design and assessment. The input variables are collected by the study team and these variables pertain to the condition of the site, namely:

a. Construction and Maintenance Factors;
b. Traffic and Growth Rate;
c. Environmental Factors;
d. Subgrade Soil;
e. Pavement Materials; and
f. Pavement Configuration.

ASTM and AASHTO standards and procedures are used in the design and assessment process. The study then proceeds to the final selection of design, the construction and monitoring of the test sites, and finally the evaluation of the performance of the said alternative pavement materials.

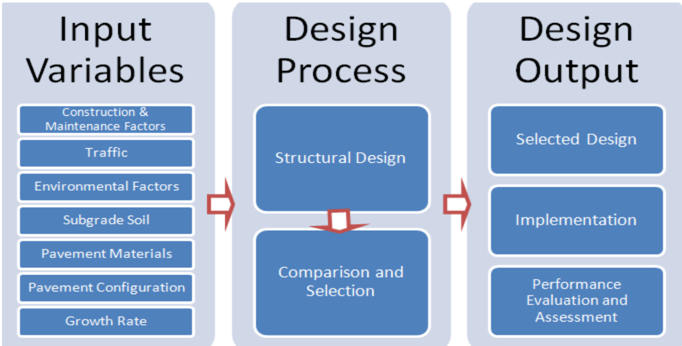


Figure 4. Design Methodological Framework of the Study

The study will locate, identify and test potential aggregate materials that are present in Guimaras. Once the aggregate materials are determined to have complied with the standard specifications for pavement materials, the study will proceed to the design of an optimum mix of pavement materials for a Cement-Stabilized Aggregate Base that will be constructed by the Provincial Government on a sample test section.

In terms of comparative pavement assessment, the study will select a base 1-km test section, preferable a section of a provincial road that contains gravel, asphalt and concrete pavements. The study will also construct a 1-km comparable test section based on the design optimum mix using the Wirtgen Road Recycler and Stabilizer of the Provincial Government. These two test sections will be monitored and evaluated in terms of pavement performance based on local traffic condition, which are also identical in nature.

4. SUMMARY OF FINDINGS

4.1. Selection of Test Sections

The study selected two test sections (see Figure 5 for the Road Map) that are similar in geophysical and traffic conditions. The base test section is the Concordia-Oracon Provincial Road, which has sections composed of gravel, asphalt and concrete pavements. In contrast, the alternative test section is the Pina-Suclaran Provincial Road (Figure 5), where the Provincial Government will construct a CSAB based from the design optimum mix of pavement materials.

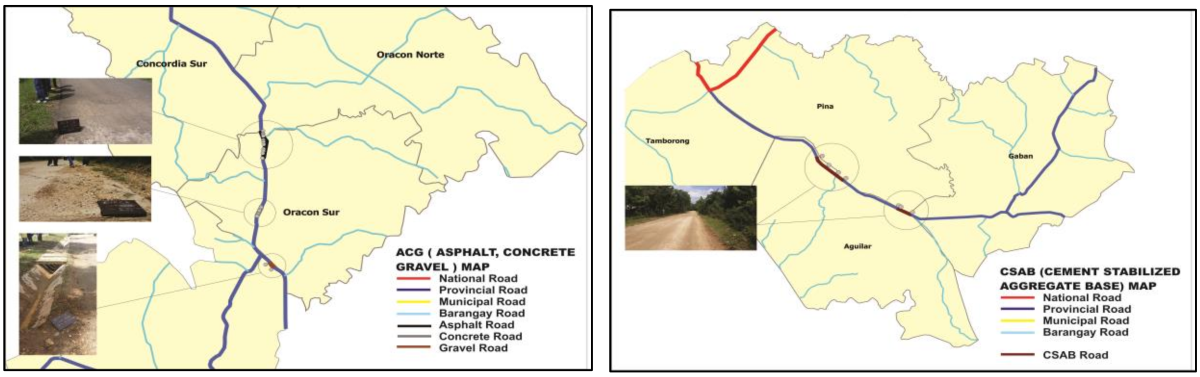


Figure 5. Road Map of Base and Alternative Test Sections

The study conducted classified traffic counts (Figure 6) on both test sections to determine if they have the same traffic volume profile and to use as basis for the design of pavement for the alternative test section. The average traffic volume in Passenger Car Units (PCUs) of the base test section is 74.22, whereas for the alternative test section is 48.17. The traffic volume counts (Figure 7) would also show that the dominant type of vehicle passing along both test sections is motorcycle. Furthermore, truck volume and loading are not significant for both test sections.

