압축력과 휨모멘트를 받는 메탈 터치된 기둥 이음부의 구조성능에 대한 실험적 연구

A Experimental Study on the Structural Performance of Column Splices with Metal Touch Subjected to Axial Force and Bending Moment

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요 약 : 철골구조물의 기둥이음 형식은 볼트연결이나 용접을 이용한다. 이러한 연결방법에서 부재의 축응력은 덧판의 볼트체결이나, 용접부위를 통하여 그 응력이 전달되는 것으로 간주하여 설계, 시공되고 있다. 우리나라의 강구조 한계상태 설계기준에 따르면, 기둥 이음부의 고력볼트 및 용접이음은 이음부의 응력을 충분히 전달하여야 하고 이들 항복내력은 피접합재 항복내력의 1/2이상이 되도록 하여야 한다. 다만, 이음부에서 단면에 인장응력이 없는 경우, 이음면이 절삭 마감으로 밀착되면 소요압축력 및 소요휨모멘트 각각의 1/4은 접촉면에 의해 직접 전달시킬 수 있다고 되어있다. 반면에, 미국 철강협회설계기준(AISC Specifications and Codes)에서는 기둥이음에서 지압력에 따라 응력이 전달되도록 접촉면이 마무리되어 있는 경우, 그 위치를 확보하는데 충분하도록 이음되어야 한다고만 되어있어, 설계자의 판단에 따라 압축력은 이음면의 직접접촉(Metal Touch)으로 상부에서 하부로 모두 전달할 수 있도록 되어있고, 또한 압축력과 휨모멘트를 받는 기둥에서는 직접접촉을 통해 최소 25%에서 최대 50%까지의 하중전달이 가능하다. 따라서 기둥이음에서 압축력에 대한 직접접촉의 활용도의 차이가 크고 또한 압축력과 모멘트가 작용할 때의 직접접촉에 대한 활용도도 그 차이가 최대 25%이므로, 직접 접촉된 이음부의 응력전달 거동에 대한 연구가 필요하다. 본 연구는 축력과 휨모멘트가 작용하는 기둥에 대해서 이루어지며 실험체의 수는 총 22개이다. 국내의 메탈터치의 평활도인 관리 허용치 1.5D/1000와 한계허용치 2.5D/1000및 AISC에서 제시하는 압축력을 받는 기둥에서의 보강 없는 틈의 한계인 1.6mm에 대해, 본 실험결과와 기존의 허용치를 비교하였다. 그 결과, 상하부재 간의 직접 접촉을 통하여, 즉 메탈터치를 이용하여 응력을 전달시키면 부재 이음에서 경제성과 효율성이 개선될 수 있다고 판단된다.

ABSTRACT : The structural framework design uses high-strength bolts and welding in column splices. However, for the column under high compression, the number of the required high-strength bolts can be excessive and the increase of welding results in difficulty of quality inspection, the transformation of the structural steels, and the increase of erection time. According to the AISC criteria, when columns have bearing plates, or they are finished to bear at splices, there shall be sufficient connections to hold all parts securely in place. The Korean standard sets the maximum 25% of the load as criteria. Using direct contact makes it possible to transfer all compressive force through it. The objective of this study is to examine the generally applied stress path mechanism of welded or bolted columns and to verify the bending moment and compression transfer mechanism of the column splice according to metal touch precision. For this study,22 specimens of various geometric shapes were constructed according to the change in the variables for each column splice type, which includes the splice method, gap width, gap axis, presence or absence of splice material, and connector type. The results show that the application of each splice can be improved through the examination of the stress path mechanism upon metal contact. Moreover, the revision of the relative local code on direct contact needs to be reviewed properly for the economics and efficiency of the splices.

핵 심 용 어 : 이음, 직접접촉, 틈의 크기, 응력전달

KEYWORD : splice, direct contact, gap, stress transmit.

1. Introduction

Welding or high-strength bolts are used in order to connect a column to another one. In these connection types, stresses are transferred from an upper column to the lower one through the splice plate or welding.

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If the high-strength bolts are used, there can be a gap between an upper column and the lower one. The effects of the gap are negligible because stress transfers through the splice like cover plate or welding. However, the number of high-strength bolts should be increased for the parts under high compression and we need longer welding time.

In Korea, the government regulations(AIK, 1997) on column splice require that high-strength bolts and welding in column splice shall transfer sufficiently stress and shall be proportioned to 50 percent of the yield strength of the member. But, when the surfaces are milled and tensile stress is not generated, 25 percent of the load can be transferred directly in bearing between the columns for compressive force and bending moment.

According to the AISC specifications and codes, when columns bear in bearing plates, or are finished to bear at splices, there shall be sufficient connections to hold all parts securely in place. It makes possible for all compressive force to transfer through the direct contact by engineer's judgements.

The tests of E.P. Popov and R.M. Stephen indicate that the lack of perfect contact at compression splices of columns may not be important, provided that the gaps are shimmed and welding is used to maintain the sections in alignment(Popov et al., 1977). But then in the book of "Design of steel structures 3rd ed.", as far as the axial load is concerned, no splice at all is needed, since the load is resisted by bearing over the area in contact. However, splice plates are required because of shears and moments due to wind or other loads, and even if no shears and moments existed, it is obvious that some sort of connection is called for(Gaylord et al., 1992).

