Fourth International Conference on FRP Composites in Civil Engineering (CICE2008)
22-24 July 2008, Zurich, Switzerland

Study on durability test methods for pultruded GFRP structural material

I. Nishizaki and T. Tomiyama
Public Works Research Institute, Tsukuba, Ibaraki, Japan

ABSTRACT: Three types of accelerated test and an outdoor exposure test were conducted for three types of pultruded GFRP plates with different matrix resin: unsaturated polyester, vinyl ester and phenol resin, including their painted specimens. Weight change was evaluated through the tests. All of the outdoor-exposed specimens without paint showed weight decrease from about 100 days, however, the painted specimens showed no remarkable weight decrease for 1000 days. An accelerated test in moist air and a weather meter showed similar changes.

1 INTRODUCTION

The application of pultruded FRP profile as a structural material is attracting growing attention. Although FRP will not corrode, it does not mean that FRP will not deteriorate, so it is important to evaluate the durability of pultruded FRP profiles using a suitable method for construction applications. Outdoor exposure tests are a reliable method for evaluating the durability of construction materials, but there are few reports on pultruded GFRP compared with hand lay-up or pressed GFRP. Furthermore, GFRP is often used with paints, but there are few reports on painted GFRP, either. The authors therefore carried out an outdoor exposure test for pultruded GFRP including painted specimens.

A main disadvantage of outdoor exposure tests is that it takes a long time to obtain results. Although there are several accelerated test methods to obtain durability results faster, there is little data showing the relation between these accelerated tests and outdoor exposure tests. The authors carried out several accelerated tests including weathering tests and moisture ambient tests for the same specimens as in outdoor exposure tests.

2 EXPERIMENTAL METHODS

2.1 *Specimens*

Table 1 shows the types of specimens used in this study. Three types of pultruded GFRP with different matrix resin were used for the tests. Unsaturated polyester resin, vinylester resin and phenol resin were selected as the matrix resin. All of the pultruded GFRPs were Plalloy$^{(TM)}$ supplied by AGC Matex Co. as plates of 200 mm width and 3 mm thickness. The pultruded GFRPs were cut into two (100 mm width) in the longitudinal direction and cut in the lateral direction with 85 mm length. The resulting plates of 100 mm width and 85 mm length (pultruded direction) were used as unpainted specimens. Painted specimens were made from each unpainted specimen, by applying, in order, both epoxy resin paint and a fluorine resin top coat with a thickness of 30 μm including the edge of the plate. Each specimen was stored in a chamber at 23°C and 50% humidity for at least 10 days, then the initial weight of each specimen was measured.

Table 1. Types of specimens

Code	Description
UN	Unpainted, Matrix: Unsaturated polyester resin (isophthalate type)
VN	Unpainted, Matrix: Vinylester resin (bisphenol type)
PN	Unpainted, Matrix: Phenol resin (resol type)
UT	Painted UN, Paint: epoxy resin paint (30 μm)/fluorine resin top coat (30 μm), white
VT	Painted VN, Paint: same as UT
PT	Painted PN, Paint: same as UT

2.2 *Natural outdoor exposure test*

Six types of specimen were tied to aluminum plates and placed on outdoor exposure racks in Tsukuba located about 60 km north of Tokyo, where the climate is moderate. Nine sets of six specimens were used for the test. The exposure racks faced south at an angle of 5 degrees. The test was started in March 2004. Different exposure durations were set for each set of specimens, ranging from 30 to 1044 days. Recovered specimens were removed from the aluminum plates and cleaned with water, placed in a chamber at 23°C and 50% humidity for at least 10 days, then weighed. The change of weight of each specimen from the initial value was calculated with Equation (1). Air temperature and humidity were measured and recorded every 1 minute during the test period using a data logger.

$$W = (W_1 - W_0) / W_0 \quad (1)$$

where, W: Ratio of weight change
W_0: Initial weight
W_1: Weight after deterioration test

2.3 *Accelerated tests*

Three types of accelerated test method were used. The test conditions of the accelerated tests including the outdoor exposure test were as shown in Table 2.

