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COMPARATIVE DESIGN OF 9-STORY REINFORCED CONCRETE BUILDING USING ATC 3-06, UBC 1982 AND CURRENT JAPANESE CODE

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SUMMARY

In each country, there are respective aseismic design codes stipulating seismic force, analysis procedure and design of 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 reinforced concrete buildings between the U.S. and Japan, by comparing trial designs of the same buildings.

INTRODUCTION

The building is a 9-story reinforced office building located in Los Angeles and was designed in accordance with the provisions of ATC 3-06 and UBC 1982. The same building has been re-designed based on current Japanese codes, assuming that it is located in Tokyo.

Outline of building

- Usage -------------------- Office Building
- Location ----------------- Tokyo, Japan
- Numbers of Stories ------ 9 + Basement 1
- Floor Area -------------- 1,022 m^2
- Total Floor Area -------- 10,449 m^2
- Floor to Floor Height --- 3.91m for typical floor,
  4.88m for 1st floor
- Total Height ------------ 36.26m
- Bay Size ----------------- 6.10m x 7.01m
- Plan Dimentions --------- 42.70m x 21.03m with a smaller
  8.84m x 14.02m wing

Figures 1 show typical framing plan and framing elevation.

Structural concept Aseismic framings at X-direction are ductile moment resisting frame system, whereas aseismic framings at Y-direction are shear wall system in the U.S. and dual system in Japan.

COMPARISON OF DESIGN

Comparative items	Building in L.A. by U.S. code/ ATC 3-06	Building in L.A. by U.S. code/ UBC 1982	Building in Tokyo by Japanese code/ New aseismic design method
1. Analysis procedure			
1) Building height	$H=36.26m<72m$	$H=36.26m<72m$	$H=36.26m>31m$ RC building
2) Building configuration	Regular	Regular	$F_{es}=1.0$
3) Analysis procedure	Equivalent lateral force procedure	Equivalent lateral force procedure	Dynamic analysis In this case, $C_o=0.2 \times 1.25$ is adopted instead of dynamic analysis.
2. Design seismic force			
1) Ground motion	Map area=7 (Los Angeles) $A_a=0.4$ $A_v=0.4$	Seismic zone=4 (Los Angeles) $Z=1.0$	$Z=1.0$
2) Importance factor (Seismic performance category)	Seismic performance category=C Seismic index=4.0 Seismic hazard exposure group=II	$I=1.0$	$I=1.0$
3) Framing system	Seismic-resisting frame X Ductile moment resisting frame w/shear wall Y Shear wall Frame not resisting lateral force To be checked by Δ $\Delta=C_d \cdot \delta=5\delta$ Cd: Deflection amplification factor δ : Deflection determined by elastic analysis	Seismic-resisting frame X Ductile moment resisting frame w/shear wall Y Shear wall Frame not resisting lateral force To be checked by Δ $\Delta=3\delta/K=3\delta$	Seismic frame (All frame) X Moment frame w/ share wall + Moment frame Y Shear wall + Moment frame
4) Structural co-efficient	X $R=5.5$ (Allotment of shear wall $\beta>75\%$) Y $R=5.5$ ($\beta=100\%$)	X $K=1.0$ ($\beta>75\%$) Y $K=1.0$ ($\beta=100\%$)	X $D_s=0.3$ ($\beta<30\%$) Y $D_s=0.35$ ($30\%<\beta<70\%$)

