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# Atmospheric Exposure Test Results of Lap Joints Fixed by Epoxy Adhesive†

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**Abstract**

*The adhesive joint is one of the future possibilities to connect large steel members in buildings and bridge, but it is not clear what the resistance to the environment such as rain, oxide in the air, ultraviolet rays in the sunshine and so on is likely to be. In this report, atmospheric exposure tests of epoxy adhesive lap joints were conducted over 6 years to collect fundamental data for applying to large steel structures.*

*The results are summarized as follows. (1) Shearing strength and fracture elongation of the paint coated epoxy joints is larger than that of the non coated epoxy joints over all periods. (2) The paint coated specimens showed only a shear fracture surface. But some of the non coated epoxy adhesive joints fractured mainly be cause of delamination of adhesive, and they had very small shearing strengths compared with shear fractured joints. (3) The paint coated epoxy adhesive joints can be used for large steel structures without considering the effects of the environment for at least in 6 years. (4) After 3 years ,the shearing strength of the non coated epoxy adhesive joints, that fractured caused by shear of adhesive, become small due to effects of the environment. So it can be said that epoxy adhesive joints can not be used for large steel structures without paint coatings beyond 3 years.*

**KEY WORDS:** (Adhesive Joints) (Atmospheric Exposure Test) (Epoxy Adhesive) (Paint Coating) (Steel Structures)

## 1. Introduction

The adhesive joint is one of the future possibilities to connect large steel members in buildings and bridges. Unlike a welded joint, the adhesive joint does not input heat to the members. So measures against deformation, the residual stress and the material deterioration by heat-input need not be considered. And also unlike bolted joints, measures against the loss of section and additional members like splice plates need not be considered. But it is not clear what the resistance to the environment, such as rain, oxide in the air, ultraviolet rays in the sunshine and so on, will be.

In this report, we conducted atmospheric exposure tests of epoxy adhesive lap joints for 6 years. Every 6 months, tensile test of exposure specimens investigated the reduction of strength. It seems that these results provide fundamental data for applying epoxy adhesive to large steel structures.

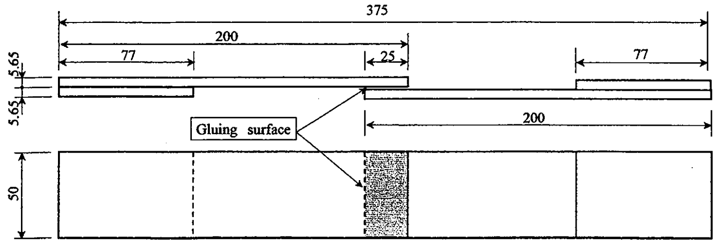


**Fig. 1** Shape and size of atmospheric exposure specimen

## 2. Experimental details

### 2.1 Specimen and atmospheric exposure condition

**Fig.1** shows the shape and size of specimens. The steel type for all tests was mild steel (SS400). The gluing area was 12.5cm$^2$ (25×50mm). To load pure shearing stress in the lap area, splice plates were fixed in the grip areas.

24 specimens were exposed on the roof of the main building of JWRI (lat. 34° 45' N, long. 135° 30' E, altitude 100m). **Fig. 2** shows a photo of atmospheric

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exposure test. Meteorological conditions of OSAKA meteorological observatory, which is the nearest big observatory from JWRI, are shown in **Table 1**[1].

Every 6 months, tensile tests of exposed specimens investigated the reduction of strength. Amsler type testing machine was used.

### 2.2 Adhesive types

One agent type epoxy adhesive for joints of structure was used in this research. This type of adhesive is developed for joints in structure and has high glueing strength and durability.[2]

Major components and glueing conditions are shown in **Fig. 2**. This type of adhesive hardens by heated to high temperature. Electric heating furnace was used to heat the specimens.

### 2.3 Paint coating

In this research, we made two series of specimen, non coated and paint coated. Since steel structures are usually painted to prevent rust. It seems that the paint layer can weaken the effect of the environment.

Paint types and conditions are shown in **Table 3**. This paint condition is usually used for outside surfaces of bridges.

Both series of specimen are shown in **Fig. 3**.

## 3. Results and discussion

Results of tensile tests on exposed specimens are shown in **Table 4**.