Table 2. Accelerated test conditions

Code	Conditions
A	Test chamber Temperature: 35°C, humidity 98% (constant)
B	Test chamber (1) Temperature: 55°C, humidity 80% (1 hour) (2) Temperature: 35°C, humidity 98% (1 hour) (Cyclic test of the above conditions)
C	Weather meter (1) Temperature: 35°C, humidity 80%, irradiation: 40 W/m^2, BP temperature 55°C (1 hour) (2) Temperature: 35°C, humidity 98%, no irradiation: (1 hour) (Cyclic test of the above conditions)
E	Outdoor exposure test at Tsukuba (moderate climate), 5° slope facing south

Note: BP: Black Panel

Test A is a constant environmental test in humid air. Test B is a cyclic test between 55 degrees with 80% humidity and 35 degrees with 98% humidity. Test C is also a cyclic test under similar conditions to test B, however, a weather meter (Atlas XC2020) was used for the test. Test C includes the irradiation of strong light by a Xenon lamp in the dry cycle. The black panel temperature was set at 55 degrees.

One set of six types of specimens were used to measure the changes of weight under each deterioration condition. Specimens after the accelerated tests were wiped clean of surface water and weighed quickly, then returned to the deterioration test machine. Specimens of the cyclic tests (B and C) were weighed just after their wet cycle had finished. The ratio of weight change was calculated with Equation (1).

3 RESULTS

3.1 *Outdoor exposure test*

Figure 1 shows the results of the outdoor exposure test. The weight of unpainted specimens (PN, UN and VN) decreased. UN showed a remarkable decrease from the early stage. PN and VN showed a decrease from about 100 days exposure. Painted specimens did not show remarkable weight changes even after 1043 days.

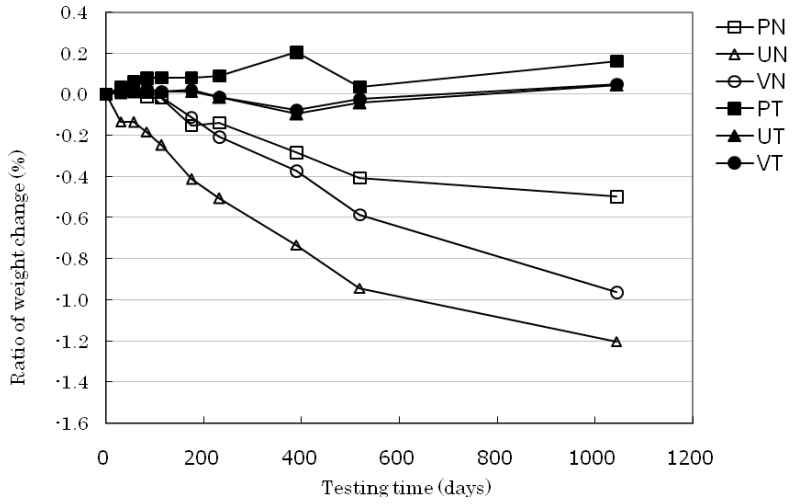

Figure 1. Weight changes of outdoor exposure test (at Tsukuba)

3.2 *Constant moisture condition*

Figure 2 shows the result of accelerated test A with constant humid air. The specimens when weighed contained water inside, hence the values cannot be compared simply with the values of Figure 1. The weight of PN, PT and UT increased in the early stage of the test and reached about 0.3–0.4% of the initial value. The weight change ratios of VN and VT in the early stage showed lower values than PN, but reached almost the same values as PN after 336 days. UN showed a remarkable weight decrease from the early stage of the test, and reached –0.16% of the initial value after 336 days.

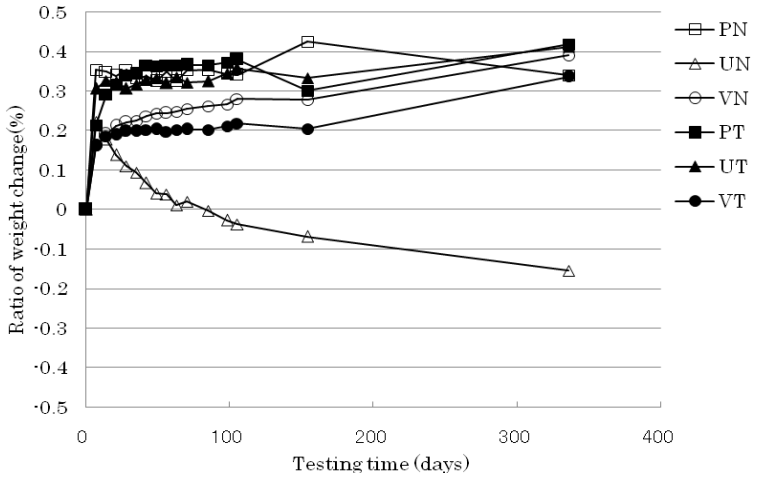

Figure 2. Weight changes of test A (Constant test: 35°C and 98%)

3.3 *Cyclic test without light irradiation*

Figure 3 shows the result of accelerated test B. UN showed a slightly faster decrease than the constant test. PN, VN and UT also showed a decrease after 336 days.