Comparative items	Building in L.A. by U.S. code/ ATC 3-06	Building in L.A. by U.S. code/ UBC 1982	Building in Tokyo by Japanese code/ New aseismic design method
5) Natural period	$T=\frac{.05\ hn}{\sqrt{L}}$ X T=0.53 sec. Y T=0.81 sec.	$T=\frac{.05\ hn}{\sqrt{D}}$ X T=0.53 sec. Y T=0.81 sec.	T=0.02H =0.02x36.26=0.72 sec.
6) Co-efficient for base shear	--	$C=\frac{1}{15\sqrt{T}}$ X C=0.092 Y C=0.074	--
7) Soil effect	S=1.2 Soil profile type: S_2	S=1.5 Predominant period to be unknown	Rt=1.0 Soil profile type: 2 Tc=0.6 sec. $Tc \leq T \leq 2Tc$ $Rt=1-0.2(\frac{T}{Tc}-1)^2$ $=1-0.2(\frac{0.72}{0.6}-1)^2$ =0.992 --- 1.0
8) Building weight	W=$10,572^{+}$	W=$10,572^{+}$	W=$11,645^{+}$ (+10%)
9) 1st-step design base shear	Limit level V=Cs W $Cs=\frac{1.2\ Av\ S}{RT^{\frac{2}{3}}}$ ${}_{X}V=\frac{1.2x0.4x1.2}{5.5x0.53^{\frac{2}{3}}}$ x10,572 =0.16x10,572 =$1,692^{+}$ ${}_{Y}X=\frac{1.2x0.4x1.2}{5.5x0.81^{\frac{2}{3}}}$ x10,572 =0.12x10,572 =$1,270^{+}$	Allowable level V=Z I K C S W ${}_{X}V$=1.0x1.0x1.0x 0.092x1.5x10,572 =$1,480^{+}$ ${}_{Y}V$=1.0x1.0x1.0x 0.074x1.5x10,572 =$1,204^{+}$	Allowable level Q=Z Rt Ai Co W ${}_{X,Y}Q$=1.0x1.0x1.0x 0.25x11,645 =$2,911^{+}$
10) 2nd-step design base shear	--	--	Q_{un}=Ds Fes Qud Qud=Z Rt Ai Co W =1.0x1.0x1.0x 1.0x11,645 =$11,645^{+}$ ${}_{X}Q_{un}$=0.3x1.0x11,645 =$3,493^{+}$ ${}_{Y}Q_{un}$=0.35x1.0x11,645 =$4,076^{+}$

Comparative items	Building in L.A. by U.S. code/ ATC 3-06	Building in L.A. by U.S. code/ UBC 1982	Building in Tokyo by Japanese code/ New aseismic design method
11) Level of design lateral force	$Q_{un}=\frac{1.0}{0.9}\times C_s W$ $_XQ_{un}=\frac{1.0}{0.9}\times 1,692$ $=1,880^{+}$ (0.54) $_YQ_{un}=\frac{1.0}{0.9}\times 1,270$ $=1,411^{+}$ (0.35)	$Q_{un}=\frac{1.4}{0.9}\ Z\ I\ K\ C\ S\ W$ $_XQ_{un}=\frac{1.4}{0.9}\times 1,480$ $=2,302^{+}$ (0.66) $_YQ_{un}=\frac{1.4}{0.9}\times 1,204$ $=1,873^{+}$ (0.46)	$_XQ_{un}=3,493^{+}$ (1.0) $_YQ_{un}=4,076^{+}$ (1.0)
12) Vertical distribution	Inverted triangular distribution $F_x=C_{vx}V$ $C_{vx}=\frac{w_x h_x}{\sum_{i=1}^{n} W_i h_i}$	Concentrated at the top & Inverted traingular distribution $F_x=\frac{(V-F_t)\,w_x h_x}{\sum_{i=1}^{n} w_i h_i}$ $F_t=0.07T\ V<0.25V$ $(T>0.7)$ $F_t=0$ $(T\leq 0.7)$ $_XT=0.53<0.7$ $F_t=0$ $_YT=0.81>0.7$ $F_t=0.07\times0.81\times1,204$ $=68t$	Ai-distribution $A_i=1+(\frac{1}{\sqrt{\alpha_i}}-\alpha_i)\frac{2T}{1+3T}$ 9F Ai=2.24 8 1.85 7 1.64 6 1.49 5 1.37 4 1.27 3 1.17 2 1.09 1 1.00
3. Horizontal distribution	X Ext. frame (Ductile moment resisting frame w/shear wall) 100% Int. frame 0% Y Ext. shear wall 100% Int. frame 0%	X Ext. frame (Ductile moment risisting frame w/shear wall) 100% Int. frame 0% Y Ext. shear wall 100% Int. frame 0%	X Ext. frame (Frame w/shear wall) 50% Int. frame 50% Y Ext. shear wall 50% Int. frame 50%
4. Horizontal torsion	Calculated plus 5% accidental	Calculated plus 5% accidental	Calculated only
5. Orthogonal effects	30% to be considered by the reason of seismic performance catagory C.	Not considered	Not considered