### 3.1 Fracture type

Two type of fracture of gluing surface, shear

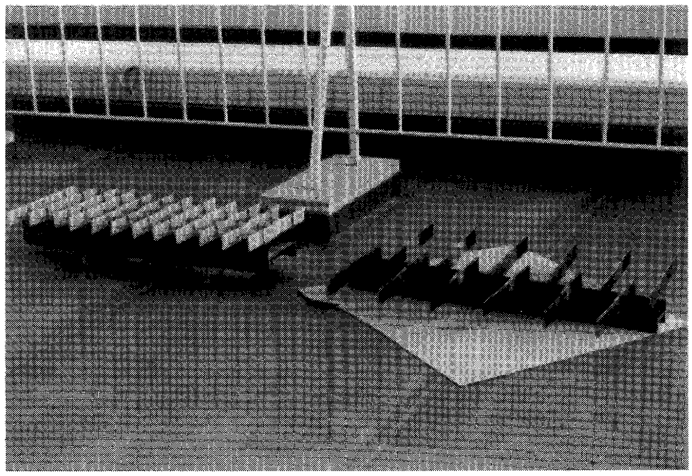


**Fig. 2** Photo of atmospheric exposure test

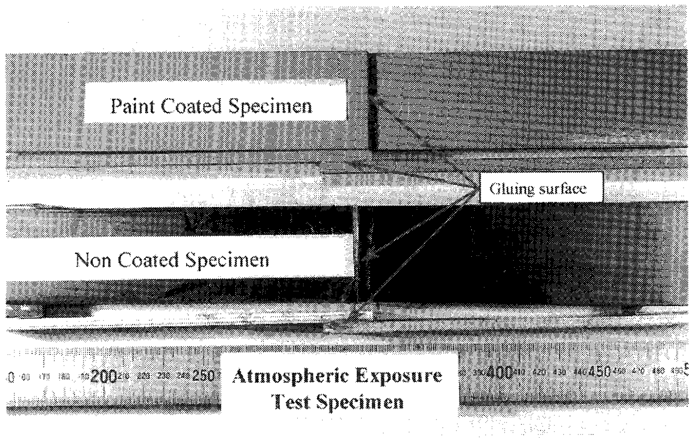



**Fig. 3** Atmospheric exposure test specimens

**Table 1** Meteorological conditions (Mean from1995 to 2000)

| Place | Annual mean temperature | Maximum temperature | Minimum temperature | Mean relative humidity | Annual sunshine duration | Annual precipitation |
|---|---|---|---|---|---|---|
| OSAKA | 17.0 °C | 36.6 °C | -1.6 °C | 63.5 % | 2,008 hours | 1,355 mm |

**Table 2** Major components of adhesive and gluing condition

| Gluetype | Major components | Roughness of gluing surface | Hardening condition | Thickness of gluing layer |
|---|---|---|---|---|
| EW-2 NS | Epoxy resin, Dicyandiamide | G80 | 150°C 20min. | 0.12 mm |

**Table 3** Paint type and condition

| | Paint type | Coating process | Thickness (μm) |
|---|---|---|---|
| Preprocessing | Inorganic zinc rich primer | Spray | 15 |
| First layer | Inorganic zinc rich paint | Spray | 75 |
| Second layer | Mist coat | Spray | - |
| Third layer | Epoxy resin primcoating coating | Spray | 60 |
| Forth layer | Epoxy resin primcoating coating | Spray | 80 |
| Fifth layer | Polyurethane resin middle coating | Spray | 30 |
| Sixth layer | Polyurethane resin finish coating | Spray | 25 |

fracture surface and delamination of adhesive, were observed in the bluing surface. **Fig. 4** shows both types of surfaces.

The paint coated specimens showed only shear fracture, with very small delamination. In non coated specimens, exposed for 2 years (right side specimen in Fig. 6) and 5.5 years specimens had delaminated surfaces, over more than half the adhesive area. As one can see from Fig. 5, the shearing strength of these two specimens were very small compared to other specimens. So it is concluded that the surface of delaminated adhesive can not stand large shearing stress. But it is not clear what the cause of delamination is in this research. Because it seems that the appearance of delaminations showed only a low correlation with exposure periods.

### 3.2 Difference between paint and non coating

Shearing stress – cross-head displacement relationships are shown in **Fig. 5** and shearing strength – exposure period relationship are shown in **Fig. 6**.