And several research results suggest that the splice material may be required to carry anywhere from 25 to 100 percent of the total load because there are discrepancies between the ideal case and the actual conditions in the structure. The 25 percent of the total load is considered to be the minimum design value necessary to assure a splice which can hold the column in place and the 75 percent of the load must be transmitted by the direct contact. In addition, for the column subjected to axial force and bending moment, from 25 to 50 percent of the total load must be transmitted by direct contact(AICS, 1999).

There is difference between AISC and Korean criteria in column splice. As the practical application in Korea is lower than that of the U.S., the direct contact in column splice is studied in order to have better understanding for practical situation and the stress transfer in column splice. The purpose of this study is to examine the effect of imperfect contact in column splice on the stress transfer and column's yielding strength. The result of this study can suggest the column splice which can improve the economical efficiency by using the direct contact.

For column design, various factors including the structural stability, connection, and member shape should be considered. In this paper, the structural performance of column splice with metal touch is investigated by considering the parameters such as he splice type, the direction and width of gap and the change of splice part including the connection type. In addition, strain gages attached on column splices were used for investigating the stress transfer.

2. Experiments

The study of the column connection has largely two types. One is a column subject to only axial force and the other is a column subject to bending moment. The former had been done by Hong and Kim(Hong, et al., 2004). The conclusion is that it is possible to transfer sufficient amounts of the load from an upper column to the lower one by directly contacting columns with splice imperfection. However, most columns are subjected to axial force and bending moment. Particularly, columns at the corner or irregularly located columns are under combined axial compression and biaxial bending. Thus, the columns subject to axial force and bending moment are studied. The tests were conducted using H-250×250×9×14 shape of SS400 materials for twenty two specimens.

During the erection of a structure, the milled or cut surfaces at column splices may not make perfect contacts. For this reason, AISC accepts a maximum gap of 1.6mm without shims. But, the Korean criteria of the evenness of metal touch suggest 1.5D/1,000mm as a tolerance limit of management and 2.5D /1000mm as a maximum tolerance limit, where D is the depth of the steel beam. So, a comparative study of this difference with experimental results. are done

2.1 Test Setup

The eccentric load to the strong axis of specimens is actuated and the specimens are acted by axial force and bending moment. Under this condition, the structural performance in column splice with high-strength bolts or welding is examined. The stress transfer is studied from the data of strain.

A column behavior relative to the stress transfer is also studied from the data of LVDT.

A typical test setup is illustrated in the Fig. 1. The load is applied to the specimen by UTM with 25cm eccentric against a strong axis. Six LVDTs are set in order to record the column behavior with several connection types. To find a behavior of column in a strong axis, four LVDTs are installed on the column. To find a bending of a weak axis, one LVDT was installed beside a beam. Finally, to check a possibility of a rotation, one LVDT is installed on the base plate. Because this study is focused on the stress transfer on the column splice, in other words toexamine how much a gap size and a location of a gap have effects on the stress transfer of the column, strain gauges from the minimum 12 to the maximum 24 were attached on the splice, respectively. The test is done to the yield condition of the column. At the same time, the data is acquired from six LVDTs and several strain gages. The deformation of the splice is analyzed with the data through the DATA LOGGER.

With these experimental setups, a testing program is conducted to investigate the behavior of partial penetration weld splices, cover plate fillet welded splices and cover plate bolted splices with the parameters of a gap width and a direction of a gap.

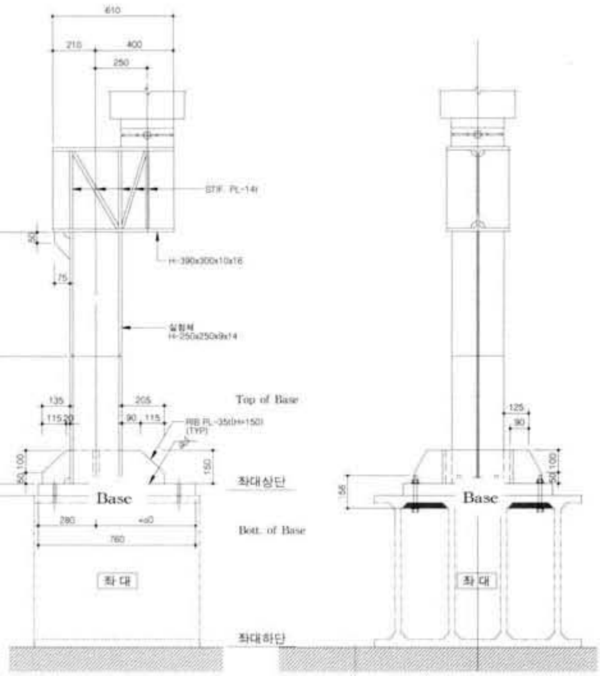


Fig 1. Test Setup

2.2 Test Specimen Configuration

According to KS D 3503 standard, the most commonly used specimen is the one with the wide-flange rolled shape. The column with induced bending deformation or bending failure has a dimension of H-250×250×9×14 (SS400) and the beam acted by the eccentric load has a dimension of H-390×300×10×16(SS400). On all specimens, the beam-to-column connection is designed to have full transfer of moment. For that reason, some stiffeners are welded to beam and beam-to-column to have full stiffness. There is no deformation of the beam after the test.