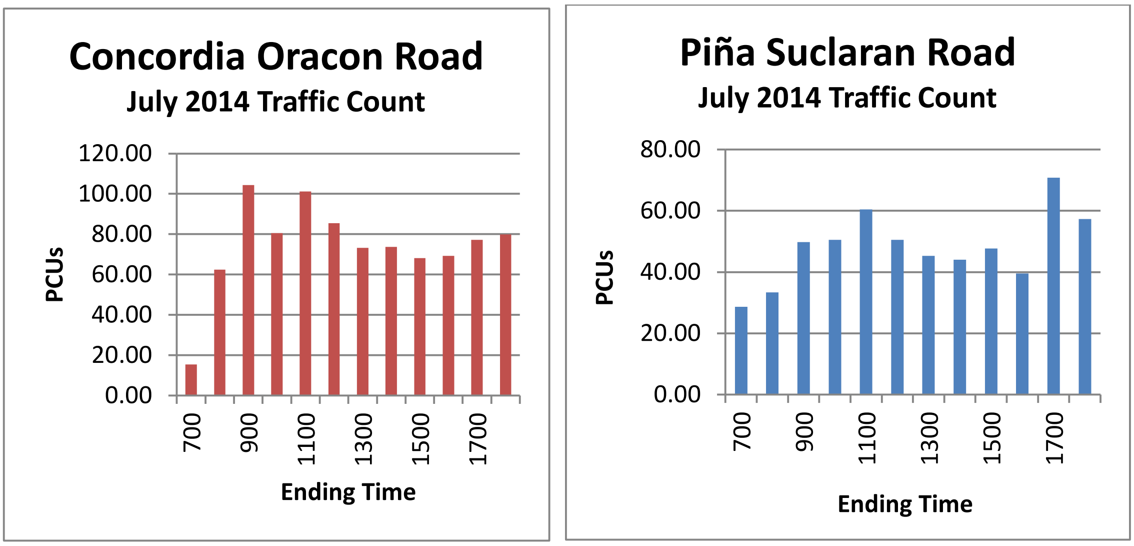


Figure 6. Traffic Volume Count of Base and Alternative Test Sections

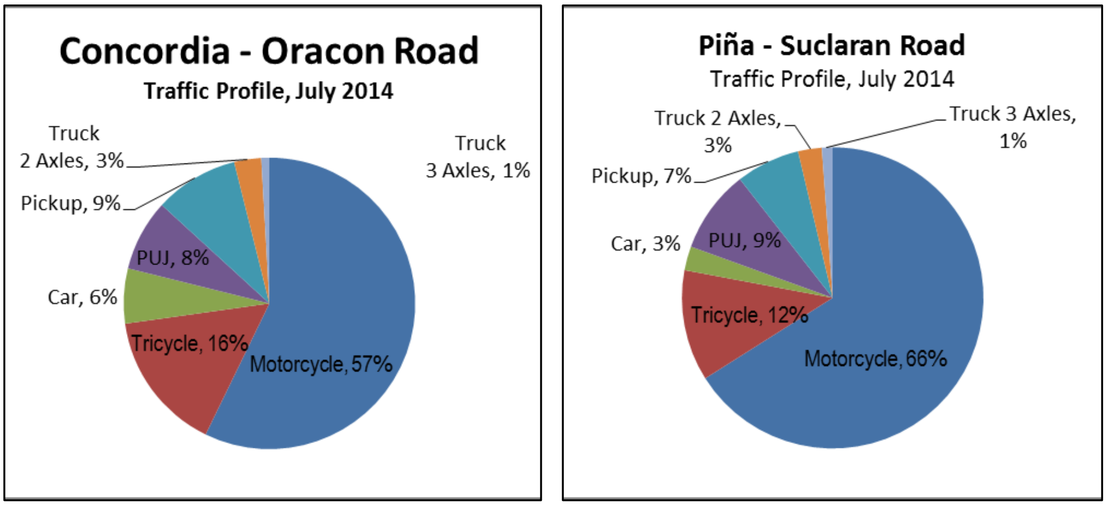


Figure 7. Traffic Volume Profile of Base and Alternative Test Sections

4.2. Testing of Potential Pavement Materials

The study sampled and tested aggregate materials from ten limestone quarry sites in the towns of Buenavista. Aggregate materials from a mine site in Nueva Valencia were also sampled and tested, as well as the aggregate materials from Alano and Cabano Rivers. The tests performed were sieve analysis, unit weight, abrasion for coarse aggregates and moisture content.

The limestone from Quarry Site No. 10 was considered as aggregate potential for the proposed CSAB road because of its low abrasion value as can be seen in Table 1. Mixed

Aggregates from San Antonio was considered as aggregate potential for the proposed CSAB road because of its abrasion value and supply sustainability as listed in Tables 2 and 3.

