Use of Cellular Concrete for Air Convection Embankment to Protect Permafrost Foundations in Cold Regions: Feasibility Study

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1. Introduction

The Air Convection Embankment (ACE) concept has been studied for many years. Previous numerical and field studies have confirmed that ACE can be successfully used to provide passive cooling for roadway embankments in permafrost zones all over the world such as China, Russia, Canada, and interior Alaska. However, in many permafrost areas, the coarse gravel or crushed rocks needed for ACE construction are not readily available. Burdened by the need to ship suitable rock to remote locations, costs for constructing an ACE is often prohibitively high, which prevents its wide use in permafrost regions.

Cellular concrete as an alternative material for ACE in permafrost regions shows great potential to get higher performance and reduce the high cost of embankment construction in the permafrost region. Density, porosity, thermal conductivity, almost all the properties of cellular concrete can be controlled and modified in the building procedure that makes it a promising alternative material to replace crushed rocks in ACE construction.

2. Objectives

- To use cellular concrete as an alternative material for ACE in permafrost regions.
- To develop a cellular concrete ACE with better performance and lower cost than crushed rock ACE.

3. Experimental Details

Materials

- Type I/II Portland cement
- Class F fly ash
- Slag
- Silica fume
- Sand
- Foam agent
- Foam stabilizer

Test Methods

- Flow table test
- Density measurement
- Permeability test
- Compressive strength test
- Freezing and thawing test
- Specific heat capacity test
- Thermal conductivity test

