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Stacking Test of Transport Package for Decommissioning Wastes of Nuclear Power Plant

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1. Introduction

Transport packages are being developed to transport the decommissioning waste from the nuclear power plant. The packages are classified with industrial package Type IP-2. Type IP-2 package is required to undergo a stacking test [1]. If the shape of the package has a stackable shape, the package shall be subjected for a period of 24 hours to a compressive load of 5 times the weight of the package. In this study, a half scale model of the transport packages was manufactured and stacking tests were performed. Strains and displacements were measured at the corner post of the package during the stacking test. The measured strains and displacements were compared with the theoretical calculation results to confirm the reliability of the test results.

2. Methods and Results

2.1 Test methods and procedures

A stacking test was performed using a half scale model for six types (T1~T6) of transport packages. In the half scale model, the cross sectional area of the corner post and weight of the model are reduced to 1/4 and 1/8, respectively, compared to the prototype. In the stacking test, a load 10 times the weight of the half scale model was applied so that the stress at the corner post was the same as that of the prototype.

For 4 types packages (T1 ~ T4), the thick steel plates were placed on the corner posts of the test model as shown in Fig. 1. In this model, strain gauges and LVDT displacement sensors were used to measure the strain and displacement of corner posts. A bracket was attached to the top of the two corner posts and holders with a LVDT sensor were placed on the base plate where the test model was installed, and displacement was measured between the base plate and the bracket.

For 2 types of packages (T5 ~ T6), a stacking load was applied using hydraulic cylinders after mounting a jig on the corner posts as shown in Fig. 2. In this model, strain gauges and laser displacement sensors were installed at the corner posts. Two brackets were installed on the corner post to measure the displacement.

After the stacking test, the height of the corner posts was measured, and visual inspection and non-destructive testing were performed to confirm the deformation of the corner posts and cracks in the welds.

Fig. 1. Stacking test of T4 transport package

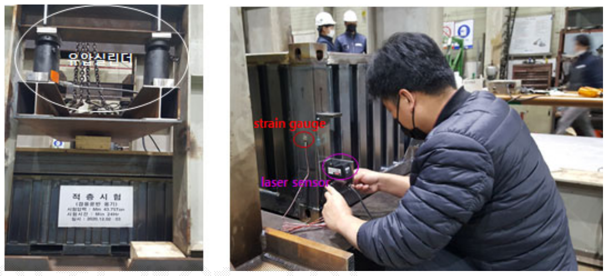
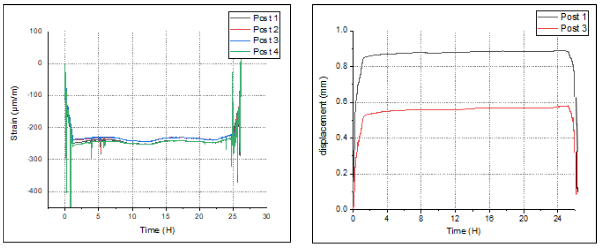


Fig. 2. Stacking test of T6 transport package

2.2 *Results and discussion*

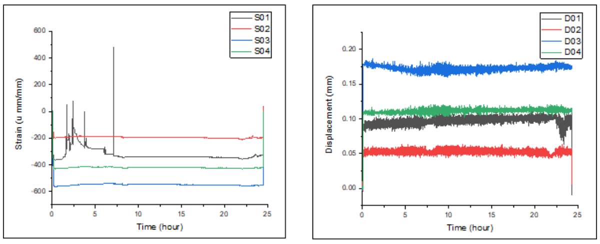
Fig. 3 shows the measurement results of strain and displacement at the corner post for T4 package. Strain and displacement were almost constant for 24 hours while loading the weight. After unloading the weight, the strain returned to the initial value, but the displacement from the LVDT was permanently deformed. The height of the corner post is 490 mm, and the average strain was measured to be 2.42E-4, which is converted into displacement to be 0.12 mm. The displacement at the corner posts of P1, P3 were measured to be 0.88 mm and 0.57 mm for 24 hours, and permanent deformations of 0.12 mm and 0.10 mm occurred after stacking test. Displacement by the LVDT showed a significant difference from the strain result.

