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The Response of Flexible Portland Cement Concrete Pavements under Ultra-Heavy Loading

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ABSTRACT:

The performance of concrete slabs and traditional interlocking paving has been variable in container terminals. This problem led to the quest for alternative solutions for ultra-heavy loading. In South Africa portland cement concrete filled geocells, termed Hyson Cells, have been used successfully in the provision of low-volume roads and streets.

An experiment at the Kaserne container terminal, consisting of 11 test panels was designed and constructed to obtain design input information on geocell pavements under ultra-heavy load conditions. The aim of this paper is to present the response and performance of the test panels under loading of up to 100-ton axle loads. The main conclusions were that there was no indication of stress sensitivity of the unbound materials, and typical stiffness values used in road pavements design could be used.

Limiting vertical compression strains were as suggested by the South African Mechanistic Design Method for road pavements. The structural design of geocell pavements for ultra-heavy loading may be performed using linear elastic layer analysis. Cost effective solutions include the use of dump rock in the upper pavement to ensure load spreading and stress reduction in the subgrade.

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The Response of Flexible Portland Cement Concrete Pavements Under Ultra Heavy Loading

TECHNICAL PAPER

Alex T Visser

SYNOPSIS

The performance of concrete slabs and traditional interlocking paving has been variable in container terminals. This problem lead to the quest for alternative solutions for ultraheavy loading. In South Africa Portland cement concrete filled geocells, termed Hyson-Cells, have been used successfully in the provision of low volume roads and streets. An experiment at the Kaserne container terminal, consisting of 11 test panels was designed and constructed to obtain design input information of geocell pavements under ultraheavy loading conditions. The aim of the paper is to present the response and performance of the test panels under loading of up to 100 ton axle loads. The main conclusions were that there was no indication of stress sensitivity of the unbound materials, and typical stiffness values used in road pavement design could be used. Limiting vertical compressive strains were as suggested by the South African Mechanistic Design Method for road pavements. The structural design of geocell pavements for ultraheavy loading may be performed using linear elastic layer analysis. Cost effective solutions include the use of dump rock in the upper pavement to ensure load spreading and stress reduction in the subgrade.

INTRODUCTION

Traditionally block paving or thick Portland cement concrete slabs have been used for pavements in container terminals. The performance has been variable, and this led to the quest for alternative solutions. In South Africa Portland cement concrete filled geocells, termed Hyson-Cells, have been used successfully in the provision of low volume roads and streets (Visser, 1994, Visser and Hall, 1995). The geocell comprises smooth walled cells fabricated from 200 micron HDPE film. The cell walls are deformed during construction so that there is approximately a 5 mm deformation in the plane surface, allowing each cast concrete block to mechanically interlock with its neighbour. Particular care was taken during construction that the cells were firmly anchored to the underlying material and that the concrete was not allowed to flow under the cell walls and so form an unjointed slab. The physical properties of the geocell and the construction techniques employed are an important element of the system. A view of the geocells is presented in Figure 1.

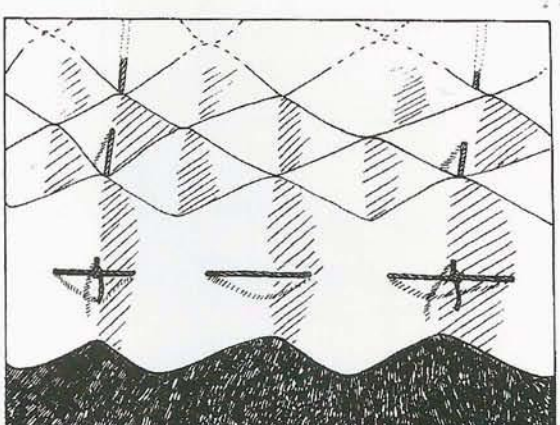

Figure 1: ***A schematic view of the welded plastic cell after placing***

This earlier work provided an insight into how the three-dimensionally interlocking cast in-situ blocks function. It was hypothesised that this system could be used effectively under the ultraheavy axle loads of 100 ton and wheel slew which are applied by the Reachstacker in container terminals, as well as to resist the punching loads of the stacked containers.

Eleven experimental test panels were constructed at the Kaserne container depot with a range of layer thicknesses and material properties according to an experimental design. These panels were instrumented with multi-depth deflectometers (MDD) to obtain the structural response of the different layers under wheel loads up to ultraheavy loads. Measurements were also obtained under container stacks. The section was trafficked by trucks and Reachstackers during normal container distribution operations.

The aim of the paper is to present the response and performance of the test panels under a range of loading and trafficking conditions, and to derive structural design parameters for container terminal pavements. Firstly the paper will present the operational requirements for container terminal pavements, thereafter the experimental design of the test panels are presented. The structural response and performance of the different panels and materials are presented next, and the structural design parameters are derived. Finally guidelines for the structural design of container terminals are presented.

OPERATIONAL REQUIREMENTS FOR CONTAINER TERMINALS

There are a number of special considerations that apply to container terminals. These include (Paterson, 1976, Edgecombe, 1988):

(a) **Static wheel loads.** A Reachstacker is stationary when lifting and stacking containers, and in this operation can apply front axle loads, because of the leverage, of up to 100 ton, carried on four tyres at an inflation pressure of up to 1000 kPa.

(b) **Dynamic wheel loads.** Besides the bouncing movement of the Reachstacker or trucks, there is also a horizontal component because of braking and turning forces. To minimise these influences an even pavement surface is required, but skid resistance must be built into the surface to prevent slipping and to allow safe braking of road vehicles. The texture should be such that undue tyre wear does not occur.

(c) **Impact and high point loads.** The contact stresses under the 176 square cm pedestals of loaded and stacked containers can be up to 21.6 MPa for five stacked containers. With fast operations carriers tend to brake and lower the container simultaneously, and this can cause scour of the surfacing by the container. This can cause up to 5 mm deep gouges in concrete.

(d) **Lubricant spillage.** The handling equipment at container terminals is typically hydraulically operated. The surfacing should be able to resist the effects of spillage of oil, and should not become slippery.

(e) **Differential settlement.** Minimum differential settlement is permitted as it could cause the container to hog and damage the contents. The pedestals are 10 mm below the main container frame, and thus the differential movement should be less than 10 mm over a 12 m length.

(f) **Limited maintenance needs.** Container terminal facilities are normally fully used and delays in operations to perform maintenance are frowned upon.

Considering these operational needs it was resolved that high

EXPERIMENTAL DESIGN

The aim of the experiment was to determine design parameters for pavements constructed with geocell filled with concrete. It was not the intention to only build test panels that would be strong enough to withstand all the loads. Consequently the test panels ranged from ultrathin structures to structures that would probably carry the loads satisfactorily, as shown in Figure 2.

The position of the test panels was selected between the maze of railway lines in an area where the in-situ reef quartzite rock layer was more than 1 m below the surface, and where the materials were relatively consistent as determined by a Dynamic Cone Penetrometer (DCP) survey. The layers were built 150 mm thick to facilitate construction.