



## CONSTRUCTION EXPERIENCE ANALYSIS OF USING CEMATRIX LIGHTWEIGHT CELLULAR CONCRETE AS A SUBBASE MATERIAL

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**Abstract:** Lightweight Cellular Concrete or LCC, also sometimes known as "foamed concrete" or "aerated concrete" is a useful construction material with many applications. LCC has some advantages such as sustainability, light weight, excellent thermal properties, freeze-thaw resistance, good flowability, cost-effectiveness. Due to its properties, it is a good material choice for contractors and transportation ministries to use in different applications in all weather conditions. It also satisfies construction requirements in poor soil areas – it is a good base for the pavement over weak soils because this material can reduce the effective stress on the underlying soil. The objective of this paper is to study and analyze the performance of the pavement sections with the LCC subbase in comparison with the regular pavement sections on the same roads. Three road sections that had been constructed with lightweight cellular concrete as a subbase were evaluated through pavement condition survey following ASTM D6433. It has shown that three sections were in good condition, without severe distresses. Preliminary failure criteria analysis was conducted using Weslea software. It has been found that using lightweight cellular concrete as a subbase has greater allowable number of load repetitions for fatigue cracking and rutting than using granular material. This indicates that lightweight cellular concrete could be considered as an alternative pavement subbase material.

### 1 Introduction

Lightweight Cellular Concrete or LCC, also sometimes known as "foamed concrete" or "aerated concrete," is a useful construction material with the different densities, in the range of 400 to 600 kg/m<sup>3</sup> (Dolton et al. 2016). The density of Cellular Concrete is four times lower than that of conventional granular material. The foaming technology has been improving since the beginning of the 20th century, but it has become more popular recently due to its properties, which can solve many construction issues. The primary application of the LCC in the roadway construction is using LCC as a subbase for the roadbed when constructing a pavement over a weak soil, such as peat, organics and soft soil deposits. (Maher and Hagan 2016). Due to the lightweight properties of the LCC, the whole pavement structure has less weight and could be prevented from the continual and long-term settlements that necessitate frequent patch repair. Having the light weight as well as being an excellent thermal and freeze-thaw resistance, LCC in some cases has potential chances to be used as an alternative to the granular subbase material such as crushed stone. One of those test sections is located at the Dixie Road, where according to the preliminary investigation, peat and marl soils were found at the depth ranging from 2.1 to 5.4 meters. Two more sections were reconstructed with LCC as a subbase by Cematrix in Ontario at different times. The findings of the performance monitoring and attained construction experience will be presented in this paper.

## 2 Field Visual Inspection

Three road sections that are constructed using the lightweight cellular concrete as subbase layer are investigated, which are the Dixie road, Winston Churchill Boulevard, and Highway 9. The three sections have similar pavement structure, including an asphalt concrete surface layer, an unbound granular base layer, a lightweight cellular concrete subbase layer, and subgrade soil. The pavement surface distresses were determined by following ASTM D6433, which classifies nineteen types of pavement distresses. These distresses such as alligator cracking, bleeding, corrugation, longitudinal and transverse cracking, and rutting were inspected. The inspection was conducted manually instead of using automated data collection vehicles. The results of field inspection are described in the following sections.

### 2.1 Dixie road

The region of Peel reconstructed a section of Dixie road in 2010. Instead of removing and replacing the embankment with granular material, the Region chose to use lightweight cellular concrete as an alternative. The pavement structure contains an LCC layer with 650 mm of CEMATRIX CMEF-475 material which was overlaid with 150 mm of Granular 'A' base material, and 140 mm of asphalt.

Griffiths and Popik (2013) investigated the in-place performance in 2013. The evaluation of the section includes visual condition survey of the existed pavement surface, Ground Penetrating Radar (GPR) survey to provide layer thicknesses and subsurface images of the pavement, and Falling Weight Deflectometer (FWD) testing to determine the structural capacity of the lightweight cellular concrete section in comparison with the adjacent pavement.

