regression analysis. In this study, age of 1, 2, 3 and 14 day, when maximum thermal stresses occur, are considered.

Thermal stresses in the structure predicted by using Fig. 5 and Table 2, which is elastic strain of the structure, are shown in Table 3.

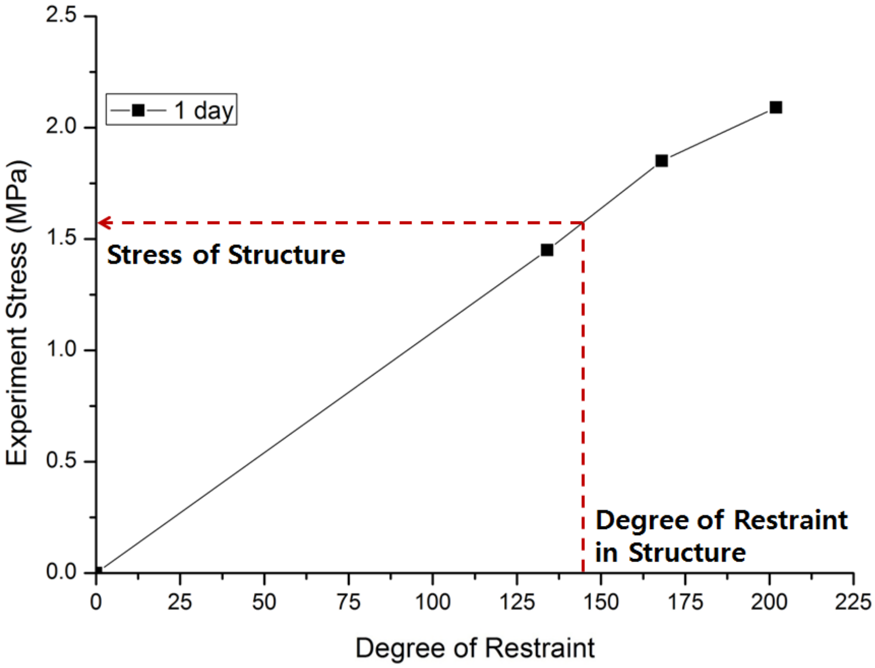


Fig. 4 Prediction of thermal stresses comparing the degree of restraints[2]

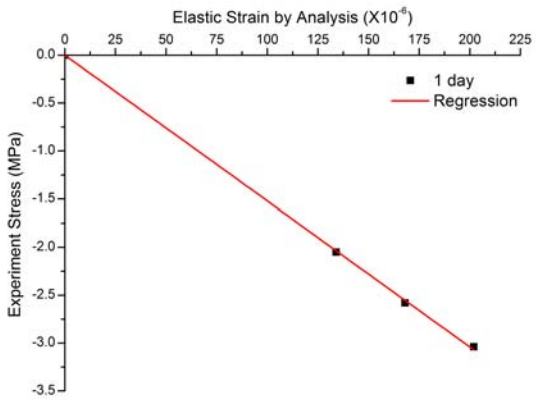
4. ESTIMATION OF CONCRETE PROPERTIES AT EARLY AGE

It is difficult to predict thermal stresses by numerical analysis because there are lots of uncertainties such as mechanical and thermal properties which change with time. Therefore, properties of concrete should be estimated appropriately considering mix proportion, materials, curing condition to improve the accuracy of numerical analysis.

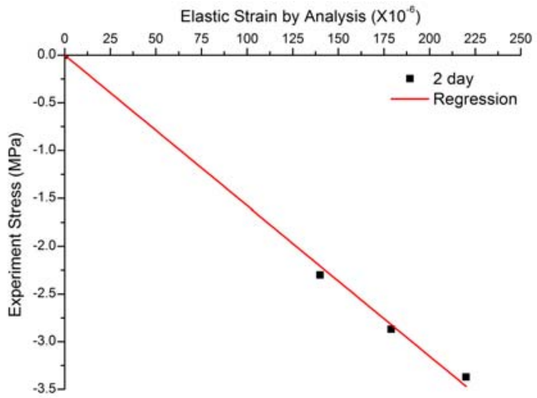
In this study, the method for the estimation of properties of concrete is suggested using the device. As shown in Fig. 6, properties of concrete can be estimated by comparing the stress results between experiments and analysis when each step of the analysis has the best values of properties of concrete, such as thermal expansion coefficient, final autogenous shrinkage and final creep coefficient, which result in similar stress results between analysis and experiments.

