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COMPARISON OF 20-STORY REINFORCED CONCRETE BUILDINGS DESIGNED USING ATC 3-06, UBC 1982 AND CURRENT JAPANESE CODE

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SUMMARY

This paper deals with comparative designs of the same reinforced concrete building, based on three codes; ATC 3-06, UBC 1982, and the current Japanese Code. The lateral forces, dimensions of members, and quantities of materials are compared to demonstrate the general features of these codes.

The results of the comparative design study lead to the conclusion that the differences between ACT and UBC are nominal except for the quantity of reinforcing bars. However, the Japanese code requires much more concrete and reinforcing bar than ATC or UBC, because of the difference in seismic load.

INTRODUCTION

The building is a 20 story office building. The structural system of the building is a "dual" type reinforced concrete lateral force resisting system consisting of shear walls combined with moment resisting frames. Comparative designs of this building were carried out assuming that it would be located in Los Angeles, applying ATC 3-06 and UBC. Another design was carried out assuming that the building would be located in Tokyo, applying the Japanese Building Standard Law.

<u>Outline of Building</u> (See Fig. 1 and 2)

- Usage ------------------- Office building
- Locations --------------- Los Angeles for ATC 3-06 and UBC
  Tokyo for the Japanese Code
- Number of Stories ------- 20
- Typical Floor Area ------ 1,811 m^2
- Total Floor Area ---------36,227 m^2
- Floor to Floor Height --- 6,992 mm for 1st story,
  3,952 mm for typical story
- Total Height ------------82,080 mm
- Bay Size ---------------- 8,512 mm x 8,512 mm
- Plan Dimensions ---------42,560 mm x 42,512 mm

Basic Conditions for the Comparative Design

· No changes were made to the framing plans or elevations.
· The same materials were used in the designs as far as possible. However, the general conditions and feasibility in each country were taken into account.
· In Japan, highrise reinforced concrete buildings are very unusual.
  The building height exceeds 60m, so a special examination is required to obtain a building permit. In this design, a simplified design procedure was adopted to approximate the requirements of the above examination.
· For the frame analysis of the U.S. seismic load, the three-dimensional analysis "ESTAB" was used. The building structural analysis system "BUILDING" was used for the Japanese code.

RESULTS OF COMPARATIVE DESIGN

The results of the three comparative designs are shown on the following pages. The compartive items are moterials used, vertical loadings, seismic loadings, dimensions of members and quantities of mateirals. Figs. 3~5 respectively show the story shears, the deflections of the buildings due to design shears and dimensions of members.