The shearing stress of the paint coated epoxy adhesive joints was larger than that of the non coated epoxy adhesive joints at all periods during the 6 years. Differences up to exposure periods of 3 years (except 2 year) were very small, so it could be concluded that the cause of this difference was reinforcement by the paint coated layer.

As well shown in Fig. 5, the stiffness of the paint coated epoxy adhesive joints tended to be small compared to that of the non coated epoxy adhesive joints. So it is not caused by the effect of the paint coated layer. It is caused by the effect of the environment on the adhesive, that were arrested in the paint coating

### 3.3 Effect of time history

As shown in Fig 6, the shearing strengths of the paint coated specimens were stable over all period up to 6 years. So the paint coated joints can be used for large steel structures without considering the effects of the environment for least 6 years.

In case of the non coated epoxy specimens, which fractured because of shear of adhesive, shearing strengths are stable for 3 years. But after 3 years, shearing strength of the non coated joints become small because of the effects of the environment. So it can be said that epoxy adhesive joints can not be used for large steel structures without paint coating beyond 3 years.

Change of stiffness over time was not observed.

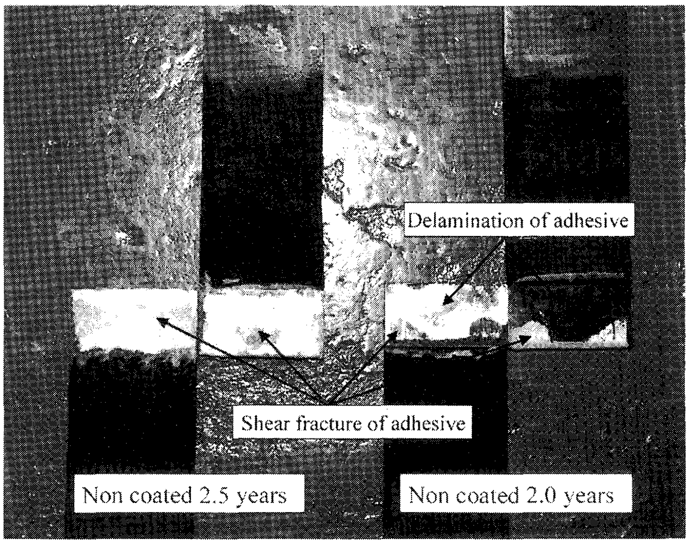


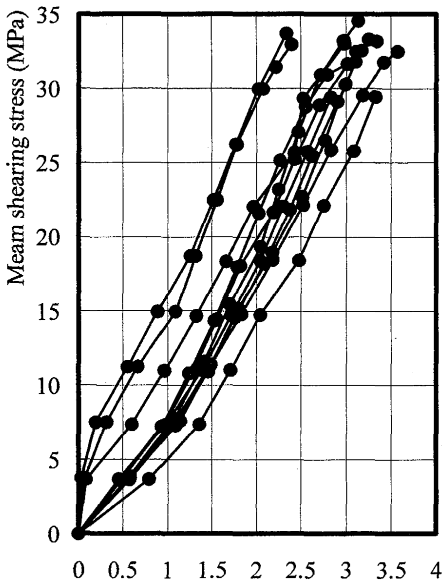

**Fig. 4** Fracture surface of adhesive

## 4. Closing remarks

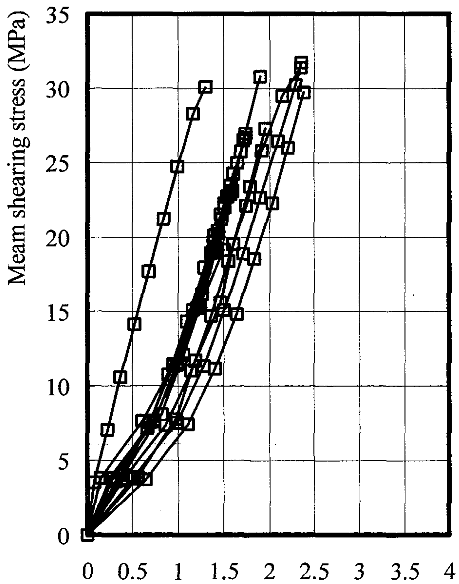
To investigate the reduction of strength, we conducted atmospheric exposure tests of epoxy adhesive joints for 6 years. Results are summarized as follows.

