Bending Test of Welded Joints for Single-Layer Latticed Domes

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Abstract

Joints of single-layer latticed domes exhibit various performances depending on their shapes, and joining systems, which can be generally divided into two joining systems such as ball joints and welded joints. Ball joints, which are assumed to be semi-rigid joints, are easy to handle and apply for the structures, while their rigidities and strength are relatively small, so that these types of joints are disadvantageous for the long span. On the contrary, welded joints have many advantages in terms of rigidity and strength. In this paper, an improved welded joint for single-layer latticed domes was suggested. In proposing the developed joint, nonlinear finite element analysis was firstly performed to investigate the rigidities of the various joints. Secondly, based on finite element analysis results, the effects of the various parameters on the flexural performance of the proposed jointing system were investigated experimentally. Test results showed that the proposed jointing system demonstrated excellent potential in improving the flexural rigidity as well as strength of welded joint for single-layer latticed dome.

Keywords: Single-layer latticed domes, Welded joints, Bending Test, Nonlinear FEA, Flexural rigidity

1. Introduction

1.1. Background and Purpose of the Study

Given the economic growth of society and gradually increasing need for leisure time, members of society have begun to require wider space and ceaselessly tried to secure spacious rooms. This calls for the development of long-spanned structures, such as membrane structures, cable structures, and steel-truss lattice structures. Among these, the steel-truss lattice system has received much attention from engineers due to its artful structural form. The single-layer latticed dome is one of the most commonly used dome systems, because it provides a structural solution to the problem of spanning large uninterrupted distances, and in doing so, also allow an immense variety of designing shapes (Yuan et al., 2002; Masayoshi et al., 2003; Lopez et al., 2007a). In other words, this system forms a shape by arranging members inside the surface in a regular pattern; thus providing several benefits such as the economical advantage of member force with fewer number of members and its structural aesthetics (Makowski et al., 1984). However, the stability of the system is relatively low when the required span is long (Abedi et al., 1996; Shen et al., 2004). Likewise, rigidity is much less in single-layer domes than in double-layer structures.

The behavior of single-layer structures is highly nonlinear and affected by various factors, such as geometric shape of domes, supporting conditions, rise-to-span ratio, and joint rigidity. The joints used for this kind of a single-layer latticed dome show a variety of behavioral characteristics according to the jointing methods, such as bolted joints, welded joints, and ball joints. Consequently, many studies of single-layer structures have been undertaken (Liew et al., 2002; 2003; Kato et al., 2002; Numata et al., 2003; Wang et al., 2007; Xing et al., 2006), especially for the effects of joint rigidity (Lopez et al., 2007a, b; Kato et al., 1998; Sohn et al., 2002; Park et al., 2003). Theses studies revealed that the rigidity of the joint required deeper study, since it significantly affects the behavior of these structures.

One possible way to enhance its joint rigidity is to apply the welded joint to the joint of latticed dome, because welded joints have many advantages in terms of rigidity and strength. The performance of a welded joint for a single-layer latticed dome varies according to the jointing method and application of its inner diaphragm, outer diaphragm and gusset plate and so on.

The purpose of this paper is to propose new welded joint for single-layer latticed dome and to investigate its structural performance such as joint rigidity and strength. In this study, nonlinear finite element analysis (FEA) for each joint, which was applicable to latticed dome as
a rigid joint, has been firstly carried out. Secondly, bending tests of joints have been conducted on various welded joints possessing different features related to joint rigidity. The analytical results were then compared with the results of the bending tests.

2. Preliminary FEA analysis

2.1. Analytical configurations

A total of three models were adopted and analyzed in order to investigate the structural performance of welded joint for single-layer latticed dome. Fig. 1 shows three types of welded joints, which consist of nodes and tubular members. Tubular single-layer structures are particularly attractive because of their lightness and elegance. In this study, all models were designed by using tubular members with the dimensions of Ø101.6 × 3.2; all dimensions are in mm and are for the outer diameter and the thickness of steel pipe, respectively. Fig. 1 (a) shows the conventional welded joint (CJ), which is almost identical to that of the Nagoya dome in terms of shape (AIJ, 2005); diaphragms are used in the interior of node rings; whereas the Nagoya dome used a partial sphere which was made by cutting out the upper and lower parts from a spherical casting for the node ring, this study used a circular steel pipe for the node ring. Fig. 1 (b) and Fig. 1 (c) show the proposed joints named as AL T1 and AL T2, respectively. The amount of material used for AL T1 and AL T2 was 7% and 28% larger than that of CJ, respectively. The AL T1 used gusset plates outside the node ring; it was designed to have the gusset plate wrapped with a plate for convenience in steel pipe’s jointing and angle adjustment. The AL T2 used the gusset plate, which was reinforced by the outer diaphragms for the outside of the node ring. The gusset plates provide a connection between the node ring and steel pipes, which are designed to resist buckling strength using the diaphragms. The outer diaphragm are welded to the node ring plays the role of bonding the node ring and the gusset plate together, which may result in the increase of the flexural rigidity of the proposed welded joints.

