

## EVALUATION OF THE MSJC 2008 SHEAR STRENGTH EQUATIONS FOR PARTIALLY GROUTED MASONRY SHEAR WALLS

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## ABSTRACT

Partially grouted masonry shear walls is a common structural system in North America. This paper validates the MSJC's (2008) shear design equations by comparing the calculated shear strength of 90 partially grouted masonry shear walls tested by different researchers to the measured experimental strength. The data were collected from researchers from Japan, US, and Canada. In addition, the paper studies the effects of moment/shear ratio, horizontal reinforcement ratio, and axial stress on the ratio of the nominal shear strength to the measured shear strength. The analyses of the data showed that the current shear design equation overestimated the strength of 60 specimens out of the 90 investigated specimens. The average of the calculated to the measured shear strength was 1 with standard deviation of 0.44 and coefficient of variation of 0.44. Replacing the net shear area in the MSJC shear design equations over predicted the shear strength predictions. The current shear design equations over predicted the shear strength of only 32 specimens. The average predicted/measured shear strength was 1.39 with standard deviation of 0.55.

KEYWORDS: partially grouted masonry walls, shear strength, reinforcement

## INTRODUCTION

Reinforced masonry shear walls are a common structural system in seismic zones in the US. To increase the cost-effectiveness of reinforced masonry, partially grouted reinforced masonry (PG-RM) shear wall system was developed. In partially grouted, vertical reinforcement is placed in fewer cells than in fully grouted masonry, and only the cells including bars are grouted. The Masonry Standard Joint Committee (MSJC) [1] allowing the use of partially grouted masonry shear walls in high seismic zones with a maximum distance between grouted cells of 48 in. Recently, there was some concern among structural engineers and researchers about the correctness of using MSJC [1] shear design equations to predict the shear strength of PG-RM shear walls. This paper evaluates and examines the MSJC's shear design equations by comparing the calculated shear strength of 90 test specimens to those measured during experimental work. this data was collected from [2-8]. In all the figures in this paper the following legend was used: Yan for data from [2], Mat for data from [3], Che for data from [4], Gha for data from [5-6], Sch for data from [7-8], and Mal for data from [9].

#### LITERATURE REVIEW

The effect of horizontal and vertical reinforcement ratio on the shear strength of masonry shear walls have been studied by several researchers [2-10]. Shear walls constructed out of concrete and clay units were tested [3-4]. Effects of wall aspect ratio, masonry compressive strength, and applied axial load on the shear strength of the walls were investigated [3-4 and 7-8]. The effects of vertical and horizontal steel distribution on the ductility and strength of PG-RM walls was investigated [5-6]. An expression to determine the minimum horizontal reinforcement ratio for partially grouted masonry shear walls was developed by Schultz [7-8].

Shear design equations for fully grouted masonry walls were developed [3 and 10]. These design equations were modified, by introducing some reduction factors, and used for shear design of PG-RM walls. The current MSJC shear design equations were developed based on research carried out on fully grouted masonry shear walls [12-13]. The current MSJC shear design provisions were not calibrated or validated against experimental data for PG-RM shear walls.

#### DATA BASE AND ANALYSIS

This paper summarizes test data of 90 specimens that were tested by several researchers in the past few decades. The data was used to evaluate the shear design provisions of the MSJC [1]. Also, it was used to investigate the effects of moment/shear ratio  $M_u/V_u d_v$ , horizontal reinforcement ratio  $\rho_h$ , and the level of the applied axial stress q on the ratio of predicted/measured shear strength of PG-RM shear walls. Only specimens that failed in shear were considered for these comparisons. Tables 1 summarizes the characteristics of the testes shear walls. All specimens were constructed out of concrete units except specimens 40 to 51 from Matsumura's experimental work [3], and specimens HCBR-2 to HCBR-11 from Chen's work [4]. One of the serious issues regarding collecting this data is that some of this data was not well documented. The authors need to assume common values for some of these missing data such as net cross sectional area or yield strength of horizontal bars. Equation (1) [1] was used to calculate the shear strength of the PG-RM shear walls from Table 1.

$$V_{n} = \left[ 4.0 - 1.75 \left( \frac{M_{u}}{V_{u} d_{v}} \right) \right] A_{n} \sqrt{f'_{m}} + 0.25P_{u} + 0.5 \left( \frac{A_{v}}{s} \right) f_{y} d$$

$$Where \begin{cases} V_{n} \leq 6A_{n} \sqrt{f'm} & for & \frac{M_{u}}{V_{u} d_{v}} \leq 0.25 \\ V_{n} \leq 4A_{n} \sqrt{f'm} & for & \frac{M_{u}}{V_{u} d_{v}} \geq 1.00 \end{cases}$$

$$(1)$$

The term  $M_u/V_u d_v = H/L$  and H/2L for single and double bending walls, respectively, where H is the wall height and L is the wall length;  $M_u/V_u d_v$  in equation 1 should not be greater than 1.  $A_n =$ the net cross sectional area = gross cross sectional area – the area of any ungrouted cells. However, other codes such as the NZS 4230 [14] consider shear stresses transferring through masonry face shells only. Hence, in this research both concepts were investigated. In this paper,  $A_{nn}$  will be used for net cross sectional area and  $A_{nf}$  will be used for face shell based cross sectional area. For each wall, the average experimental ultimate strength  $V_u$  was divided by the calculated nominal shear strength  $V_n$ . The results are presented in Fig. 1 for  $A_{nn}$ , and  $A_{nf}$ . Table 2 summarizes the predicted and measured shear strength of the test specimens based on  $A_{nn}$ .



Figure 1: the relation between  $(V_u/V_n)$ , and  $(M_u/V_ud_v)$  based on (a)  $A_{nn}$ , and (b)  $A_{nf}$ 

## Effects of Characteristics of PG-RM Walls on Shear Predictions Using MSJC

To evaluate the effects of the different parameters of the tested specimens on the accuracy of the shear strength predictions using MSJC [1], the data from each research group was collected and categorized into several subgroups. Each subgroup has the same parameters except one variable. The variables investigated were the moment/shear ratio ( $M_u/V_ud_v$ ), axial stress level (q) defined as the axial load  $P_u$  divided by the gross area of the wall, the horizontal reinforcement ratio  $\rho_h = A_v/tL$  where  $A_v$  is the shear reinforcement ratio, t is the wall thickness, L is the wall length. The effects of these parameters on the ratio  $V_u/V_n$  are presented in Figs. 2 through 4.

## **RESULTS AND DISCUSSION**

As shown in Fig. 1, the MSJC shear design equations underestimates the shear strength of 60 specimens out of 90 specimens with an average  $V_u/V_n = 1.00$  with a standard deviation of 0.44 and coefficient of variation of 0.44. In addition, 30% of the data fall within 20% of  $V_u/V_n = 1.00$ . Using  $A_{nf}$  instead of  $A_{nn}$  in equation 1, improved the prediction of the shear strength with only 32 specimens became unsafe with an average  $V_u/V_n$  of 1.39, a standard deviation of 0.76, and a coefficient of variation of 0.55. 22% of the data fall within 20% of  $V_u/V_n = 1.00$ . Using  $A_{nf}$  is not the best parameter to consider partially grouting.

#### Effects of Walls Characteristics on Predictions Using MSJC

#### *Effects of moment /shear ratio* $(M_u/V_u d_v)$

The effects of moment /shear ratio  $(M_u/V_ud_v)$  on  $V_u/V_n$  are demonstrated in the Fig. 2. Specimens tested by [3 and 9] show a trend of decreasing  $V_u/V_n$  with increasing  $M_u/V_ud_v$  except for subgroup Mat.G1. In contradiction with the previous observation, Fig. 2(c) shows that  $V_u/V_n$  increase with increasing  $M_u/V_ud_v$ 

