Transactions of the 15th International Conference on
Structural Mechanics in Reactor Technology (SMiRT-15)
Seoul, Korea, August 15-20, 1999

Estimation and Environment-Deterioration Testing of Non-Metallic Liner Physically

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ABSTRACT

Up to date, it is difficult to estimate durability of epoxy liner in service time because an estimation of the long term environment-deterioration with aging has not been processed. In the study, the estimation on epoxy liner is carried out by the physical test for 7 rounds. There are the elongation test and the crack bridging test in the part of physical tests. An elongation test is carried out with epoxy membrane and a crack bridging test is carried out with epoxy-coated specimen on mortar. The subjects of test and estimation are a containment quality system and a fibre-glass reinforced system. The materials of these subjects are ET5140, CL890, and EH2340. Ensuring the test data, properties of epoxy liner was estimated and the change of properties was predicted on epoxy liners.

1. Introduction

The objective of non-metallic liner system is the leakage protection of radioactivity and the resistance for inner environment conditions in containment building. Purpose of the study is to obtain a basic data for a safe service on nuclear power plants by test and estimation with a physical aging effects on the epoxy liner. Target of the study is to predict and estimate a safety serviceability on nuclear power plant. Physical tests are carried out to grasp an elastic property and an ability of crack bridging on the epoxy liners in the physical part. Materials of the tests are epoxy liners as the containment quality system and the fibre-glass reinforced system. These materials should be stand the test by CSA N287.2 and AECL TESTING REQUIREMENTS.

In the environment-deterioration, an elongation test is to measure the largest elongation of epoxy liners by epoxy membrane to the appointed term. And a crack bridging ability test is to measure the ability of crack bridging on the surface of epoxy liner coated on concrete at the appointed term. There are two methods on the tests. ① Steady load crack bridging test, ② Step load crack bridging test. The reason carried two types of crack bridging test are to evaluate influence of holding time on the resistance for crack.

2. Specimen Preparation

2.1 *Elongation test specimen*

Casting methods of membrane specimen are two way. (1) Method of spray : Placing the silicon coated detach paper having the adhesives attached on one side→ Spray to the necessary thickness of the specimen as crack bridging lining. (2) Method of applicator : Attaching the detach paper through the equal method of spray→ Manufacturing the membrane of the necessary thickness with the applicator. The others, operating through the procedures for the detailed steps in the lining operation.

The manufactured membrane specimens were stored on the consistent conditional room(23K1.7℃, 50% RH) to given test date. The shape of specimen is shown in Fig.1.

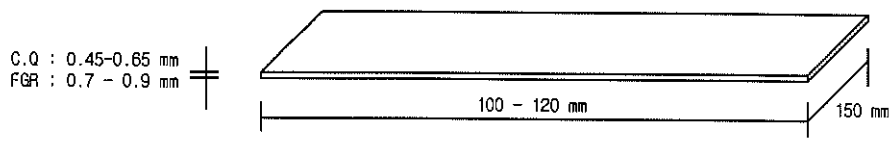


Fig.1 Shape of the specimen for elongation measurement

2.2 *Crack bridging test specimen*

2.2.1 *Preparation of mortar specimen*

The specimen for the crack bridging test was based on the concrete mix design employed in a Korea N.P.P. However, aggregate and chemical admixture was excluded. W/C ratio was 45% and cement content was 500kg/m'. The mortar specimen had been cured on water at the thermostat (23K3℃) for the first two weeks, and it was cured and dried on air for the second two weeks to spread the epoxy. Fig.2 shows the size and the shape of the ground mortar specimen.

