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PARAMETRIC SIMULATING STUDY ON THE EFFECT OF COUPLING BEAMAS ON THE CARRYING SHEAR FORCE RATIO IN 12 – STORY COUPLED SHEAR WALLS

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SUMMARY

The Hybrid Wall System (HWS) building has composed of center core reinforced concrete walls and exterior steel frame. The center core wall is divided into several walls that are linked together by coupling beams and forms coupled shear walls. The coupled shear walls are the primary lateral load-resisting element in the HWS building. The coupling beams can be designed to absorb the most of the seismic energy as well as the wall foots. It is necessary to develop design methodologies for the HWS buildings that withstand against the most of lateral load with the coupled shear walls and expect the most energy dissipation at the coupling beams and wall foots.

It is very important to recognize sheer force in each walls, when the seismic performance in the coupled sheer walls would be evaluated. The seismic test on 1/3-scale 12-story T-shaped coupled shear walls was performed. Most remarkable findings from the seismic test are that the ratio of carrying shear forces in the tensile side wall and compressive side wall would be different at the lower story though those ratio on the upper parts of HWS would be kept about equal at relative small displacement level. Especially, shear force at the lower story was concentrated on the compressive side wall. The change of the ration for carrying shear force in coupled shear wall would be mainly carried by the restriction of the coupling beam with the coupled shear walls. By studying the mechanism of changing the ration for carrying shear force in each walls.

In order to investigate the seismic performance of the coupled shear walls especially carrying shear force ratio of each wall, the parametric simulating study on the coupled shear walls was done. This paper discusses the effect of the coupling beams on carrying shear force ratio between each side walls in coupled shear walls. In the case of cutting off the 2nd and 3rd floor coupling beams in the coupled shear walls, the carrying shear force ratio between each side walls are nearly even, as the result. It will be easy to do for seismic design of coupled shear walls.

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INTRODUCTION

The U.S. - Japan cooperative structural research project on composite and hybrid structures have been accomplished from 1994 to 2000. A building with center core reinforced concrete walls with combined exterior steel frame was adopted as the target building for HWS. The HWS building has generally the open space around the center core wall with architectural design request. The center core wall is divided into several walls that are linked together by coupling beams and forms coupled shear walls. The coupled shear walls behavior are the primary lateral load-resisting element in the HWS building. Flange part of each wall in the coupled shear walls can reduce seismic compressive stresses, and hence improve the overall seismic performance of the coupled shear wall. In seismic test on 1/3 scale 12-story coupled shear wall with flange walls [1], it was confirmed that the HWS building had an excellent seismic performance. Its hysteresis characteristics was stable until building drift of 1/67, at deflection angle at the 12th floor. The coupling beams and the wall foots absorbed the most of the seismic energy. Its deformation capacity was at 1/25 angle.

The coupling beams can be designed to absorb the most of the seismic energy as well as the wall foots, and the coupled shear walls are the primary lateral load resisting element in the HWS building. It is very important to evaluate the carrying shear force in the walls for the design of the HWS building. The fluctuation of shear force in the coupled shear walls are observed in the 12-story coupled shear walls test [1] (Figure 1). The mechanism of fluctuating shear force in the coupled wall was checked, comparing the axial force measured by the load transducer with the value estimated from simplified model.

The ratio of carrying shear force of first story was the largest at the maximum strength, and the ratio was about 9:1 for compressive vs. tensile sides. And, the fluctuation on carrying shear force was remarkably observed at 1st and 2nd stories but rather less at 3rd and upper stories in this test [2].

This paper discusses the effect of the coupling beams on carrying shear force ratio between each side walls in coupled shear walls.

TEST SPECIMEN

Figure 1 shows the test building consisting of two flanged wall coupled by coupling beams, and 12-stories with 1.2m story height. Total height of test building is 14.4m. This specimen was designed as no tensile force was occurred at walls when the fracture mechanism was developed, and the carrying load ratio of overturning moment was 6:4 by walls vs. by coupling beams. The model scale was 1/3.

Rebars arrangement is detailed in Figure 2. Rebars were arranged based on the consideration of flexural yield both at walls foos and at the end of coupling beams. Compressive zone was set as the area which bears compressive force due to overturning moment, with specified concrete strength. X-shaped rebar arrangement was applied to coupling beams. Wall shear reinforcement ratio Ps in the walls was 0.64%, while confinement reinforcement ratio Pw was double 1.2% at compressive zone.

The rebars arrangements are displayed in Table 1.The material properties are displayed in Table 2.