4.1 analysis program

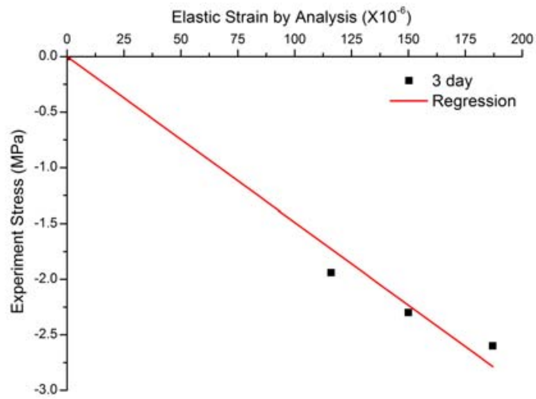
Hydration heat analysis program, which is developed based on CONSA/HS developed in KAIST concrete lab., and regression program based on Levengerg-Marquardt method are united to compare the stress results between the experiments and analysis.



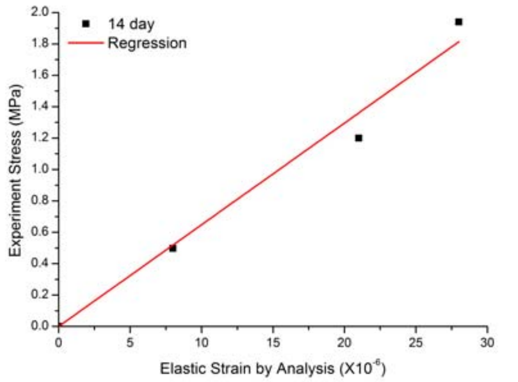
(a) 1 day



(b) 2 day



(c) 3 day



(d) 14 day

Fig. 5 Relation between thermal stresses and the degree of restraints

Table 2 Degree of restraints of the structures (elastic strain)

	Age (d)			
	1	**2**	**3**	**14**
Elastic strain ($X10^{-6}$)	222	239	196	14

Table 3 Thermal stresses from comparison of the degree of restraints

	Age (d)			
	1	**2**	**3**	**14**
Stress (MPa)	-3.37	-3.77	-2.92	0.91

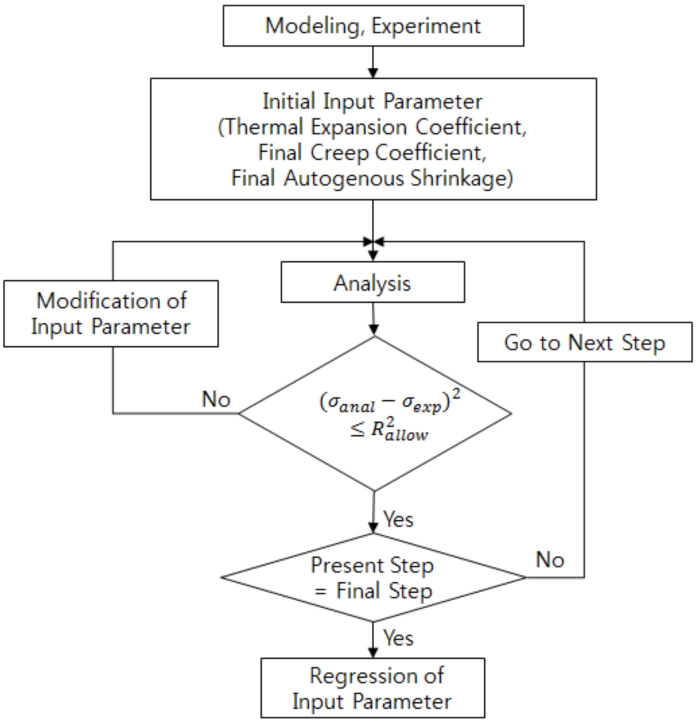


Fig. 6 Estimation of properties of concrete

4.2 Estimated properties of concrete

Properties of concrete are estimated by using above mentioned method. As shown in Fig. 7 there are 6 thermal stress results in each step. The results are shown in Fig 8. Final creep coefficient and final autogenous shrinkage are estimated using ACI model and B3 model respectively. [3], [4]

With respect to thermal expansion coefficient and final creep coefficient they changes rapidly at early age and then converge to constant value of 9.8 $\times 10^{-6}$/℃ and 2.5 respectively. However, Final autogenous shrinkage is almost constant.