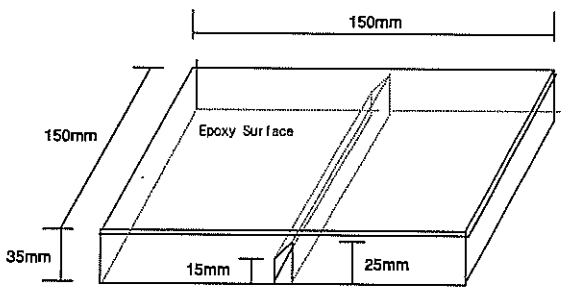


Table 1 shows the compressive strength of mortar specimen on the twenty-eighth day per each Batch. These test results have similar value of compressive strength of concrete to the containment building.

Fig.2 The shape of the specimen for the crack bridging test

Table 1. Compressive strength of mortar specimen

Batch No.	Batch I	Batch II	Batch III	Batch IV	Batch V	Avg.
Value (kg/cm^2)	464	428	526	400	440	432

2.2.2 *Specimen lining*

Surfacing was carried out as following order. Pine hole chipping→ Surface grinding with power grinder→ Blowing away dust with high pressure air spray→ Filling all holes with the surfacing material→ Completing the surfacing work after securing the necessary thickness. Also, main coating (Lining) was accompanied by the order. As the surfacing of the ground material finished, grinding the surface with fine sandpaper→ Curing through the procedures after lining with airless spray→ Completing four times lining→ Only for Fiber-Glass Reinforce(FGR) system using EH2340, after the first lining, continuing subsequently attaching and absorbing fibre-glass after the first lining to complete the four times lining.

During the lining operation, the temperature and the humidity in coating room was 8～10℃ and 30～40%, respectively and the specimen completely coated per each layer had been cured and stored in the lab which can maintain the temperature of 23K3℃ and the humidity of 50K15%.

3. Elongation test result and analysis

The elongation test is mainly to test the maximum elongation of the liner-membrane using the tensile tester and to measure the tensile strength given at the time. The elongation test items are (1) Maximum elongation length, (2) Maximum elongation, (3) Tensile strength, (4) Thickness variation on the fracture surface.

The specimen manufactured by method of spray and of applicator for C.Q, and to test only that of spray for F.G.R were measured. Fig.3 shows the marking rule of sample number.

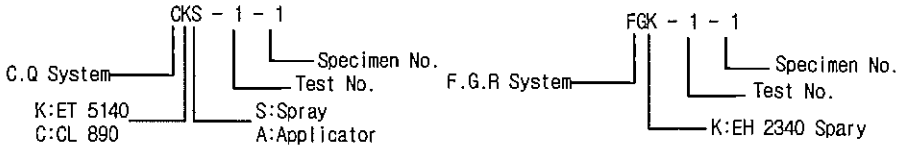


Fig.3 The marking rule of sample number

3.1 *Elongation test*

Fig.4 shows the average elongation in each round from the seven round experiments on ET5140, CL890 and EH2340. The physical characteristics on the base of the results from the experiments were arranged as follows.

(1) As shown in Fig.4, there is relatively much variation of the elongation by the fourth round of the experiment as a whole and we can see the state of maintaining with no variation between the fifth and the seventh round. Therefore, the results from the elongation tests indicate that the system adopted to the non-metallic liner has stable physical properties in the periods of the fourth and the fifth round, lying between the thirty-third and the fifty-third week after the sample had been manufactured.

(2) As we compare three kinds of system ET5140 has higher elongation than that of other two systems in the initial stage while it reveals that reduces the elongation abruptly as the time elapses. This means that in case of this system the initial change of the physical property proceeds rapidly.

(3) We can decide that the physical property is changing abruptly by the initial fourth round in ET5140 system, though, after the fourth, the system has the common elongation that hardly changing like the other two systems. Therefore, ET5140 initially has rapid change of the physical property, and after that, it maintains the physically stable state.

(4) Because ET5140 includes rubber-added-filler the elongation fluctuate largely, according to the conditions of temperature given to the experiment. Therefore, we can estimate that the changing ratio of the physical property is high in the surroundings of this system.