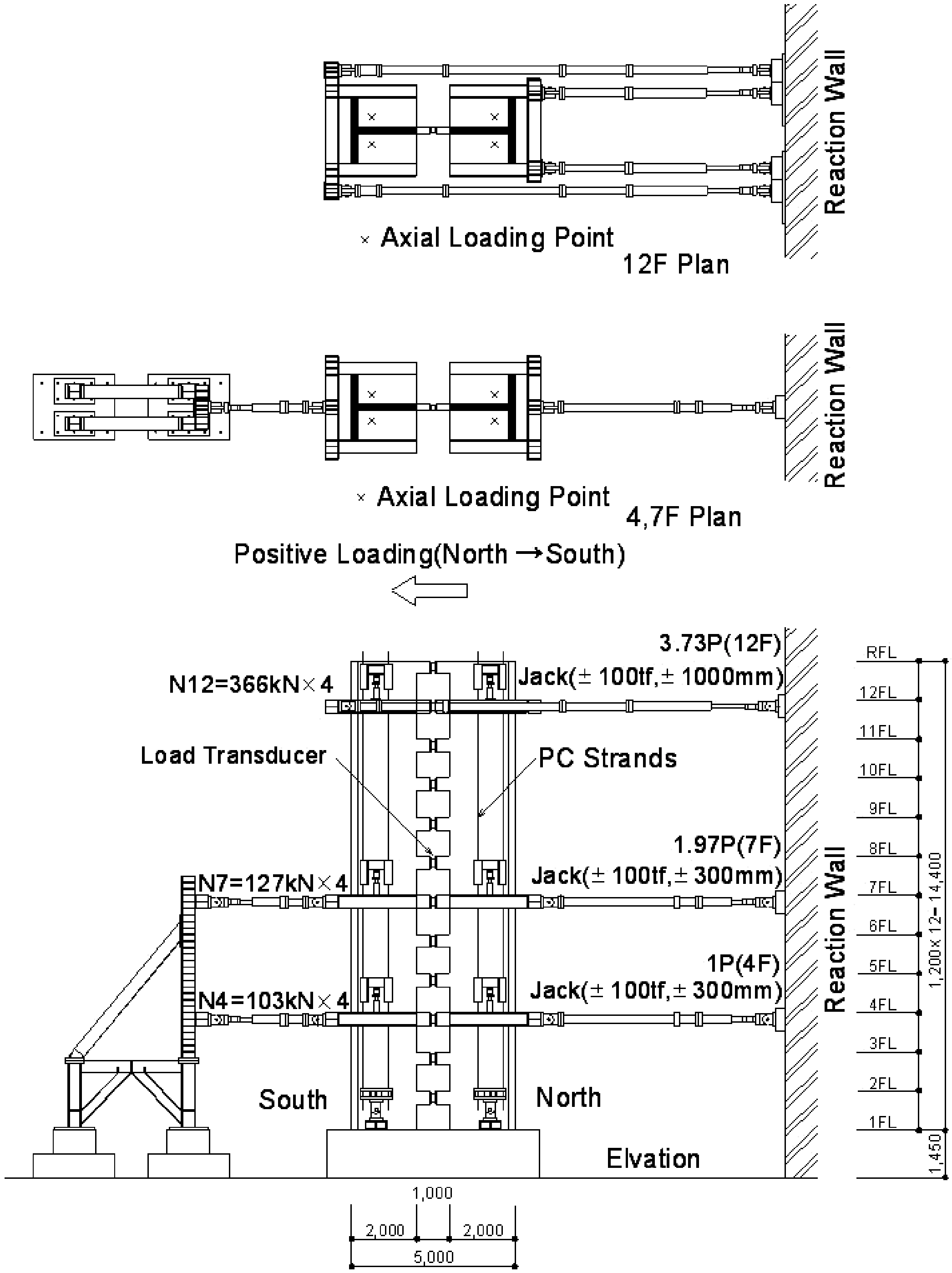

Figure 1: Test specimen and loading system

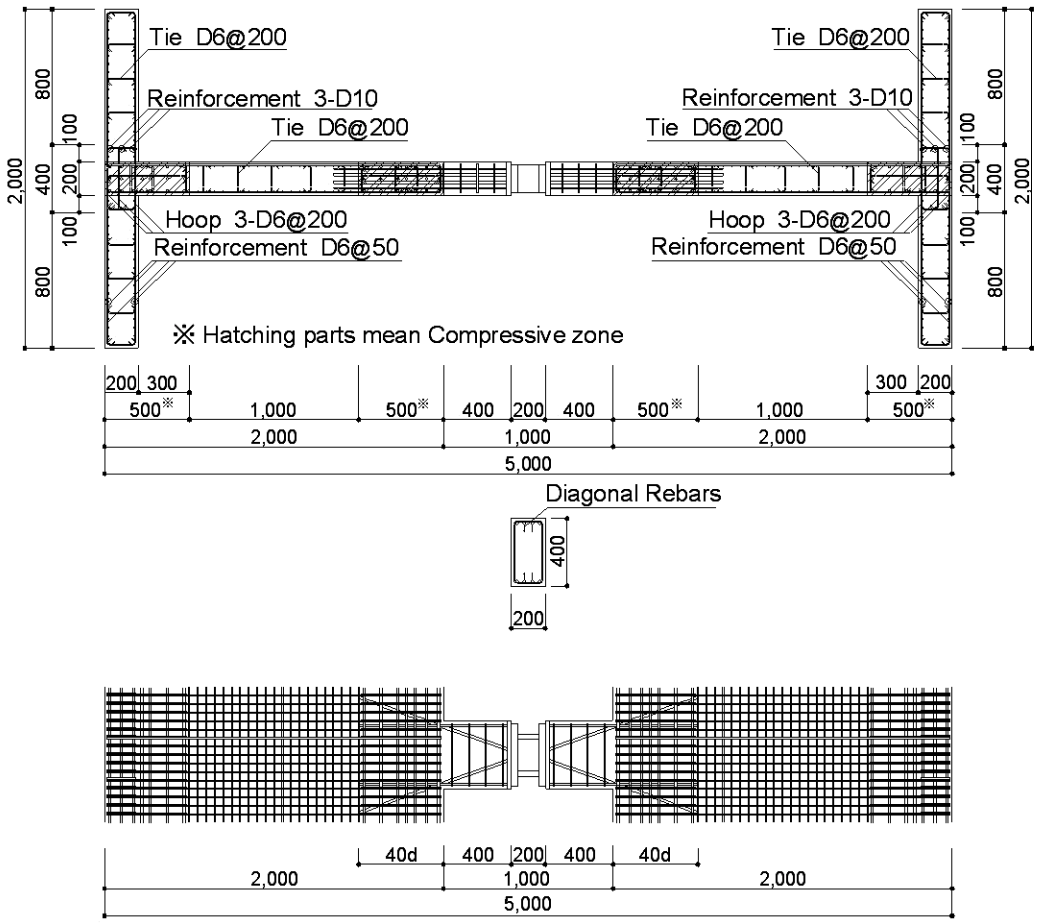

Figure 2: Rebars arrangement

Table 1: Rebars arrangement

Compressive Zone of Wall	B x D (mm)	Main Reinforcement	Hoop	Pw (%)
10-12 Story	200 x 300	14-D13	- D6@50	0.64
7-9 Story	200 x 400	17-D17	- D6@50	0.96
4-6 Story	200 x 500	20-D13	- D6@50	0.96
1-3 Story	200 x 500	20-D13	- D6@40	1.20

Wall	t (mm)	Vertical and Horizontal Reinforcement	Ps (%)	Tie
1-12 Story	200	D6@50	0.64	D6@200

Coupling Beam	B x D (mm)	Main Reinforcement Lateral / Diagonal	Stirrup	Pw (%)
8-R Floor	200 x 400	2-D10 / 2-D13	2-D6@100	0.32
2-7 Floor	200 x 400	2-D10 / 2-D16	2-D6@100	0.32

Table 2: Material properties

Rebars	Yield Strength σ_y (N/mm^2)	Break Strength (N/mm^2)	Youg's Modulus ${}_sE$ (kN/mm^2)	Elongation at Break Point (%)
D 6	355	569	19.0	22.2
D10	364	501	17.5	19.7
D13	349	484	18.1	21.7
D16	358	507	17.8	18.2

Concrete	Age of Test (days)	Compressive Strength σ_c (N/mm^2)	Youg's Modulus ${}_cE$ (kN/mm^2)	Tensile Strength (N/mm^2)
12 Story	75	28.1	1.93	3.44
10,11 Story	84	27.2	1.89	3.48
7-9 Story	98	28.6	2.00	3.05
4-6 Story	109	29.7	1.96	3.05
2,3 Story	120	41.5	2.23	4.78
1 Story	140	40.1	2.38	4.09

FLUCUATING FACTORS FOR CARRYING SHEAR FORCE IN COUPLED SHEAR WALLS

The factors affecting on the mechanisms of shear force carrying ratio in coupled shear walls are appointed as follows; 1) difference of stress distribution in tension and compression side walls, 2) slip effect of the wall, 3) wedge action of the coupling beams, and 4) residual compressive axial force in the coupling beams.
Among these factors, slip of the wall, wedge action of the coupling beams and residual compressive axial force of the coupling beams are main factors to explain this mechanisms. But difference of the wall stiffness is not a effective factor in this test [2].