Table 1. Test Results for Sampled Limestone Materials

QUARRY SITE NO.	MOISTURE CONTENT (MC)	ABRASION VALUE (AV)	REMARKS
2	12.7	64.4	MC >2.5, AV>40
6	2.917	64.8	MC >2.5, AV>40
7	22.419	61.6	MC >2.5, AV>40
8	5.522	56.4	MC >2.5, AV>40
9	3.1	58.4	MC >2.5, AV>40
10	3.348	33.2	MC >2.5, AV is ok
15	6.823	60.4	MC >2.5, AV>40
17	1.613	49.2	MC is ok, AV>40
18	5.926	54.8	MC >2.5, AV>40
21	4.301	79.6	MC >2.5, AV>40

Table 2. Test Results for Sampled Coarse Aggregate Materials

Test	San Antonio	Cabano River	Avila River	Remarks
Average Size of Coarse Aggregate	25.4mm	4.76mm	25.4mm	San Antonio have mixed fine and coarse aggregates
Average Size of Fine Aggregate	2.38mm	NA	NA	
Unit Weight (kg/m3)	Loose = 1418 Rodded = 1542	Loose = 1737 Rodded = 1826	Loose = 1806 Rodded = 1924	All values > 1120, acceptable
Abrasion Loss (for Coarse Aggregate)	33.32%	36.38%	27.76%	All values < 40%, acceptable, hardest aggregates from Avila River
Moisture Content(MC)	6.47%	0.93%	1.39%	Cabano and Avila MC<2.5%, Acceptable
Wash Loss % on No. 200	24.85	0.58%	0.78%	Cabano and Avila Wash Loss % <1%, Acceptable

Table 3. Test Results for Sampled Fine Aggregate Materials

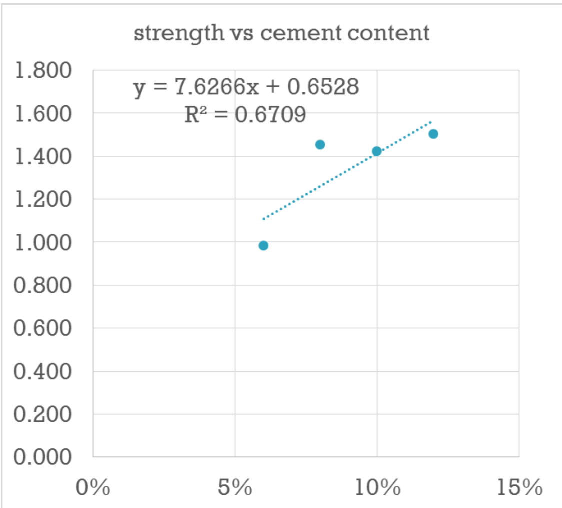
Test	San Antonio	Cabano River	Avila River	Remarks
Average Size of Fine Aggregate	NA	0.595mm	2.38mm	Mixed aggregate for San Antonio
Unit Weight (kg/m^3)	NA	Loose = 1418 Rodded = 1562	Loose = 1461 Rodded = 1711	All values > 1120, acceptable
Moisture Content(MC)	NA	1.07%	4.14%	only Cabano MC<2.5%, Acceptable
Wash Loss % on No. 200	NA	1.12%	2.92%	Cabano and Avila Wash Loss % <3%, Acceptable

4.3. Preparation and Test of Design Mix

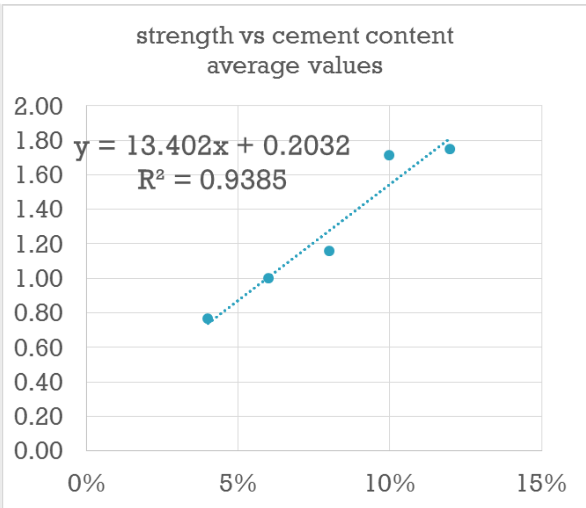
Four CSAB Design Mixes were made, namely: (1) Soil and Cement; (2) Soil and Aggregate Mix (1:1); (3) Soil and Aggregate Mix (1:2); and (4) Soil, Limestone and Aggregate Mix

(1:1:1). Five proportions were prepared for each design mix at 4, 6, 8, 10 and 12 percent by volume *(note: the sample for 4% cement content for soil-cement mix was discarded due to very low compressive strength results)*. ASTM Tests for Soil Cement Mixes were followed in making and curing of the laboratory specimen samples. Three samples for each proportion were made and tested at 7 days.