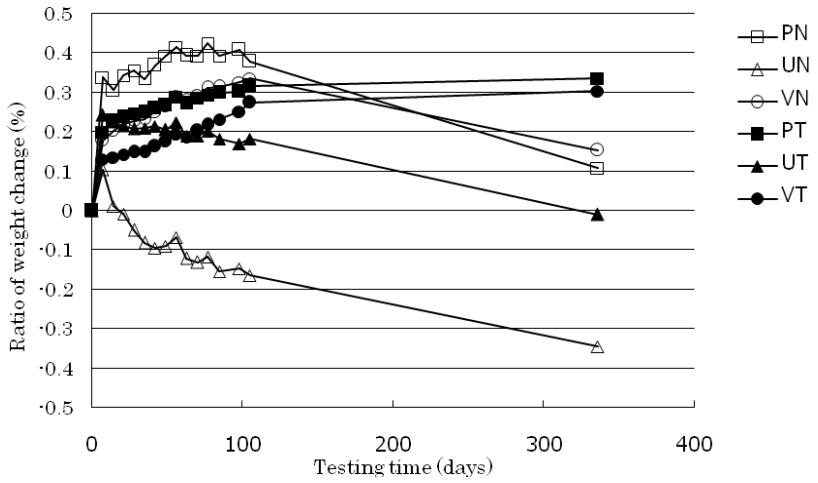

Figure 3. Weight changes of test B (Cyclic test: 35°C and 98% (1 hour) / 55°C and 80% (1 hour))

3.4 *Cyclic test with light irradiation and the influence of light irradiation*

Figure 4 shows the result of accelerated test C. Only UN showed a decrease from the early stage of the test. UN did not show a weight increase in the fast stage of the test. Other specimens showed a slight increase of weight, and the values remained at 0.05–0.1%, which are smaller than those of test B. The humidity control of the weather meter may not have been adequate compared with the chamber used for test B.

Figure 5 compares the weight changes of UN specimens. Except for the difference of the increase in the fast stage of the test, there seems to be no remarkable difference between test B and C. This result suggests that the light irradiation has no strong influence when the testing time is not so long. Test C could be continued for only 106 days because of the limitation of the

testing machine, however this testing duration may be too short to observe the influence of light irradiation.

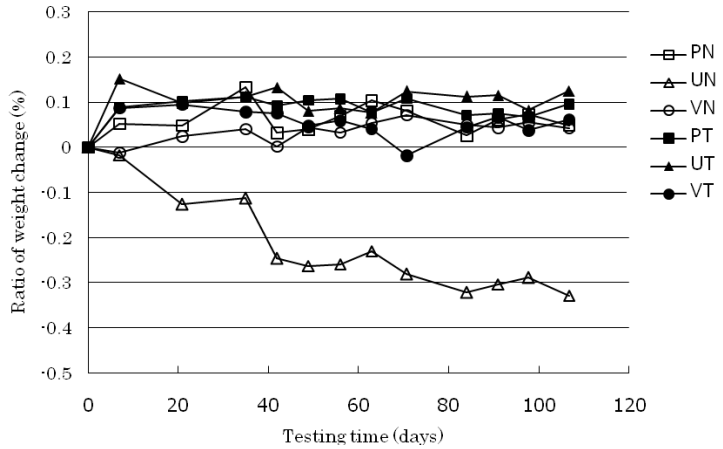

Figure 4. Weight changes of test C (Cyclic test: 35°C and 98% without light irradiation (1 hour) / 35°C and 80% with light irradiation at 40 W/m^2, Black panel temperature: 55°C (1 hour))