The Numerical analysis were performed by using the equivalent truss structure model with brace to the specimen to recognize the influence when he coupling beams were constraint by the walls. The used model is showed as Figure 3.The displacements in the analysis were almostly similar to the experimental results at the maximum strength in the 12 story specimen. There are horizontal displacements in table3 by comparing the values for both vesurts.

Table 3: Displacements at maximum strength

Measurement floors	12F	7F	6F	5F	4F	3F	2F
Experimental results	198.4	102.1	78.6	60.0	47.0	26.5	12.3
Analitical results	202.3	108.7	89.8	69.7	49.0	30.8	13.2

unit:mm

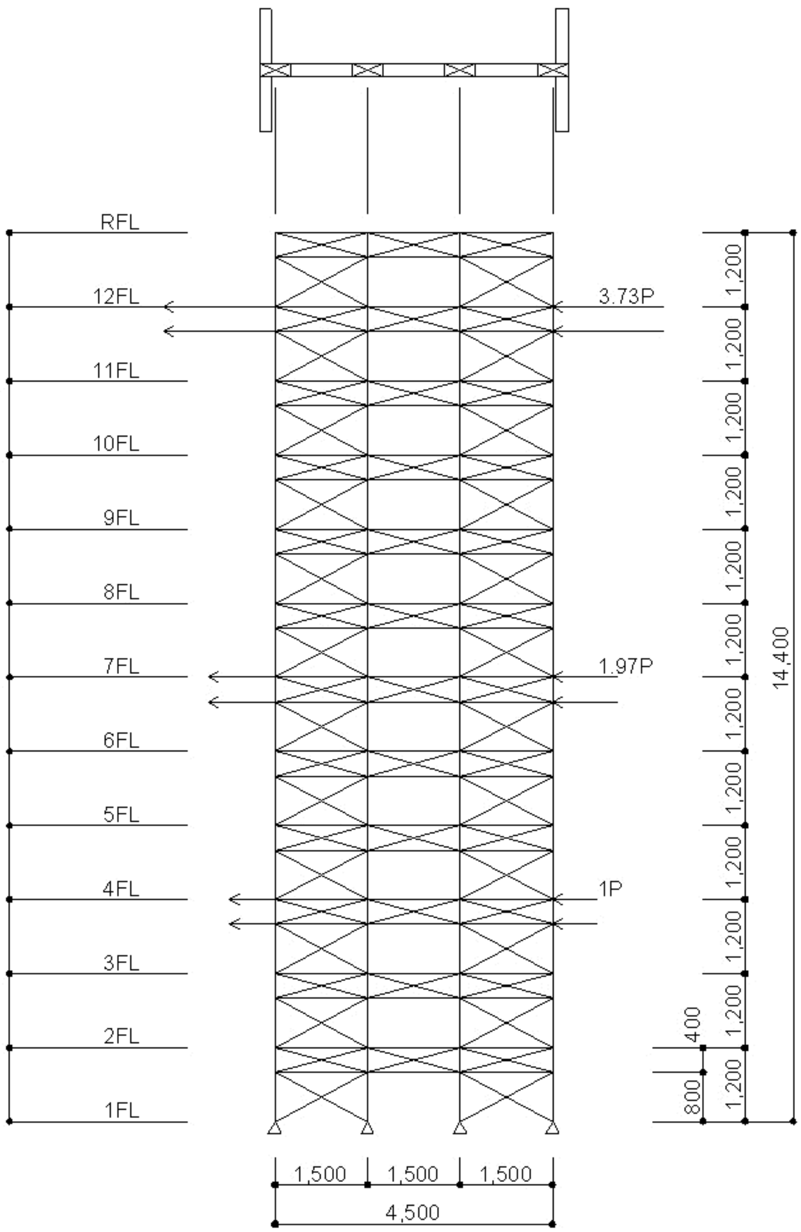

Figure 3: Analytical model

PARAMETRIC SIMULATING STUDY

The studies for the behaviors and the changes of the shear for us in each walls were performed by using the prescribed truss structure models that are showed in Figure4. In these models, the black parts shown there are not a coupling beam.

