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COMPARATIVE DESIGN OF 10-STORY STEEL BUILDING USING ATC 3-06, L.A. CITY CODE AND CURRENT JAPANESE CODE

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SUMMARY

In each country, there are respective aseismatic design codes stipulating seismic force, analysis procedure and design of member sections, and it is not proper to compare different design codes by only seismic force.

The objective of comparative design is to clarify the difference of structural design method of steel buildings between the U.S. and Japan, comparing trial designs of the same buildings.

INTRODUCTION

The building is a 10-story steel office building assumed to build in Los Angeles and was designed in accordance with ATC 3-06 and Los Angeles City Code based on UBC. The same building has been redesigned based on current Japanese codes, assuming that it is located in Tokyo.

Outline of building

- Usage --------------------- Office Building
- Location ------------------ Los Angeles, USA and Tokyo, Japan
- Number of Stories -------- 10 stories
- Floor Area ---------------- 2,092 m^2
- Total Floor Area --------- 20,917 m^2
- Floor to Floor Height ---- 4.115 m for typical floor
  6.863 m for 1st floor
- Total Height ------------- 43.898 m
- Bay Size ------------------ 7.625 m x 9.144 m
- Plan Dimensions ---------- 38.125 m x 54.864 m

Figure 1 shows typical framing plan and framing elevation.

Structural concept   The seismic-resisting system of the building is ductile moment resisting frames system. The ductile moment-resisting frames of the building in U.S. are only arranged along the perimeter of the building and all the interior horizontal and vertical members are designed to support vertical load only. But all the frames of the building in Tokyo are designed not only to support vertical loads but also to resist seismic loads.

Comparison of Design

Comparative items	U.S. code ATC 3-06	Los Angeles City code	Japanese code New aseismatic design method
1. Location	Los Angeles	Los Angeles	Tokyo
2. Analysis procedure			
1) Building height	H=44.1m < 50m	H=44.1m < 50m	H=44.1m < 31m
2) Building configuration	Regular	Regular	Fes=1.0
3) Analysis procedure	Equivalent lateral force procedure	Equivalent lateral force procedure	Equivalent lateral force procedure
3. Design seismic force			
1) Ground motion	Map area=7 Aa=0.4 Av=0.4	Seismic zone=4 Z=1.0	Seismic hazard zoning coefficient Z=1.0
2) Importance factor	Seismicity index=4 Seismic hazard exposure group=II Seismic performance category=c	I=1.0	I=1.0
3) Framing system	Seismic-resisting frame. Frames at the perimeter of building are ductile moment resisting frame. All the interior frame is not ductile moment resisting frame.	Seismic-resisting frame. Frames at the perimeter of building are ductile moment resisting frame. All the interior frame is not ductile moment resisting frame.	All frame is ductile moment resisting frame.
4) Ductility factor	Response modification coefficient R=8	K=0.67	Ds=0.25

Comparative items	U.S. code ATC 3-06	Los Angeles City code	Japanese code New aseismatic design method
5) Natural period	$T=2\pi\sqrt{\frac{\sum w_i \delta_i^2}{g\sum f_i \delta_i}}$ =1.79 sec.	$T=0.25\sqrt{\frac{\Delta T}{Cs}}$ $\Delta T=0.005$ K H =0.005x0.67 x144x12 =5.788 $Cs=\frac{1}{15\sqrt{T}}1.5$ T =2.36 sec.	T=0.03H =0.03x44.1 =1.32 sec.
6) Soil effect	Soil profile; type S2 or S3 S=1.5	Soil factor S=1.5	Soil profile type2 Tc=0.6 sec. T > 2Tc $Rt=1.6\frac{Tc}{T}$ $=1.6x\frac{0.6}{1.32}$ =0.727
7) Coefficient for base shear	$Cs=\frac{1.2\ Av\ S}{R\ T^{\frac{2}{3}}}$ $=\frac{1.2x0.4x1.5}{8x(1.79)^{\frac{2}{3}}}$ =0.061	$C=\frac{1}{15\sqrt{T}}$ $=\frac{1}{15\sqrt{2.36}}$ =0.0434	Co=0.2
8) Building weight for seismic load	W=10,623t	W=10,623t	W=13,567t (+27.7%)
9) Base shear	V=Cs W =0.061x10,623 =648t	V=Z I K C S W =1.0x1.0x0.67 x0.0434x1.5 x10,623 =464t	Q=Z Rt Ai Co W =1.0x0.727x1.0 x0.2x13,567 =1,972t
10) Seismic shear distribution	Inversted triangular distribution $Fx=\frac{Wx\ hx^k}{\sum Wi\ hi^k}V$ $K=1.0+\frac{T-0.5}{2.0}$ =1.645	Concentrated at the top and inversted triangular distribution $Fx=\frac{(V-Ft)\ Wx\ hx}{\sum Wi\ hi}$ Ft=0.07 T V =0.07x2.36x464 =76t	Ai distribution $Ai=1+(\frac{1}{\sqrt{\alpha_i}}-\alpha_i)\frac{2T}{1+3T}$ 10F Ai=3.17 9F =2.26 8F =1.91 7F =1.69 6F =1.53 5F =1.40 4F =1.29 3F =1.19 2F =1.09 1F =1.0

