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Autor: Fukumoto, Toshiyuki / Kato, Ben / Sato, Kuniaki
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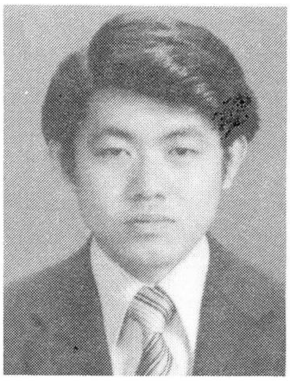
Concrete Filled Steel Bearing Walls

Murs porteurs constitués de parois d'acier et de béton

Tragwände in Stahlzellenverbundbauweise

Toshiyuki FUKUMOTO
Research Eng.
Kajima Corp.
Tokyo, Japan



Toshiyuki Fukumoto, born in 1956, graduated from Tokyo Denki Univ. in 1979 is now working on composite steel and concrete structures.

Ben KATO
Professor, Dr.
Tokyo Univ.
Tokyo, Japan

Kuniaki SATO
Kozo TOYAMA
Mikio KOBAYASHI
Katsuhiko EMORI
Koji ISHII
Mitsuo SAKAMOTO
Kajima Corp.
Tokyo, Japan

SUMMARY
SC bearings walls are composed of box steel(S) and filled concrete (C). They are expected to reduce construction time and labor compared with reinforced concrete bearing walls with especially complicated re-bars. However, it is necessary to use comparatively thin steel plates for SC bearing walls from an economical view point. The objective of this investigation is to clarify the structural behavior of SC bearing walls with thin steel plates by axial and shear loading tests.

RÉSUMÉ
Les murs porteurs SC se composent du coffrage d'acier (S) rempli de béton (C). Comparés aux murs porteurs de béton armé avec des barres de répartition particulièrement compliquées, ils permettent de réduire le temps de construction et la main d'œuvre nécessaire. Mais pour des raisons économiques, il serait souhaitable de renforcer ces coffrages par de minces tôles d'acier. Le but de cette recherche est de déterminer le comportement structural de ces murs porteurs SC comportant de minces plaques d'acier par des tests de charges axiales et de cisaillement.

ZUSAMMENFASSUNG
Tragwände in Stahlzellenverbundbauweise bestehen aus einer mit Beton verfüllten Stahlzelle. Man erwartet von dieser Bauweise verkürzte Bauzeiten und eine Einsparung an Arbeitskräften im Vergleich zu den herkömmlichen Tragwänden aus Stahlbeton mit besonders komplizierter Bewehrung. Für eine Kostenersparnis ist allerdings die Verwendung verhältnismässig dünner Stahlplatten notwendig. Das Ziel dieser Untersuchung ist die Klärung des Tragverhaltens solcher Tragwände unter Druck- und Schubbeanspruchung.

1. INTRODUCTION

The concrete-filled steel (SC) bearing walls consist of elements of steel plate box units filled with concrete. Their structural behavior can be characterized by high strength and sufficient ductility owing to the composite effect of the steel plate and the concrete. By applying SC instead of reinforced concrete (RC) for structural constructions it can be foreseen that the arduous task of arranging and placing of rebars are eliminated, which should result in reducing construction time. This SC structural method should prove valuable to countries such as Japan which is located in high seismicity zone and is subjected to large seismic loads.

Regarding the SC bearing wall, the researches by Kato, Suzuki, et al.[1)2)] has confirmed, by basing on tests, that the relationship between loads and displacements show sufficient ductility when steel plates with width-thickness ratio of about 100 is used. They also show that the maximum shear strength could be estimated by an ultimate limit analysis.

The SC bearing walls proposed by the authors are constructed by assembling welded box steel units and filling the inside with concrete (see Fig. 1). The box units are composed of comparatively thin steel plates (width-thickness ratio of 200) in view of economical considerations. However, anxieties did exist that the composite effect to the SC bearing wall may not be adequate due to buckling of the thin steel plates at an early stress stage. In this paper, the authors describe the elasto-plastic structural behavior of the proposed SC bearing wall units by applying stiffening to the thin steel plates such as insert plates, L-shaped steel angle members and headed studs in loading tests. The tests conducted were compressive loadings and shear loadings.