In addition, the column-to-base plate is welded to fix the base of the column and additional rib plates are welded to have full stiffness. The specimens with the splice located 575mm above the base plate have a length of 1595mm including the depth of the beam and the thickness of the base plate.

The total twenty two specimens are fabricated and one had no splice. The existing connection methods are applied to three specimens. And the others had the three kinds of gap width and two types of the direction of the gap. Two types of the direction were put for a gap on a web and flanges or a web and a flange. The details of the specimens are summarized in Table 1 and Fig. 2. The splice plates used in the column-to-column connection have the thicknesses of 4.5mm, 6mm, 9mm, 12mm and 18mm. Fasteners are the high-strength bolts of F10T M20 or F10T M16. To attach a cover plate, fillet weld was used.

[Specimen FPW] This sample is connected to two columns by a full penetration weld.

[Specimen FCW] This specimen is connected to two columns by using a cover plate PL-18×200×300 in the outer-surface of the flange and two cover plates PL-9×120×120 in both sides of the web. Here, welding is fillet weld.

Table 1. The definitions of specimen.

Splice type	Direction of the gap	The gap width	Specimen name
No splice	-	-	USC
Full penetration welding	-	-	FPW
Full cover plate welding	Both axes	5.0mm	FCW
Full cover plate bolting	Both axes	5.0mm	FCB
Partial penetration welding	Strong axis	1.6mm	PW-W16
		2.4mm	PW-W24
		3.2mm	PW-W32
	Weak axis	1.6mm	PW-F16
		2.4mm	PW-F24
		3.2mm	PW-F32
Cover plate welding	Strong axis	1.6mm	CW-W16
		2.4mm	CW-W24
		3.2mm	CW-W32
	Weak axis	1.6mm	CW-F16
		2.4mm	CW-F24
		3.2mm	CW-F32
Cover plate Bolting	Strong Axis	1.6mm	CB-W16
		2.4mm	CB-W24
		3.2mm	CB-W32
	Weak Axis	1.6mm	CB-F16
		2.4mm	CB-F24
		3.2mm	CB-F32

[Specimen FCB] This sample is designed to have full continuity so that the applied load is transferred as much as 100 percent. So, PL-9×245×405 and 2PL-9×95×405 are fastened with the twelve high- strength bolts of F10T M20 in flanges and 2PL-9 ×140×285 had the eight ones. This specimen have a gap, but it is not ignored. For this connection type, the compressive stress is transmitted through the splice plate.

[Specimen PW-W16, 24, 32] While FPW used a full penetration weld, these have a maximum gap of 1.6mm, 2.4mm, 3.2mm and a partial penetration weld is used. The wedge shaped gaps ranged from a full contact condition on one side of the splice to the desired gap width on the other. W presents the intentional gap which is made to occur about the strong axis so that the compressive load is transferred only through the partial penetration weld.

[Specimen PW-F16, 24, 32] Similar to PW-W series, the wedge shaped gaps are located on both flanges. Both flange have a full contact condition on one edge of flange and the maximum gap of 1.6mm, 2.4mm and 3.2mm on the other. So, web have discontinuity. F presents the intentional gap which is made to occur about the weak axis. Thus, most stress is transferred through the partial penetration weld.

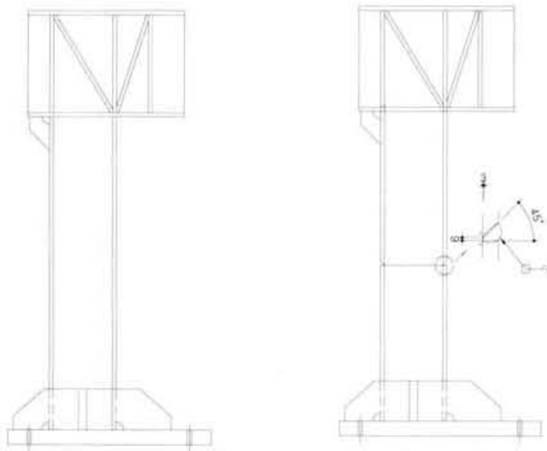
Table 2. The yield strength comparisons.

Specimen name	Yield Strength (kN)	Yield Strength ratio	Displace -ment (mm)
USC	1077.559	1.000	9.98
FPW	1159.095	1.076	10.24
FCW	1104.166	1.025	10.29
FCB	1166.592	1.083	8.92
PW-W16	1068.837	0.992	9.69
PW-W24	1158.556	1.075	10.06
PW-W32	1080.793	1.003	10.52
PW-F16	1099.56	1.020	8.37
PW-F24	1113.574	1.033	10.94
PW-F32	1154.93	1.072	9.98
CW-W16	1165.944	1.085	11.04
CW-W24	1120.14	1.040	10.79
CW-W32	1076.236	0.999	10.25
CW-F16	1177.47	1.093	11.20
CW-F24	1135.183	1.053	10.96
CW-F32	1151.696	1.069	11.47
CB-W16	1267.777	1.176	12.80
CB-W24	1017.436	0.944	9.39
CB-W32	1231.321	1.143	14.77
CB-F16	1148.903	1.066	11.90
CB-F24	1224.167	1.136	13.35
CB-F32	1175.657	1.091	14.43