Fig. 4 shows the measurement results of strain and displacement for T6 package. Strain and displacement were almost constant for 24 hours, and returned to their initial values after unloading the weight. Therefore, in the stacking test, the stress of the corner post was within the elastic range. The strain and displacement showed a similar distribution, but the large deviation was observed in each of the four corner posts. This is presumed to be result of non-uniform loads applied to the four corner posts. The height of the corner posts of the T6 package is 482 mm, and the average displacement is calculated to be 0.181 mm from the measured strain. Based on the average displacement of 0.11 mm (at 150 mm length between the two brackets) from the laser sensor, the total displacement of the corner post was calculated to be 0.354 mm.



(a) Strain (b) Displacement

Fig. 3. Strain and displacement of T4 transport package



(a) Strain (b) Displacement

Fig. 4. Strain and displacement of T6 transport package

The stress, strain and displacement of the corner post are calculated as follows.

- Stress: $\sigma = \frac{W}{4A}$ .... (1)
- Strain: $\varepsilon = \frac{\sigma}{E}$ .... (2)
- Displacement: $\delta = L\,\varepsilon$ .... (3)

Where

W : Stacking weight of test model [kg_f]

A : Cross section area of corner post [㎠]

L : Length of corner post [㎝]

E : Young's modulus of material [kg_f/㎠]

The stress at the corner post was calculated to be 545.4 kg_f/㎠ for the T4 package, which is 19% of the yield stress of 275 MPa (2,800 kg_f/㎠) for carbon steel (SS275). The stress at the corner post was calculated to be 1,088 kg_f/㎠ for the T6 package, which is 30% of the yield stress of 355 MPa (2,620 kg_f/㎠) for SPA-H steel. Therefore, in the stacking test, the stress of the corner post was within the elastic range.

Table 1 compares the average strain & displacement between the test and theoretical calculation results. In the T4 package, the measured strain matched the calculation result within 5%, but the measured displacement by LVDT showed an error of 6 times with the calculated result. The measured strain was elastically recovered, but the measured displacement showed an average permanent deformation of 0.11 mm. In the theoretical calculation, the stress of the corner post was estimated as 19% of the yield stress. Therefore, the measured strain is reliable, while the displacement by the LVDT has a large error. The reason that the displacement has a large error is that the LVDT holder is not fixed on the rigid body, but it is installed on the base plate on which the test model is placed and the base plate behaves together with the test model during the stacking test.

The strain and displacement measured from the strain gauge and laser sensor in the T6 package were consistent with the calculation results within 35% and 44%, respectively. Therefore, the reliability of the measurement results was confirmed. In all test models, there was no deformation of the corner post, and no cracks occurred in the weld area after the stacking test. Therefore, the structural integrity of the package was verified in the stacking test.

Table 1. Comparison of strain and displacement between test and calculation results

Transport package	Items	Test results	Calculation results	Error
T4	- Average strain	2.42E-4	2.55E-4	5%
	- Average disp. . Permanent disp.	0.73 mm 0.11 mm	0.12 mm 0.0 mm	608% -
T6	- Average strain	3.77E-4	5.08E-4	35%
	- Average disp. . Permanent disp.	0.354 mm 0.00 mm	0.245 mm 0.00 mm	44% 0%

3. Conclusions

In the T4 package, the measured strain was in good agreement with the calculation results, but measurement displacement by the LVDT showed a large error. The reason that the displacement has a large error is that the LVDT holder is installed on the base plate and the base plate behaves with the test model during the stacking test. The strain and displacement measured from the strain gauge and laser sensor were consistent with the calculation results for the T6 package. In all test models, there was no deformation of the corner post, and no cracks occurred in the weld area after the stacking test. Therefore, the structural integrity of the package was verified in the stacking test.

Acknowledgement

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REFERENCES

[1] NSC Notice No. 2021-02, "Regulation for Packaging and Transportation of Radioactive Materials", Nuclear Safety and Security Commission Notice, 2021.