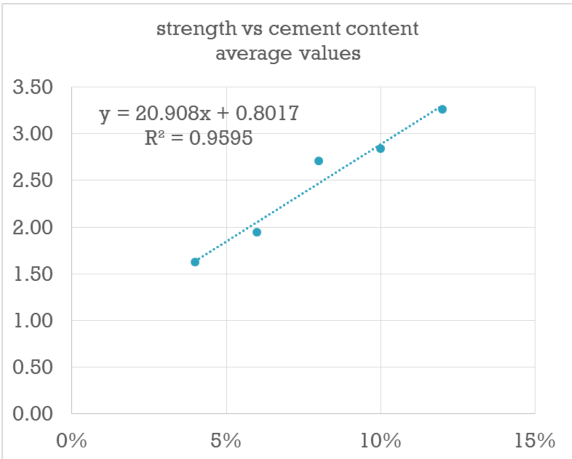
The results of the testing of the four design mixes are shown in Figure 8. From the tests, the ideal design mix to attain the required compressive strength for CSAB pavement is Soil-Aggregate (1 part Soil: 2 parts aggregate) with a cement content of 5.73%, and Soil-Aggregate-Lime (1 part Soil: 1 part aggregate: 1 part lime) with a cement content of 5.90%. These two design mixes will be adopted in the alternative test section as they use the minimum amount of cement, thereby lowering the cost of construction and maintenance. The required percentage cement contents are shown in Table 4 to attain the design compressive strength of 2 MPa, which is the design specification of DPWH for CSAB pavements.



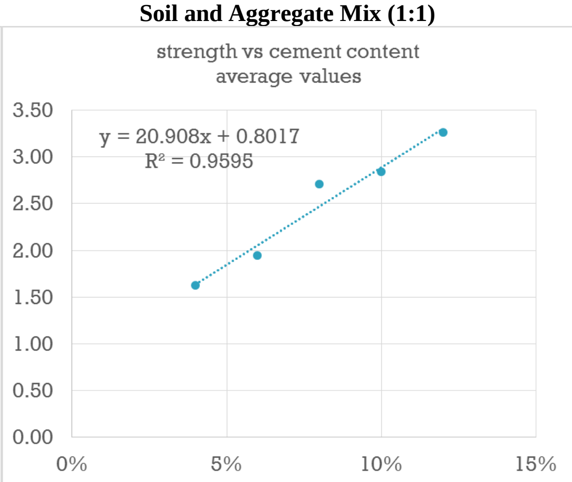
Soil and Cement Mix



Soil and Aggregate Mix (1:1)



Soil and Aggregate Mix (1:2)



Soil, Limestone and Aggregate Mix (1:1:1)

Figure 8. Summary Graph of CSAB Design Mix and Compressive Strength in Mpa

Table 4. CSAB Cement Content Required to Attain 2 MPa Compressive Strength

DESIGN MIX	% CEMENT
Soil-Cement	17.66
Soil-Aggregate (1 part Soil: 1 part aggregate)	13.41

DESIGN MIX	% CEMENT
Soil-Aggregate (1 part Soil: 2 parts aggregate)	5.73
Soil-Aggregate –Lime (1 part Soil: 1 part aggregate: 1 part lime)	5.90

4.4. Comparative Cost Assessment

The construction costs for the design mixes were comparatively assessed to determine cost efficiency (Table 5). The costs assume only the construction of sub-base course and surface of the 1-km carriageway width of 6.1 m, but excluding costs for drainage and shoulders. The design mixes for Soil-Aggregate (1 part Soil: 2 parts aggregate) and Soil-Aggregate–Lime (1 part Soil: 1 part aggregate:1 part lime) have the lowest construction costs and cost per square meter. The costs in Table 5 includes the cost of materials including cement and aggregates.

Table 5. Comparative Cost Assessment of CSAB Design Mixes

CSAB Design Mix	Recommended Cement Content (%)	Construction Cost (PhP)	Cost per m^2 (PhP/m2)	Total No of Cement Bags	No of Bags/m^2
Soil Cement	17.66	7,836,550.15	1,284.68	23804	3.9
Soil-Aggregate (1 part Soil:1 part aggregate)	13.41	6,552,807.37	1,074.23	18,076	3.0
Soil-Aggregate (1 part Soil:2 parts aggregate)	5.73	3,599,537.80	590.09	7,724	1.3
Soil-Aggregate – Lime (1 part Soil:1 part aggregate:1 part lime)	5.90	3,601,703.50	590.44	7,953	1.3

On the other hand, the construction cost of the two selected CSAB design mixes were compared against the construction costs of concrete, asphalt, and gravel pavement (Table 6). The CSAB is shown to have a lowest cost at Php 3.599 Million compared against other pavements.

