Some construction methods with three-dimensional thermal and stress coupling analysis for high quality control of concrete structures in cold region*1

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Abstract

The purpose of this research is to control cracking of concrete structures that undergo repeated freezing and thawing in winter in cold regions by applying three dimensional thermal and stress coupling analysis. The temperature, strain, stress etc. of each construction method are examined to improve the process of quality improvement.

By applying the equation of three dimensional thermal and stress coupling analysis, this study examined potential for and control of the cracks in concrete structures in the regions, especially in a three dimensional short span of the structure.

Relieving restraints on the existing base concrete by a retarder concrete layer, the effects of crack prevention of a crack were better than with either fiber concrete and reinforcing ku concrete.

It is necessary to examine the mix proportion suitable for each construction method, because the consistency of the concrete will differ by the construction method.

1. Introduction

1.1 Background

Concrete structures in very cold regions deteriorate as a result of external factors such as freeze-thaw cycles, consequently the construction of the higher quality is desired in order to prolong service life. With the ISO quality system be coming more common among enterprises, efforts are focusing at more an prevention and correction of anomalies caused by cracking and frost damage etc., with the gradually developing level.

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1.2 Purpose of study

The purpose of this research is to apply the three-dimensional thermal and stress coupling analysis the control of the concretes cracking in structure located in the cold regions. The temperature, strain, and also stress changed by each construction method are examined to work toward quality improvement.

2. Research method

2.1 Study process

Three dimensional thermal and stress coupling analysis is carried out using data an each method of construction and weathers condition, done. And evaluating it by the crack index, to feed and back the result of the analysis is tried to examine into the process of the quality improvement. Experimental constructions is backed up and done with simulations..

2.2 Theory of the coupling analysis

2.2.1 Equations of three-dimensional thermal and stress coupling analysis

The main equations of thermal and stress are given in [1] to [3]. The analysis that solves temperature and stress alternately analyzes in the equation [1] as the non-steady heat conduction problem taking into account the heat generated by cement with the hydration.

$\partial T/\partial t= \lambda c/C_c \rho c\ (\partial^2 T/\partial x^2+\partial^2 T/\partial y^2+\partial T^2/\partial z^2)\ +dQ\ (t)/dt$---------[1]

The thermal conduction, strain, stress in equations [2] and [3] are request in the coupling analysis with the value obtained in the equation [1].

T: concrete temperature (℃),

Q: heat insulation rise quantity (℃),

λ c: thermal conductivity (kcal/mh ℃)

$Mu''+D(T)u'+K(T)\ u=f$-------[2]

$C(T)\ T'+k\ (T)T=Q+QI$------- [3]

u: strain

QI: calorific value by the inflexibility job

D(T)u': creep

This analysis system is constructed as a model of fundamental properties of matter model by using MARK MENTATⅡ analysis system, and developed as temperature with hydration heat, strain, and stress analysis evaluation system.

2.2.2 Definition of crack index

Crack index Icr(t) at each age t is defined as the following equation [4],

$Icr\ (t) = f\ (t)/\sigma t\ (t)$----- [4]

F (t): tension strength of each which is calculated from the flexural test data

σ t (t): stress at each age with tension positive

It makes to control crack from the result of the crack indexes 1.5 or more.

2.3 Analysis conditions

2.3.1 The object model

The analysis object is the three -dimensional model in Figure 2.2.1 of general breakwater. The length of block of a analysis model made 2.5 m at the symmetric center position of fixation edge 5 m and analyzed one side. Case 1 is normal concrete. Case 3 is concrete that cuts the restricted condition relation between the upper part and lower part with retarder concrete layer. As construction method parameters, Case 2 is fiber concrete and Case 4 is reinforcing concrete.

2.3.2 Mix proportion condition and physical properties

The mix proportions and physical properties for cases 1～4 in this analysis are shown in Table 2.2.1 and Table 2.2.2. This mix proportion is a standard mix proportion ocean structures. Case 4 was analyzed as comparing with assuming that there is not retarder concrete layer and old concrete a restraint.