Comparative items	U.S. code ATC 3-06	Los Angeles City code	Japanese code New aseismatic design method
4. Horizontal distribution	Transverse dir. Ext. Frame 100% (Ductile moment resisting frame) Int. Frame 0%	Transverse dir. Ext. Frame 100% (Ductile moment resisting frame) Int. Frame 0%	Transverse dir. Ductile moment resisting frame 100%
	Longitudinal dir. Ext. Frame 100% (Ductile moment resisting frame) Int. Frame 0%	Longitudinal dir. Ext. Frame 100% (Ductile moment resisting frame) Int. Frame 0%	Longitudinal dir. Ductile moment resisting frame 100%
5. Torsional effect	Calculated plus 5% accidental	Not considered	Not considered
6. Member section			
1) Girder at 5FL (Trans. dir)	H-932x309x21x35 (A=399cm)	H-840x292x15x22 (A=247cm)	H-588x300x12x20 (A=192.5cm)
2) Column at 4FL	H-926x308x19x32 (A=368cm)	H-700x356x17x28 (A=306cm)	H-550x550x25x25 (A=525cm)
7. Lateral defl. at the top of building (cm)	Trans. defl.=10.6 Longi. defl.=10.3	Trans. defl.=11.7 Longi. defl.=13.1	Trans. defl.=17.1 Longi. defl.=17.6
8. Story drift			
1) Maximum story drift	1/329 (5th)	1/324 (3rd)	1/214 (4th)
2) Story drift of 1st st.	1/540	1/530	1/258
9. Quantity of steel	1627t	1329t	2080t

CONCLUDING REMARKS

1. The current Japanese code imposes the design shear force of 2 or 3 times as large as US codes while the drift requirement by US code are severe than those by the Japanese code.
2. The difference of Building weight for seismic load is caused by the live load as a seismic load and the dead load of frames.
   Design seismic force in Japan is considerably larger than that in the U.S.
3. The member sizes required by the U.S. design are larger than those required under the Japanese design. This is caused by the difference in the number of aseismatic frames, i.e., 2 frames in the U.S. and 7 frames in Japan.
4. Fig. 2 and 3 shows the comparison of design shear force and resulted deflection between ATC3-06, L.A. city code and Japanese code design. The ratio of the base shear force of Japanese design to ATC 3-06 design is approximately 3.0 while the resulted deflection ratio is 1.6-2.3. The estimated quantity of the steel required under Japanese code is about 1.28 times as large as that under ATC3-06. The difference of the steel quantities between two codes design may be well explained by the stiffness index, that is force/deflection, which is roughly calculated in this case by 3.0/2.3 = 1.30.