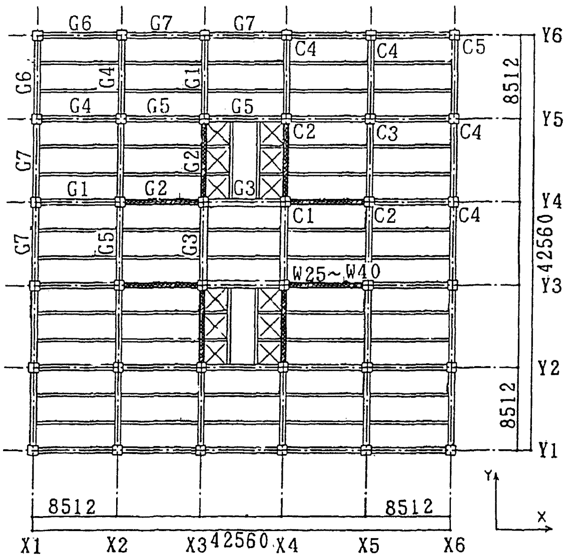


Fig-1 Framing Plan of Typical Floor

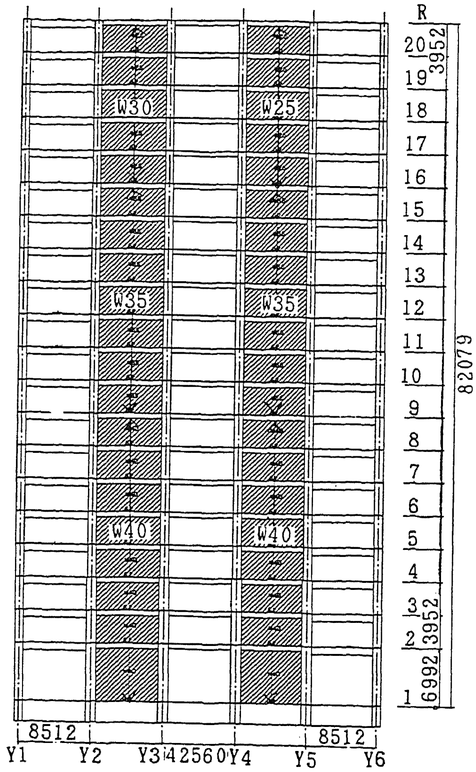


Fig-2 Framing Elevation of Line X3

RESULTS OF COMPARATIVE DESIGN (1)

Comparative Items	U.S. Code ATC 3-06	U.S. Code UBC 1982	Japanese Code
1. Material used			
1) Concrete: 13F-Roof	$Fc=290\ kg/cm^2$ (r=1.85)	$Fc=290\ kg/cm^2$ (r=1.85)	$Fc=240\ kg/cm^2$ (r=1.90)
3F-12F	$Fc=290\ kg/cm^2$ (r=1.85)	$Fc=290\ kg/cm^2$ (r=1.85)	$Fc=300\ kg/cm^2$ (r=2.30)
1F- 2F	$Fc=363\ kg/cm^2$ (r=2.42)	$Fc=363\ kg/cm^2$ (r=2.42)	$Fc=300\ kg/cm^2$ (r=2.30)
2) Reinforcing Bar	$fy=4,360\ kg/cm^2$	$fy=4,360\ kg/cm^2$	$fy=3,000\ kg/cm^2$ (dia<19mm) $fy=4,000\ kg/cm^2$ (dia>22mm)
2. Vertical loadings			
1) Floor slab thickness	11.3 cm	11.3 cm	13 cm
2) Live load	$98\ kg/m^2$	$98\ kg/m^2$	$80\ kg/m^2$ (for seismic force)
3. Seismic loadings			
1) Natural period: T	1.37 sec	2.10 sec	1.40 sec(elastic) 1.80 sec (reduced stiffness)
2) Total weight of building	26,400 t	26,400 t	35,300 t
3) 1st-step design base shear	$V_B=C_S \cdot W$ $C_S=\dfrac{1.2AviS}{R \cdot T^{2/3}}$ $V_B=1.2x0.4x1.2/x(8x1.37^{2/3})$ x26,400 =0.0584x26,400 =1,540 t	$V_B=Z \cdot I \cdot K \cdot C \cdot S \cdot W$ V_B=1.0x1.0x0.80 x0.046x1.15 x26,400 =0.0423x26,400 =1,120t	Q=Z·Rt·Ai·Co·W Q=1.0x0.53x1.0 x0.24x35,300 =4,520 t
4) 2nd-step design base shear	—	—	Qun=Ds·Fes·Qud =Ds·Fes·Z·Rt·Ai·Co·W Qun=0.35x1.0x1.0 x0.53x1.0x1.0 x1.0x1.0x35,300 =6,550 t

Fc : compressive strength of concrete
fy : yielding stress of reinforcing bar
γ : relative density of concrete

RESULTS OF COMPARATIVE DESIGN (2)