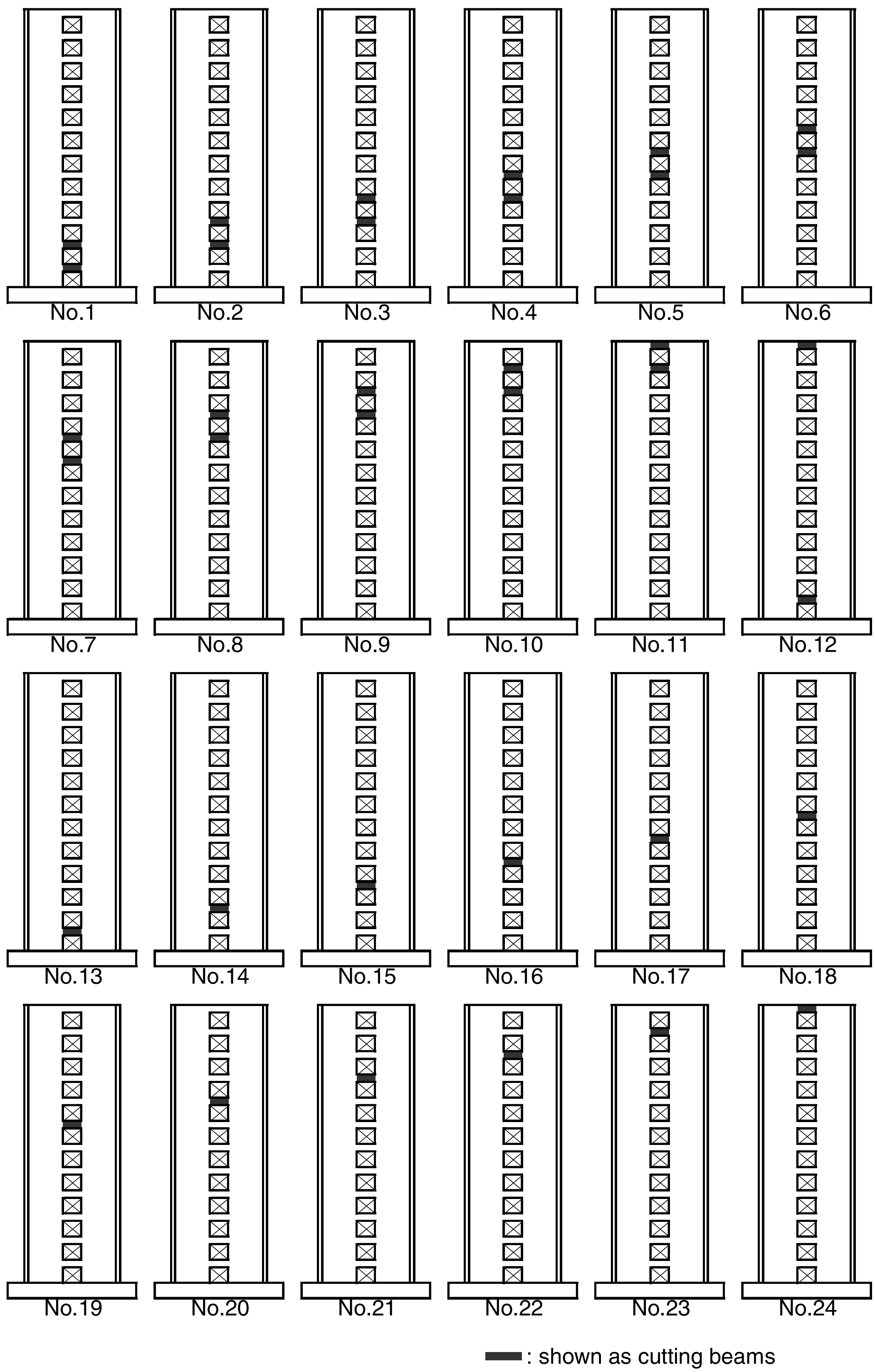

Figure 4: Number of simulating study

Table 4: Parametric simulating study results

Number of simulating study	No.1	No.2-11	No.12,13	No14-24
Ratio of carrying shear force in 1st. story compressive wall vs. tensile wall	5:5	9:1	6:4	9:1

RESULTS

There are ratios of carrying shear forces in the first story showed in Table 4.A Ratio of carrying shear forces in the structure model No.1 is nearly 5:5. A Ratio of carrying shear forces in the structure model No.12 and No.13 is nearly 6:4. A Ratio 9:1 in other cases in Table 4 is showed.

CONCLUSION

The case of cutting off the 2nd and 3rd floor coupling beams in the coupled shear walls, the carrying shear force ratio between each side walls are nearly even, as the result. It will be easy to do for seismic design of coupled shear walls. However, as capacity to absorb energy in the coupled shear walls would be less than normal one, it would be marked about it.

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