Table 6. Comparative Cost Assessment of Different Pavements

Type of Pavement	Cost (PhP)
Concrete	13,097,560.00
Asphalt	12,021,186.00
CSAB	3,599,537.80
Gravel	4,339,386.00

4.5. Pavement Performance

As mentioned, different pavements on the base section were assessed and compared against the performance of the alternative section having the CSAB pavement. Where applicable, core samples were taken and tested from a representative section of the respective pavements.

4.5.1. Asphalt Pavement (Base Section)

There is observed weathering of asphalt and raveling of exposed aggregate particles is evident in the constructed asphalt road. This may occur because of the loss of bond between asphalt and aggregates due to various factors such as dust in the aggregates, hardening of asphalt cement, segregation of aggregates, and inadequate compaction. Table 7 shows the core sample testing of the asphalt pavement.

Table 7. Thickness and Density of Core Sample of Asphalt Pavement (Base Section)

Sample No.	Average Thickness	Specific Gravity (lab. standard at 2.26)	% Degree of Compaction
1	49.8 mm	2.206	97.61
2	58.50 mm	2.210	97.79
3	51.35 mm	2.207	97.65

4.5.2. Gravel Pavement (Base Section)

Dust formation is apparent in the gravel road due to weathering of aggregates. The presence of wheel track rutting is also seen on this road (STA 0+240 to STA 0+720). Loose gravel is noticeable near STA 1+000. Some portions of the drainage ditches are clogged by debris such as leaves and small branches of trees (near STA 1+240 and STA 2+000). Cracked drainage canals were seen at STA 1+820 and STA 1+860.

4.5.3. Concrete Pavement (Base Section)

Small potholes are observed scattered in the concrete pavement. These holes could be due to breakup of small aggregates protruding from the pavement. Rebound hammer tests were conducted at the beginning, middle and end of this pavement to determine its compressive strength. Table 8 shows the test results for the strength of the existing concrete pavement at selected locations of the test section.

Table 8. Rebound Hammer Test Results for Concrete Pavement (Base Section)

Location	Ave. Compressive Strength (MPa)
#1	25.03
#2	33.54
#3	29.26

4.5.4. Cement-Stabilized Aggregate Base [CSAB] (Alternative Section)

Two design mixes were used in the CSAB road construction, namely; 1 Soil : 2 Aggregates and 1 Soil : 1 Aggregates: 1 Limestone. The first design mix was made for the first 500 meters while the second design mix was constructed in the next 500 meters. Table 9 shows the strength test results of actual samples from the CSAB section.

Table 9. Compression Test Results of Actual CSAB Samples

	1 Soil : 2 Aggregates				1 Soil : 1 Aggregates: 1 Limestone	
Date sample taken:	11/12/2014	11/13/2014	11/14/2014	11/18/2014	11/23/2014	11/25/2014
Date Tested:	11/20/2014	11/21/2014	11/21/2014	11/25/2014	12/1/2014	12/2/2014
Location (station)	**0+040**	**0+140**	**0+260**	**0+450**	**0+720**	**0+970**
	Compressive strength(MPa)					
A	1.832	1.730	2.496	2.568	3.320	4.022

	1 Soil : 2 Aggregates				1 Soil : 1 Aggregates: 1 Limestone	
B	1.899	1.910	2.432	3.338	3.627	4.119
Average Compressive Strength (MPa)	**1.866**	**1.820**	**2.464**	**2.953**	**3.473**	**4.070**

All samples except two have reached the design strength of 2.10 MPa. The test results further show that the 2nd design mix (1 soil: 1 aggregate: 1 limestone) has significantly higher compressive strength than the 1st design mix (1 soil: 2 aggregates). Table 10 lists the strength hammer test results of the CSAB section. On the other hand, the comparison of the strength test results between concrete and CSAB sections is summarized in Table 11. The design mixes for both sections of the CSAB exhibited compressive strengths that are almost comparable to the concrete section. This despite the absence of any surfacing course of the CSAB section.

Table 10. Rebound Hammer Test Results of CSAB Road

Location	Average Compressive Strength
STA 00 + 440	21.57 MPa
STA 00 + 540	22.02 MPa
STA 00 + 760	19.78 MPa
STA 00 + 980	24.70 MPa

Table 11. Comparison of Concrete and CSAB Compressive Strengths

CONCRETE PAVEMENT		CSAB DESIGN MIX 1		CSAB DESIGN MIX 2	
Location	***Ave. Compressive Strength***	***Location***	***Ave. Compressive Strength***	***Location***	***Ave. Compressive Strength***
#1	25.03 MPa	STA 00 + 440	21.57 MPa	STA 00 + 540	22.02 MPa
#2	33.54 MPa			STA 00 + 760	19.78 MPa
#3	29.26 MPa			STA 00 + 980	24.70 MPa
AVE.	**29.28 MPa**		**21.57 MPa**		**22.17 MPa**

Figure 9 illustrates the constructed cement-stabilized aggregate base (CSAB) that was used as the alternative section for this study. The CSAB pavement is 1 km long and was constructed by the Provincial Engineer's Office (PEO) of the Provincial Government of Guimaras, as their counterpart equity fund for this study. The CSAB section was completed in December 2014.