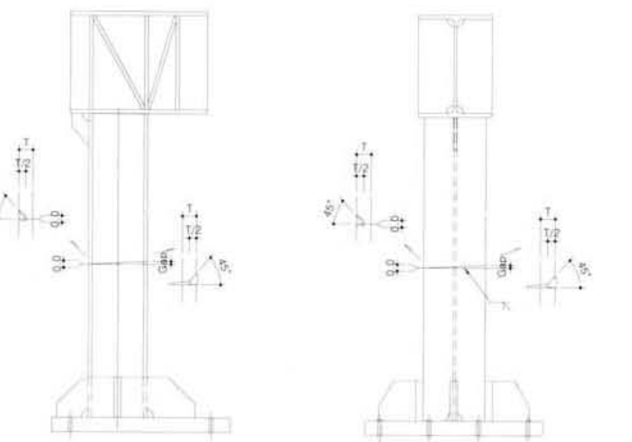
[Specimen CW-W16, 24, 32] Like PW-W series, these have the wedge shaped gaps. While PW-W series transferred the compressive and tensile stress through the partial penetration weld, CW-W series did it by cover plates. The cover plates are attached to flanges and a web by using fillet weld. Splice plates are used for PL-12×200×260 on the flanges and PL-4.5×120×120 on the web.

[Specimen CW-F16, 24, 32] Similar to PW-F series, these have the wedge shaped gaps. So, initially, it has little contact. As load increase, contact surface spreads out. These use the same splice as CW-W series.

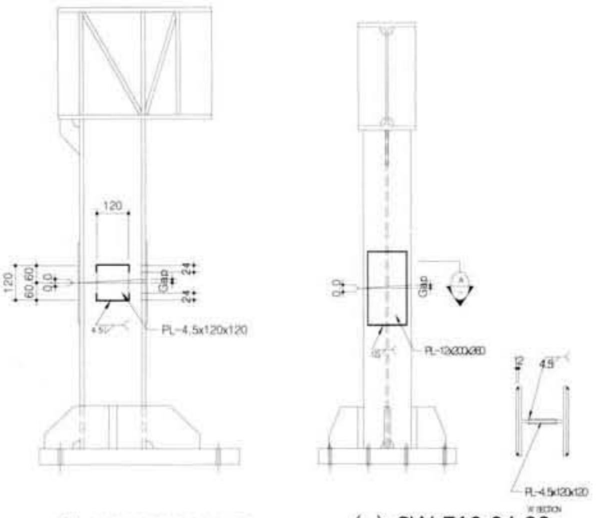
[Specimen CB-W16, 24, 32] Like PW-W series, these have the wedge shaped gaps. While the splice of the FCB is transferred as much as 100 percent, that of the CB-W is designed to be transferred the applied.



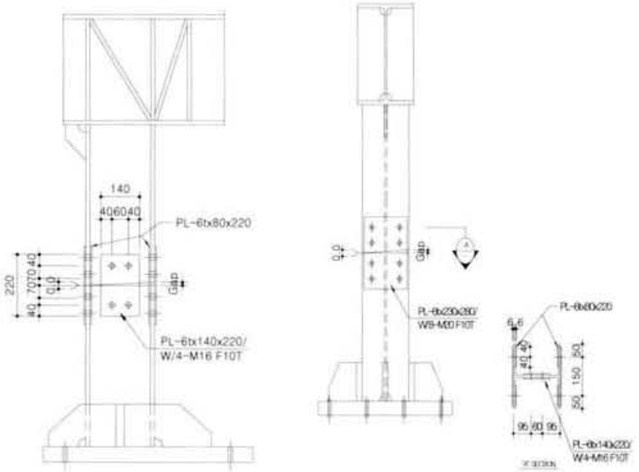
(a) USC (Unspliced Column) (b) FPW(Full penetration welding)



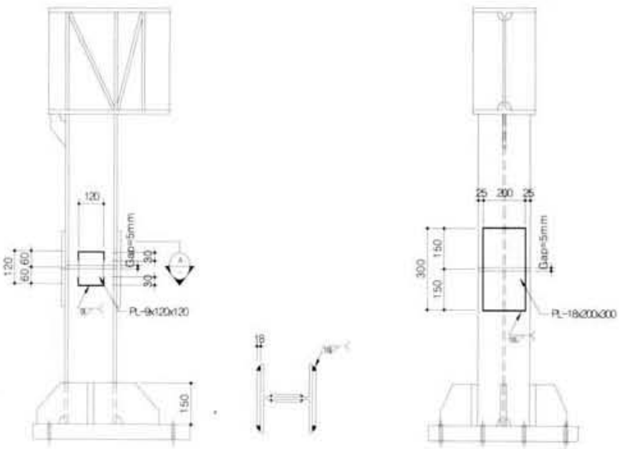
(d) PW-W16,24,32 (e) PW-F16,24,32



(f) CW-W16,24,32 (g) CW-F16,24,32



(h) CB-W16,24,3.2 (i) CB-F16,24,32



(j) FCW(Full Cover plate welding)

Fig. 2. Details of Specimens

3. Test Results

In order to determine the material properties, coupon tests are conducted. According to KS B 0801 (Metal materials - Tension tests), specimens which were extracted from flange locations were used to the tests. The yield points varied over the section as expected. Results exhibited the average yield stress of 343 MPa and the extreme tensile stress of 476 MPa. And the value of E was 190512 MPa.