2. OUTLINE OF THE PROPOSED SC BEARING WALLS

Process of the proposed SC bearing walls are 1) prefabricating a box unit consisting of two-surface plates and vertical and horinzontal insert plates, 2) assembling box units to the required length and width of the wall, 3) welding the joints of the boxes, and 4) filling the inside of the box units with concrete. The thickness of the proposed SC bearing wall is 1.25 m and the thickness of the steel plates are 12 mm. This possess equivalent strength and economy as a RC bearing wall which has wall thickness of 2 m and rebar reinforcement ratio of 1.2%. The outer dimensions of the box steel unit, which was determined in view of the convenience of construction and transportation, has the width of 2.5 m, and the height of 3 m (see Figs. 1 and 2). As a bearing wall, the proposed SC bearing wall has a smaller self-load than a RC bearing wall used in the same place because of its smaller cross section. Thus can contribute to reduce seismic loads.

The methods devised to prevent early stage buckling of the surface plate are as follows: 1) place one or two vertical insert plates in appropriate places

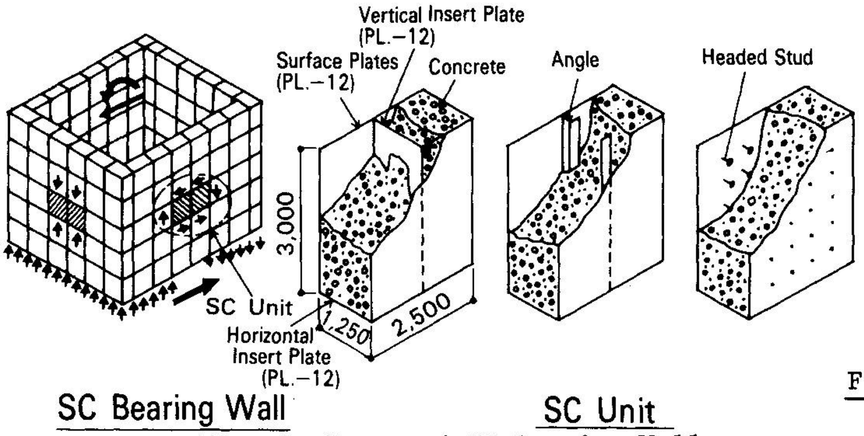


Fig. 1 Proposed SC Bearing Wall

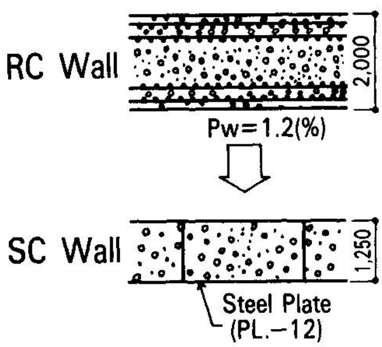


Fig. 2 Comparison of RC Wall and SC Wall

within the unit; 2) stiffen the surface plates by attaching four L-shaped steel angle members instead of the two vertical insert plates; 3) weld headed studs on the surface plates to conform with the AIJ standard for structural design of steel structures (width-thickness ratio ≤ 41)[3]; etc.

3. STRUCTURAL BEHAVIOR OF THIN STEEL PLATE SC BEARING WALLS

3.1 Outline of Loading Test Program

Table 1 and Figs. 3 and 4 show the specimens and their shapes. The specimens are approximately 1/4 scale-models of the proposed units of the SC wall. Seven respective specimens were tested each for compressive loadings and shear loadings to study the test parameters as follows.

- the composite effect of the steel plate and the concrete
- the effect of the insert plates interval (width-thickness ratio of the surface plates)
- the effect of the stiffening method to the surface plates

Table 2 and 3 show the mechanical properties of the materials.

3.2 Test Results

Figs. 5 and 6 show the compression and shear test results for each parameter. Table 4 show the final state of the surface plates and the filled concrete. Table 5 show the maximum strengths of the specimens.

Specimen	Cross Section	Structure	Width Thickness Ratio	Stiffening Method
Non Stiffening 200K		SC	200	Non Stiffening
One Insert Plate 100k		SC	100	Insert Plate (1-PL.-3.2)
Two Insert Plates 67K		SC	67	Inser Plate (2-PL.-3.2)
Angle 67A		SC	67	Angle (4-L50X 50X4)
Stud 35S		SC	35	Headed Stud (ϕ6,ℓ=40, @80)
Steel 100S		Steel	100	Insert Plate (1-PL.-3.2)
Concrete 0C(Com.) 1C(Shear)	0C / 1C	Concrete	—	—

※Concrete : Fc240 Surface Plate : PL.-3.2
Side Plate : PL.-22(Com.),PL-19(Shear)