The visual pavement condition survey of the site was found to be in good condition. Total of three longitudinal slight severity cracks and one moderate severity pavement distortion/heave were observed in the area. Figure 1 demonstrates those cracks. The adjacent pavement is also investigated, and it appears to be in excellent condition without any distress. In general, the condition of the section performs competently after three years of construction.

The collected FWD data were analyzed base on the pavement thickness measured by the GPR survey. Two parameters were determined, which are the composite elastic pavement modulus and the structural coefficient. The composite elastic pavement modulus of LCC section range from 714 to 737 MPa, which is higher than the adjacent section (514 to 670 MPa). This resulted in increasing of the composite pavement structural number of LCC section, which ranges from 175 to 224 mm while the adjacent section range from 128 to 154 mm.

The structural coefficient of the LCC material was determined by the analysis of FWD data. The structural coefficient of asphalt layer and granular base layer used in the analysis is 0.38 and 0.12. The result of back-calculated presented that the structural coefficient of LCC material is approximately 0.2. (Dixie road pavement evaluation report, 2013)



Longitudinal Cracking (Mid lane)



Minor crack

Transverse Cracking



Transverse Cracking

Figure 1 Condition of Dixie road

## 2.2 Winston Churchill Boulevard

The reconstruction of Winston Churchill Boulevard is similar to the Dixie road project. It is a two-lane rural road with 30% less traffic than the Dixie road. The project is completed in 2016. The pavement structure consists of a 120mm asphalt concrete layer, a 240 mm Granular A base layer, and a 550 mm lightweight cellular concrete at the density of  $475 \text{ kg/m}^3$  on top of the peat. The field inspection found that the pavement remains in good condition after one year of construction. No severe cracks or rutting were found during the inspection.



Overall condition-1



Overall condition-2

Figure 2 Condition of Winston Churchill Boulevard

## 2.3 Highway 9

The construction project in Highway 9 aims to solve the weak soil problem. The groundwater level range from 1.5m to 2.3m below the surface of the pavement. LCC was chosen as an economical and sustainable remediation treatment to arrest the continued settlement and reduced safety concerns and maintenance cost. The section was reconstructed in 2014. The settlement remediation treatment included excavation of a length of a 100m to a depth of 1.5m to provide the pavement structure of a 200mm asphalt concrete layer, 200 mm Granular O base layer, and 1100 mm lightweight cellular concrete at the density of  $475 \text{ kg/m}^3$  on top of the subgrade (Maher and Hagan 2016). The use of LCC reduced the need of deep excavation, thus,

reducing a considerable amount of excess material requiring disposal, construction time, amount of backfill material, and reducing the impact on the environment. The field inspection found that the pavement remains in good condition after three years of construction. No severe cracks or rutting were found during the inspection.



Overall condition-1

Overall condition-2

Figure 3 Condition of Highway 9, three years after the construction

### 3 Failure Criteria Analysis

In order to understand the expected vertical stress and tensile stress that will occur in the pavement structure the failure criteria analysis is conducted using the Weslea software. The pavement structure and material properties are assumed in this analysis based on engineering experience. Two types of pavement structure using a different material for subbase layer are analyzed and compared, which are the lightweight cellular concrete and the unbound granular base material. The pavement structure and material properties are demonstrated in Table 1. With the use of Weslea software, the vertical stress and tensile stress happened on the top of the subbase layer and bottom of the subbase layer at different load are shown in Figure 4 and 5. Figure 4 presents the expected vertical stress that will be applied to the subbase layer. The vertical stress applied to the LCC layer is higher than the granular B layer for every loading set. However, the typical compressive strength of the LCC at low density is range between 0.5 MPa to 1.0 MPa. Thus, the LCC layer is considered to be strong enough to support the pavement. The results of the tensile stress happen at the bottom of the subbase layer are demonstrated in Figure 6. It is clear that the tensile stress happened at the LCC layer is higher than the tensile stress occurring at the granular B layer. According to Narayanan and Ramamurthy (2000), the flexural strength of lightweight cellular concrete is 15% to 35% of its compressive strength, which is between 0.075 to 0.35 MPa for typical low density lightweight cellular concrete. Compared to the Figure 5, it showed that both of the subbase layers are capable of resisting the tensile stress and prevent the layer from damage.