Comparative items	Building in L.A. by U.S. code/ ATC 3-06	Building in L.A. by U.S. code/ UBC 1982	Building in Tokyo by Japanese code/ New aseismic design method
6. Member section (dimension:cm)			
1) Girder at @ 5FL			
Int. frame	BxD=35x70	BxD=35x70	BxD=50x90
Ext. frame	35x110	35x110	35x150
2) Column at @ 4FL			
Int. frame	BxD=50x50	35x50	80x80
Ext. frame	70x70	70x70	80x80
3) Shear wall	T=30-40	T=30-40	T=20-30

CONCLUDING REMARKS

1. Design seismic force in Japan is considerably larger than that in the U.S., and so are design sections of members.
2. In Japan all frames are used as aseismic frames in order to resist large seismic forces, whereas only exterior frames are used as aseismic frames in the U.S.
3. In case of the computation of seismic force, ductility is considered at both country, but the values are different.
4. Also, Soil-structure interaction effect is considered at both country, but the values are different.
5. Regarding sectional design, there is the difference between the U.S. and Japan at the points of assurance of flexural yielding of beams, confinement of rebars, upper limit of axial stress of columns and design of girder-column joint.

REFERENCES

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2. UBC 1982
3. New assismic design method in Japan
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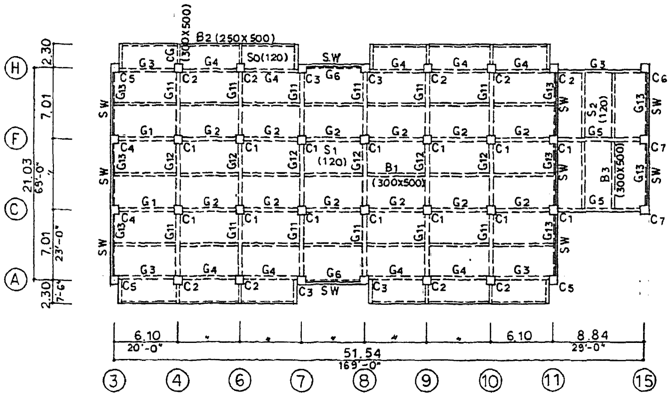
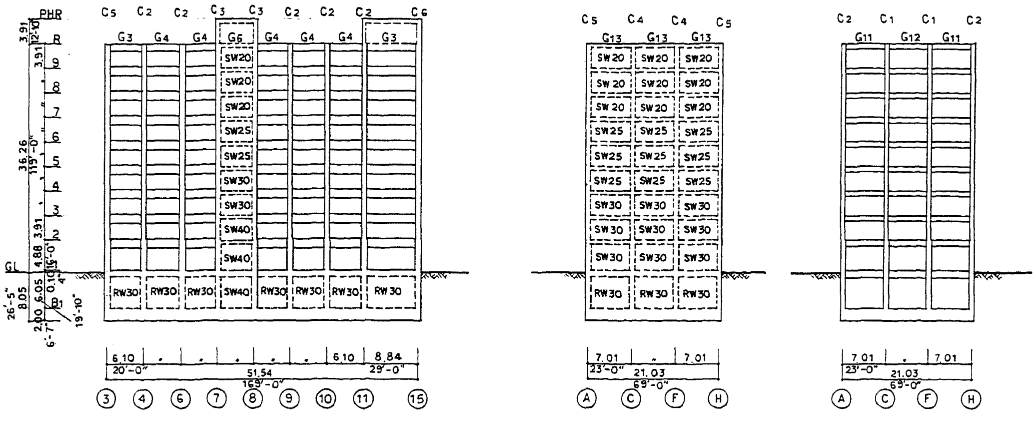


TYPICAL FLOOR FRAMING PLAN



H-LINE FRAMING ELEVATION

3 (11)-LINE FRAMING ELEVATION

4-LINE FRAMING ELEVATION

Figures 1 Typical framing plan and framing elevation.