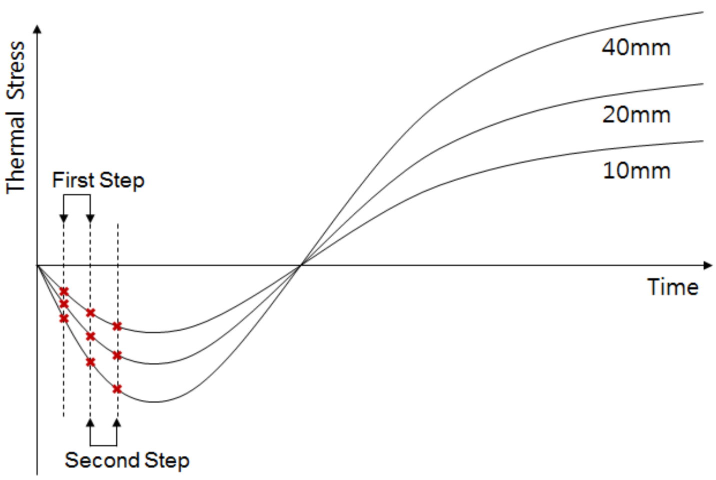
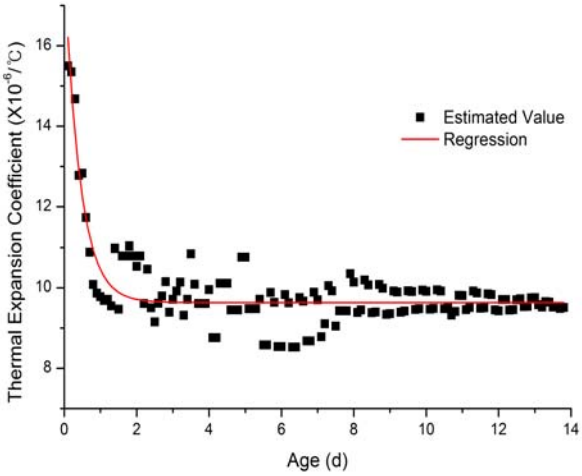
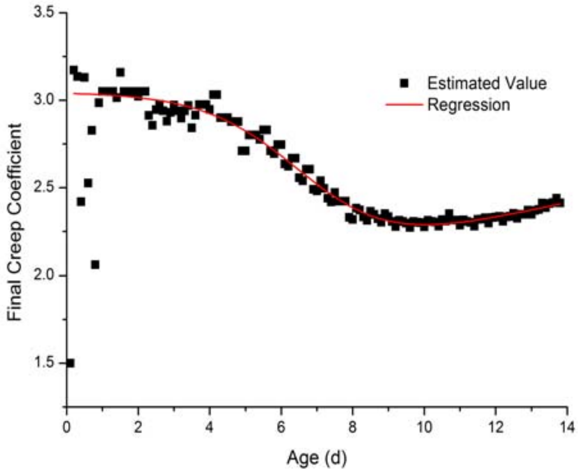


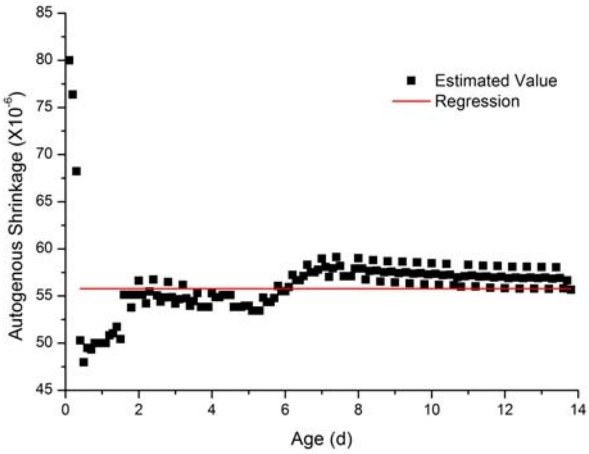
Fig. 7 Compared stresses in each step



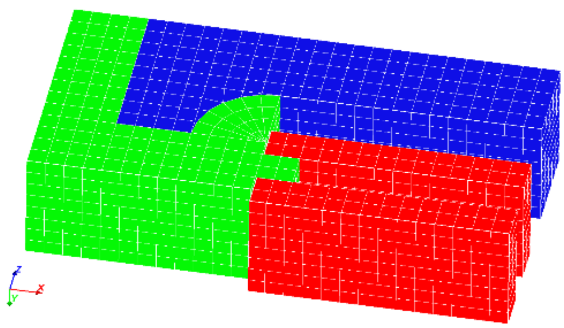
(a) Thermal expansion coefficient



(b) Final creep coefficient



(c) Final autogenous shrinkage



(d) Modeling of thermal stress device

Fig. 8 Estimated concrete properties and modeling of the device

5. CONCLUSIONS

With regard to comparison of the degree of restraints, the approach is simple and convenient. However, there is limitation that the approach should be applied for strong external restraints. For second approach it estimates properties of concrete reasonably and it is helpful to improve the accuracy of analysis. However, although estimated properties of concrete is quite similar to existing research, they should be verified through various experiments.

6. ACKNOWLEDGMENTS

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[3] Z. P. Bažant and S. Baweja (1995) “Creep and Shrinkage Prediction Model for Analysis and Design of Concrete Structures: Model B3” *RILEM Recommendation, Materials and Structures,* 28 (1995)

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