2.2. FEA modeling

A three-dimensional finite element model was generated to represent structural subassemblages. The general-purpose FEA program ANSYS was used for this study and accounted for the material nonlinearity through the classical metal plasticity theory based on the von Mises yield criterion. The studies presented do not address the issue of fracture propagation. This work was concerned with the examination of the flexural performance of the welded joints. For the convenience of the FEA analysis, the effect of the welding characteristics and residual stress of the welding areas at the joints were excluded in this study.

Figure 2 shows the numerical model for a welded joint. Eight-node solid elements (SOLID 45 element) were used for the model. The ends of the steel pipes were supported with simple support boundary conditions. The model was loaded in displacement control. The displacement was applied at the center of the node ring.
until displacement reached 100 mm (0.113 rad) in the downward direction. For monotonic analyses, multilinear isotropic hardening was used for the model based on the material test results.

2.3. FEA results

Figure 3 presents the moment versus rotation for all models to examine the global behavior of the joints. Figure 3 shows that the CJ has significantly higher flexural rigidity and strength than ALT 1, which meant ALT 1 was not efficient in enhancing the joint rigidity. This was probably because the ALT 1 joint was not equipped with a diaphragm unlike the other joints. The flexural rigidity of the ALT 2 was slightly higher than that of CJ. In addition, at the same rotation level after the elastic range, the strength of ALT 2 was remarkably higher than that of CJ.

Von Mises stress distribution plot are shown in Fig. 4. The results of the finite element analyses for the CJ, ALT 1 and ALT 2 joints revealed various stress distribution patterns according to each shape. As shown in Fig. 4(a), there was almost no change in stress at the central area of the CJ. Stress was evenly distributed across the steel pipes and concentrated on the areas of the steel pipes adjacent to the joint. There was no stress concentration on the node ring due to the rigid inner diaphragm. Fig. 4(b) also shows a similar type of stress distribution at the steel pipes ends. However, stress level of node ring of ALT 2 was higher than that of CJ, which may be due to the out-of-deformation of node ring as well as outer plate wrapped the gusset plates. Fig. 4(c) shows that, unlike two models addressed above, ALT 2 moved the stress concentration away from the node ring, in other words, stress concentration was observed at the tip of gusset plates. The joint strengthened by outer diaphragm resulted in a lower stress level on the node ring. Therefore, ALT
developed more increased rotational rigidity and strength of joint.

3. Test Program

3.1. Test specimens

Structural testing was performed based on finite element analysis to examine the structural performance of welded joints for single-layer latticed domes. Figure 5 shows the test specimen representing a structural subassemblage isolated from a lattice structure. Six steel pipes were attached to the central node. Test specimen had a 1760 mm span and the height of specimen was 160 mm. All the steel pipes were 101.6 mm in diameter and 3.2 mm thickness.

All of ten specimens were designed and fabricated, which included the three models which had been analyzed by finite element method, such as CJ, ALT1 and ALT2. The list of specimens is given in Table 1. The result of finite element analysis exhibited that among the joints, ALT2 particularly developed the excellent rotational rigidity as well as strength. Therefore, eight of ALT2 series specimens were designed as the following test parameters: the inserted length and thickness of the gusset plate; angle of steel pipe, and the presence of slot at the tip of gusset plate. The gusset plates were welded to the node ring and the six outer diaphragms were welded to the gusset plates and node ring using fillet welding. The gusset plates inserted into the steel pipes were also welded to the steel pipes using fillet welding. In the name of specimen, the first number means the length of the gusset plate and the second number means the inserted length of gusset plate. 7D and S also mean steel pipe angle of 7.0 degree and slot, respectively. The angle between the steel pipe and the horizontal for all specimens was 2.5 degree, except for one specimen, W100-09-7D, of 7.0 degree. W100-09, which is the same specimen as ALT2 model described in previous paragraph, was constructed as a base-line specimen in order to provide a comparison with the proposed welded joints in terms of the rotational rigidity, strength, and the collapse mode. The materials used in the test were KS SS400 mild steel for steel plates and KS SPS490 for steel pipes. Coupon test results are shown in Table 2.