The test was actuated by eccentric force to the strong axis. To study column splices with the Metal Touch, twenty two specimens under axial force and bending moment were tested. Here, the Metal Touch is that stress transfer in steel structures is attained by using the direct contact. The parameters of these specimens are column splice types, a gap width, and a direction of gap. Increasing a load, a deformation and the effects of connection with these parameters was examined. At first, data acquired from the test were used to compare the load-displacement graph. The graphs were sorted to the column splice types and the gap width. Next, the column behaviors with the column splice types and the gap width were compared. Third, column splice parts through the measurement and the observation before and after the test were examined. Finally, the stress transfer with the data acquired from strain gauge on the column splice was examined. These were analyzed to study the column splice with Metal Touch subjected to axial force and bending moment.

In strength design philosophy, the design strength provided by the resulting design must at least equal to the summation of the applied factored service loads. In any case, the design strength is determined by a limit state. The limit states means "those conditions of a structure at which it cease to fulfill its intended functions". Strength limit states are such behavioral phenomena as achieving ductile maximum strength, buckling, fatigue, fracture, overturning, sliding and yielding. In this study, we selected 30, 50, 70 percent of the yielding strength for the comparison points about all specimens(Salmon et al., 1996).

3.1 Load-Displacement Curve

The relation between the load of the splice types of the parameter and the vertical displacements is showed in the Figs. 3 to 8. Generally, the load-displacement graph represents linear conditions within elastic range. In practice, there are a little difference depending on the splice types. Yield strength and yield strength ratio of specimen are arranged in the Table 2 and yield strength ratio represents the yield strength of other specimens to that of the USC. The decision of yield strength was done by using the method of 0.2 offset.

Splice plates were used in CW series CB series, and this variance of stiffness can influence on the column's strength and behavior. However, because stress flows through the column from an upper beam to a lower base plate, the general behavior of columns is similar regardless of this variance of stiffness. As it was expected from the analysis of ANSYS 8.0, the stress concentration occurred on the flange of an upper column in compressive region(Kim, 2004).

In the Figs. 3 to 6, except for cover plate bolting, the behavior of columns with Metal Touch is similar to that of the existing method. These phenomena show that the importance parameter is not the direction of gap and the gap width. From the experimental data, it is noted that the strength of the columns is decided by the capacity of the welding in splice part. In addition, in these tests the partial penetration weld can perform the behavior like the full penetration weld.

From Fig. 7 and Fig. 8, it is observed that the splice in the FCB was transferred as much as 100 percent while in the CB series, only the 50 percent of the applied load was transferred. The increase of vertical displacement around 400kN is higher than that of the others. These results can be explained from the fact that sliding phenomena occurred between the splice plate and column. In addition, these sliding phenomena result in a rotation of the upper column. But, after the occurrence of these phenomena, an upper column contacts the lower one directly and the gradient of column recovery to an original level. Conclusively, the splice plate in CB series played a part not in transferring the load but in holding the upper column in place and resisting a bending moment. The splice plate in CB series endured the initial load.

There are differences among the connection types; CB series differ from other types in particular. On account of space consideration, the graph of 2.4mm and 3.2mm of the gap size is omitted.

The yield strength of the specimens was different with maximum 23 percent. But, all specimens had a local buckling at a part of a beam-to-column connection around the yield strength. As previously stated, the stress concentration occurred in the upper flange of the compressive region.

From Fig. 9 and Fig. 10, the deformation of the specimens is not necessarily related to the connection types, the size of the gap, and the direction of the gap. Although several factors contributed to the behavior of the column splice, in this study the PW series can behave like one column and the CW and CB series have the advantage of increasing the stiffness in splice part.

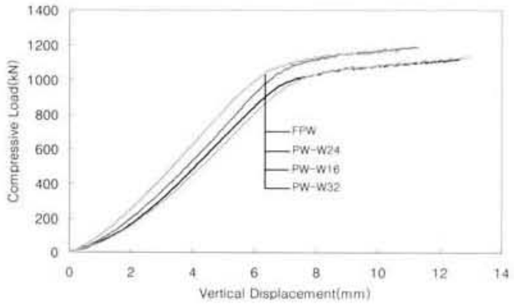


Fig. 3. Load-Displacement for PW-W series.

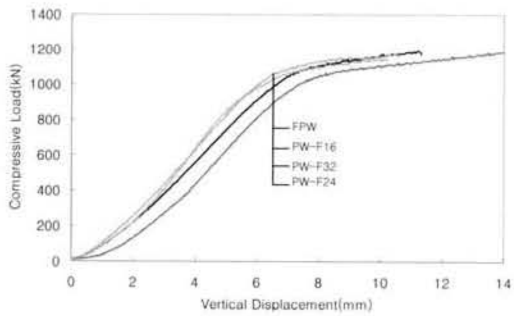


Fig. 4. Load-Displacement for PW-F series.