Table 1 Weslea Settings (Material Properties of the pavement)

	Surface	Base	Subbase	Subgrade	
	Hot-mix asphalt concrete	Granular A	Granular B	LCC	Soil
E (MPa)	3445	275	192	800	82
Poisson's Ratio	0.35	0.35	0.35	0.18	0.45
Thickness (mm)	140	140	600	600	-

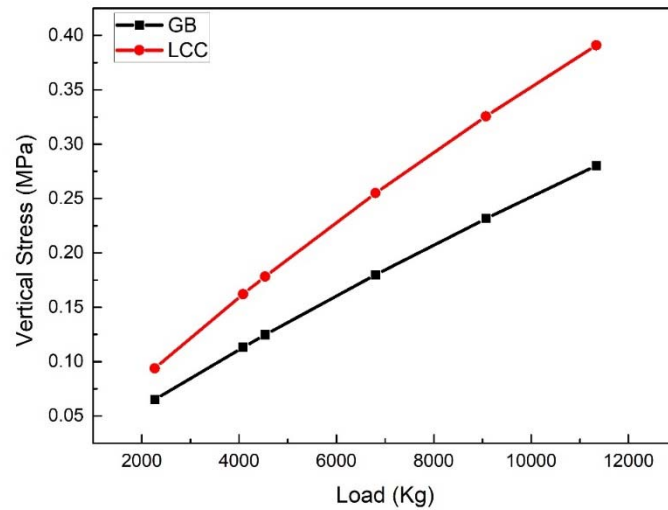


Figure 4 Results of the Vertical Stress

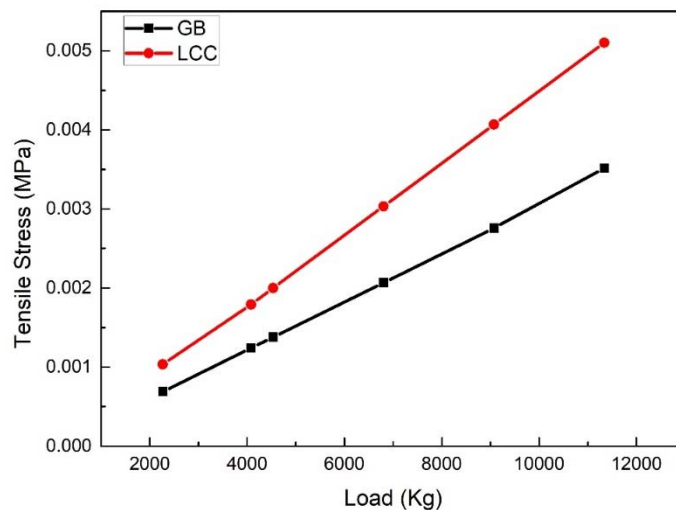


Figure 5 Results of the Tensile Stress

The Weslea software could perform the damage analysis for fatigue cracking and permanent deformation. The results are shown in Figure 6 and 7. It is clear that the pavement with LCC subbase is more durable than the pavement with granular B layer at same thickness since the allowable number of load repetitions for fatigue cracking and permanent deformation are higher. The results indicated that the pavement thickness using LCC as subbase material could be thinner than the conventional pavement, which reduced the excavation depth during the construction and saves more time.

The results show that using lightweight cellular concrete as subbase layer material could be practical and possible. However, the software does not consider the environmental impacts such as temperature and moisture. In-Situ field inspection is needed to evaluate the environmental effect on the pavement when using lightweight cellular concrete as a subbase layer.