### Table 1. List of test specimens

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Node Ring</th>
<th>Steel pipe</th>
<th>Thickness of gusset plate (mm)</th>
<th>Inserted length of gusset plate (mm)</th>
<th>Angle between steel pipe and horizontal</th>
<th>Slot at the tip of gusset plate (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CJ</td>
<td>Ø267.4×8</td>
<td>Ø101.6</td>
<td>9</td>
<td>-</td>
<td>2.5°</td>
<td>-</td>
</tr>
<tr>
<td>ALT1</td>
<td>Ø267.4×8</td>
<td>Ø101.6</td>
<td>9</td>
<td>-</td>
<td>2.5°</td>
<td>-</td>
</tr>
<tr>
<td>W50-09</td>
<td>9</td>
<td>50</td>
<td>2.5°</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W80-09</td>
<td>9</td>
<td>80</td>
<td>2.5°</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W100-06</td>
<td>6</td>
<td>100</td>
<td>2.5°</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALT2 series</td>
<td>Ø139.8×4.5</td>
<td>Ø101.6×3.2</td>
<td>9</td>
<td>100</td>
<td>2.5°</td>
<td>-</td>
</tr>
<tr>
<td>W100-09*</td>
<td>12</td>
<td>100</td>
<td>2.5°</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W100-09</td>
<td>12</td>
<td>100</td>
<td>2.5°</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W100-09-7D</td>
<td>9</td>
<td>100</td>
<td>7.0°</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W100-09-S</td>
<td>9</td>
<td>100</td>
<td>2.5°</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W120-09</td>
<td>9</td>
<td>120</td>
<td>2.5°</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*W100-09 is the same specimen as ALT2 described in previous paragraph.

### Table 2. Material properties

<table>
<thead>
<tr>
<th>Test coupon</th>
<th>Yield stress (MPa)</th>
<th>Tensile stress (MPa)</th>
<th>Yield ratio (%)</th>
<th>Elongation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ø267.4×8.0 (SPS490)</td>
<td>PL-8.0t</td>
<td>418</td>
<td>523</td>
<td>78</td>
</tr>
<tr>
<td>Ø139.8×4.5 (SPS490)</td>
<td>PL-4.5t</td>
<td>409</td>
<td>501</td>
<td>80</td>
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<tr>
<td>Ø101.6×3.2 (SPS490)</td>
<td>PL-3.2t</td>
<td>431</td>
<td>508</td>
<td>83</td>
</tr>
<tr>
<td>Gusset plate (SS400)</td>
<td>PL-6.0t</td>
<td>301</td>
<td>377</td>
<td>80</td>
</tr>
<tr>
<td>Gusset plate (SS400)</td>
<td>PL-9.0t</td>
<td>280</td>
<td>373</td>
<td>75</td>
</tr>
<tr>
<td>Gusset plate (SS400)</td>
<td>PL-12.0t</td>
<td>282</td>
<td>373</td>
<td>67</td>
</tr>
</tbody>
</table>
3. Test Results

Figure 6 shows the test setup for a welded joint specimen before load application. The tested single-layer structure consisted of six steel pipes attached to a central node. The other ends were simply supported on the hexagonal test bench and reinforced by crossed type stiffeners against local buckling. In addition, a guide plate was welded to the supporting plate to prevent safety accidents such as the movement of steel pipes in the side direction or springing out in the process of load application. The load was applied on the central node using an oil jack system with maximum load of 980 kN. A circular plate of 20 mm thick was made and placed on the node ring to secure even load application on the central part and have the load distributed on the facets of steel pipes through the plate. The monotonic load was applied under control displacement conditions, as a speed of 0.05 mm per second. Applied load was measured using a load cell installed on the lower part of the oil jack. On the other hand, vertical displacement was measured using two LVDTs installed at the center. The average value of the two was then obtained. In addition, strain in all parts of joint was recorded using the strain gauges.