Figure 9. Constructed 1-Km Cement-Stabilized Aggregate Base (Alternative Section)

There were three (3) typhoons for the month of December 2014, which brought heavy precipitation in the Province of Guimaras, including the base and alternative sections. The photograph in Figure 9 was taken in January 2015 and showed the same level of surface condition as it was constructed a month ago. Based on official surface condition descriptive rating of the DILG Local Road Management Manual, the subject section can still be visually categorized as in Good to Fair Condition.

4.6. Assessment of Factors for Selecting Pavement Options

The study assessed factors that may be considered in selecting pavement options that may be available in Guimaras as summarized in Table 12. The typical pavements for low-volume local roads are gravel, CSAB gravel, double-bitumen surface treatment (DBST), asphalt and concrete. These pavement types have been adopted by Guimaras for its provincial roads but had mixed results although none were analyzed in an objective manner by the Provincial Engineer's Office (PEO) until this study was conducted under PRMF.

The most common pavement type in Guimaras is gravel followed by an insignificant amount of sections of other pavement types. For most low traffic volume roads, which are the situation for many of the local roads, it is difficult to justify a high initial investment cost of using Portland Cement Concrete pavements, particularly when they are not maintained properly and have to be totally reconstructed. Hence, the use of concrete pavement on long road stretches is not recommended. For this condition, a flexible pavement (i.e. bitumen) is more appropriate.

Table 12. Assessment of Factors for Selecting Pavement Options in Guimaras

No.	Factors to Consider in Choosing	Remarks	Gravel	CSAB	Asphalt	Concrete
1	**Economic Lot Size**	Minimum amount of binding material per batch order and the economic size of contract for plant set-up	Can be sourced locally (no limitation lot size)	40 kg cement bag (1.4 bags for every m^2) depending on the type of soil and cement content. No cost for existing base materials or minimal borrow)	48.78 cu.m. (depending on distance of asphalt batching plant)	40 kg cement bag (less than 1 m); economic lot size can be low as one block (less than 5 m)
2	**Road Safety**					
2.1	Gradient and Resulting Friction	Potential for skidding in wet condition	Potential for skidding due to loose gravel	Slightly slippery when wet	slippery when wet aggravated by gravel transport	Moderate roughness even on wet condition
2.2	Speed Reduction and Accident Rates	Road safety issue due to steepness of gradient	10-20 kph speed reduction for less than 200 m distance for grades higher than 9% for all types			
3	**Traffic Loading**					
3.1	Axle Load	Load Capacity	Lowest Load Capacity	Higher Load Capacity, (can be designed to carry up to AADT of 2,000 with 8% heavy vehicles)	Load capacity depends on thickness; intermediate capacity of minimum recommended thickness of 100 mm	Highest maximum loads at minimum recommended thickness (200 mm)
3.2	Traffic Volumes	Typical Economic Traffic Range	ADT<400	ADT>400	ADT>400	ADT>400

No.	Factors to Consider in Choosing	Remarks	Gravel	CSAB	Asphalt	Concrete
4	**Construction Method**					
4.1	Time	Constriction time considering preparation; hauling and curing of 1 km section	No Additional Time	2 days for 1 km stretch using Recycler; Rapidly stabilized and can be used immediately	65 days from completion of surface preparation	57 days from completion of surface preparation(including curing time with fast curing admixture)
4.2	Cost (Unit Price Analysis)	Unit price of work item UPA for Guimaras	1,200 to 1,400 Php/sqm	500 to 700 Php/sqm	1,970 to 2,200 Php/sqm	2,100 to 2,300 Php/sqm
4.3	Capacity of Local Industry	Capacity to undertake the required contract size	Can be maintained by community or contractors	can be constructed by PEO or local contractor	Prepared by asphalt mix suppliers	Can be preapred by community or local contractors
5	**Maintenance**					
5.1	Capacity of Local Industry and PEO	Capacity to undertake the required contract size	Can be maintained by community or contractors	Prepared by PEO or local contractors	Prepared by asphalt mix suppliers	Can be prepared by community or local contractors
5.2	Average of routine maintenance	Unit price of work items	Php 49,000 /km/yr	Up to Php 40,000 /km/yr;	Php 45,600 /km/yr	Php 39,292 /km/yr
6	**Environmental**					
6.1	Rainfall	Effect of area rainfall and flooding	loose if surface course on steep slopes during rain	Potential loss of surface course during heavy rain (depending on type of wearing course)	After setting potential loss of surface course during heavy rain	After setting minimal loss of surface course during heavy rain
6.2	Fumes/Particulates	Occurrence of Fumes and Suspended Particulates in Atmosphere	Very Likely	Moderate	Moderate	Moderate
7	**Implication to Local Labor**					
7.1	Readiness of Local Labor	Familiarity of the Technology	Minimal Capacity Development needed to allow participation of local labor	Requires Capacity Development needed to allow participation of local labor due to specialized technology	Moderate Capacity Development needed to allow participation of local labor	Minimal Capacity Development needed to allow participation of local labor due to familiarity of Technology