## Table 1: Specimen's properties

No         Wall ID         Immon (mm)         Immon (mm)         Vertical Internation (mm)         Immon (mm)         Imm			ш	T			Reinforcement		Vertical	Horizontal	f	Axial
Image: Problem: Control of the second state	No	Wall ID	( <i>mm</i> )	( <i>mm</i> )	( <i>mm</i> )	(H/L)	Vertical	Horizontal	ent spacing	ent spacing	J m (MPa)	stress
Matsumura's experimental work [3]           I 1020 150 1.05 0.0525 0.071 N.G N.G N.G 9.5 0           CW4-1-2         1800 1720 150 1.36 0.4525 0.071 N.G N.G N.G 9.5 0           CW3-1-2         1800 1320 150 1.36 0.429 0.071 N.G N.G N.G 15.6 0           CW3-1-2         1800 1320 150 1.36 0.429 0.071 N.G N.G N.G 15.6 0           CW2-1-1 1800 202 150 1.96 0.447 0.071 N.G N.G N.G 15.6 0           CW3-0-2         1800 1320 150 1.36 0.463 0         N.G N.G 9.5 0           CW3-0-2         1800 1320 150 1.36 0.463 0.071 N.G N.G 9.5 0           CW3-1' 1800 1320 150 1.36 0.463 0.071 N.G N.G 9.5 0           CW3-1' 1800 1320 150 1.36 0.463 0.071 N.G N.G 9.5 0           CW3-1-4 1800 1320 150 1.36 0.463 0.071 N.G N.G N.G 15.6 1           120 CW3-1-4 1800 1320 150 1.36 0.463 0.071 N.G N.G N.G 15.6 1           1800 1320 150 1.36 0.463 0.071 N.G N.G K.G 15.6 1.5           15 CW3-0.42 1800 1370 150 1.31 0.446 0.222 N.G N.G 8.1 0.5           15 CW3-0.42 1800 1370 150 1.31 0.446 0.222 N.G N.G 8.1 0.5           17 CW3-3.42 1800 1370 150 1.31 0.446 0.222 N.G N.G 8.1 0.5           17 CW3-3.42 1800 1370 150 1.31 0.446 0.222 N.G N.G 8.1 0.5           17 CW3-3.42 1800 1370 150 1.31 0.446 0.222 N.G N.G 8.1 0.5 <th< td=""><td></td><td></td><td>( )</td><td>. ,</td><td>. ,</td><td>. ,</td><td>%</td><td>%</td><td>(<i>mm</i>)</td><td>(<i>mm</i>)</td><td></td><td>(MPa)</td></th<>			( )	. ,	. ,	. ,	%	%	( <i>mm</i> )	( <i>mm</i> )		(MPa)
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $					Matsu	mura's	experim	ental work	[3]			
2         CW4-1-2         1800         1720         150         1.36         0.463         0.071         N.G         N.G         N.G         9.5         0           4         CW3-1-1         1800         920         150         1.36         0.463         0.071         N.G         N.G         N.G         156         0           5         CW2-1-1         1800         920         150         1.96         0.47         0.071         N.G         N.G         N.G         15.6         0           6         CW2-1-2         1800         1320         150         1.36         0.463         0         N.G         N.G         N.G         9.5         0           7         CW3-1'         1800         1320         150         1.36         0.463         0.148         N.G         N.G         9.5         0           10         CW3-2         1800         1320         150         1.36         0.463         0.071         N.G         N.G         1.56         0.5         0           11         CW3-1-A2         1800         1320         150         1.36         0.463         0.071         N.G         N.G         1.5.6         1.5.6	1	CW4-1-1	1800	1720	150	1.05	0.3825	0.071	N.G	N.G	9.5	0
3         CW3-1-1         1800         1320         150         1.36         0.463         0.071         N.G         N.G         N.G         1.56         0           5         CW2-1-1         1800         920         150         1.96         0.664         0.071         N.G         N.G         N.G         9.5         0           6         CW2-1-2         1800         1320         150         1.36         0.463         0         N.G         N.G         9.5         0           6         CW2-1-2         1800         1320         150         1.36         0.463         0         N.G         N.G         9.5         0           9         CW3-1-1         1800         1320         150         1.36         0.463         0.071         N.G         N.G         9.5         0           10         CW3-1-A2         1800         1320         150         1.36         0.463         0.071         N.G         N.G         1.56         1.5           12         CW3-1-A2         1800         1320         150         1.36         0.463         0.071         N.G         N.G         N.G         N.G         N.G         N.G         N.G	2	CW4-1-2	1800	1720	150	1.05	0.4525	0.071	N.G	N.G	15.6	0
4         CW3-1-2         1800         1320         150         1.46         0.464         0.071         N.G         N.G         9.5         0           6         CW2-1-2         1800         920         150         1.96         0.464         0.071         N.G         N.G         9.5         0           7         CW3-0-1         1800         1320         150         1.36         0.463         0         N.G         N.G         9.5         0           9         CW3-1         1800         1320         150         1.36         0.463         0.071         N.G         N.G         9.5         0           10         CW3-2         1800         1320         150         1.36         0.463         0.071         N.G         N.G         9.5         0           12         CW3-1-A3         1800         1320         150         1.36         0.463         0.071         N.G         N.G         N.5         0.5         0.5           12         CW3-1-A3         1800         1320         150         1.31         0.463         0.071         N.G         N.G         N.6         N.6         N.6         N.6         N.6         N.6	3	CW3-1-1	1800	1320	150	1.36	0.463	0.071	N.G	N.G	9.5	0
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	4	CW3-1-2	1800	1320	150	1.36	0.429	0.071	N.G	N.G	15.6	0
6         CW2-1-2         1800         920         150         1.76         0.471         N.G         N.G         15.6         0           8         CW3-0-2         1800         1320         150         1.36         0.463         0         N.G         N.G         9.5         0           9         CW3-1         1800         1320         150         1.36         0.463         0.071         N.G         N.G         9.5         0           10         CW3-2         1800         1320         150         1.36         0.463         0.071         N.G         N.G         9.5         0           11         CW3-1-A3         1800         1320         150         1.36         0.463         0.071         N.G         N.G         N.56         0.5           12         CW3-1-A3         1800         1370         150         1.31         0.446         0         N.G         N.G         N.56         0.5         1.56         1.5         1.5         1.5         1.5         1.5         1.5         1.5         1.5         1.5         1.5         1.5         1.5         1.5         1.5         1.5         1.5         1.5         1.5 <t< td=""><td>5</td><td>CW2-1-1</td><td>1800</td><td>920</td><td>150</td><td>1.96</td><td>0.664</td><td>0.071</td><td>N.G</td><td>N.G</td><td>9.5</td><td>0</td></t<>	5	CW2-1-1	1800	920	150	1.96	0.664	0.071	N.G	N.G	9.5	0
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	6	CW2-1-2	1800	920	150	1.96	0.47	0.071	N.G	N.G	15.6	0
8         CW3-0-2         1800         1320         150         1.36         0.463         0         N.G         N.G         9.5         0           10         CW3-2         1800         1320         150         1.36         0.463         0.148         N.G         N.G         9.5         0           11         CW3-1A2         1800         1320         150         1.36         0.463         0.071         N.G         N.G         9.5         0           12         CW3-1A3         1800         1320         150         1.36         0.463         0.071         N.G         N.G         15.6         1.5           13         CW3-1A3         1800         1320         150         1.36         0.463         0.0071         N.G         N.G         8.1         0.5           14         CW3-1A4         1800         1370         150         1.31         0.446         0.222         N.G         N.G         8.1         0.5           15         CW3-A2         1800         1370         150         1.31         0.446         0.335         N.G         N.G         8.1         0.5           16         CW3-A3         1800         13	7	CW3-0-1	1800	1320	150	1.36	0.463	0	N.G	N.G	9.5	0
9         CW3-1         1800         1320         130         1,36         0.403         0.0/1         N.G         N.G         9.5         0           110         CW3-2         1800         1320         150         1.36         0.463         0.222         N.G         N.G         9.5         0           12         CW3-1-A2         1800         1320         150         1.36         0.463         0.071         N.G         N.G         15.6         1           14         CW3-1-A4         1800         1320         150         1.36         0.463         0.071         N.G         N.G         15.6         1.5           15         CW3-A2         1800         1370         150         1.31         0.446         0.148         N.G         N.G         8.1         0.5           16         CW3-A2         1800         1370         150         1.31         0.446         0.222         N.G         N.G         8.1         0.5           17         CW3-A2         1800         1370         150         1.31         0.446         0.222         N.G         N.G         1.5         0.5         1.3         0.20         N.G         N.G <td< td=""><td>8</td><td><i>CW3-0-2</i></td><td>1800</td><td>1320</td><td>150</td><td>1.36</td><td>0.463</td><td>0</td><td>N.G</td><td>N.G</td><td>9.5</td><td>0</td></td<>	8	<i>CW3-0-2</i>	1800	1320	150	1.36	0.463	0	N.G	N.G	9.5	0
10         CW3-2         1800         1320         150         1,36         0.463         0.748         N.G         N.G         9.5         0           11         CW3-1         1800         1320         150         1,36         0.463         0.071         N.G         N.G         15.6         1.5           12         CW3-1-A3         1800         1320         150         1,36         0.463         0.071         N.G         N.G         15.6         1.5           14         CW3-1-A4         1800         1370         150         1.31         0.446         0         N.G         N.G         8.1         0.5           15         CW3-A2         1800         1370         150         1.31         0.446         0.222         N.G         N.G         8.1         0.5           16         CW3-A2         1800         1370         150         1.31         0.446         0.232         N.G         N.G         8.1         0.5           18         CW3-A3         1800         1320         150         1.36         0.463         0         N.G         N.G         1.6         1.1           19         CW3-2-A3         1800         1	9	CW3-1'	1800	1320	150	1.36	0.463	0.0/1	N.G	N.G	9.5	0
11       CW3-1       1800       130       130       130       130       130       0.033       0.071       N.G       N.G       N.G       15.6       1.5         13       CW3-1-A2       1800       1320       150       1.36       0.463       0.071       N.G       N.G       N.G       15.6       1.5         14       CW3-1-A4       1800       1320       150       1.31       0.446       0       N.G       N.G       N.G       N.G       8.1       0.5         15       CW3-A2       1800       1370       150       1.31       0.446       0.222       N.G       N.G       8.1       0.5         16       CW3-A2       1800       1370       150       1.31       0.446       0.222       N.G       N.G       8.1       0.5         18       CW3-A2       1800       1370       150       1.31       0.446       0.222       N.G       N.G       N.G       8.1       0.5         19       CW3-A3       1800       1320       150       1.36       0.463       0       N.G       N.G       N.G       N.G       N.G       1.6       1.6         21       CW3-A3 <t< td=""><td>10</td><td><i>CW3-2</i></td><td>1800</td><td>1320</td><td>150</td><td>1.36</td><td>0.463</td><td>0. 148</td><td>N.G</td><td>N.G</td><td>9.5</td><td>0</td></t<>	10	<i>CW3-2</i>	1800	1320	150	1.36	0.463	0. 148	N.G	N.G	9.5	0
12       CW3-1-A2       1800       1320       150       1.36       0.403       0.0071       N.G       N.G       15.6       0.1         14       CW3-1-A1       1800       1320       150       1.36       0.463       0.0071       N.G       N.G       15.6       1.5         15       CW3-4-2       1800       1370       150       1.31       0.446       0       N.G       N.G       8.1       0.5         16       CW3-4-2       1800       1370       150       1.31       0.446       0.222       N.G       N.G       8.1       0.5         17       CW3-4-2       1800       1370       150       1.31       0.446       0.335       N.G       N.G       8.1       0.5         19       CW3-1-A2       1800       1320       150       1.36       0.463       0       N.G       N.G       8.1       0.5         20       CW3-0-A3       1800       1320       150       1.36       0.463       0       N.G       N.G       1.6       1         21       CW3-2-A21       1800       1320       150       1.36       0.463       0.222       N.G       N.G       1.6       1	11	<i>CW3-3</i>	1800	1320	150	1.36	0.463	0. 222	N.G	N.G	9.5	0