Foam generating Mixing grout with foam Cubic specimens

Fig. 1 Cellular concrete making procedures

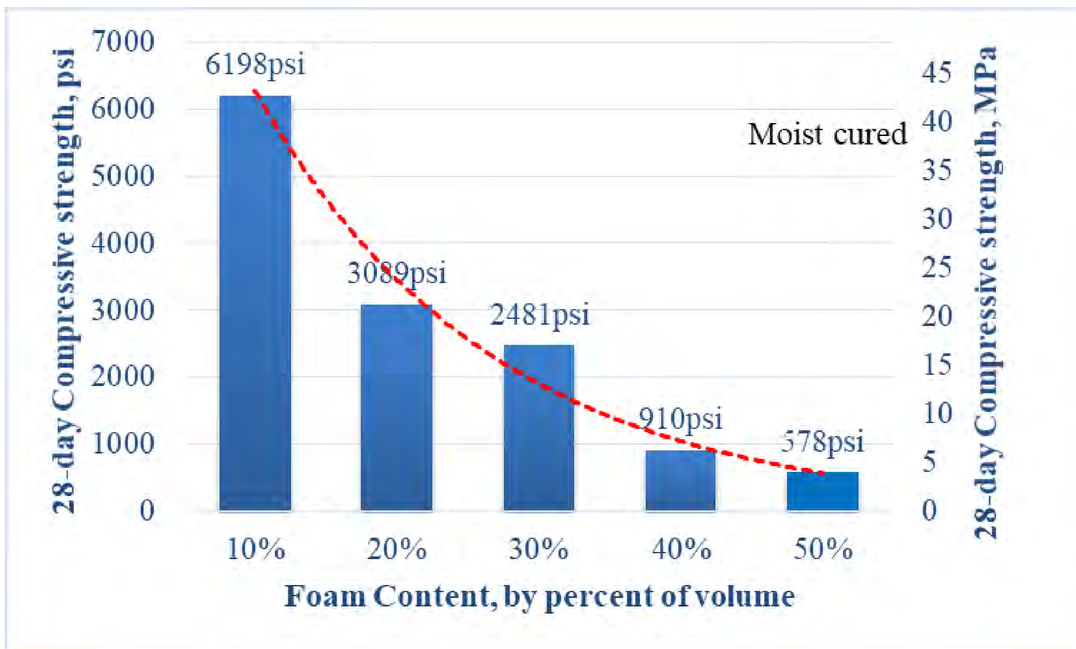

Fig. 2 28-day Compressive strength vs foam content

4. Numerical Simulation of ACE

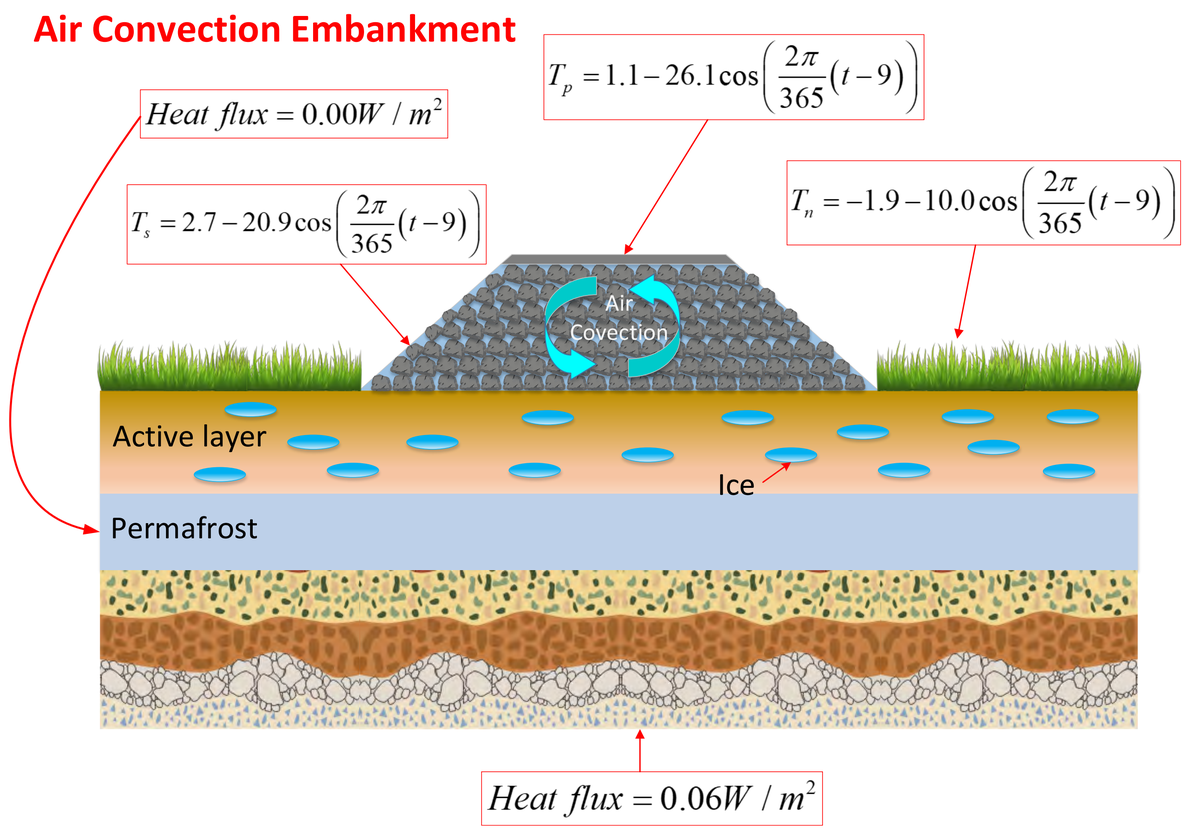

Fig. 3 Air convection embankment and boundary conditions

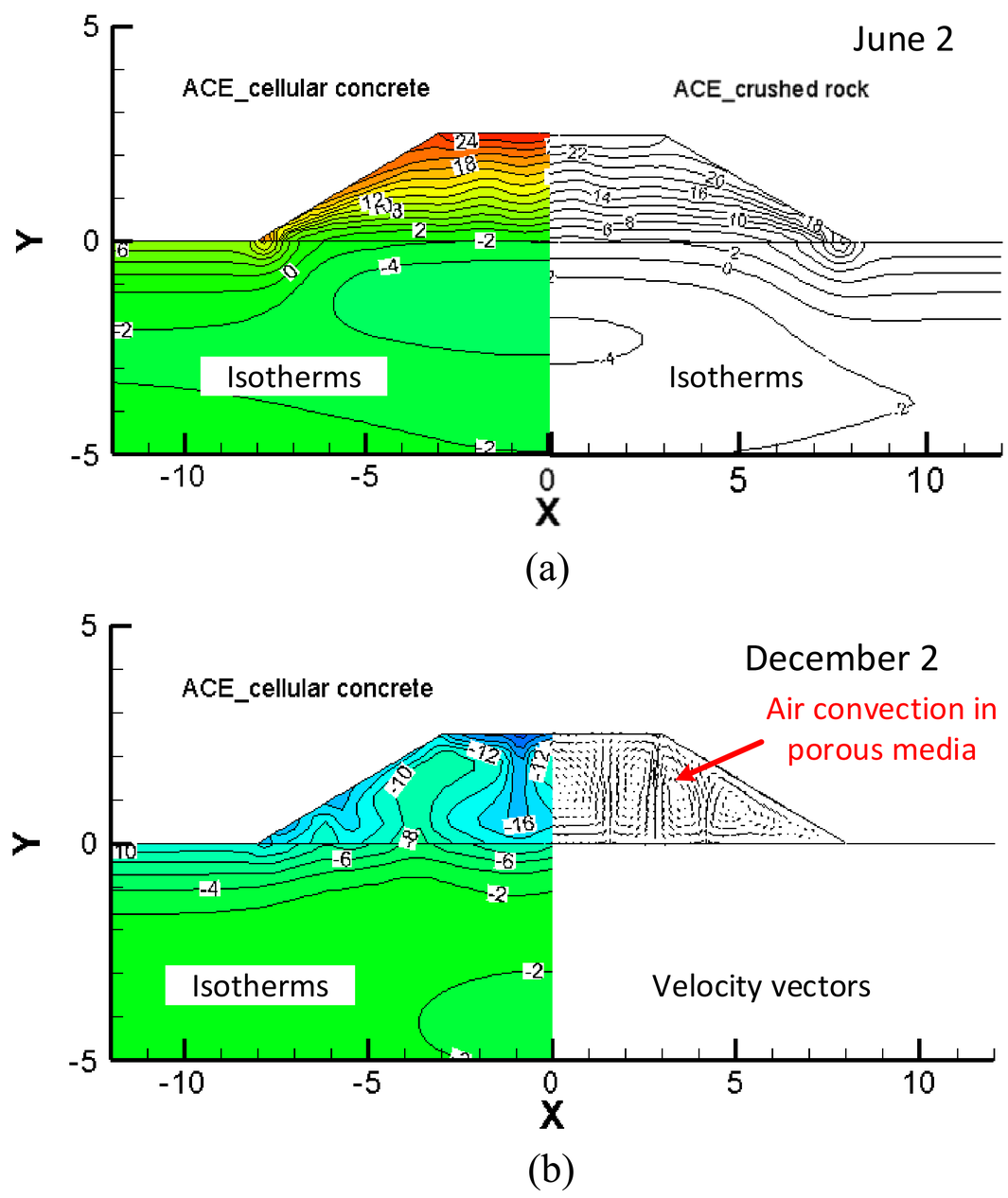

Fig. 4 Instantaneous isotherms (°C) and velocity vectors for cellular concrete ACE and crushed rock ACE

5. Conclusions

- The insulation property of cellular concrete can prevent heat transfer from surroundings to the permafrost foundation.
- The annual cooling effect of cellular concrete ACE is much better than that of crushed rock ACE.
- Cellular concrete as an alternative material for ACE can significantly reduce the high cost of construction practice.