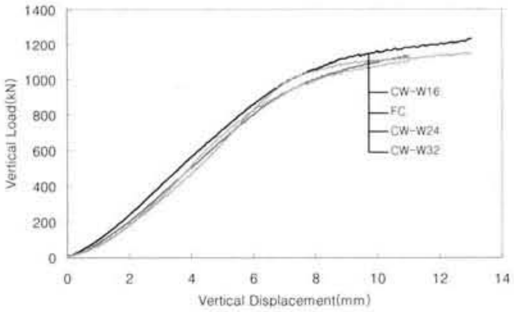


Fig. 5. Load-Displacement for CW-W series

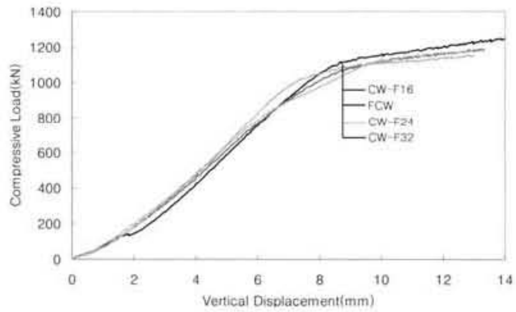


Fig. 6. Load-Displacement for CW-F series.

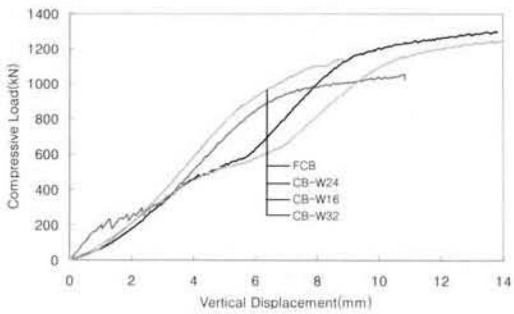


Fig. 7. Load-Displacement for CB-W series.

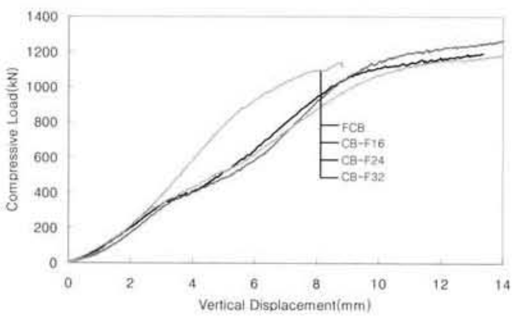


Fig. 8. Load-Displacement for CB-F series

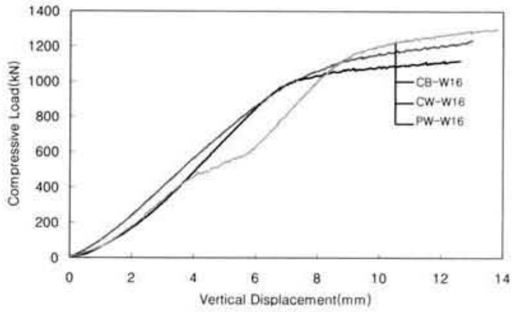


Fig. 9. Load-Displacement for the strong axis gap.

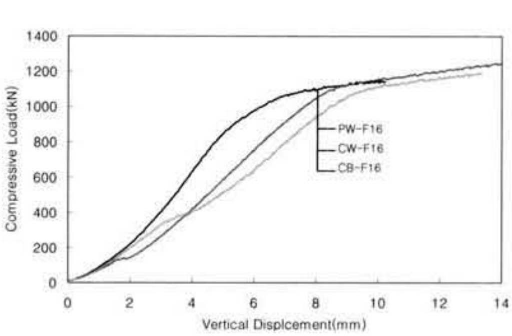


Fig. 10. Load-Displacement for the weak axis gap.

3.2 Column Behavior

The relation between the connection types and the column behavior is showed in the Figures 11-19.

On account of space consideration, the graph of 2.4mm and 3.2mm of the gap size is omitted. The column part of the specimens is 1145mm and LVDTs were installed at four points except for a fixed end. The maximum lateral displacement is about 10mm. So the scale of the graph is under the distortion. Generally, the increase of the load induced the bending of the column regardless of the splice types.

In Fig. 14 and Fig. 17, PW-W series and PW-F series behaved as one column. This is due to the character of a weld. When column had the deflection, the crack and failure of the weld was not observed in column splice. Beyond 70 percent of yield strength, the behavior of the column subjected to axial force and bending moment was started to be altered from the first mode to the second mode. These results represent that the sufficient stress transfer can be possible by using not only full penetration welding but also partial penetration welding. Although there were differences in weld penetration, the crack of weld and the tearing of the flange did not occur.

In Fig. 16 and Fig. 19, CB-W series and CB-F series obviously differed from FCB. The deformation of splice part occurred in CB series. Bending moment induced the rotation of the upper column, the sliding phenomena, and the deformation of the splice plate. For these reasons, the lateral displacement is bigger than the others at the 600mm height of specimens. In addition, for the CB-W series, the upper column is rotated about one degree.

In Fig. 15 and Fig. 18, the behavior of CW-F series are similar to that of PW series and CW-W series are similar to CW series. But, in all of the CW series, columns were directly contacted each other after being buckled in the compressive region of the cover plate. These buckling of the splice plate can change the role of the cover plate from the transfer of load to the role of holding the upper column in place and resisting bending moment. The crack and the failure were not observed in the fillet welding.