13       CW3-1-A3       1800       130       130       130       130       130       130       130       130       130       130       131       0.446       0       N.G       N.G       N.G       13.6       1.5.6       1.5         15       CW3-2-A2       1800       1370       150       1.31       0.446       0       N.G       N.G       8.1       0.5         16       CW3-2-A2       1800       1370       150       1.31       0.446       0.222       N.G       N.G       8.1       0.5         17       CW3-A2       1800       1370       150       1.31       0.446       0.335       N.G       N.G       8.1       0.5         19       CW3-1/A2       1800       1320       150       1.36       0.463       0       N.G       N.G       8.1       0.5         20       CW3-0-A3       1800       1320       150       1.36       0.463       0.148       N.G       N.G       15.6       1         21       CW3-2-A3       1800       1320       150       1.36       0.463       0.148       N.G       N.G       8.8       0.5         25       CW5-2'A2-1	12	CW3-1-A2	1800	1320	150	1.36	0.463	0.0/1	N.G	N.G	15.6	0.5
14       CW3-1-A4       1800       1320       130       1.30       0.463       0.011       N.G       N.G       13.0       1.50       1.3         15       CW3-2-A2       1800       1370       150       1.31       0.446       0.148       N.G       N.G       8.1       0.5         16       CW3-2-A2       1800       1370       150       1.31       0.446       0.222       N.G       N.G       8.1       0.5         17       CW3-A-A2       1800       1370       150       1.31       0.446       0.322       N.G       N.G       8.1       0.5         18       CW3-A-A2       1800       1370       150       1.36       0.463       0       N.G       N.G       8.1       0.5         20       CW3-A3       1800       1320       150       1.36       0.463       0.148       N.G       N.G       15.6       1         22       CW3-2-A21       1800       170       150       1.91       0.357       0.148       N.G       N.G       8.8       0.5         25       CW2-2-A2-1       1800       170       150       1.91       0.357       0.148       N.G       N.G	13	<i>CW3-1-A3</i>	1800	1320	150	1.30	0.463	0.0071	N.G	N.G	15.6	1
15       CW3-0-A2       1800       1370       150       1.31       0.446       0       N.G	14	CW3-1-A4	1800	1320	150	1.30	0.403	0.071	N.G	N.G	15.0	1.5
16       CW3-2-A2       1800       1370       130       1.31       0.446       0.148       N.G       N.G       8.1       0.5         17       CW3-3-A2       1800       1370       150       1.31       0.446       0.232       N.G       N.G       8.1       0.5         18       CW3-4-A2       1800       1370       150       1.31       0.446       0.335       N.G       N.G       8.1       0.5         20       CW3-0-A3       1800       1320       150       1.36       0.463       0       N.G       N.G       N.G       8.1       1.56       1         21       CW3-0-A3       1800       1320       150       1.36       0.463       0       N.G       N.G       N.G       8.1       1         22       CW3-2-A3       1800       1320       150       1.36       0.463       0.222       N.G	15	CW3-0-A2	1800	1370	150	1.31	0.446	0 1 4 9	N.G	N.G	8.1	0.5
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	10	CW3-2-A2	1800	1370	150	1.31	0.440	0.148	N.G	N.G	8.1	0.5
18         CW3-4-A2         1800         1370         1.31         0.249         0.071         N.G         N.G         N.G         8.1         0.5           20         CW3-0-A3         1800         1320         150         1.36         0.463         0         N.G         N.G         8.1         0.5           21         CW3-0-A3         1800         1320         150         1.36         0.463         0         N.G         N.G         8.1         1           22         CW3-2-A3         1800         1320         150         1.36         0.463         0.148         N.G         N.G         15.6         1           23         CW3-2-A2         1800         1970         150         0.91         0.357         0.148         N.G         N.G         8.8         0.5           25         CW4-2'A2         1800         1970         150         1.91         0.357         0.148         N.G         N.G         8.8         0.5           26         CW4-2'A2         1800         1370         150         1.31         0.315         0.148         N.G         N.G         8.8         0.5           27         CW3-2'A2-1         1800	1/	CW3-3-A2	1800	1370	150	1.31	0.440	0.222	N.G	N.G	8.1	0.5
19         CWB5-1-A2         1800         1320         1.31         0.209         0.071         N.G         N.G         8.1         0.5           20         CW3-0-A3         1800         1320         150         1.36         0.463         0         N.G         N.G         8.1         1           21         CW3-0-A3         1800         1320         150         1.36         0.463         0         N.G         N.G         8.1         1           22         CW3-2-A3         1800         1320         150         1.36         0.463         0.222         N.G         N.G         15.6         1           23         CW3-2-A2-1         1800         1970         150         1.91         0.357         0.148         N.G         N.G         8.8         0.5           25         CW3-2'A2-1         1800         1770         150         1.02         0.322         0.148         N.G         N.G         8.8         0.5           26         CW2-2'A2-1         1800         1770         150         1.36         0.315         0.148         N.G         N.G         8.8         0.5           27         CW3-2'A2-1         1800         1770 </td <td>18</td> <td>CW3-4-A2</td> <td>1800</td> <td>1370</td> <td>150</td> <td>1.31</td> <td>0.440</td> <td>0.335</td> <td>N.G</td> <td>N.G</td> <td>8.1</td> <td>0.5</td>	18	CW3-4-A2	1800	1370	150	1.31	0.440	0.335	N.G	N.G	8.1	0.5
20         CW3-0-A3         1800         1320         150         1.36         0.463         0         N.G         N.G         1.5.6         1           21         CW3-2-A3         1800         1320         150         1.36         0.463         0         N.G         N.G         8.1         1           22         CW3-2-A3         1800         1320         150         1.36         0.463         0.222         N.G         N.G         15.6         1           24         CW5-2'A2-1         1800         1970         150         1.91         0.357         0.148         N.G         N.G         8.8         0.5           25         CW5-2'A2-2         1800         1970         150         1.91         0.357         0.148         N.G         N.G         8.8         0.5           26         CW2-2'A2         1800         1970         150         1.31         0.316         0.148         N.G         N.G         8.8         0.5           28         CW2-2'A2-1         1800         970         150         1.36         0.315         0.148         N.G         N.G         8.8         0.5           20         CW2-2'A2-2         1800 <td>19</td> <td>CWB3-T-A2</td> <td>1800</td> <td>1370</td> <td>150</td> <td>1.31</td> <td>0.209</td> <td>0.071</td> <td>N.G</td> <td>N.G</td> <td>8.1</td> <td>0.5</td>	19	CWB3-T-A2	1800	1370	150	1.31	0.209	0.071	N.G	N.G	8.1	0.5
21       CW3-0-A3       1800       1320       150       1.36       0.463       0       N.G       N.G       8.1       1         22       CW3-3-A3       1800       1320       150       1.36       0.463       0.222       N.G       N.G       15.6       1         24       CW5-2'A2-1       1800       1970       150       0.91       0.357       0.148       N.G       N.G       8.8       0.5         25       CW5-2'A2-1       1800       1970       150       1.91       0.357       0.148       N.G       N.G       8.8       0.5         26       CW2-2'A2       1800       1770       150       1.31       0.316       0.148       N.G       N.G       8.8       0.5         27       CW3-2'A2       1800       970       150       1.86       0.315       0.148       N.G       N.G       8.8       0.5         29       CW2-2'A2-1       1800       995       150       1.86       0.315       0.148       N.G       N.G       8.8       0.5         30       CNS3-0-1       190       520       150       1.13       1.018       0       N.G       N.G       9.6 <t< td=""><td>20</td><td>CW3-0-A3</td><td>1800</td><td>1320</td><td>150</td><td>1.30</td><td>0.403</td><td>0</td><td>N.G</td><td>N.G</td><td>15.0</td><td>1</td></t<>	20	CW3-0-A3	1800	1320	150	1.30	0.403	0	N.G	N.G	15.0	1
22         CW3-2-A3         1800         1320         150         1.36         0.463         0.148         N.G         N.G         15.6         1           23         CW3-3-A3         1800         1320         150         1.36         0.463         0.222         N.G         N.G         15.6         1           24         CW3-2'A2-1         1800         1970         150         0.91         0.357         0.148         N.G         N.G         8.8         0.5           25         CW3-2'A2-1         1800         1770         150         1.02         0.322         0.148         N.G         N.G         8.8         0.5           26         CW2-2'A2-1         1800         970         150         1.31         0.316         0.148         N.G         N.G         8.8         0.5           28         CW2-2'A2-1         1800         970         150         1.86         0.315         0.148         N.G         N.G         8.8         0.5           29         CW2-2'A2-2         1800         995         150         1.86         0.315         0.148         N.G         N.G         N.G         N.G         0.50         0         33         CN	21	CW3-0'-A3	1800	1320	150	1.30	0.463	0	N.G	N.G	8.1	1
25         CW3-3-A3         1800         150         1.30         0.403         0.222         N.G         N.G         15.6         1           24         CW5-2'-A2-1         1800         1970         150         0.91         0.337         0.148         N.G         N.G         8.8         0.5           25         CW5-2'-A2-2         1800         1970         150         1.91         0.337         0.148         N.G         N.G         8.8         0.5           26         CW4-2'-A2         1800         1770         150         1.31         0.316         0.148         N.G         N.G         8.8         0.5           27         CW3-2'-A2         1800         995         150         1.86         0.315         0.148         N.G         N.G         8.8         0.5           28         CW2-2'-A2-2         1800         995         150         1.86         0.315         0.148         N.G         N.G         8.8         0.5           30         CNS3-0-1         1900         520         150         1.13         1.018         0         N.G         N.G         9.5         0           31         CNS6-0-1         1190         52	22	<i>CW3-2-A3</i>	1800	1320	150	1.30	0.463	0.148	N.G	N.G	15.0	1
24         CW5-2-A2-1         1800         1970         150         0.91         0.337         0.148         N.G         N.G         8.8         0.5           25         CW5-2'-A2-2         1800         1970         150         1.01         0.337         0.148         N.G         N.G         8.8         0.5           26         CW4-2'-A2         1800         1370         150         1.02         0.322         0.148         N.G         N.G         8.8         0.5           27         CW3-2'-A2         1800         970         150         1.86         0.315         0.148         N.G         N.G         8.8         0.5           28         CW2-2'-A2-1         1800         970         150         1.86         0.315         0.148         N.G         N.G         8.8         0.5           30         CNS3-0-1         190         520         150         1.13         1.018         0         N.G         N.G         9.5         0           31         CNS6-01         1190         520         150         2.29         1.018         0         N.G         N.G         9.6         0           32         CNS6-1-1         1190	23	CW3-3-A3	1800	1320	150	1.30	0.463	0.222	N.G	N.G	15.0	1
25         CW5-2*A2-2         1800         1970         150         1.91         0.357         0.148         N.G         N.G         8.8         0.5           26         CW4-2*A2         1800         1770         150         1.02         0.332         0.148         N.G         N.G         8.8         0.5           27         CW3-2*A2         1800         1370         150         1.31         0.316         0.148         N.G         N.G         8.8         0.5           28         CW2-2*A2-1         1800         970         150         1.86         0.315         0.148         N.G         N.G         8.8         0.5           29         CW2-2*A2-2         1800         995         150         1.86         0.315         0.148         N.G         N.G         8.8         0.5           30         CNS3-0-1         590         520         150         1.29         1.018         0         N.G         N.G         9.5         0           31         CNS6-0-1         1190         520         150         2.29         1.018         0.71         N.G         N.G         9.5         0           32         CNS6-1-2         1190	24	CW5-2'-A2-1	1800	1970	150	0.91	0.357	0.148	N.G	N.G	8.8	0.5