Table 2.2.1 Mix proportion

Case	W/C %	s/a %	Cement kg/m³	Water kg/m³	Fine Aggregate kg/m³	Coarse Aggregate kg/m³	S.F kg/m³	Admixture kg/m³
1, 3 4	48.6	38.3	282	137	698	1248	—	0.56(AE agent)
2	48.6	50.0	282	137	941	959	117.75 (1.5%)	2.03(high-performance AE decreasing agent)

Table 2.2.2 Analyzing condition

	Case	Initial temperature ℃	Specific heat kcal/kg℃	Heat conductivity kcal/mh℃	Density kg/m³	Coefficient of expansion 1/℃	Poisson's ratio
New concrete	1, 3 R.C.	20.0	0.25	2.2	2365	10×10^{-6}	0.2
	2	20.0	0.25	2.2	2439	10×10^{-6}	0.2
Old concrete	1, 3 R.C.	17.0	0.25	2.2	2365	10×10^{-6}	0.2
	2	17.0	0.248	2.2	2365	10×10^{-6}	0.2

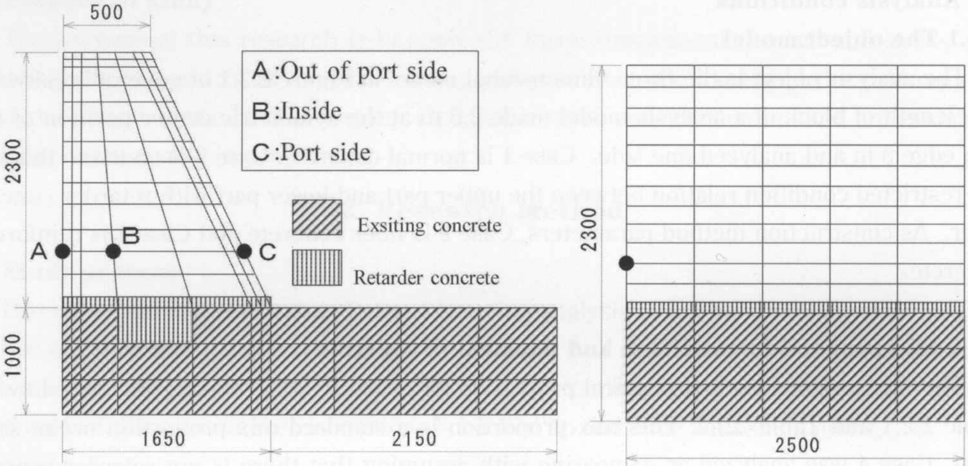

Fig 2.2.1 Analysis model

3. Results and consideration

3.1 Results

3.1.1 Hydration heat

One of the results of analysis is shown in Figure 3.1.1. All cases indicate a lot of hydration heat until 3 days, although the distribution temperature is 27.5℃. The concrete temperature is fairly higher than outside temperature by the placing in fall. Temperature did not drop sharply due to the generation of concrete. The heat is notified base concrete after concrete forming. There is no cracks in case 2 and case 3 in next spring.

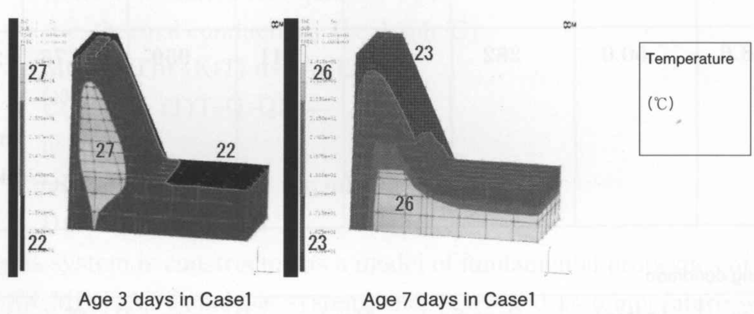

Fig 3.1.1 Thermal distribution

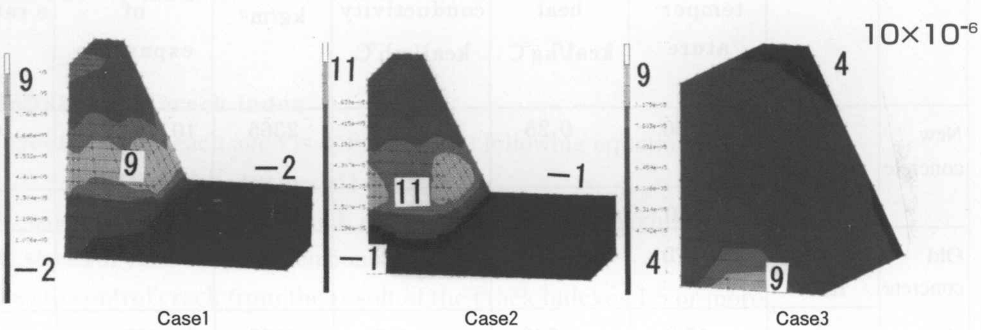

Fig 3.1.2 strain distribation(Case1～3)