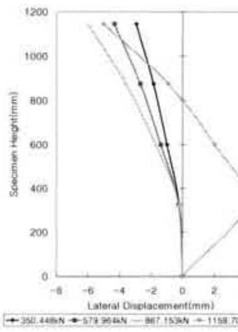


Fig. 11. Deflection of FPW

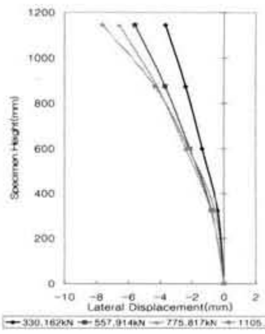


Fig. 12. Deflection of FCW

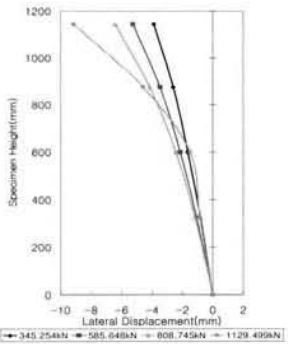


Fig. 13. Deflection of FCB.

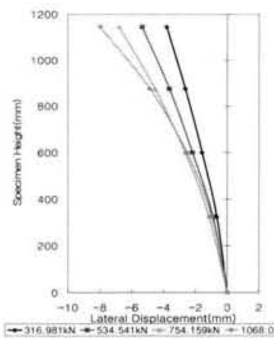


Fig. 14. Deflection of PW-W16

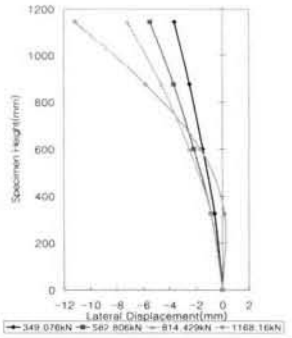


Fig. 15. Deflection of CW-W16

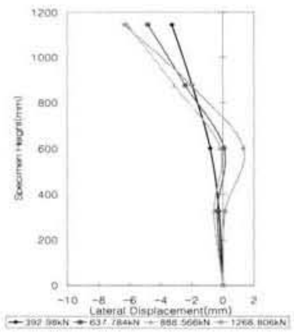


Fig. 16. Deflection of CB-W16

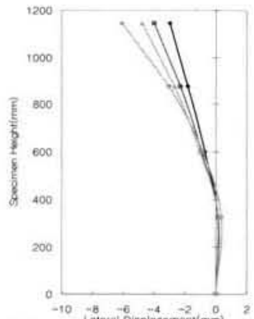


Fig. 17. Deflection of PW-F16.

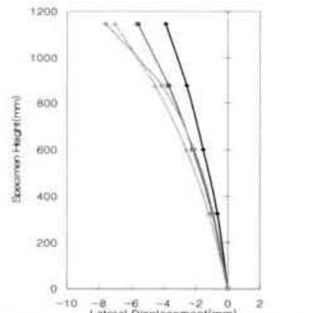


Fig. 18. Deflection of CW-F16.

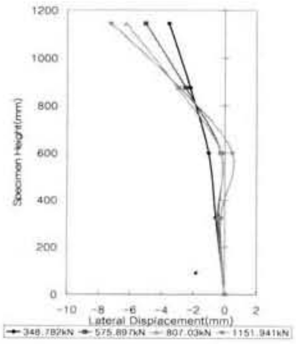


Fig. 19. Deflection of CB-F16.

3.3 Stress Transfer

In the case of the USC, strain gauges were attached at the middle point of the column height as the location of splice to compare the stress transfer of USC to that of the other specimens. And, in the case of using the welding such as FPW and PW series, strain gauges were attached to the both upper(U.C.) and lower columns(L.C.) to investigate the stress transfer through the weld in splice. In the case of using the splice plate such as CW series and CB series, strain gauges were attached at the splice plate to investigate the relation between the deformation of the splice plate and the stress transfer.

Before the 1994 Northridge and the 1995 Kobe earthquakes, engineers had traditionally designed beam-to-column connections in steel frames using classical Euler-Bernoulli beam theory which assumes the moment transfer of flanges while the web connection primarily resists the shear force. However, the results of a recent finite element study have shown that stress distribution in the vicinity of moment connections drastically differs from the pattern expected from the classical beam theory. This is in agreement with the boundary effect postulate expressed by the famous Saint Venant's Principle. In other words, the magnitude and direction of the principle stresses in the connection region are better approximated by using truss analogy rather than the classical beam theory. Thus, both the bending moment and the shear force are transferred across the connection near the beam flanges through diagonal strut action(Goel, 1997).

These researches represent the understanding of stress distribution which can be varied depending on the situation.

In the cases of the USC, FPW, PW-W and PW-F, the test results as Table 3 show that stress distribution is not equal in whole section of the column subjected to axial force and bending moment. Timoshenko and Goodier's principle suggested that the stress distribution and magnitude of deformation were affected by the boundary condition. Thus, this study show that the middle of the flange restricted to the web transfer more stress than the edge of the flange. However, it is obvious that the stress transfer and stress concentration consider several factors such as the details of connections, the residual stress in rolled column, the residual stresses induced by restrained weld shrinkage and punching, etc.