26         CW4-2'-A2         1800         1770         150         1.02         0.322         0.148         N.G         N.G         8.8         0.5           27         CW3-2'-A2         1800         1370         150         1.31         0.316         0.148         N.G         N.G         8.8         0.5           28         CW2-2'-A2-1         1800         970         150         1.86         0.315         0.148         N.G         N.G         8.8         0.5           29         CW2-2'-A2-1         1800         970         150         1.86         0.315         0.148         N.G         N.G         8.8         0.5           30         CNS3-0-1         590         520         150         1.13         1.018         0         N.G         N.G         9.5         0           31         CNS6-0-1         1190         520         150         2.29         1.018         0         N.G         N.G         9.5         0           33         CNS6-1-2         1190         520         150         2.29         1.018         0.071         N.G         N.G         9.5         0           35         CNS9-1-1         1790	25	CW5-2'-A2-2	1800	1970	150	1.91	0.357	0.148	N.G	N.G	8.8	0.5
27         CW3-2'-A2         1800         1370         150         1.31         0.316         0.148         N.G         N.G         8.8         0.5           28         CW2-2'-A2-1         1800         970         150         1.86         0.315         0.148         N.G         N.G         8.8         0.5           29         CW2-2'-A2-2         1800         995         150         1.86         0.315         0.148         N.G         N.G         8.8         0.5           30         CNS3-0-1         590         520         150         1.13         1.018         0         N.G         N.G         9.6         0           31         CNS6-0-1         1190         520         150         2.29         1.018         0         N.G         N.G         9.6         0           33         CNS6-0-2         1190         520         150         2.29         1.018         0.071         N.G         N.G         9.6         0           34         CNS6-1-1         1190         520         150         3.44         1.018         0.071         N.G         N.G         9.5         0           35         CNS9-1-1         1790         <	20	CW4-2'-A2	1800	1//0	150	1.02	0.322	0.148	N.G	N.G	8.8	0.5
28         CW2-2-A2-1         1800         970         130         1.86         0.315         0.148         N.G         N.G         8.8         0.5           29         CW2-2'-A2-2         1800         995         150         1.86         0.315         0.148         N.G         N.G         8.8         0.5           30         CNS3-0-1         590         520         150         1.13         1.018         0         N.G         N.G         9.5         0           31         CNS3-0-1         1190         520         150         2.29         1.018         0         N.G         N.G         9.5         0           32         CNS6-0-1         1190         520         150         2.29         1.018         0         N.G         N.G         9.5         0           33         CNS6-1-1         1190         520         150         2.29         1.018         0.071         N.G         N.G         9.5         0           35         CNS6-1-2         1190         520         150         3.44         1.018         0.071         N.G         N.G         9.5         0           36         CNS9-0-1         1790         520 <td>2/</td> <td>CW3-2'-A2</td> <td>1800</td> <td>13/0</td> <td>150</td> <td>1.31</td> <td>0.310</td> <td>0.148</td> <td>N.G</td> <td>N.G</td> <td>8.8</td> <td>0.5</td>	2/	CW3-2'-A2	1800	13/0	150	1.31	0.310	0.148	N.G	N.G	8.8	0.5
29         CW2-2-A2-2         1800         995         130         1.36         0.143         N.G         N.G         8.8         0.3           30         CNS3-0-1         590         520         150         1.13         1.018         0         N.G         N.G         9.5         0           31         CNS3-0-2         590         520         150         1.13         1.018         0         N.G         N.G         9.5         0           32         CNS6-0-1         1190         520         150         2.29         1.018         0         N.G         N.G         9.6         0           33         CNS6-0-2         1190         520         150         2.29         1.018         0         N.G         N.G         9.6         0           34         CNS6-1-1         1190         520         150         2.29         1.018         0.071         N.G         N.G         9.5         0           35         CNS9-0-1         1790         520         150         3.44         1.018         0.071         N.G         N.G         9.5         0           36         CNS9-1-2         1790         520         150         <	28	$CW2-2^{-}A2-1$	1800	970	150	1.80	0.315	0.148	N.G	N.G	8.8	0.5
30       CN35-0-1       S90       S20       IS0       I.13       I.018       0       N.G       N.G       9.5       0         31       CNS3-0-2       590.       520       I50       1.13       I.018       0       N.G       N.G       9.6       0         32       CNS6-0-1       I190       520       I50       2.29       I.018       0       N.G       N.G       9.5       0         33       CNS6-0-2       I190       520       I50       2.29       I.018       0.071       N.G       N.G       9.5       0         34       CNS6-1-2       I190       520       I50       2.29       I.018       0.071       N.G       N.G       9.5       0         35       CNS9-1-1       I790       520       I50       3.44       1.018       0       N.G       N.G       9.5       0         37       CNS9-0-2       1790       520       I50       3.44       1.018       0.071       N.G       N.G       9.5       0         38       CNS9-1-1       1790       520       I50       3.44       1.018       0.071       N.G       N.G       9.5       0	29	$CW2-2^{-}A2-2$	1800	995 520	150	1.80	0.315	0.148	N.G	N.G	8.8 0.5	0.5
S1       CNS1-0-2       S90.       S20       IS0       I.IS       I.OI8       O       N.G       N.G       S0.       O         32       CNS6-0-1       1190       520       150       2.29       1.018       O       N.G       N.G       9.5       O         33       CNS6-0-2       1190       520       150       2.29       1.018       O       N.G       N.G       9.5       O         34       CNS6-1-1       1190       520       150       2.29       1.018       0.071       N.G       N.G       9.5       O         35       CNS6-1-2       1190       520       150       2.29       1.018       0.071       N.G       N.G       9.6       O         36       CNS9-0-1       1790       520       150       3.44       1.018       0       N.G       N.G       9.5       O         37       CNS9-0-2       1790       520       150       3.44       1.018       0.071       N.G       N.G       9.5       O         38       CNS9-1-2       1790       520       150       3.44       1.018       0.077       N.G       N.G       16.2       O	21	CNS3-0-1	500	520	150	1.15	1.010	0	N.G	N.G	9.5	0
32         CN30-0-1         1190         320         130         2.29         1.018         0         N.G         N.G         9.3         0           33         CNS6-0-2         1190         520         150         2.29         1.018         0         N.G         N.G         9.6         0           34         CNS6-1-1         1190         520         150         2.29         1.018         0.071         N.G         N.G         9.6         0           35         CNS6-1-1         1190         520         150         2.29         1.018         0.071         N.G         N.G         9.6         0           36         CNS9-0-1         1790         520         150         3.44         1.018         0         N.G         N.G         9.5         0           37         CNS9-0-2         1790         520         150         3.44         1.018         0.071         N.G         N.G         9.5         0           39         CNS9-1-2         1790         520         150         3.44         1.018         0.071         N.G         N.G         16.2         0           40         WS4         1600         1319	22	CNS5-0-2	<u> </u>	520	150	1.15	1.010	0	N.G	N.G	9.0	0
35         CNS0-0-2         1190         520         150         2.29         1.018         0         N.G         N.G         9.5         0           34         CNS6-1-1         1190         520         150         2.29         1.018         0.071         N.G         N.G         9.5         0           35         CNS6-1-2         1190         520         150         2.29         1.018         0.071         N.G         N.G         9.5         0           36         CNS9-0-1         1790         520         150         3.44         1.018         0         N.G         N.G         9.5         0           37         CNS9-0-2         1790         520         150         3.44         1.018         0         N.G         N.G         9.5         0           38         CNS9-1-1         1790         520         150         3.44         1.018         0.071         N.G         N.G         9.5         0           40         WS4         1600         1319         150         1.21         0.463         0.107         N.G         N.G         16.2         0           41         WS4-B         1600         720 <td< td=""><td>32</td><td>CNS6.0.2</td><td>1190</td><td>520</td><td>150</td><td>2.29</td><td>1.010</td><td>0</td><td>N.G</td><td>N.G</td><td>9.5</td><td>0</td></td<>	32	CNS6.0.2	1190	520	150	2.29	1.010	0	N.G	N.G	9.5	0
34         CN36-1-1         1190         320         130         2.29         1.018         0.071         N.G         N.G         9.3         0           35         CNS6-1-2         1190         520         150         2.29         1.018         0.071         N.G         N.G         9.6         0           36         CNS9-0-1         1790         520         150         3.44         1.018         0         N.G         N.G         9.6         0           37         CNS9-0-2         1790         520         150         3.44         1.018         0         N.G         N.G         9.6         0           38         CNS9-1-1         1790         520         150         3.44         1.018         0.071         N.G         N.G         9.5         0           39         CNS9-1-2         1790         520         150         3.44         1.018         0.071         N.G         N.G         9.5         0           40         WS4         1600         1319         150         1.21         0.463         0.107         N.G         N.G         16.2         0           41         WS4-B         1600         720	33	CNS6-1-1	1190	520	150	2.29	1.010	0.071	N.G	N.G	9.0	0
35       CN30-1-2       1190       320       150       2.29       1.018       0.071       N.G       N.G       9.0       9.0       0         36       CNS9-0-1       1790       520       150       3.44       1.018       0       N.G       N.G       9.5       0         37       CNS9-0-2       1790       520       150       3.44       1.018       0       N.G       N.G       9.5       0         38       CNS9-1-1       1790       520       150       3.44       1.018       0.071       N.G       N.G       9.5       0         39       CNS9-1-2       1790       520       150       3.44       1.018       0.071       N.G       N.G       9.5       0         40       WS4       1600       1319       150       1.21       0.463       0.107       N.G       N.G       16.2       0         41       WS4-B       1600       1320       150       1.21       0.463       0.107       N.G       N.G       16.2       0         43       WS2-1       1600       720       150       2.22       0.783       0.107       N.G       N.G       16.2       0	25	CNS6 1.2	1190	520	150	2.29	1.010	0.071	N.G	N.G	9.5	0
30         CNOPORT         1720         320         150         3.44         1.018         0         N.G         N.G         9.5         0           37         CNS9-0-2         1790         520         150         3.44         1.018         0         N.G         N.G         9.6         0           38         CNS9-1-1         1790         520         150         3.44         1.018         0.071         N.G         N.G         9.5         0           39         CNS9-1-2         1790         520         150         3.44         1.018         0.071         N.G         N.G         9.5         0           40         WS4         1600         1319         150         1.21         0.463         0.107         N.G         N.G         16.2         0           41         WS4-B         1600         1320         150         2.22         0.783         0         N.G         N.G         16.2         0           42         WS2-0         1600         720         150         2.22         0.783         0.107         N.G         N.G         16.2         0           44         WS2-2         1600         644         150	35	CNS0-1-2	1700	520	150	2.29	1.010	0.071	N.G	N.G	9.0	0