4. Test Results

Figure 7 shows moment versus rotation curves of the test specimens, which compares the results of the nonlinear FEA and the structural test. The horizontal axis is the rotation calculated as the center displacements divided by the distance between the support and the center of the joint. The vertical axis shows the moment at the center of joint. Agreement between curves of the analysis result and test result was found to be quite satisfactory. Figure 8 shows failure mode of some specimens. As shown in Fig. 8, fractures of all specimens occurred on the steel pipes adjacent to the joint, and then moment tended to decrease after the fracture of specimen. On the contrary, no drastic reduction in load was observed in the FEA, since analytical studies presented did not address the issue of fracture propagation.

As shown in Fig. 8(a), CJ failed by fracture of the lower parts of the steel pipes. The initial crack was located in the heat-affected zone (HAZ) of steel pipes adjacent to the joints. The crack progressed outward along the steel pipe width during successive loading. Little deterioration in the overall strength of the specimen was observed before the fracture of the steel pipes. Once the steel pipes failed, the behavior was extremely poor and degraded abruptly during later loading (Fig. 7). In the case of CJ, cracks and ruptures were found on four out of six steel pipes. Figure 9(a) shows the moment versus strain curves of the CJ. As shown in Fig. 9(a), the strain level on the upper and lower parts of a steel pipe was drastically increasing from the moment of 90 kN·m and 92 kN·m, respectively, while there was little strain distribution on the upper or lower part of the node ring.

In the case of ALT1, the node ring at the center started to be deformed into a hexagon (Fig. 8(b)). Ruptures then occurred at HAZ on the lower parts of the steel pipes as shown in (Fig. 8(b)). Like CJ, once such a fracture occurred, the joint experienced a significant loss of flexural rigidity and strength to resist the load that tends to open the crack. Based on the moment versus strain curve in Fig. 9(b), the strain distribution on the upper and lower parts of the steel pipe can be said to have started to increase sharply at 96 kN·m and 94 kN·m, respectively.

In ALT2 (W100-09), the lower parts of steel pipes failed in a ductile manner, with a crack emanating from the HAZ or metallurgical notches at the tip of gusset plates. Based on the moment versus strain curve in Fig. 9(c), drastic strain distribution on the upper and lower parts of the steel pipes started at 103 kN·m and 105 kN·m, respectively, while the maximum strain level of gusset plates and node ring was 0.15% and 0.07%, respectively and remained in the elastic range.

For the proposed joints, ALT2 series, a total of eight specimens were tested using parameters such as thickness and inserted length of gusset plate, steel pipe angle, and the presence of slot. The failure modes of W50-09, W80-09, W100-12, W120-09, and W100-09-7D were very similar to that of the W100-09(ALT2). However, the W6T test model exhibited a fracture pattern that is different from those of the other ALT2 series (Fig. 8(d)). Lateral buckling occurred on the gusset plate ahead of the steel pipe, thereby causing premature strength reduction. Compared to the case of the other ALT2 series, the moment versus strain curve of the W100-06 test model shown in Fig. 9(d) revealed the highest strain level at the gusset plate. For the W100-09-S, it was expected that slot holes were made on the steel pipes where the gusset plate ended to secure extra space so that stress concentration on the steel pipe can be prevented. However, irrespective of the presence of the slot, fracture on the W100-09-S started at the slot end and showed a failure mode of rupture on the lower part of the steel pipe. Fig. 8(e) shows that three steel pipes were ruptured and one steel pipe was cracked.
5. Discussion

The moment versus rotation curves derived from the test specimens are shown in Fig. 10, which were plotted until the ultimate strength for the convenience of the performance comparison. Table 3 summarizes the test results from the moment versus rotation relationships of each specimen. Figure 11 shows the bar chart for the flexural performance of three specimens. As mentioned above, ALT2 (W100-09) was constructed as a base-line specimen in order to provide a comparison with the proposed welded joint in terms of the flexural rigidity and strength. Therefore, each flexural performance such as flexural rigidity, yield moment and ultimate moment was generalized by divided by the flexural performance of the ALT2. In other words, this means that the flexural performance of ALT2 is “1.00”.