Table 1 List of Specimens

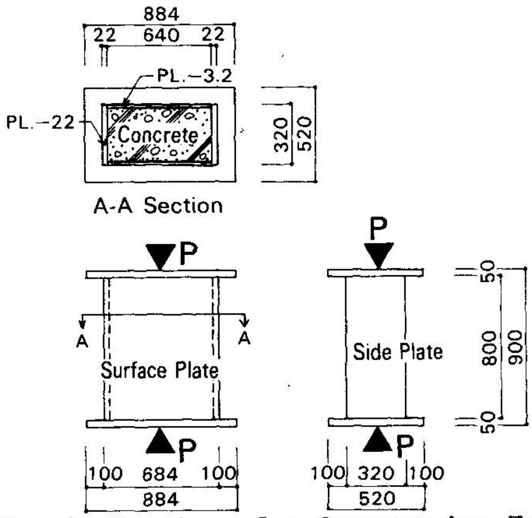


Fig. 3 Specimen for Compression Test

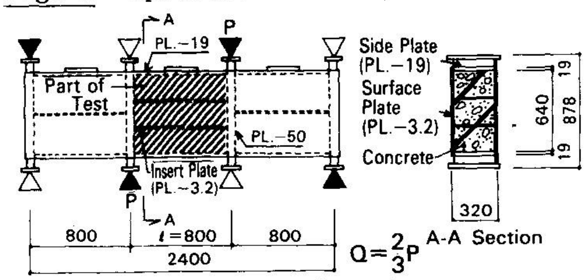


Fig. 4 Specimen for Shear Test

Thickness (mm)	Yield Stress σ_y(MPa)	Tensile Strength σ_u(MPa)	Elongation ε(%)
3.2	253	402	30.5
19	352	514	27.9
22	343	515	27.5

Table 2 Mechanical Properties of Steel

Test	Compressive Strength (MPa)	Tensile Strength (MPa)	Elastic Modulus (kN/mm²)	Age (days)
Compression	23.3	2.7	21.5	47
Shear	23.4	2.4	23.0	72

Table 3 Mechanical Properties of Concrete

3.2.1 Composite Effects of Steel Plate and Concrete (see Figs. 5(a) and 6(a))

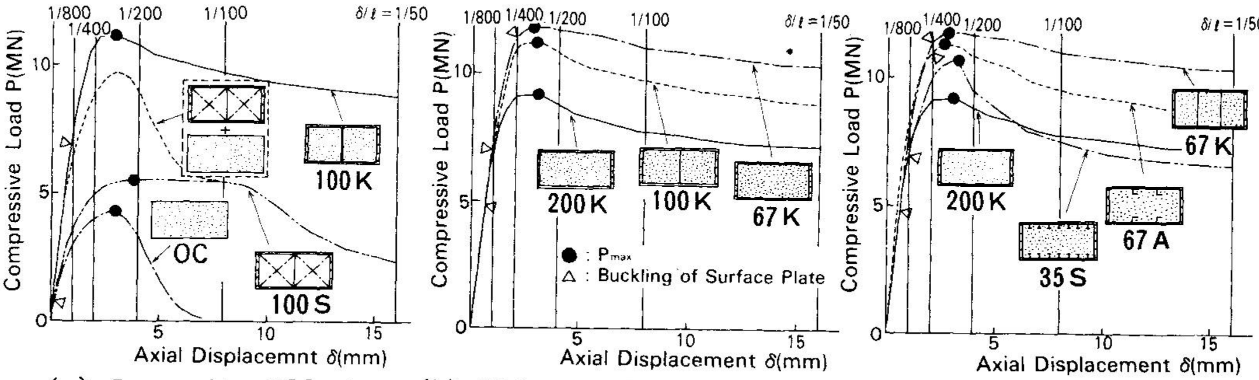
When compared with the superposed strength of the steel (100S) and the concrete (0C, 1C) specimens, the maximum strength of the SC specimen (100K) was stronger by 1.14 times in the compression test, and by 1.40 times in the shear test. The ductility was excellent in both tests.

3.2.2 Effects of Insert Plate (see Figs. 5(b) and 6(b), Table 4)

When three specimens with varying insert plate intervals (200K, 100K, 67K) were compared, their elastic rigidities were almost the same. In the compression tests, the maximum strengths were different due to the number of insert plates which support divided parts of compressive force, and due to the stiffening effects to the surface plates which increase the strengths against bucklings. In the shear tests, the maximum strengths were almost the same, but as the insert plate interval decreased, the rigidity beyond the elastic range decreased, and the displacement at the maximum strength increased. It was thought that each of the concrete blocks divided by the insert plate were deformed separately. In both tests, the early stage buckling of the surface plates had little affect on the relationship between the loads and the displacements.