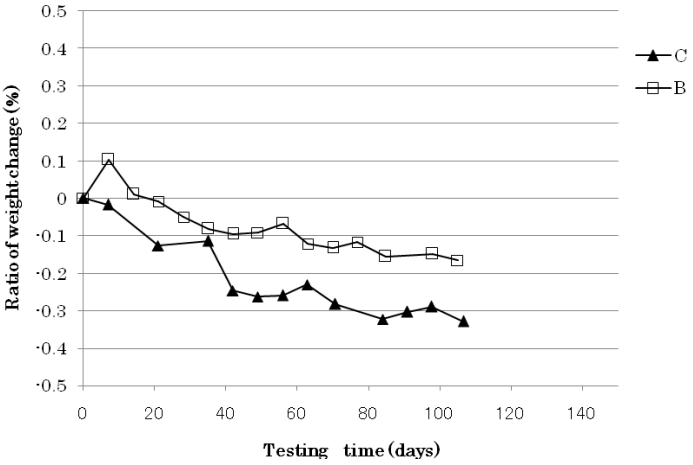

Figure 5. Weight changes of UN of test B and C

3.5 *Comparison of accelerated test and exposure test*

The specimens for the exposure test were weighed after being stored in a chamber at 23°C and 50% for ten days, hence we cannot simply compare the results with those of other tests. In order to compare the exposure test with the accelerated test, one more test based on test A was added: it was test A with a seven-day interval. One set of unpainted specimens was used for the test; the specimens were set in the chamber of test A for seven days, then recovered and weighed. The weighed specimens were not returned to the chamber soon, but were stored at room temperature for the next seven days. After seven days, the specimens were weighed again and then returned to the chamber. This cycle was continued several times.

Figure 6 shows the result of the test. The x axis of the figure is not the real time scale, but indicates the total days set in the test chamber. The weight of the specimens with interval was almost the same as in test A when each wet cycle had finished. The specimens became dry while being stored outside of the test chamber, and the weight decreased due to loss of water from inside of the specimen.

Figure 7 shows the ratio of weight changes of UN of the dried data of test A with interval and the exposure test. The x axis is total days for both specimens set under the wet condition. The

total time in the wet condition for the exposure test was calculated from the air humidity data measured at the exposure site, and the duration that the humidity was more than 98% was summed.

Figure 7 shows that the weight decrease of the dried data of test A with interval is similar to that of the exposure test. It seems that the rate of decrease of test A with interval is slightly faster than in the exposure test; this may have been because test A with interval was performed at a higher temperature than the exposure test.

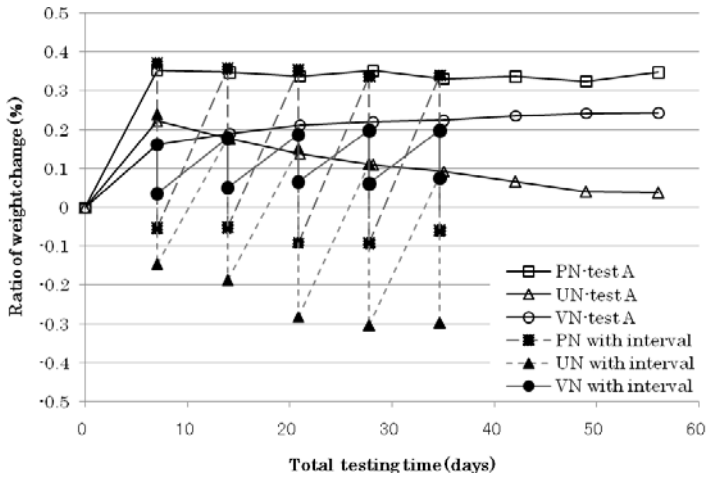

Figure 6. Weight change of test A with and without test interval of every seven days

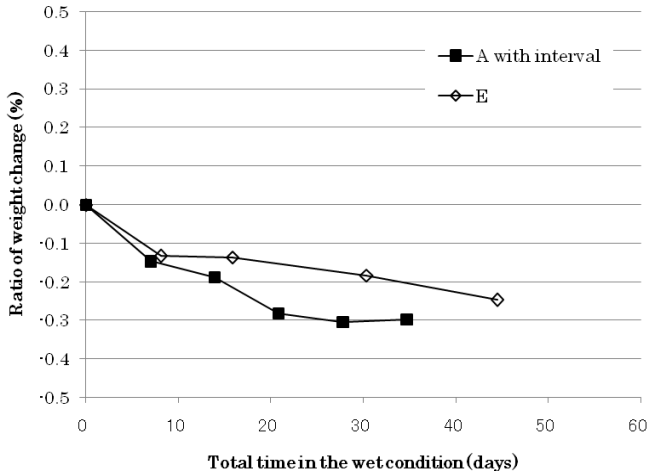

Figure 7. Weight change of UN test A with and without test interval of every seven days

4 CONCLUSIONS

Three types of accelerated test and an outdoor exposure test were conducted for three types of pultruded GFRP plates with different matrix resin: unsaturated polyester, vinyl ester and phenol resin, including their painted specimens. Weight change was evaluated through the tests. All of the outdoor-exposed specimens without paint showed weight decrease from about 100 days, however, the painted specimens showed no remarkable weight decrease for 1000 days. An accelerated test in moist air and a weather meter showed similar changes.