5.1. Influence of jointing methods on flexural performance

In Fig. 10(a), the test results for the CJ, ALT1, and ALT2 joints were very similar to the results of the FEA. It was found that specimen ALT2, with the outer diaphragm, had a higher initial flexural rigidity than any other specimen; whereas specimen ALT1 had a lower initial flexural rigidity than any other specimen. Although
no significant difference was found in initial rigidity between CJ and ALT2. ALT2 showed a slightly higher initial flexural rigidity compared to CJ. In addition, the results showed that specimen ALT2 had higher yield and ultimate strength than any other specimen; whereas specimen ALT1 had lower yield strength than any other specimen. These results suggested that outer diaphragm in the ALT2 joint played a significant role of bonding the node ring and the gusset plate together, resulting in the improvement of the flexural rigidity and joint strength. It was exhibited that ALT1 was not applicable for the jointing system of single-layer lattice dome due to its...
lower flexural rigidity and strength. Test results as well as preliminary FEA results exhibited that ALT 2 joint demonstrated very good potential in improving the flexural rigidity as well as strength of welded joint for single-layer latticed dome.

5.2. Influence of the parameters on flexural performance (ALT2 series)

For the ALT2 series, comparisons of each result of the tests using parameters such as the length and thickness of the gusset plate, angle between the steel pipe and horizontal, and the presence of the slot were made to find out the influence of the parameters on flexural rigidity on the design of a joint. Comparisons were made in terms of the flexural rigidity and strength through Table 3 and bar charts for the region up to the point a sharp decrease after fracture on the moment versus rotation curve started.

5.2.1. Inserted length of the gusset plate

Figure 10 (b) plots the moment versus rotation curves by inserted length of gusset plate as follows: 50, 80, 100, and 120 mm. Table 3 and Fig. 11(b) compare the rigidity and strength according to the inserted length of the gusset plate. Note that initial rotational rigidity increased as the length of an inserted plate increased. The rotational rigidities of W50-09 and W80-09 decreased to approximately 0.8 times, 0.9 times and 0.9 times that of W100-09, respectively, while the rotational rigidity of W120 slightly increased by
1.03 times that of W100-09. In addition, the yield moment of W50-09 and W80-09 decreased to about 0.85 times and 0.99 times, respectively, while the yield moments of W100-09 and W120-09 were almost identical. In addition, the ultimate moment of W50-09 and W80-09 decreased to about 0.82 times and 0.94 times, respectively, while the ultimate moment W120-09 increased to 1.02 times that of W100-09. The yield load and ultimate moment increased in proportion to the length of the insertion plate, although there was almost no difference in the yield moment and maximum moment between the W100-09 and the W120-09. It is believed that the proposed joint of which the inserted length of gusset plate exceeds 90 mm shows minimal influence with respect to the rotational rigidity and strength caused by the inserted length of gusset plate. It is thus necessary to investigate the optimal inserted length of the gusset plate.

5.2.2. Thickness of the gusset plate

Figure 10 (c) plots the moment versus rotation curves by thickness of gusset plate as follows: 6, 9, and 12 mm. Table 3 and Fig. 11(c) compare the rigidity and strength according to the thickness of the gusset plate. The flexural rigidity of W100-06 decreased to approximately 0.94 times that of W100-09. No significant difference was found in flexural rigidity between W100-09 and W100-12. W100-09 had a higher ultimate moment than that of W100-06 as well as W100-12. As shown in Fig. 10 (c), flexural rigidity increased with increasing gusset plate thickness. In the case of the W100-06, moment was found to decrease prematurely due to the lateral buckling of the gusset plate. It is exhibited that lateral buckling of the gusset plate needs to be considered for joints having shallow gusset plate. The comparison between the W100-09 and the W100-12 revealed minimal difference between yield and ultimate moment. This result suggests that the strength increment or decrement is minimal when thickness of gusset plate is above a certain degree.

5.2.3. Angle between the steel pipe and the horizontal

Fig. 10 (d) plots the moment versus rotation curves by steel pipe angle as follows: 2.5° degree and 7° degree. Table 3 and Fig. 11(d) compare the rigidity and strength according to the angle between the steel pipe and the horizontal. The rotational rigidity of W100-09 was found to be a bit higher than that of W100-09-7D, whereas yield moment and ultimate moment were similar for both the W100-09-7D and the W100-09. Lopez et al. (2007b) addressed that the span/depth ratio affected the critical load of single-layer domes because it affected the angle between members and investigated the effects of span/depth ratio on the critical loads. The research showed that as the span/depth ratio increased, the critical load decreased.