**Table 4** Results of tensile test on exposed specimens

| Exposure period (year) | Paint coating | | | Non coating | | |
|---|---|---|---|---|---|---|
| | Max. load (kN) | Shearing strength (MPa) | Max. elongation (mm) | Max. load (kN) | Shearing strength (MPa) | Max. elongation (mm) |
| 0.5 | 43.9 | 32.2 | 3.02 | 41.7 | 30.1 | 1.30 |
| 1.0 | 44.5 | 33.3 | 2.98 | 41.7 | 31.4 | 2.35 |
| 1.5 | 43.3 | 32.6 | 3.57 | 41.2 | 31.7 | 2.36 |
| 2.0 | 42.1 | 33.3 | 3.39 | 14.7 | 11.8 | 1.18 |
| 2.5 | 45.7 | 34.9 | 2.34 | 42.9 | 32.5 | 2.39 |
| 3.0 | 43.9 | 32.9 | 2.84 | 40.0 | 31.4 | 1.90 |
| 3.5 | 43.8 | 34.5 | 3.14 | 30.4 | 22.2 | 1.51 |
| 4.0 | 45.8 | 33.2 | 3.34 | 33.6 | 27.7 | 1.61 |
| 4.5 | 43.4 | 33.5 | 3.25 | 34.8 | 26.9 | 1.71 |
| 5.0 | 43.7 | 32.8 | 3.33 | 36.0 | 28.6 | 1.96 |
| 5.5 | 43.6 | 33.3 | 2.39 | 24.5 | 19.1 | 1.50 |
| 6.0 | 40.4 | 30.0 | 2.91 | 37.7 | 29.3 | 1.73 |



(a) Paint coated specimens



(b) Non coated specimens

**Fig. 5** Shearing stress – cross-head displacement relationships

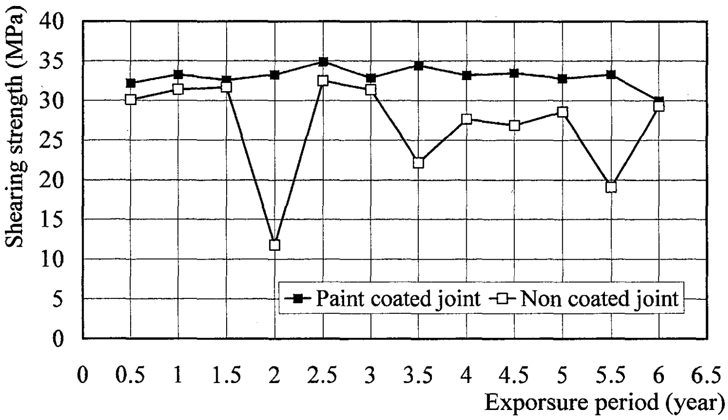



**Fig. 6** Shearing strength – exposure period relationships

(1) Shearing strength of the paint coated epoxy adhesive lap joints was larger than that of the non coated epoxy adhesive lap joints for all periods up to 6 years. And fracture elongations of the paint coated epoxy adhesive joints were also large compared to those of the non coated epoxy adhesive joints.

(2) Stiffness of the paint coated epoxy adhesive lap joints tended to be small compared to those of the non coated epoxy adhesive lap joints.

(3) The paint coated epoxy adhesive lap joints showed only shear fracture. But some of the non coated epoxy adhesive lap joints fractured mainly because of delamination of adhesive, and they had very small shear strengths compared to shear fractured joints.

(4) Shearing strengths of the paint coated epoxy adhesive lap joints were stable for all periods up to 6 years. So the paint coated epoxy adhesive joints can be used for large steel structures without considering the effects of the environment for least 6 years.

(5) Shearing strengths of the non coated epoxy adhesive lap joints that fractured caused by shear of adhesive, are stable up to 3 years. But after 3 years, shearing strength of the non coated epoxy adhesive joints becomes small because of effects of the environment. So it can be said that epoxy adhesive lap joints can not be used for large steel structures without paint coating beyond 3 years.

**Reference**


1) Japan Meteorological Agency: The weather information electronic reading room, http://www.data.kishou.go.jp/
2) Sumitomo 3M Japan: Scotch-weld, http://www.mmm.co.jp /tape-adh/adh/ind/scotch_weld/index02.html