37       CN32-0-2       1720       320       150       3.44       1.018       0       N.G       N.G       9.0       0         38       CNS9-1-1       1790       520       150       3.44       1.018       0.071       N.G       N.G       9.5       0         39       CNS9-1-2       1790       520       150       3.44       1.018       0.071       N.G       N.G       9.5       0         40       WS4       1600       1319       150       1.21       0.463       0.107       N.G       N.G       16.2       0         41       WS4-B       1600       1320       150       1.21       0.463       0.107       N.G       N.G       16.2       0         42       WS2-0       1600       720       150       2.22       0.783       0       N.G       N.G       16.2       0         43       WS2-1       1600       644       150       2.22       0.783       0.107       N.G       N.G       16.2       0         44       WS2-2       1600       644       150       2.22       0.783       0.335       N.G       N.G       16.2       0	30	CNS0_0 2	1790	520	150	3.44	1.010	0	N.G	N.G	9.5	0
38       CN39-1-1       1790       320       130       3.44       1.018       0.071       N.G       N.G       9.5       0         39       CNS9-1-2       1790       520       150       3.44       1.018       0.071       N.G       N.G       9.5       0         40       WS4       1600       1319       150       1.21       0.463       0.107       N.G       N.G       16.2       0         41       WS4-B       1600       1320       150       1.21       0.463       0.107       N.G       N.G       16.2       0         42       WS2-0       1600       720       150       2.22       0.783       0       N.G       N.G       16.2       0         43       WS2-1       1600       720       150       2.22       0.783       0.107       N.G       N.G       16.2       0         44       WS2-2       1600       644       150       2.22       0.783       0.335       N.G       N.G       16.2       0         45       WS2-3       1600       644       150       2.22       0.783       0.335       N.G       N.G       16.2       0	20	CNS9-0-2	1790	520	150	3.44	1.010	0.071	N.G	N.G	9.0	0
39       CN39-1-2       1790       320       130       3.44       1.018       0.071       N.G       N.G       9.5       0         40       WS4       1600       1319       150       1.21       0.463       0.107       N.G       N.G       16.2       0         41       WS4-B       1600       1320       150       1.21       0.463       0.107       N.G       N.G       16.2       0         42       WS2-0       1600       720       150       2.22       0.783       0       N.G       N.G       16.2       0         43       WS2-1       1600       720       150       2.22       0.783       0.107       N.G       N.G       16.2       0         44       WS2-2       1600       644       150       2.22       0.783       0.222       N.G       N.G       16.2       0         45       WS2-3       1600       644       150       2.22       0.783       0.335       N.G       N.G       16.2       0         46       NS3-1       300       400       150       1.75       0.845       0.107       N.G       N.G       19.1       0	20	CNS9-1-1	1790	520	150	3.44	1.010	0.071	N.G	N.G	9.5	0
40       WS4       1000       1319       130       1.21       0.405       0.107       N.G       N.G       10.2       0         41       WS4-B       1600       1320       150       1.21       0.463       0.107       N.G       N.G       17.6       0         42       WS2-0       1600       720       150       2.22       0.783       0       N.G       N.G       16.2       0         43       WS2-1       1600       720       150       2.22       0.783       0.107       N.G       N.G       16.2       0         44       WS2-2       1600       644       150       2.22       0.783       0.222       N.G       N.G       16.2       0         45       WS2-3       1600       644       150       2.22       0.783       0.335       N.G       N.G       16.2       0         46       NS3-1       300       400       150       0.75       0.845       0.107       N.G       N.G       19.1       0         47       NS3-2       300       400       150       1.75       0.845       0.107       N.G       N.G       19.1       0         <	<i>39</i> <i>4</i> 0	WS4	1600	1210	150	3.44	0.462	0.071	N.G	N.G	9.5	0
41       W34-B       1000       1320       130       1.21       0.403       0.107       N.G       N.G       17.0       0         42       WS2-0       1600       720       150       2.22       0.783       0       N.G       N.G       16.2       0         43       WS2-1       1600       720       150       2.22       0.783       0.107       N.G       N.G       16.2       0         44       WS2-2       1600       644       150       2.22       0.783       0.222       N.G       N.G       16.2       0         45       WS2-3       1600       644       150       2.22       0.783       0.335       N.G       N.G       16.2       0         46       NS3-1       300       400       150       0.75       0.845       0.107       N.G       N.G       19.1       0         47       NS3-2       300       400       150       1.75       0.845       0.107       N.G       N.G       19.1       0         48       NS6-1       600       400       150       1.5       0.845       0.107       N.G       N.G       19.1       0 <t< td=""><td>40</td><td>WS4 WS4 D</td><td>1600</td><td>1319</td><td>150</td><td>1.21</td><td>0.403</td><td>0.107</td><td>N.G</td><td>N.G</td><td>10.2</td><td>0</td></t<>	40	WS4 WS4 D	1600	1319	150	1.21	0.403	0.107	N.G	N.G	10.2	0
42       W32-0       1000       720       150       2.22       0.783       0       N.G       N.G       10.2       0         43       WS2-1       1600       720       150       2.22       0.783       0.107       N.G       N.G       16.2       0         44       WS2-2       1600       644       150       2.22       0.783       0.222       N.G       N.G       16.2       0         45       WS2-3       1600       644       150       2.22       0.783       0.335       N.G       N.G       16.2       0         46       NS3-1       300       400       150       0.75       0.845       0.107       N.G       N.G       19.1       0         47       NS3-2       300       400       150       1.75       0.845       0.107       N.G       N.G       19.1       0         48       NS6-1       600       400       150       1.5       0.845       0.107       N.G       N.G       19.1       0         49       NS6-2       600       400       150       1.5       0.845       0.107       N.G       N.G       19.1       0         5	41	WS4-D WS2 0	1600	720	150	1.21	0.405	0.107	N.G	N.G	16.2	0
+3       H32-1       1600       720       150       2.22       0.765       0.107       N.G       N.G       10.2       0         44       WS2-2       1600       644       150       2.22       0.783       0.222       N.G       N.G       16.2       0         45       WS2-3       1600       644       150       2.22       0.783       0.335       N.G       N.G       16.2       0         46       NS3-1       300       400       150       0.75       0.845       0.107       N.G       N.G       16.2       0         47       NS3-2       300       400       150       1.75       0.845       0.107       N.G       N.G       19.1       0         48       NS6-1       600       400       150       1.5       0.845       0.107       N.G       N.G       19.1       0         49       NS6-2       600       400       150       1.5       0.845       0.107       N.G       N.G       19.1       0         50       NS9-1       900       400       150       2.25       0.845       0.107       N.G       N.G       19.1       0       0	42	WS2-0 WS2-1	1600	720	150	2.22	0.703	0.107	N.G	N.G	16.2	0
47       1000       044       150       2.22       0.765       0.222       N.G       N.G       10.2       0         45       WS2-3       1600       644       150       2.22       0.783       0.335       N.G       N.G       16.2       0         46       NS3-1       300       400       150       0.75       0.845       0.107       N.G       N.G       19.1       0         47       NS3-2       300       400       150       1.75       0.845       0.107       N.G       N.G       19.1       0         48       NS6-1       600       400       150       1.5       0.845       0.107       N.G       N.G       19.1       0         49       NS6-2       600       400       150       1.5       0.845       0.107       N.G       N.G       24.5       0         50       NS9-1       900       400       150       2.25       0.845       0.107       N.G       N.G       19.1       0         51       NS9-2       900       400       150       2.25       0.845       0.107       N.G       N.G       30.2       0	43 41	WS2-2	1600	644	150	2.22	0.783	0.222	N.C	N.C	16.2	0
45       1000       044       150       2.22       0.765       0.355       N.G       N.G       10.2       0         46       NS3-1       300       400       150       0.75       0.845       0.107       N.G       N.G       19.1       0         47       NS3-2       300       400       150       1.75       0.845       0.107       N.G       N.G       24.5       0         48       NS6-1       600       400       150       1.5       0.845       0.107       N.G       N.G       19.1       0         49       NS6-2       600       400       150       1.5       0.845       0.107       N.G       N.G       24.5       0         50       NS9-1       900       400       150       2.25       0.845       0.107       N.G       N.G       19.1       0         51       NS9-2       900       400       150       2.25       0.845       0.107       N.G       N.G       19.1       0	45	WS2-3	1600	644	150	2.22	0.783	0.222	N.C	N.C	16.2	0
40         N.05         N.05         N.05         N.05         N.05         19.1         0           47         NS3-2         300         400         150         1.75         0.845         0.107         N.05         N.05         19.1         0           48         NS6-1         600         400         150         1.75         0.845         0.107         N.05         N.05         24.5         0           49         NS6-2         600         400         150         1.5         0.845         0.107         N.05         N.05         19.1         0           50         NS9-1         900         400         150         2.25         0.845         0.107         N.05         N.05         24.5         0           51         NS9-2         900         400         150         2.25         0.845         0.107         N.05         N.05         19.1         0	46	NS3_1	300	400	150	0.75	0.705	0.355	N.C	N.C	10.2	0
47         N.G         N.G         24.3         0           48         NS6-1         600         400         150         1.75         0.845         0.107         N.G         N.G         24.3         0           48         NS6-1         600         400         150         1.5         0.845         0.107         N.G         N.G         19.1         0           49         NS6-2         600         400         150         1.5         0.845         0.107         N.G         N.G         24.5         0           50         NS9-1         900         400         150         2.25         0.845         0.107         N.G         N.G         19.1         0           51         NS9-2         900         400         150         2.25         0.845         0.107         N.G         N.G         19.1         0	40	NS3-2	300	400	150	1.75	0.845	0.107	N.G	N.G	24.5	0
49         NS6-2         600         400         150         1.5         0.845         0.107         N.G         N.G         19.1         0           49         NS6-2         600         400         150         1.5         0.845         0.107         N.G         N.G         24.5         0           50         NS9-1         900         400         150         2.25         0.845         0.107         N.G         N.G         19.1         0           51         NS9-2         900         400         150         2.25         0.845         0.107         N.G         N.G         30.2         0	4/	NS6-1	600	400	150	1.75	0.845	0.107	N.G	N.G	10.1	0
49         NG         24.3         0           50         NS9-1         900         400         150         2.25         0.845         0.107         N.G         N.G         24.3         0           51         NS9-2         900         400         150         2.25         0.845         0.107         N.G         N.G         19.1         0	40	NS6-2	600	400	150	1.5	0.845	0.107	N.G	N.G	24.5	0
51 NS9-2 900 400 150 2.25 0.845 0.107 N.G N.G 19.1 0	<del>4</del> 9 50	NSQ_1	000	400	150	2.5	0.845	0.107	N.G	N.G	10.1	0
	51	NS9-2	900	400	150	2.25	0.845	0.107	N.G	N.G	30.2	0