Short concrete pavements, however, are justified in some situations such as those with steep road gradients, flooding problems, geotechnical issues, severe soil or moisture conditions, severe traffic stop-start situations such as at some main road intersections, or where traffic volumes are very high with a high proportion of heavy vehicles. Also for short sections of less than 2 km, economies of scale is difficult to achieve with a bitumen-based pavement as the cost and technical requirement for maintaining quality work become disproportionately huge. Bitumen paving (as specified by the DPWH Standard Procedures which are aligned with AASHTO and ASTM standards) requires a limited range of controlled temperature for effective application (107 degrees Celsius for Asphalt).

The gravel is still the most cost-efficient material for the pavement of low-volume roads such as the provincial roads in Guimaras. Aggregate materials are available locally. It can be prepared by the PEO and contractors with small capitalization. The most important assumption, however, is that there is routine and periodic maintenance of the gravel pavement as gravel loss increases considerably if the drainage are blocked, there is no cross-slope of the carriageway, and aggregate sizes become disproportionate due to the lack of gravel resurfacing.

The CSAB is a good alternative as it is just slightly higher in cost against gravel pavements but it can carry higher traffic load and presents minimal dust problems. Compared against asphalt and concrete pavements, CSAB is a better value for money as more kilometers can be constructed with the same cost considerations.

4.7. Life-Cycle Cost Analysis of Pavement Options

The study made an life-cycle cost analysis of the different pavement options for a one kilometer segment of a provincial road in Guimaras, assuming uniform and similar traffic loading. Using current prices at Year 1 and on a cash-flow budgeting basis of the Provincial Government of Guimaras, the life-cycle cost of maintaining a one-kilometer segment of a sample road in Guimaras is shown in Table 13, assuming minimum requirements to sustain the section over a common period of 20 years,. A discount rate of 12% is used in determining the Net Present Value, which is normally used by the Government of the Philippines in determining rate of returns for development projects. The initial year (Year 0) is assumed to be a full construction of a one-kilometer segment. Routine maintenance is assumed to be conducted every year. In contrast, periodic maintenance is undertaken at different life-cycles of the pavement. Concrete will not need a periodic maintenance over its life-cycle. Asphalt is expected to have a periodic maintenance after 8 years. CSAB gravel will have a periodic maintenance on the 5th year. Gravel pavements have periodic maintenance every 3 years. The net present value (NPV) are determined for all of these annual costs (in cash-flow basis). As shown in Table 13, CSAB pavement has the lowest Net Present Value (NPV) of life-cycle costs at roughly Php 3.5 million with asphalt having the highest NPV at approximately Php 16.1 million. However, the NPV of the life-cycle costs should be qualified against potential benefits of road users, which will vary across different pavement types. This will entail a full economic appraisal of different pavement options for local roads, which is outside the coverage of this study.

Table 13. Life-Cycle Cost Analysis of Pavement Options

Year	Concrete	Asphalt	CSAB	Gravel
0	13,097,560.00	12,021,186.00	3,019,230.00	4,339,386.00
1	39,292.00	45,600.00	40,000.00	49,000.00
2	39,292.00	45,600.00	40,000.00	49,000.00
3	39,292.00	45,600.00	40,000.00	187,520.00
4	39,292.00	45,600.00	40,000.00	49,000.00
5	39,292.00	45,600.00	**200,000.00**	49,000.00
6	39,292.00	45,600.00	40,000.00	187,520.00
7	39,292.00	45,600.00	40,000.00	49,000.00
8	39,292.00	**4,460,000.00**	40,000.00	49,000.00
9	39,292.00	45,600.00	40,000.00	187,520.00
10	39,292.00	45,600.00	**200,000.00**	49,000.00
11	39,292.00	45,600.00	40,000.00	49,000.00
12	39,292.00	45,600.00	40,000.00	187,520.00
13	39,292.00	45,600.00	40,000.00	49,000.00
14	39,292.00	45,600.00	40,000.00	49,000.00
15	39,292.00	45,600.00	**200,000.00**	187,520.00
16	39,292.00	**4,460,000.00**	40,000.00	49,000.00
17	39,292.00	45,600.00	40,000.00	49,000.00
18	39,292.00	45,600.00	40,000.00	187,520.00
19	39,292.00	45,600.00	40,000.00	49,000.00
20	**13,097,560.00**	**12,021,186.00**	**200,000.00**	4,339,386.00
NPV @ 12%	**14,744,757.78**	**16,106,249.28**	**3,506,129.84**	**5,447,760.02**

5. CONCLUSIONS AND RECOMMENDATIONS

The study is a project funded by the Australian Government (through the PRMF), starting from May 2014 to March 2015. This paper presents the findings of the study arising from research activities conducted to date. Results in the rest of the research activities would generally be more after the completion of the project when the over-all project test results and performance monitoring have been completed, consolidated and reviewed.