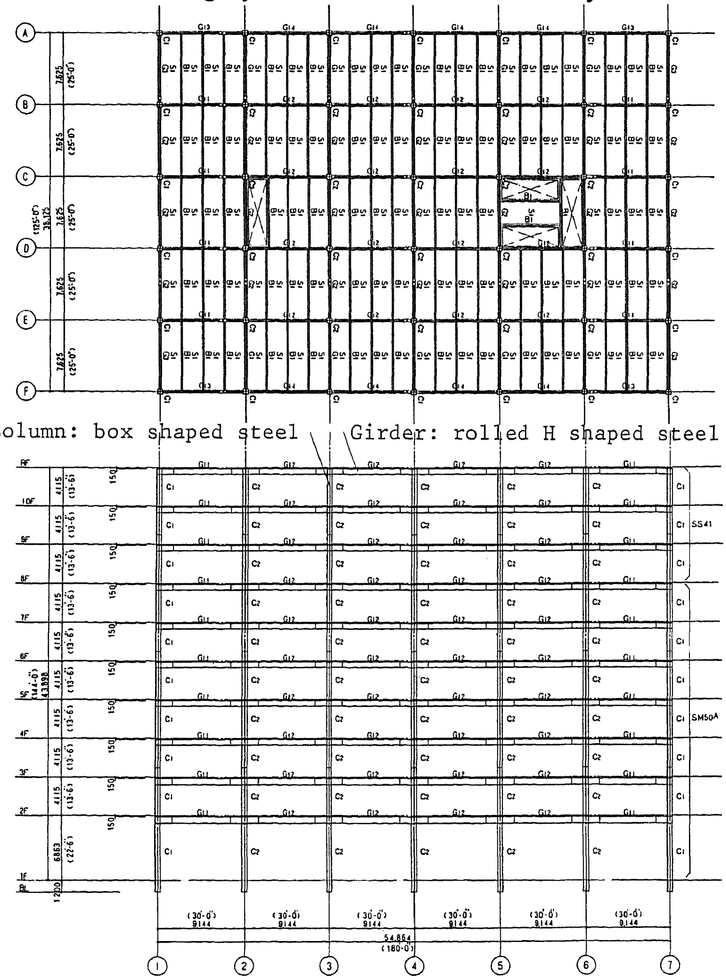

Fig.1 Typical Framing Plan and Framing Elevation

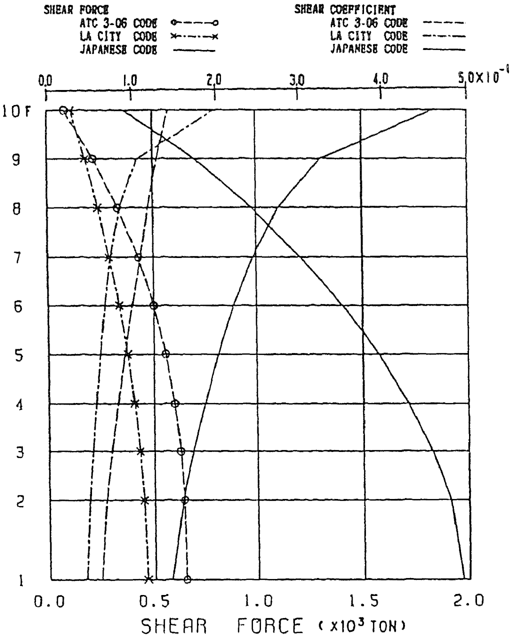

Fig.2 Comparison of Shear Forces

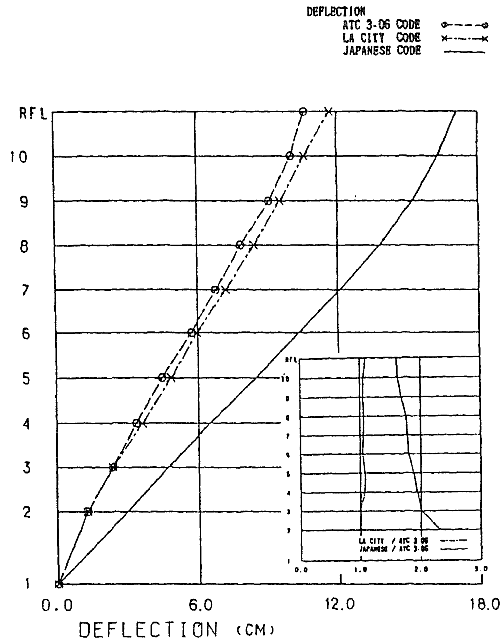

Fig.3 Comparison of Deflection

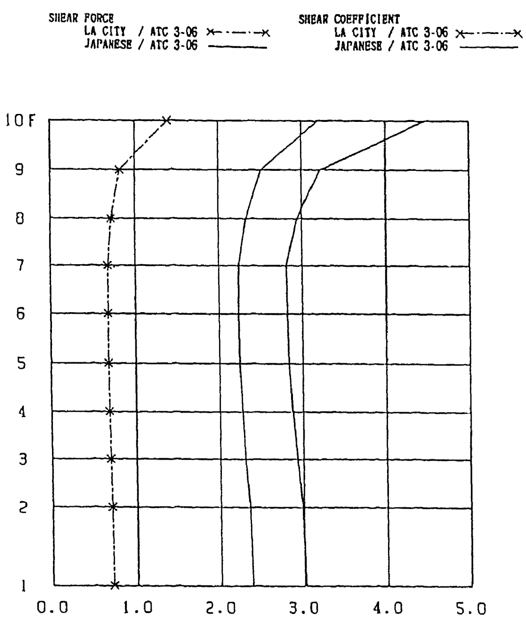

Fig.4 Ratios per ATC CODE for Shear Force and Shear Coefficient

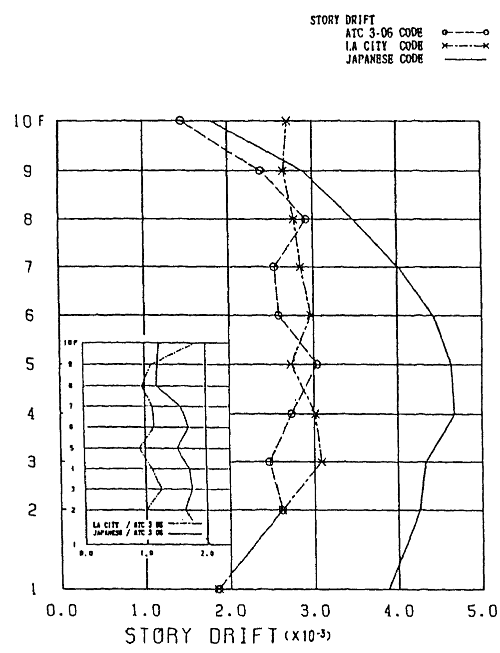

Fig.5 Comparison of Curve of Story Drift (Trans. Dir.)