No	Wall ID	Н	L	t	r	Reinforcement		Vertical reinforce-	Horizontal reinforcem	$\dot{f_m}$	Axial
110	wall ID	<i>(mm)</i>	<i>(mm)</i>	(mm)	(H/L)	Vertical %	Horizontal %	ent spacing (mm)	ent spacing (mm)	(MPa)	(MPa)
	NIST's experimental work [2]										
1	R1-N	1423	1220	194	1.17	0	0	0	0	9	0.73
2	R2-N	1423	1220	194	1.17	0	0.0242	0	406	8.5	0.73
3	R4-N	1423	1220	194	1.17	0	0.0566	0	203	7.7	0.73
4	R5-N	1423	1220	194	1.17	0	0.0936	0	711	8.4	0.73
5	R6-N	1423	1220	194	1.17	0	0.218	0	711	8.7	0.73
6	R7-N	1423	1220	194	1.17	0	0.145	0	813	7.5	0.73
7	R8-N	1423	1220	194	1.17	0	0.218	0	711	8.6	0.73
8	R9-N	1423	1220	194	1.17	0	0.0757	0	406	7.6	0.73
9	R10-N	1423	1220	194	1.17	0	0.215	0	203	6	0.73
10	R11-N	1423	1220	194	1.17	0	0.145	0	813	7.4	0.73
UC's experimental work [4]											
1	HCBL-2	1422	1220	194	1.17	0	0	0	0	12.4	0.8
2	HCBL-5	1422	1220	194	1.24	0.17	0.08	1067	711	12.4	0.6
3	HCBL-8	1422	1220	194	1.24	0.43	0	1067	0	12.4	0.6
4	HCBL-10	1422	1220	194	1.24	0.43	0.17	1067	474	12.4	0.7
5	HCBR-2	1422	1220	194	1.17	0	0	0	0	12.4	1.5
0	HCBR-5	1422	1220	194	1.24	0.18	0.09	1067	/11	12.4	1.0
/	HCBR-9	1422	1220	194	1.24	0.45	0	1067	0	12.4	0.7
8	HCBR-11	1422	1220	194	1.24	0.45	0.18	1067	4/4	12.4	0.79
1		1.(22	20.45	Schu	ltz's exp	berimenta	al work [7-	8	711	17.1	0.5
1	R05-B05	1422	2845	195	0.5	0.2049	0.05	2042	/11	17.1	0.5
2	R0/-B05	1422	2032	195	0.7	0.2808	0.05	1829	711	17.1	0.5
3	R10-B03	1422	1422	195	1	0.4098	0.05	1219	711	17.1	0.5
4	R03-B12	1422	2843	195	0.5	0.2049	0.12	2042	711	17.1	0.5
5	RU/-D12	1422	2032	195	0.7	0.2000	0.12	1029	711	17.1	0.45
7	R10-D12 R05_I05	1422	2845	195	0.5	0.4098	0.12	2642	203	1/.1	0.5
8	R07-105	1422	2045	195	0.5	0.2049	0.056	1820	203	14.5	0.5
0	R10-105	1422	1422	195	1	0.2000	0.056	1219	203	14.5	0.46
10	R05-112	1422	2845	195	0.5	0 2049	0.11	2642	203	14.5	0.40
11	R07-112	1422	2032	195	0.7	0.2868	0.11	1829	203	14.5	0.5
12	R10-J12	1422	1422	195	1	0.4098	0.11	1219	203	14.5	0.5
	•			Ghan	em's ex	periment	al work [5	-6]			J
1	SWA	940	940	48	1	0.1185	0.1185	873	871	16	0.7
2	SWB	940	940	48	1	0.1246	0.1246	436	435	16	0.7
3	SWA2	940	940	48	1	0.1246	0.1246	436	435	16	0.7
4	SWA3	940	940	48	1	0.1246	0.1246	436	435	16	1.4
				Ma	leki's ex	periment	al work [9	]			
1	wall # 1	1800	1800	90	1	0.185	0.0335	855	855	12.5	0.75
2	wall # 2	1800	1800	90	1	0.175	0.0378	570	570	12.5	0.75
3	wall # 3	1800	1800	90	1	0.16	0.0126	1710	1710	12.5	0.75
4	wall # 4	900	1800	90	0.5	0.185	0.0252	855	855	12.5	0.75
5	wall # 5	2700	1800	90	1.5	0.185	0.0335	855	855	12.5	0.75