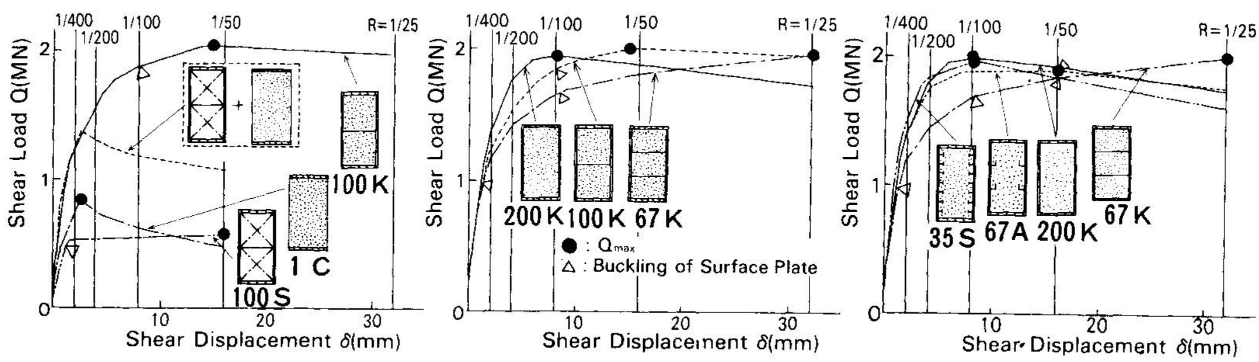
3.2.3 Effect of Stiffening Method (see Figs. 5(c) and 6(c))

In compression tests, the maximum strengths were different from aforementioned. In the relationship between loads and displacements of the shear tests, the non stiffening type (200K), the L-steel angle type (67A) and the stud type (35S) were about the same, but the two insert plates type (67K) showed a different behavior. In the case of stiffening by headed studs, the load carrying ability beyond the displacement at maximum strength was reduced earlier than others due to the failure of the concrete in between the stud head and the surface plate.



(a) Composite Effects (b) Effects of Insert Plate (c) Stiffening Methods

Fig. 5 Load-Displacement Relationship for Each Parameter in Compression Tests



(a) Composite Effects (b) Effects of Insert Plate (c) Stiffening Methods

Fig. 6 Load-Displacement Relationship for Each Parameter in Shear Tests

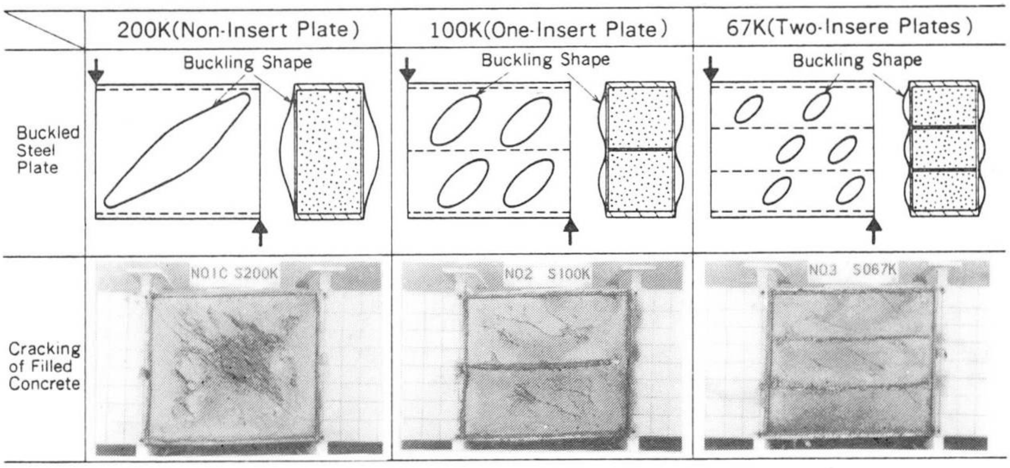


Table 4 Final State of the Steel Plate and the Filled Concrete

Specimen	Compression			Shear				
	Test	Calculated		Test	Calculated			
	Pe(MN)	Pc(MN)	Pe/Pc	Qe(MN)	Q_1(MN)	Qe/Q_1	Q_2(MN)	Qe/Q_2
200K	9.15	9.56	0.96	1.97	1.74	1.13	1.07	1.84
100K	11.30	10.20	1.11	2.04	1.74	1.17	1.07	1.91
67K	11.80	10.90	1.08	2.00	1.74	1.15	1.07	1.87
67A	11.40	10.80	1.06	1.89	1.74	1.09	1.07	1.77
35S	10.70	10.50	1.02	1.95	1.74	1.12	1.07	1.82
100S	5.44	5.00	1.09	0.58				
0C,1C	4.31	4.78	0.90	0.85				