However, in this study, the flexural rigidity and strength of the W100-09-7D with higher steel pipe angle was slightly inferior to that of the W100-09. It is thought that this was because specimens of this study did not subject the axial force by the simple supports. Considering the axial force, the rigidity and strength of joint may be increased as its angle increases or its span/depth ratio decreases. Further study based on the various angles is necessary to verify the influence on the angle between the steel pipe and the horizontal.

5.2.4. Presence of slot at the tip of the gusset plate

Figure 10 (e) plots the moment versus rotation curves by the presence of the slot. Table 3 and Fig. 11(d) compare the rigidity and strength according to with or without the slot on steel pipe at the tip of gusset plate. As shown in Fig. 11(d), flexural rigidity and strength of W100-09-S were significantly lower than that of W100-09. The deformation capacity of W100-09-S was also inferior to W100-09. The decrease in the rigidity and strength of W100-09-S was attributed to the decrease in the section area of the predicted part of the pipe. The presence of slot did not prohibit the steel pipe from the stress concentration, resulting in premature fracture of the slot end. The reason might be the unsatisfactory workmanship of the slot. To prevent these defects, the reliable workmanship should be needed.

### Table 3. Summary of test results

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Initial rigidity (kN·m/rad)</th>
<th>Yield moment (kN·m)</th>
<th>Yield rotation (rad)</th>
<th>Ultimate moment (kN·m)</th>
<th>Ultimate rotation (rad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CJ</td>
<td>4832</td>
<td>75</td>
<td>0.0165</td>
<td>107</td>
<td>0.0779</td>
</tr>
<tr>
<td>ALT1</td>
<td>3991</td>
<td>65</td>
<td>0.0181</td>
<td>103</td>
<td>0.0922</td>
</tr>
<tr>
<td>W50-09</td>
<td>4096</td>
<td>75</td>
<td>0.0194</td>
<td>103</td>
<td>0.0536</td>
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<tr>
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<td>87</td>
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<tr>
<td>W100-09*</td>
<td>5130</td>
<td>88</td>
<td>0.0186</td>
<td>126</td>
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<td>W100-12</td>
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<td>94</td>
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<tr>
<td>W120-09</td>
<td>5539</td>
<td>88</td>
<td>0.0180</td>
<td>128</td>
<td>0.0549</td>
</tr>
</tbody>
</table>
6. Conclusion

The new welded joint has been studied experimentally and analytically through the finite element model. A variety of joints were fabricated using the parameters of the inserted length and thickness of gusset plate, angle of the steel pipe, and existence of slot applied to the proposed joints.

Based on the results of the finite element analyses and bending tests, the ALT2 type of specimen, among these three types of welded joints, was the best in terms of flexural rigidity and strength. Outer diaphragm in the ALT2 joint played a significant role of bonding the node ring and the gusset plate together, resulting in the improvement of the flexural rigidity and joint strength. Test results as well as preliminary FEA results exhibited that ALT 2 joint demonstrated very good potential in improving the flexural rigidity as well as strength of welded joint for single-layer latticed dome.

Initial rigidity and rotational rigidity increased with the increasing the inserted length and thickness of the gusset plate. It is believed that when thickness and inserted length of gusset plate are properly designed to prohibit the lateral buckling, the proposed joint shows little influence with respect to the rotational rigidity and strength caused by the inserted length of gusset plate. It is thus necessary to investigate the optimal inserted length and thickness of the gusset plate. However, although the thickness and inserted length of gusset plate are large enough, when the gusset plate was too thin, flexural strength of joint tended to decrease prematurely due to lateral buckling of the gusset plate. It is exhibited that joint having the shallow gusset plate need to be considered the lateral buckling of the gusset plate. Based

![Figure 11. Structural performance (Ki: flexural rigidity, M_y: yield moment, M_u: Ultimate moment).](image)
Bending Test of Welded Joints for Single-Layer Latticed Domes

on the test results, it was observed that the influence of pipe angle on flexural performance was negligible. Test result also showed that the slot at the tip of gusset plate played an important role on the flexural performance such as rigidity and strength.

This study was limited to only flexural performance by bending test of joint. Therefore, this study did not include the buckling problem result from the axial force. Supplemental nonlinear FEA and experimental study is currently being performed in order to investigate buckling of truss member by axial force and to establish a reliable numerical model for the analysis of latticed truss system.

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References


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