Evaluation of Material Stock of Roadways: The Case Study of the Philippines

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1. Introduction

Transport system in the Philippines relies highly on road transport that handles 90% of the country's passenger movement and 50% of freight movement. In recognition of its importance, transport sector investment of the Philippines has been focused on the road network development (Velasco, 2003). Since Philippines is an archipelagic country, there are limitations on the ease of transportation or movement of construction materials from one area to another. Thus, consumed construction materials in the Philippines rely on the domestic production. The gravel and sand are locally extracted from the nearest available sources to the construction areas. Limestone deposits is also abundant, supplying locally produced cement to the market. The growing economy resulted to the increasing consumption of construction minerals from 10% in 1985 to 35% in 2010 of the total domestic material consumption. This study therefore is important to evaluate the materials consumed and stocked in the roadways of the Philippines. Since material stock evaluation of infrastructures is not common in most of the developing countries, this would served as the baseline study in the Philippines that could be utilized in the evaluation of current practices and policies related to the construction, quarrying and production of construction minerals.

2. Methodology

The calculation of the material stocks in road infrastructures in Philippines is based on the road section design utilized by the Department of Public Works and Highways (DPWH, 2012). Figure 1 illustrates the flow diagram for the calculation of the stock per material utilized in the road system. The Philippine road networks are classified in terms of the surface types such as paved or unpaved roads. Paved roads are the concrete and asphalt roads while unpaved roads are the gravel and earth roads. This study did not include the earth-covered unpaved roads since this kind of roadway are mostly the newly opened roadways and involved clearing and compacting of earth only.

The Philippine roadways are typically composed of aggregate base course layer and the surface layer. The three surface types are concrete, asphalt and gravel or the crushed aggregates. Based on these, the cement, asphalt and sand and gravel are the major construction minerals considered in this evaluation. Figure 2 shows the cross section profile of different road surface types according to the design specifications for roadways and used as the basis for the calculations of material stock (DPWH, 2004).

For estimation of material stock of roadways, the following equation is used:

$$MS_{x,y(t)} = A_{y(t)} \times I_{x,y(t)} \qquad \text{Eq.1}$$

Where $MS_{x,y(t)}$ is the amount of material x stocked in structure y in year t, and $A_{y(t)}$ is the total amount of physical structure y in the year t and I stands for material intensity of each type of material x. The material types include cement, sand and gravel and asphalt. Material intensity is estimated using the average ratio of cement, sand and gravel used based in the design mixture of concrete that is 1:2:4 (DPWH, 2004).

3. Results

With the continuing effort of the Government of the Philippines, the total road length steadily increased in the past years. Figure 3 shows the historical development of the Philippine road network, at which total road length had increased gradually from 1985 to 2009 with a remarkable increase of 21.9% that was noted in 1997-1998. The

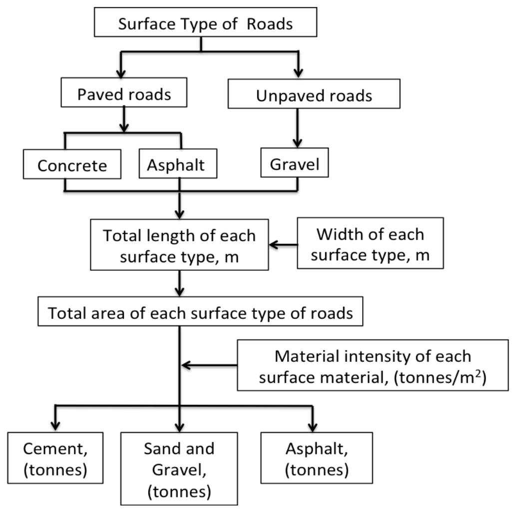

Fig. 1. Flowchart for the calculation of the material stock of roadways.

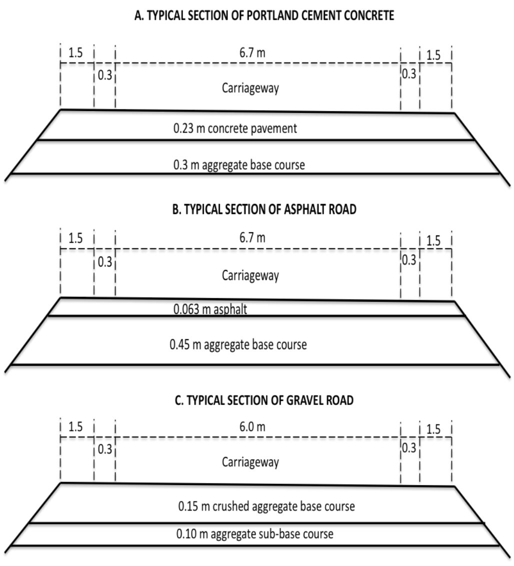

Fig. 2. The cross section profile of different road surface types.

total length of roadways classified according to surface type rose from 161,880 km in 1985 to 213,151 km in 2009. The paved roads percentage comprised by asphalt and concrete roads increased from 13% in 1985 to 26% in 2009. In contrast, unpaved gravel roads decreased from 81% of the total road networks in 1985 to 48% in 2009.