(5) CL890 reveals too low data of the initial elongation comparing to ET5140. Although it shows the tendency to reduce the elongation steadily by the initial fourth, the reduction range is too narrow in the initial experiments.

(6) As CL890 system has no considerable change as we set the experimental condition with the addition of an inorganic filler having the component of silica to the epoxy resin, it is estimated that the system is not sensitive to change the elongation with the change of the temperature.

(7) Like ET5140, CL890 maintains the stable state in the absence of the change of the elongation after the fourth round was carried out.

(8) For EH2340 system, as we, to add the fiber, restricted the elongation of the epoxy resin, the ratio is low in the initial rounds, and even for the time elapsing gradually to the later rounds, there is no significant change, as shown. As the time elapsing, the elongation of the epoxy resin is reduced, but, on the other hand, as the cohesion between the epoxy and the fiber becomes stronger, the elongation will be not reduced significantly in this system.

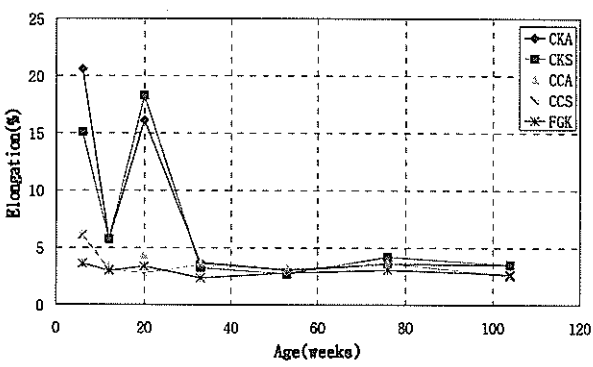


Fig.4 Average elongation in each round

(9) In the initial round or the later round after much time elapsed, it is estimated that there is no considerable change of the elongation. Even after more time would have been elapsed, we can find that the present physical properties will be maintained in a certain period of time.

3.2 *Tensile strength*

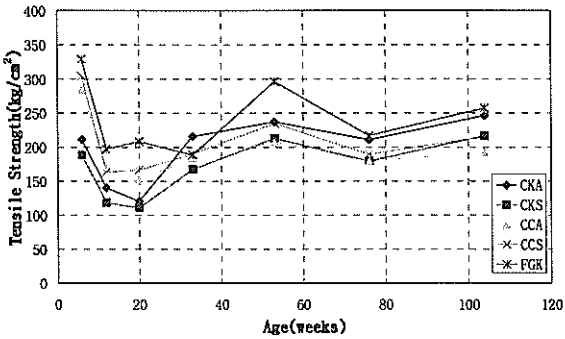
Fig.5 demonstrates the test value with each system and each round averaged. The physical characteristic relative to tensile strength by each system based on test result until 7th round testing can be described as follows; in case of arrangement

(1) Generally test result of tensile strength shows a similar tendency upon the courses of time, in 3 different systems during the progress of all rounds.

(2) Tensile strength at 1st round shows relatively higher and till 3rd round a little or more reducing tendency. Thereafter the strength recovered at the 4th round and then between 5th

and 7th round at a little gap, repeating increase and decrease of tensile strength-phenomenon to be stabilized can be seen:

(3) On account of the reason that liner ET5140 and CL890 as a similar containment quality is added by a different type of fillers. The tensile strength at the initial stage of test and the strength at the later stage of test shows a contradictory trend, however the differences of testing measurement are so little that time passing changes, belittling of difference can be judged to be similar.



(4) Therefore in decision of results after 4th round, for the future considerable period 200kg/cm^2□250kg/cm^2 can be maintained a complete hardening of epoxy liner in a stabilized construction without a rapid change of circumstance, changes of the basic physical performance will be presumed to be nothing.

