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THERMAL CONDUCTION AND THERMAL STRESS ANALYSES OF ROAD BRIDGE STRUCTURE WITH ASPHALT PAVEMENT BY VISCOELASTIC FINITE ELEMENT METHOD

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1 INTRODUCTION

The performance of road bridge is often concerned with the influence of traffic loads. Deformation of the materials due to axle loads is very obvious but at the same time deformation due to the influence of temperature upon the characteristics of asphalt layer was rarely being reported. Although the analysis regarding the thermal influence had been presented, the study with respect to viscoelastic character is almost disregarded. It is relatively difficult to obtain the accuracy of a solution by reason of the given particular viscoelastic material and the history of load and environment. Moreover it is remarkably time dependent with highly sensitive to temperature change. Under the influence of large surface stresses, asphalt material tends to flow viscously and this tendency also increases with temperature. On the other side, under low temperature, asphalt material becomes brittle and more liable to fatigue failures. In very cold area, road heating is introduced to overcome such problem and also to prevent the road surface from frost. Heating medium is laid and embedded within the asphalt layer and heat is generated electrically with appropriate intensities. Heat is distributed within the interior body of bridge materials by means of conduction from the heating medium source. In this paper, the element model representing part of road bridge structure was chosen in estimating thermal distribution and induced stress under a given environment temperature and applied heat.

2 ANALYTICAL METHOD

Thermal conduction and thermal stress analyses are evaluated based on a viscoelastic theory by means of 2 dimensional, plane strain finite element formulation. The associated, finite element computer program is used and its flow chart is as shown in Figure 1. The material properties chosen correspond to asphalt, concrete and steel representing composite bridge structure, and nicrom as the line heating medium. In looking for more realistic stress-inducing temperature within the interior body, the experimental data of asphaltic material obtained from the Hokkaido University [1] is used. The asphalt pavement specimen was taken from the National Road in Hokkaido. Relaxation modulus of the asphaltic mixture is expressed in term of Prony Series [2]. The data for ambient temperature is also representing the actual environment (Figure 2).

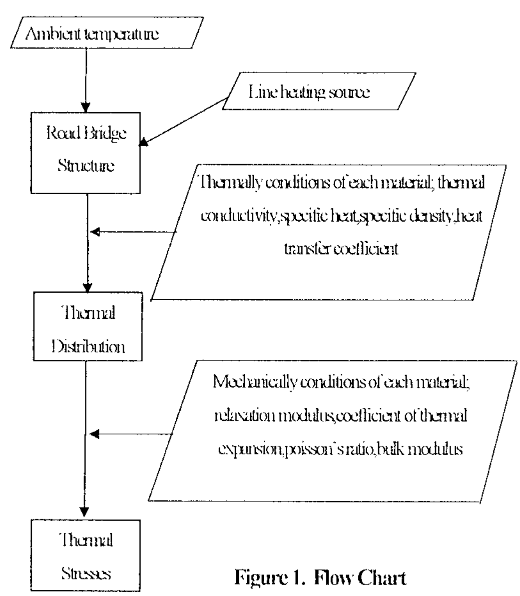


Figure 1. Flow Chart

3 ANALYSIS RESULTS

Figure 3 shows temperature distribution in the interior of an element model of bridge section subjected to the environment and applied heating source. Under the ambient temperature, cold temperature is distributed in strips shape and the entire element falls below freezing point. On the exposed surface, asphalt material is the most affected compare to steel material. When heating source of 20 watts is introduced, heat is distributed in contours shape and temperatures increase above freezing point. In asphalt material, heat is stored through out the heating period and temperature maintains about 3°C on its surface. With respect to thermal stresses, Figure 4 shows horizontal stresses distribution on the materials surface correspond to time. For asphalt material exposed to ambient temperature, the induced stress is peaked at 7 hours period and then starts to decline. The graph indicates that relaxation starts taking place after 5 hours period. The stresses are linearly distributed in concrete and steel materials. The results show that concrete material induced high cooling stress. When line heating is introduced, the cooling stresses in the materials seems to reduce.

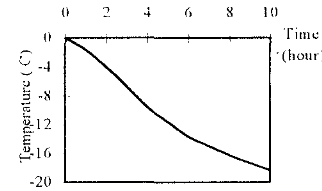


Figure 2. Ambient Temperature

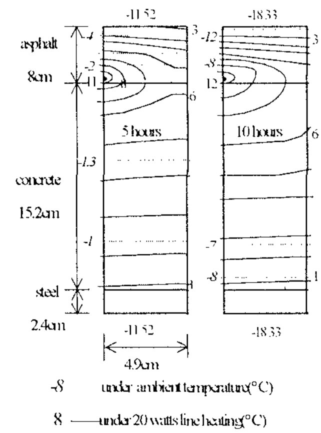


Figure 3. Temperature distribution in the element model at 5 and 10 hours period

4 CONCLUSIONS

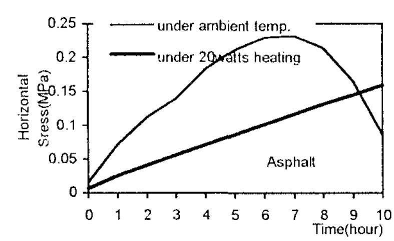
(1) Road bridge when exposed to very cool environment, its composite materials are frozen and the most affected component is asphalt pavement.

(2) 20 watts was found to be the most economic usage when generation of heat occurs by means of heating line source. Temperature on asphalt surface was maintained about 3°C, thus sufficient enough to prevent snow from covering its surface.

(3) Based on stress behaviour, the chosen asphalt mixture was seemed to be in a good agreement with viscoelastic characteristics.

(4) The influence of cool stress in asphalt material was small, however in concrete and steel materials were significant. Therefore the effect of thermal influence should not be disregarded.

(5) Line heating source contributed to the reduction of cooling stress gradient.



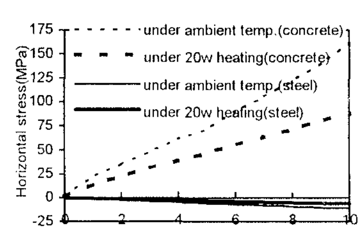


Figure 4. Horizontal stresses on asphalt, concrete and steel surface under environment and applied heat source

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