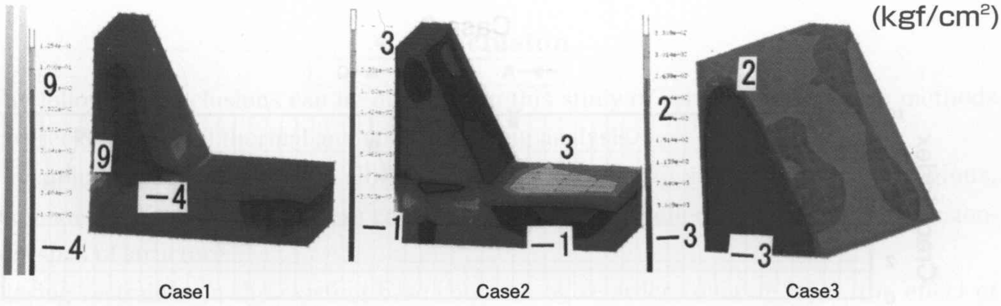

Fig 3.1.3 stress distribution(Case1～3)

3.1.2 Strain

The value of the strain distribution is high at the surface in case 1 and case 2 in touches with outside air on the level at the part 50 cm from the base concrete. There was not large value place especially in case 3 without the restraint on the boundary interface of new concrete and old concrete.

3.1.3 Stress

The value of the stress value is high at the boundary line at the surface part of new concrete and old concrete of the same place as the strain in the case 1 of normal concrete. In case 2, the difference between the maximum value and minimum value of the stress becomes small. The stress distribution is uniform. In the case 3, the stress is uniforiming with same tendency.