# Table 1: Specimen's properties (Cont'd)

		Experimental	Predicted shea	r force by MSJC	V /V	V /V	Entleand			
No	Wall ID	$V_u$	Using A <sub>nn</sub>	Using A <sub>nf</sub>	$V_u/V_{n1}$	$V_u / V_{n2}$	F dilure mode			
		(KN)	$V_{n1}$ (KN)	$V_{n2}$ (KN)			moue			
Matsumura's experimental work [3]										
1	CW4-1-1	113.61	177.43	121.57	0.64	0.93	Shear			
2	CW4-1-2	157.51	218.50	145.81	0.72	1.08	Shear			
3	CW3-1-1	90.17	128.16	87.32	0.70	1.03	Shear			
4	CW3-1-2	117.92	155.90	104.27	0.76	1.13	Shear			
5	CW2-1-1	78.73	76.95	53.11	1.02	1.48	Shear			
6	CW2-1-2	73.17	93.13	62.72	0.79	1.17	Shear			
7	CW3-0-1	58.45	99.35	60.23	0.59	0.97	Shear			
8	CW3-0-2	72.33	99.93	60.23	0.72	1.20	Shear			
9	CW3-1'	82.25	127.97	87.32	0.64	0.94	Shear			
10	CW3-2	89.19	157.12	116.72	0.57	0.76	Shear			
11	CW3-3	110.98	185.17	144.97	0.60	0.77	Shear			
12	CW3-1-A2	136.74	180.45	128.60	0.76	1.06	Shear			
13	CW3-1-A3	142.65	204.79	152.89	0.70	0.93	Shear			
14	CW3-1-A4	179.35	229.16	177.17	0.78	1.01	Shear			
15	CW3-0-A2	96.66	124.49	83.85	0.78	1.15	Shear			
16	CW3-2-A2	152.17	182.85	142.48	0.83	1.07	Shear			
17	CW3-3-A2	172.77	212.35	171.79	0.81	1.01	Shear			
18	CW3-4-A2	195.37	257.17	216.58	0.76	0.90	Shear			
- 19	CWB3-1'-A2	138.83	153.14	111.96	0.91	1.24	Shear			
20	CW3-0-A3	158.53	177.30	125.75	0.89	1.26	Shear			
21	CW3-0'-A3	87.19	141.41	104.22	0.62	0.84	Shear			
22	CW3-2-A3	167.43	234.10	182.24	0.72	0.92	Shear			
23	CW3-3-A3	184.29	262.47	210.49	0.70	0.88	Shear			
24	CW5-2'-A2-1	232.15	287.72	219.21	0.81	1.06	Shear			
25	CW5-2'-A2-2	224.77	287.44	219.21	0.78	1.03	Shear			
26	CW4-2'-A2	196.61	252.49	194.48	0.78	1.01	Shear			
27	CW3-2'-A2	146.04	187.84	144.97	0.78	1.01	Shear			
28	CW2-2'-A2-1	78.64	121.75	95.41	0.65	0.82	Shear			
29	CW2-2'-A2-2	81.45	125.84	98.57	0.65	0.83	Shear			
30	CNS3-0-1	56.18	45.07	25.40	1.25	2.21	Shear			
31	CNS3-0-2	74.91	45.30	25.53	1.65	2.93	Shear			
32	CNS6-0-1	38.25	30.09	16.90	1.27	2.26	Shear			
33	CNS6-0-2	36.70	29.93	16.95	1.23	2.17	Shear			
34	CNS6-1-1	56.98	40.71	27.58	1.40	2.07	Shear			
35	CNS6-1-2	56.18	40.76	27.62	1.38	2.03	Shear			
36	CNS9-0-1	28.87	14.90	8.36	1.94	3.45	Shear			
37	CNS9-0-2	38.25	14.95	8.41	2.56	4.55	Shear			
38	CNS9-1-1	53.87	25.48	19.04	2.11	2.83	Shear			
39	CNS9-1-2	48.40	25.42	19.04	1.90	2.54	Shear			
40	WS4	198.92	166.53	123.04	1.19	1.62	Shear			
41	WS4-B	285.35	187.42	126.69	1.52	2.25	Shear			
42	WS2-0	92.97	50.31	31.45	1.85	2.96	Shear			
43	WS2-1	145.95	72.68	53.69	2.01	2.72	Shear			
44	WS2-2	154.66	81.33	54.67	1.90	2.83	Shear			
45	WS2-3	146.92	87.71	54.67	1.68	2.69	Shear			
46	NS3-1	132.11	64.11	43.19	2.06	3.06	Shear			
47	NS3-2	141.72	70.89	47.28	2.00	3.00	Shear			
48	NS6-1	76.87	54.04	37.14	1.42	2.07	Shear			
49	NS6-2	94.88	59.40	40.43	1.60	2.35	Shear			
50	NS9-1	58.85	43.83	31.09	1.34	1.89	Shear			
51	NS9-2	78.69	51.79	35.94	1.52	2.19	Shear			