Figure 4 shows material stock of roadways in the Philippines from 1985 to 2009. In terms of the materials accumulation in the roadways every year, the sand and gravel comprised the highest amount of materials stock with an amount increasing from 145 million tonnes (Mt) in 1985 to 332 Mt in 2009. The growing percentage of concrete roads resulted to the increase of the cement stock from 9.6 Mt in 1985 to 39 Mt in 2009, and asphalt likewise rose from 4.9 Mt in 1985 to 6.8 Mt in 2009.

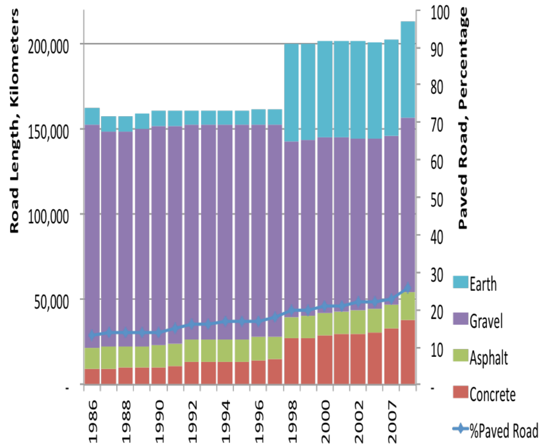

Fig. 3. Existing road length by surface type and paved percentage

4. Discussion

The growth in the material stock is related to the roadway construction and development. Road infrastructure policies were among of the priorities of the Medium Term Philippine Development Plan for 1993-1998. This resulted to the significant increase in the road length resulted in 1997-1998. The road construction together with other infrastructure development during this period increased the amount of extracted construction minerals in the Philippines. Sand and gravel extraction increased from 31 Mt in 1996 to 76 Mt in 1997. The amount of extracted limestone, at which greater portion were utilized for cement production also increased from 3.8 Mt in 1996 to 10.2 Mt in 1997 (PSY 2005). The development of road networks was still supported by the succeeding medium term development plans and policies. The 2005-2010 Medium Term Development Plan gave priority on the maintenance, rehabilitation and construction of new roads serving key agricultural production areas, tourism destinations, and growth centers, and those which will improve law and order. While infrastructure development is tantamount to economic development, the consequent environmental impacts of extraction of construction materials in the environment should also be taken into considerations. In the Philippines, the sand and gravel quarrying activities are usually undertaken in river bodies that resulted to the deterioration of the water quality and decrease the river's beneficial usage to the humans and the communities and eventually damage the river ecosystem. There is a continuous challenge to keep the construction activities responsive to the economic growth yet mindful of the irreversible environmental consequences.

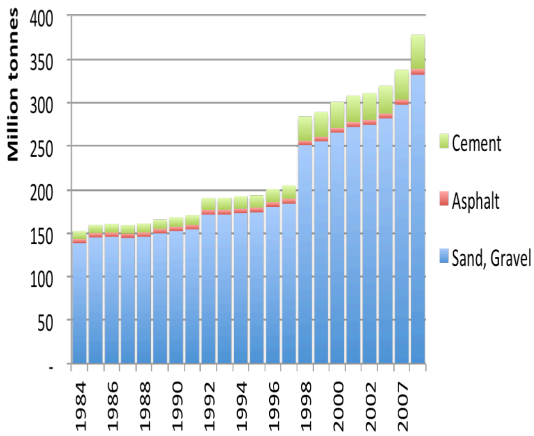

Fig. 4. Material stock of roadways in Philippines

4. Conclusion

This research calculated and characterized the material stock of roadways in the Philippines. Significant portion of these construction minerals are domestically extracted, which has consequent environmental impacts. This analysis could be utilized in the evaluation of current practices and policies related of the construction, quarrying and production of construction minerals and in building national database about construction material stock in infrastructures. Further research in the material stock of other transportation infrastructures and its relation to the construction material consumption and economic development in the Philippines will be undertaken.

Acknowledgements

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