Table 3. Stress comparison at the flange of column

Speci-men	Loca.	Applied Load		Stress calculated from strain gauge (kN/cm2)		
		P (kN)	M (kN · cm)	0.04B	0.5B	0.96B
FPW	U.C.	350.45	8761.20	10.45	9.07	6.31
	L.C.			10.19	8.46	5.34
	U.C.	579.96	14499.10	18.06	19.73	13.90
	L.C.			17.65	17.73	12.25
	U.C.	867.15	21678.83	31.26	51.90	27.01
	L.C.			34.42	31.39	32.62
	U.C.	1158.70	28967.58	93.43	88.83	103.06
	L.C.			236.34	119.62	61.76
PW-W16	U.C.	316.98	7924.53	8.58	9.09	9.07
	L.C.			6.62	9.30	8.10
	U.C.	534.54	13363.53	15.80	28.02	16.74
	L.C.			11.98	26.60	14.54
	U.C.	754.16	18853.98	25.90	43.76	28.05
	L.C.			21.59	48.32	24.91
	U.C.	1068.05	26701.33	43.45	131.54	101.31
	L.C.			55.24	249.31	115.42
PW-F16	U.C.	328.25	8206.28	8.74	12.23	14.52
	L.C.			7.55	12.52	9.88
	U.C.	551.99	13799.63	15.30	21.32	25.03
	L.C.			13.44	22.13	16.91
	U.C.	774.54	19363.58	22.29	31.12	36.64
	L.C.			20.17	33.30	24.75
	U.C	1101.08	27526.98	37.47	160.54	222.21
	L.C			85.48	219.39	29.98

In the cases of the CW-W and CW-F, strain gauges were attached at both the splice plate of the outside of the flange and the inside surface of the flange. The tensile stress was shown at 0.04B and 0.96B of the splice plate near to the weld and the compressive stress was observed at 0.5B. Here, B is the width of splice plate. The tensile stress was generated for the bending of splice plate which was occurred by contacting columns.

In the cases of the CB-W and CB-F, the stress contribution is contrary to the cases of CW series. In the CB series, there was slided between the splice plate and the flange and it rotated the upper column beyond about 30 percent of the yielding strength. The splice plate in compressive region was needed to prevent these alterations accompanied by transfer of the load. So, compressive stress was represented at the middle of the plate which resisted the rotation of the web and flange.

3.4 Discussion on the Connection Type.

3.4.1 Partial Penetration Weld

In the tests of the column subjected to axial force and bending moment, partial penetration welding had a sufficient capacity of the stress transfer and behaved as one column without splices. Thus, it is expected that the respectable compressive stress is transferred by using the Metal Touch with imperfection splice. However, the quality of the weld should need to be inspected and the capacity of the deformation of steel should be guaranteed: the appropriate poison's ratio is provided for it.

3.4.2 Cover plate Weld

In the tests of the cover plate fillet welding, the crack and failure to compressive load did not be shown. But, the cover plate was bended after tests as the gap was contacted. These results were generated to transfer the compressive stress and remove the gap. After generating the direct contact and the buckling of the slice plate, the stress on the splice plate was increased by playing the role of fixing the place of the column and resisting to the bending moment. These results indicate that the buckling capacity of the plate was important in this connection.

3.4.3 Cover Plate Bolt

While the splice of the FCB was transferred as much as 100 percent, that of the CB-W was transferred the 50 percent of the applied load. The gap of the FCB was decreased only a little and the gap of the CB disappeared. The disappearance of the gap in the CB and the rotation of the upper column resulted in the loss of the resistance to the load. However, after the direct contact, the cover plate performed a role of holding the upper column in place and resisting the bending moment. The gap width did not affect the strength of the column, but the behavior of the column such as the sliding and rotation. Thus, the splice of the cover plate which transferred some of load needs to consider the gap width.

4. Conclusions

The conclusions drawn from this study were based on the structural performance experiment of column splice with metal touch by the parameters such as the splice type, the direction and width of gap and the change of splice part including the connection type. The following conclusions are derived from the experimental results.

(1) In the aspect of the behavior as one column, partial penetration welding is more superior to cover plate bolting. Also, the test results of partial penetration show a similar behavior due to the transfer of load through the welding when compared with that of USC and FPW. Therefore, the partial penetration welds can provide a good solution to common design problems because the amount of the weld in the partial penetration welds was less than that of full penetration welding and the decreases of the weld brings improvement in construction work.

(2) The CB types are necessarily considered to the appropriate gap width because of the shortage of the strength in splice. If there is an unfit gap in the course of the erection of column, the increase of the load will bring on the sliding at 30% yielding load and the rotation of columns in accordance with the direction of gap. Thus, it is necessary to observe a maximum tolerance limit of gap at domestic regulation to resist the initial load and to play a role of holding a column in place.

(3) Comparing the stress transfer of USC with no splice type to that of the other specimens, when column is subjected to both axial force and bending moment, 94.4%~117.6% of the applied load is transferred. And in case of the column subject to only axial force, 97.8%~104.9% of the applied load is done. Thus, it is necessary to increase the 25% stress transfer value of required capacity to 50% through direct contact as specified in the Structural Steel Design Code

(4) Considering to the magnitude of gaps, the column that had a gap of 1.6mm is transferred the stress of 101.6% by axial force and is done the stress of 99.2% by bending moment. And in case of a gap of 2.4mm, they were estimated 101.1%, 94.4% individually. Therefore it is proposed that the allowable tolerance for Metal Touch precision (2.5D/1000 presented in the domestic Architectural Work Standard Specification) can be increased to 2.0mm.

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