Table 2: Measured and predicted shear strength

		Experimental	Predicted	shear force	V /V	V /V	E 11					
No	Wall ID	Vexp (KN)	Using A <sub>nn</sub> V <sub>n1</sub> (KN)	Using $A_{nf}$ $V_{n2}$ (KN)	$V_u/V_{n1}$	$V_u / V_{n2}$	ratture mode					
			NIST's experiment	mental work [2]								
1	R1-N	114.10	137.34	103.15	0.83	1.11	Shear					
2	R2-N	142.34	142.92	109.60	1.00	1.30	Shear					
3	R4-N	145.23	148.98	117.30	0.97	1.24	Shear					
4	R5-N	195.50	171.71	138.56	1.14	1.41	Shear					
5	R6-N	150.79	249.24	215.47	0.61	0.70	Shear					
6	R7-N	160.14	195.46	164.14	0.82	0.98	Shear					
7	R8-N	118.77	231.68	198.17	0.51	0.60	Shear					
8	R9-N	169.03	157.00	125.57	1.08	1.35	Shear					
9	R10-N	196.39	206.58	178.77	0.95	1.10	Shear					
10	R11-N	159.69	192.72	161.65	0.83	0.99	Shear					
UC's experimental work [4]												
1	HCBL-2	116.99	170.62	134.65	0.69	0.87	Shear					
2	HCBL-5	220.63	188.47	152.49	1.17	1.45	Shear					
3	HCBL-8	168.59	156.16	120.19	1.08	1.40	Shear					
4	HCBL-10	223.30	224.69	188.69	0.99	1.18	Shear					
5	HCBR-2	118.32	191.33	186.29	0.62	0.64	Shear					
6	HCBR-5	233.09	215.58	210.53	1.08	1.11	Shear					
7	HCBR-9	218.41	147.74	142.70	1.48	1.53	Shear					
8	HCBR-11	230.86	231.41	226.37	1.00	1.02	Shear					
		S	chultz's experi	mental work [7-8	8]							
1	R05-B05	178.11	382.64	320.94	0.47	0.55	Shear					
2	R07-B05	245.01	285.19	226.55	0.86	1.08	Shear					
3	R10-B05	133.00	209.58	155.47	0.63	0.86	Shear					
4	R05-B12	239.98	409.14	347.45	0.59	0.69	Shear					
5	R07-B12	191.99	308.43	249.77	0.62	0.77	Shear					
6	R10-B12	154.00	236.07	181.98	0.65	0.85	Shear					
7	R05-J05	261.33	360.76	303.99	0.72	0.86	Shear					
8	R07-J05	253.50	268.67	214.72	0.94	1.18	Shear					
9	R10-J05	175.88	198.62	148.84	0.89	1.18	Shear					
10	R05-J12	243.36	381.52	324.76	0.64	0.75	Shear					
11	R07-J12	270.36	289.84	235.89	0.93	1.15	Shear					
12	R10-J12	211.34	220.01	170.23	0.96	1.24	Shear					
		G	hanem's experi	imental work [5-	6]							
1	SWA	24.47	31.58	27.36	0.77	0.89	Shear					
2	SWB	30.25	33.51	27.36	0.90	1.11	Shear					
3	SWA2	25.80	33.51	27.36	0.77	0.94	Shear					
4	SWA3	34.25	33.51	27.36	1.02	1.25	Shear					
	Maleki's experimental work [9]											
1	wall # 1	94.04	128.00	125.00	0.73	0.75	Shear					
2	wall # 2	98.44	133.67	129.04	0.74	0.76	Shear					
3	wall # 3	90.57	115.21	113.87	0.79	0.80	Shear					
4	wall # 4	118.55	155.14	150.97	0.76	0.79	Shear					
5	wall # 5	81.71	97.38	95.55	0.84	0.86	Shear					

# Table 2: Measured and predicted shear strength (cont'd)



Figure 2: the relation between  $V_u / V_n$  and  $M_u / V_u d_v$  in selected sub-groups from references (a) [3], (b) [9], and (c) [7-8]

#### Effects of axial stress

The change in the applied axial stress influenced  $V_u/V_n$  slightly as shown in Fig. 3 (a and b). The value of  $(V_u/V_n)$  ranging from 0.8 to 1.1 suggests that the applied axial stress has a minimal influence on the underestimation of the shear strength using equation 1. However, Fig. 3(c) shows that by increasing q the value of  $V_u/V_n$  decreases. The discrepancy in the results between Fig. 3(c) and Fig. 3(a and b) may be explained by the fact that some specimens (who had solid legend in Fig. 3(c)) were constructed using CMU units and the rest were constructed out of clay units. In the case of Fig. 3(a and b) all the specimens were constructed using CMU units.



Figure 3: the relation between  $V_u / V_n$  and q in selected subgroups from references (a) [3], (b) [6-7], and (c) [4]

#### Effects of horizontal reinforcement ratio.

Fig. 4 shows the effects of horizontal reinforcement ratio and the value of  $V_u/V_n$ . There is no clear trend of the different test data except for tests by Schultz et al. [7-8] where wire reinforcement was embedded in bed-joints. In Schultz's tests (Fig.4c), by increasing the horizontal reinforcement ratio  $V_u/V_n$  decreased. For the rest of the specimens, the value of  $V_u/V_n$  change randomly with increasing horizontal reinforcement ratio suggesting that equation (1) needs significant revisions. Finally, the experimental work from [2] (Fig. 4b) including two groups, namely G1 and G2. G1 were built using bond beam while G2 used a bed joint reinforcement. Group G1 showed a similar trend to Schultz's tests i.e. by increasing the horizontal reinforcement ratio  $V_u/V_n$  decreased. Such observation suggested that equation (1) over-weight the contribution of horizontal reinforcement to shear strength.



Figure 4: the relation between  $(V_u / V_n)$ , and  $(\rho_h f_y)$  in selected sub-groups from references (a) [3], (b) [2], (c) [7-8], and (d) [5-6]

#### SUMMARY AND CONCLUSION.

Evaluating the shear strength of 90 partially grouted shear wall using MSJC design provisions revealed that the code consistently over predicts the shear strength. Moreover, careful examination of the results of each group of test data suggested that the shear design provisons for partially grouted shear walls need significant revision. However, in order to achieve such revision a more experimental data is required since current available data are not well documented and missing some important information. Also, available data came from different places and different periods representing different construction practice.

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