Fig.5 Average of tensile strength in each round

4. Crack bridging test result and analysis

This experiment is mainly to test the non-metallic liner coated on the concrete ground resisting how much degree of crack while the ground is cracking with the crack bridging tester. The test includes two test items, steady loading that continuing the test until the non-metallic liner fail at a constant speed and step loading that producing the fixed displacement and maintaining that state for some time to do the following displacement. The experiments were carried out in the room maintaining the standard temperature(23K3℃) and humidity(50%K5, RH) and the crack bridging was measured on the isolated measure point of the test material on which LVDT was settled with the precision of 0.02mm using DATA LOGGER(TDS-302).

Fig.6 shows the test result of crack bridging executed until 7th round with ET5140, CL890 also EH2340 applied at testing. Performance upon each system can be described as follows;

(1) In progress of 2nd, 3rd round from the total system similar to test results of tensile strength and elongation the crack bridging performance are inclined to reduce also.

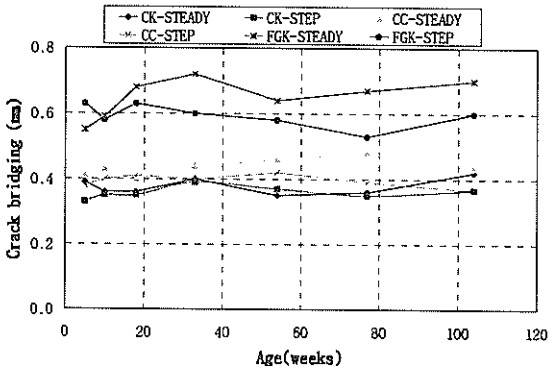
(2) After 4th round same as testing results shows that the crack bridging performance is recovering until 7th round. It shows a tendency that approaches a definite value of the crack bridging by each system, repeating increase and reduction of the crack bridging performance in general, a little bit of difference with testing results of tensile strength forehead by system.

(3) EH2340 system reinforced by fiber has a more strength than other system due to fiber-reinforcing membrane, the section is bigger and tensile stress is high so, the crack bridging performance is judged to be big.

(4) In a state of a definite crack occurrence tensile creep breaking degree of epoxy membrane grain should be checked. Through the 2 kinds of testing of results, step loading-crack bridging performance is little compared with continuous time of crack-increase, in a definite crack-width and by steps on time.

(5) The crack bridging performance differently from elongation and physical features of tensile strength does not show a big change in rounds and system. This reason depends upon non-metallic liner on account of restraints in elongation action on basic testing material. And non-metallic liner was restrained in its contacted surface between mortar and liner.

(6) The crack bridging performance in epoxy membrane of which correlation with the elongation stemmed from grain-order change of membrane to the direct to tensile, with tensile stress and tensile strength as well, comparatively more closer relation has.



(7) After 4th round, every non-metallic liner system shows that the test result is not clear in reduction status of the crack bridging performance. With this status considered, the crack bridging performance is anticipated to keep physical ability for the considerable period.

Fig.6 Test average value of crack bridging performance

5. Synthetic analysis of physical testing results

With the above mentioned elongation and crack bridging performance testing result in synthetic analysis, after formation, 40 weeks, elongation and tensile strength property in changed, thereafter a stabilized state can be kept. Presumably 7th round final testing considered, the physical properties can be maintained considerably long period. Two kinds of C,Q system with different material structure shows at the initial stage of material different physical characteristics. However, in testing of 4th, 5th and the following, elongation and tensile strength show almost same degree. The other hand concerning with the surrounding temperature, moisture conditions at stage of testing, in case of ET5140, very sensitive but in case of CL890, not sensitive to influences of temperature and moisture.

Comparatively testing piece used for elongation test is membrane-testing piece deformed free. On the other hands, the testing piece used for crack bridging performance testing is coated on mortar and deformation of liner-membrane is restrained, so part to arise deformation is very small comparative to testing piece for elongation, from this reason, the behavior of aging changes can not be observed easily. Since, according to the results of crack bridging test, crack bridging performance has a closer relation with tensile strength than with elongation of every testing system. This means that a crack of epoxy membrane coated on

mortar happens from lower base of membrane to upper surface. Therefore, ability of crack-bridging performance will be bigger as higher as tensile strength.