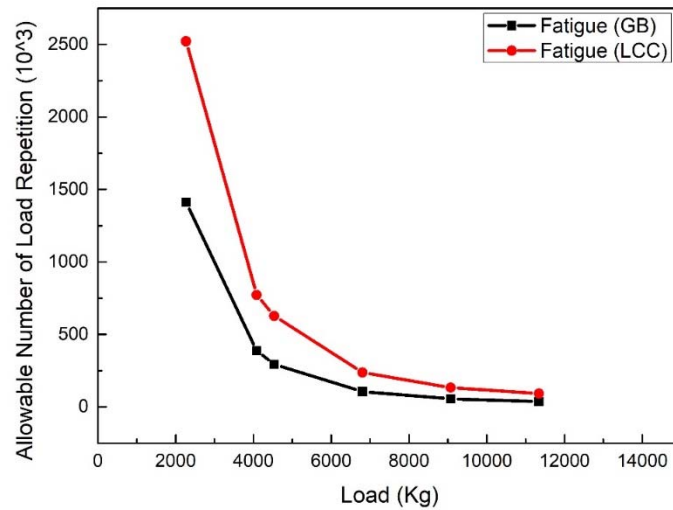


Figure 6 Allowable number of load repetition (Fatigue cracking)

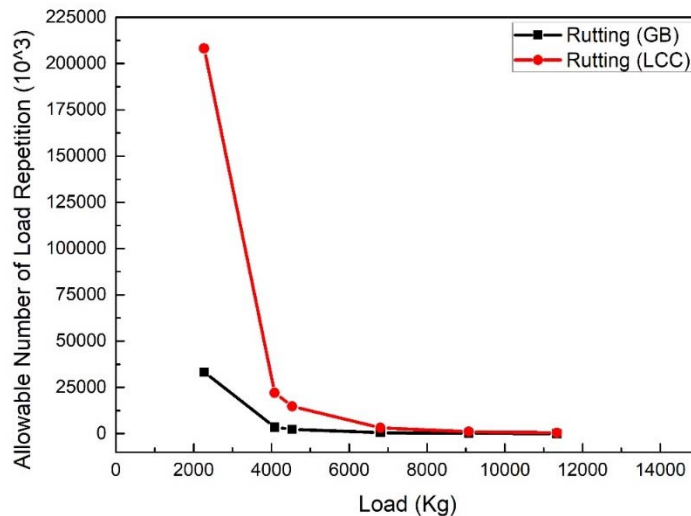


Figure 7 Allowable number of load repetition (Permanent deformation)

#### 4 Conclusion

With a greater emphasis on sustainability, such material as Lightweight Cellular Concrete can minimize the generation of waste and deliver better performing pavements that require less maintenance. The use of LCC has been proving its properties and suitability of using it in certain conditions. Such requirements were met in the case studies presented in this paper. The inspections were done after the construction on those sections at different times. Preliminary failure criteria analysis were also done in this study, and the findings of this paper are as follows:

- According to the report and visual inspection that was done at the Dixie road, not significant transverse and longitudinal cracks were observed.
- Both, Winston Churchill Boulevard and Hwy 9 sections are in good condition with no visual distresses
- The use of LCC as a pavement subbase layer could be practical and feasible.
- It is clear from the failure criteria analysis that the pavement with LCC subbase is more durable than the pavement with granular B layer at the same thicknesses.
- The analysis mentioned above indicates that the pavement thickness using LCC as subbase material could be thinner than the conventional pavement, which reduced the excavation depth during the construction and saves more time.

This study provides an overlook of the current pavement condition of the three sections that were constructed using lightweight cellular concrete as subbase layer material. Results shown that the three sections were in good pavement condition. However, in-depth pavement data collection has to be done in order to provide a comprehensive review of the performance of the sections with lightweight cellular concrete as subbase layer. Therefore, further investigation is recommended. This could be achieved by using pavement instrument such as asphalt gauge, earth pressure cell, and environmental equipment.

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