$Pc=As\cdot\sigma_{cr}+(Ap+Ar)\sigma_Y+Ac\cdot Fc$, $\sigma_{cr}=k\frac{\pi^2E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2$, k=6.98(SC Specimen), k=4.00(100S)

Q_1 : Kato and Suzuki's Analysis $Q_2=As\cdot\tau_s+Ac\cdot\tau_c$, $\tau_s=\sigma_Y/\sqrt{3}$, $\tau_c=0.1Fc$

As,Ap,Ar,Ac : Area of Surface Plate, Side Plate, Stiffening Member, Concrete

Table 5 Maximum Strength

3.2.4 Maximum Strength (see Table 5)

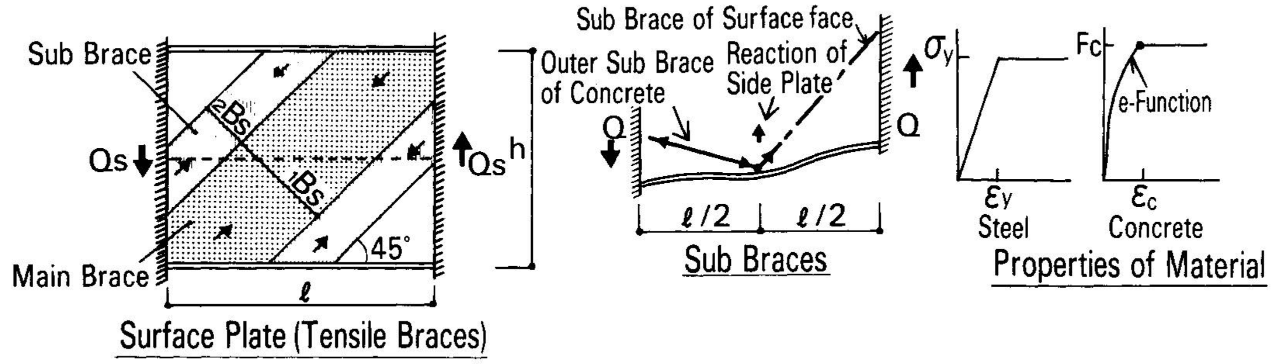
The calculated maximum strength (Pc, Q_2) of the SC bearing walls, obtained from superposed values of calculated steel strength and calculated concrete strength showed similar values with the rsults of the compression tests. The ratio of (Pe/Pc) were in the range of 0.96 ~ 1.11. But in shear tests, the ratio of (Qe/Q_2) showed safety margins of 1.77 ~ 1.91. The maximum shear strength Q_1 by Kato and Suzuki's theory showed that the (Qe/Q_1) ratios were 1.09 ~ 1.17 indicating good agreement with the shear test values.

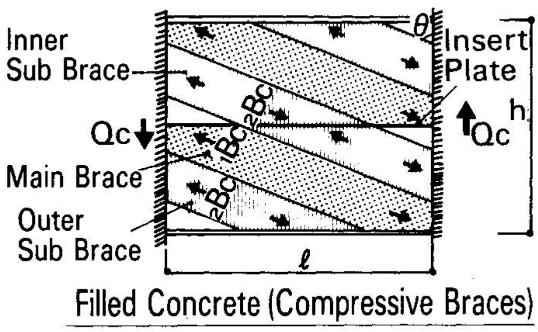
3.3 Analysis of Load-Displacement Relationship under Shear Load

Shear test results for differing insert plate intervals showed differences in the rigidity beyond the elastic range and displacement at the maximum strength. Therefore the analysis of relationship between load and displacement described below was carried out.

The analytical model was replaced by 45° direction tensile braces for surface plates, and diagonal direction compressive braces for separated concrete (in rectangle block formed by side plate and insert plates, see Fig. 7). The angle of each brace was determined by observation of the steel buckling pattern and the concrete cracking pattern after the tests (see Table 4).