Nevertheless, there are a number of conclusions that can be gleaned from the results of the study to date. There is a common misconception in Guimaras that there are no sufficient aggregate materials having qualities that are sufficient for pavement courses. However, the material testing conducted by the study on potential quarry and riverine materials would show that they do exist in Guimaras. These materials will be used in the test sections for observation and assessment of actual traffic loading on the abovementioned roads.

The traffic count have been conducted on the subject roads that will be used as test sections in Guimaras. The traffic count results validates the common observation of traffic pattern along the provincial roads of Guimaras. Vehicles passing along these provincial roads (including those of the two subject roads) are dominated by motorcycles and tricycles. This would mean that the movement of people and goods are usually through two-wheel transport modes whose capacities would range from two to a maximum of five (for tricycles). These transport modes are characterized by small capacities but frequent and numerous trips. This is also consistent with the land use profile of Guimaras where less than 1% of the land are built-up areas. This means that trips between urban centers of the province, which are mostly through provincial roads as connector roads, are relatively small.

The main findings of the study points to an optimum ratio of 1:1:2 mixture of cement, soil and aggregates with a 5.73% content for cement, which result to attaining the required compressive strength of 2 MPa (DPWH specifications for cement-stabilized aggregate base). The soil and aggregates are native abundant materials in Guimaras. The estimated construction cost for a one kilometer section of this design mix is Php 3.599 Million with a unit cost of Php 590.09 per sqm and requiring 1.3 cement bags per sqm. On the other hand, a mixture ratio of 1:1:1:1 of cement, soil, aggregates and lime with a 5.90% content for cement will achieve the same required compressive strength. This design mix will cost Php 3.601 Million with a unit cost of Php 590.44 per sqm and requiring 1.3 cement bags per sqm.

The study assessed factors for selecting different pavement options for local roads in Guimaras. This analysis shows that CSAB seems to be the most cost efficient pavement for low-volume roads such as the provincial roads in Guimaras. Nonetheless, there are site conditions that would merit the use of non-gravel pavements such as those with steep road gradients, flooding problems, geotechnical issues, severe soil or moisture conditions, severe traffic stop-start situations such as at some main road intersections, or where traffic volumes are very high with a high proportion of heavy vehicles.

The research made an indicative life-cycle cost analysis of the pavement options that may be available for the provincial roads in Guimaras. Early computations would show that CSAB pavements have the lowest NPV of investment and maintenance costs, whereas asphalt pavement would have the highest NPV over similar cost assumptions.

Most importantly, the test results of the CSAB section showed that its strength is almost comparable to the strength of concrete pavements. At a lower cost per kilometre, CSAB therefore would have better value for money than concrete pavements. If pavement selection can be rationalized, the government can utilize the same amount of fund over longer distances of CSAB pavements rather than concrete roads. And at the same time, the pavement performance is almost the same for low-volume local roads in Guimaras.

ACKNOWLEDGMENT

This Study is a research and innovation project under the Provincial Road Management Facility (PRMF) that is funded by the Australian Government, and that is being implemented with the Department of the Interior and Local Government (DILG) and ten partner provinces in Visayas and Mindanao. The partners of this study are the PRMF, the DILG, the Provincial Government of Guimaras, and the University of San Agustin (USA).

REFERENCES

Abat-Bangasan, R. (2006) *Application of Low-Volume Road Maintenance Management Systems in New Zealand to thePhilippines*. Unpublished Thesis, University of Canterbury, Christchurch, New Zealand.

Abdo, F.Y. (2009) *Cement-Stabilized Base Courses, Concrete Airport Pavement Workshop*, Portland Cement Association.

Domingo, R. (2002) *Adopting a Pavement Management System (PMS) for Local Governments*. Unpublished Thesis, University of the Philippines, Diliman, Quezon City.

Kestler, M.A. (2009) *Stabilization Selection Guide for Aggregate and Native-Surfaced Low-Volume Roads*. Forest Service, San Dimas Technology and Development Center.

Republic of the Philippines (2013) *Local Road Management Manual*. Unpublished Final Draft, Department of the Interior and Local Government, Quezon City.

Republic of the Philippines (2013) *Standard Specifications for Highways, Bridges and Airports*. Department of Public Works and Highways, Manila.