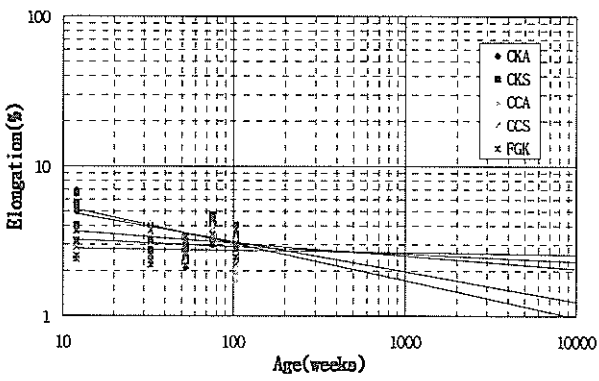
In analysis of testing results upon crack bridging performance executed till 7th round, reduction situation of crack bridging performance during the overall rounds is not apparent and test value at the last round keeps higher than a definite criterion. Through this process, if chemical deformation rapidly does not happen, a considerable degree of crack bridging performance can be maintained

6. Prediction of degradation characteristics by environment-deterioration test

The case of environment-deterioration testing for non-metallic liner executed testing target mainly upon aging change dependent on the courses of time(t) accordingly to testing factors decided by system, prior research has not been made at all before this environment-deterioration testing. Therefore mathematic model and model in probability are difficult to be introduced. So in this place with 7th round, 24months-executed testing result based, along with regression analysis, a long term deterioration characteristics would be anticipated.

6.1 *Regression analysis on testing results about elongation*

If a regression analysis of elongation with lineal function, be made, under ET5140 system, which has high elongation at the initial stage, although it at the later stage can be stabilized, it returns to the point that there is no elongation in due courses of time. Therefore this result of regression analysis is not regression model to anticipate the trend of elongation in future. The curve of regression analysis in LOG function is comparatively proper to presume the forthcoming elongation from CL890 and EH2340 system, however is not proper as a regression model for anticipation of elongation upon ET5140, as in case of lineal regression analysis.



On the other hand, index-function regression model is assumed to be a regression model expressing aging change comparatively and properly except EH2340 system, which has very low elongation.

Fig. 7 Index regression for elongation data on 2,4-7 rounds

It is difficult to anticipate elongation during commercial life of containment building in future, due to the reason that the test does not show mutual dependent trends. Therefore to anticipate long term deterioration based on regression analysis reliable comparatively, it must be based on tests results after 2nd round and 4th round.

For a reliable anticipation of the long-term deterioration, regression should be carry out by the data of only 2, 4-7 rounds as Fig.7. From this regression, the environment-deterioration can be anticipated.

6.2 *Regression analysis of test results on crack bridging performance*

Regression analysis model to crack bridging test results generally has very low correlation coefficient except a part of system. This depends upon repeating of increase and decrease of testing results. In consideration of the characteristic of regression analysis, with a certain degree of inclination, data could be analyzed and correlation coefficient could be high. However, test value of crack bridging is not a consistent trend with rounds. Therefore, it is difficult for crack bridging ability of epoxy lining to be predicted by regression analysis.

7. Conclusion

According to this study, There is relatively much variation of the elongation by the fourth round of the experiment as a whole and we can see the state of maintaining with no variation between the fifth and the seventh round. Therefore, the results from the elongation tests indicate that the system adopted to the non-metallic liner has stable physical properties in the periods of the fourth and the fifth round

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Up to date, According estimation and analysis in epoxy liner, the potential deterioration on epoxy liner was not high for shot term. But the potentiality of sudden deterioration could not be ignore in the long term prediction. Therefore, it is necessary to take care maintenance on epoxy liner.

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