The results of analysis agreed approximately with the test results (see Fig. 8). From the analyzed results, it can be seen that the maximum strength is dependent on the compressive strength of the main concrete braces, and the more the angle of the concrete braces increase due to the insert plate intervals, the more shear displacement at compressive strength increased. And also, the analytical elastic limit points were determined by the tensile yield of the surface plate. This phenomenon is the same as in the tests.





Shear Strength : $Q_{sc} = Q_s + Q_c$

$Q_s = t_s \{ {}_1B_s \cdot \sigma_s(\varepsilon_s) + {}_2B_s \cdot \sigma_s(\varepsilon'_s) \} \cos 45^\circ$

$Q_c = t_c \{ (n+1) \cdot {}_1B_c \cdot \sigma_c(\varepsilon_c) + n \cdot {}_2B_c \cdot \sigma_c(\varepsilon_c) + {}_2B_c \cdot \sigma_c(\varepsilon'_c) \} \cos\theta$

Effective Width : ${}_1B_s = (h - \ell/4)\cos 45^\circ$, ${}_2B_s = \frac{\ell}{4}\cos 45^\circ$

${}_1B_c = {}_2B_c = \frac{h\sin\theta}{2(n+1)}$

$\theta = \tan^{-1}\{(n+1)\ell/h\}$, n : Number of Insert Plate

t_s, t_c : Thickness of Steel Plate and Concrete

σ_s, σ_c : Stress of Steel Plate and Concrete

$\varepsilon_s, \varepsilon_c$: Strain of Main Brace of Steel Plates, Main Brace and Inner Sub Broce of Concrete

$\varepsilon'_s, \varepsilon'_c$: Strain of Outer Sub Brace of Steel Plates and Concrete

Fig. 7 Analytical Model of Load-Displacement Relationship under Shear Load

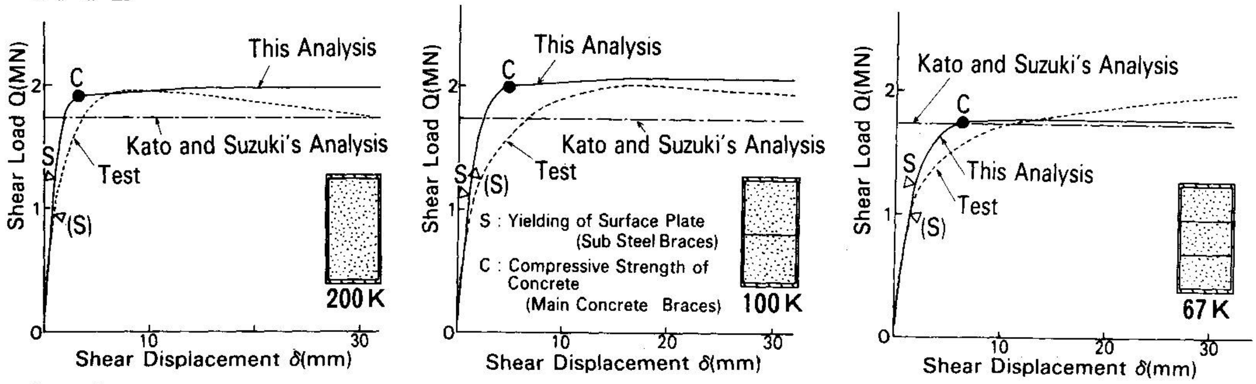


Fig. 8 Calculated Results of Load-Displacement Relationship under Shear Load

4. CONCLUSIONS

The thin steel plate SC bearing walls showed high strength and sufficient ductility due to the composite effect of the steel plate and the concrete. The buckling of the thin steel plate had little affect on the relationship between loads and displacements. The superposed values of the calculated steel strength and concrete strength is considered as a possible method to evaluate the strength of those structure. The calculated relationship between loads and displacements using a replaced brace model was in agreement with the test results.

REFERENCES

1. KATO, B et al., Shear Strengths of Concrete Filled Steel Wall (Part 1,2), Abstracts of the Annual congress of AIJ, Sept. 1980, pp1937-1940 (in Japanese).
2. KATO, B and SUZUKI, H, Shear Strengths of Concrete Filled Steel Box Elements, Transactions of AIJ, No. 341, Feb. 1984, pp.27-36, (in Japanese).
3. Architectural Institute of Japan, AIJ Standard for Structural Design of Steel Structures, 1973.