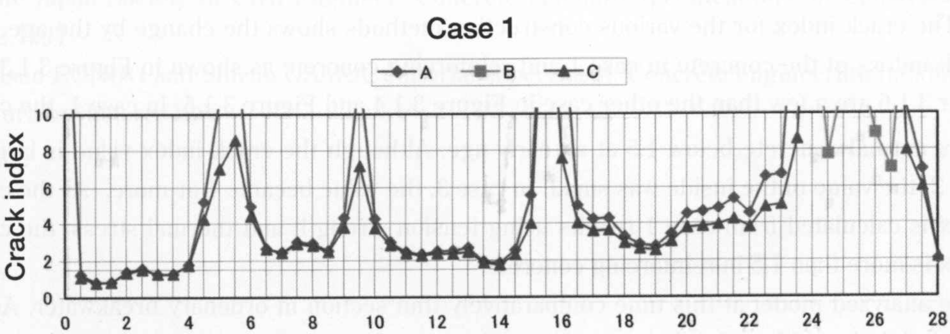

Fig 3.1.4 Crack index in case1 of normal concrete

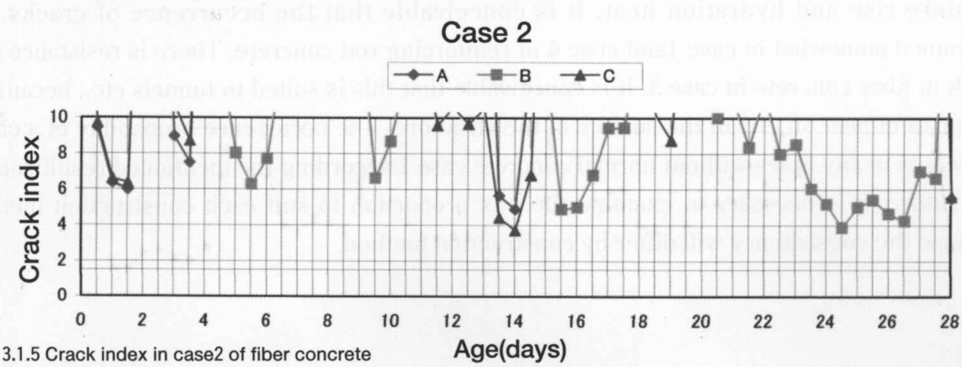

Fig 3.1.5 Crack index in case2 of fiber concrete

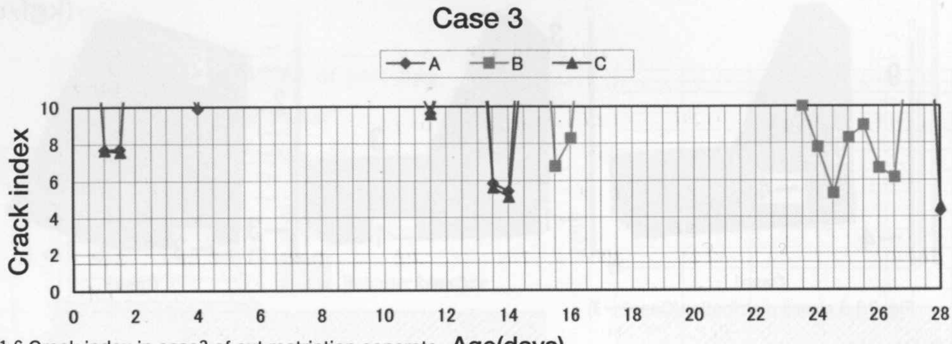

Fig 3.1.6 Crack index in case3 of cut restriction concrete

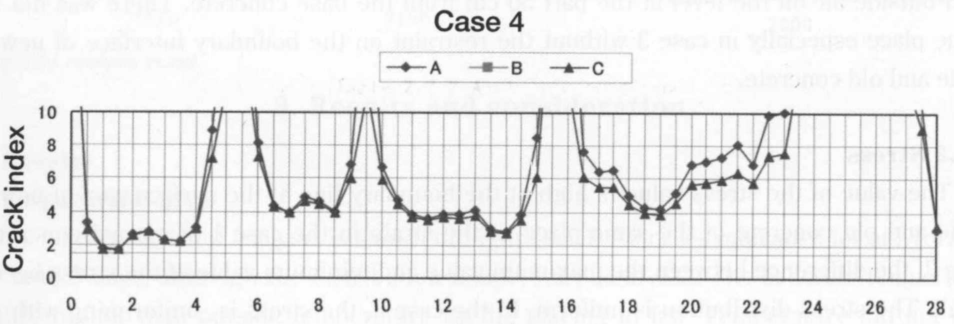

Fig 3.1.7 Crack index in Case 4 of reinforcing comerete

3.2 Consideration

The crack index for the various construction methods shows the change by the age. The crack indexs of the concrete in case 1 and reinforcing concrete as shown in Figure 3.1.3 and Figur 3.1.6 are a few than the other case in Figure 3.1.4 and Figure 3.1.5. In case 1, the crack index normal concrete below 1.5 at an early age. Although the crack index value is large in case 2, the value of the inside was small. In case 3, the value became 4 or more. As the crack index is calculated from case 1 results using tension strength and thermal stress, the crack index is more than 1.5 in reinforcing concrete.

The analyzed model at this time comparatively thin section in ordenary breakwater. As for the crack index, although it became to raise. In case 1 it came close to cutting 1.5 by the temperature rise and hydration heat. It is conceivable that the occurrence of cracks are restrained somewhat in case 1and cose 4 of reinforcing rod concrete. There is resistance to a crack in fiber concrete in case 3. It is conceivable that this is suited to tunnels etc., because it can prevent peel off etc. of the surface of the structure. The occurrence probability of a crack decreases in any cases without normal concrete case 1 according the mentioned resultfrom .

In future, it is neessary to examine the mix proportion to suit each construction method because the consisitency will differ by construction method.

4. Conclusion

The following conclusions can be drawn from this study of various construction methods using three-dimensional thermal and stress coupling analysis.

1)To examine and control the possibility cracking in concrete structures in cold regions, three-dimensional thermal and stress coupling equations offer effective in a three dimensional short span of structure.

2)Relieving restraints on the existing base concrete by retarder concrete layer, the effect of the prevention of a crack is better than fiber concrete and reinforcing concrete.

3)Mix proportions have to be suitably choser for each construction method, because the consistency of concrete will differ by construction method to prevent crack.

4) There are no cracks in case 2 of retarder concrete layer concrete and case 3 of fiber concrete.

Acknowledgement

The authors would like to thank the head officer Mr. Watanabe, the chief Mr. M. Kato, and the engineer Mr. S. Uesugi at Monbetsu Port Construction Office of The Hokkaido Development Bureau, the ngineer Mr. S. Morita and Mr. H. Hashizume at Omu Remicon Co. Ltd, Dr. T. Takeuchi and Mr. Genba at PFK Co. Ltd as well as all other involved.

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