Comparative Items	U.S. Code ATC 3-06	U.S. Code UBC 1982	Japanese Code
4. Dimensions of members(cm)			
1) Columns			
Exterior frames (C4) 10F	90x90 Pg=1.44	90x90 Pg=1.44	100x100 Pg=1.82
	Ps=0.86	Ps=0.86	Ps=0.80
1F	90x90 Pg=1.44	90x90 Pg=1.44	100x100 Pg=1.82
	Ps=0.86	Ps=0.86	Ps=0.80
Interior frame (C2) 10F	100x100 Pg=1.00	105x105 Pg=2.12	100x100 Pg=2.14
	Ps=0.17	Ps=0.16	Ps=0.51
1F	100x100 Pg=2.34	105x125 Pg=5.33	120x120 Pg=1.86
	Ps=0.17	Ps=0.16	Ps=0.66
2) Girders			
Exterior frames (G6) 10F	68x90 Pt=0.75	68x90 Pt=0.75	60x110 Pt=1.35
	Ps=0.19	Ps=0.19	Ps=0.66
2F	68x90 Pt=0.75	68x90 Pt=0.84	60x120 Pt=1.22
	Ps=0.19	Ps=0.19	Ps=0.66
Interior frames (G4) 10F	45x60 Pt= -	45x60 Pt= -	65x90 Pt=1.56
	Ps= -	Ps= -	Ps=0.61
2F	45x60 Pt= -	45x60 Pt= -	65x90 Pt=1.56
	Ps= -	Ps= -	Ps=0.61
Link beam (G3) 10F	60x60 Pt=1.64	60x60 Pt=1.75	75x60 Pt=1.70
	Ps=0.23	Ps=0.41	Ps=0.53
2F	60x60 Pt=1.64	60x60 Pt=1.75	75x60 Pt=1.70
	Ps=0.23	Ps=0.41	Ps=0.53
3) Shear walls			
Shear wall thickness 16F	30 Ps=0.28	30 Ps=0.28	25 Ps=0.51
9F	35 Ps=0.28	35 Ps=0.28	35 Ps=0.57
1F	40 Ps=0.32	40 Ps=0.32	40 Ps=0.72
5. Quantities of materials			
1) Slabs Forms	28,000 m^2	28,000 m^2	29,300 m^2
Concrete	4,300 m^3	4,300 m^3	4,900 m^3
Rebar	180 t	180 t	440 t
2) Girders Forms	12,700 m^2	12,700 m^2	21,700 m^2
Con crete	2,600 m^3	2,600 m^3	5,100 m^3
Rebar	400 t	460 t	1,560 t
3) Beams Forms	9,800 m^2	9,800 m^2	11,400 m^2
Concrete	1,000 m^3	1,000 m^3	1,300 m^3
Rebar	200 t	200 t	370 t
4) Columns Forms	9,800 m^2	9,800 m^2	11,600 m^2
Concrete	2,600 m^3	2,600 m^3	2,900 m^3
Rebar	450 t	580 t	680 t
5) Walls Forms	9,500 m^2	9,500 m^2	8,400 m^2
Concrete	1,600 m^3	1,600 m^3	1,500 m^3
Rebar	90 t	110 t	190 t
6) Total Forms	69,800 m^2	69,800 m^2	82,400 m^2
	(5.77m^2/m^3)	(5.77m^2/m^3)	(5.25m^2/m^3)
Concrete	12,100 m^3	12,100 m^3	15,700 m^3
	(0.33m^3/m^2)	(0.33m^3/m^2)	(0.44m^3/m^2)
Rebar	1,320 t	1,530 t	3,240 t
	(0.109t/m^3)	(0.126t/m^3)	(0.206t/m^3)

Pg : total reinforcing bar area ratio (%)
Ps : shear reinforcing bar area ratio (%)
Pt : tensile reinforcing bar area ratio (%)

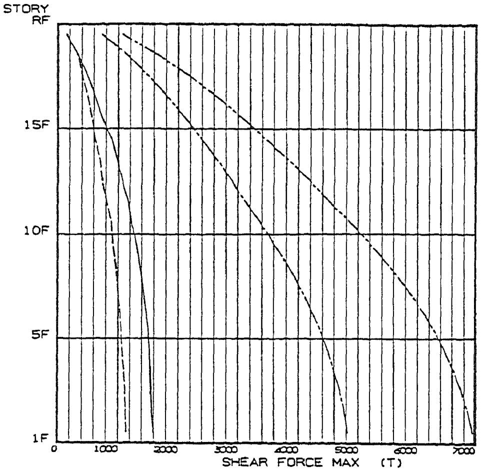


Fig-3 Design Story Shear

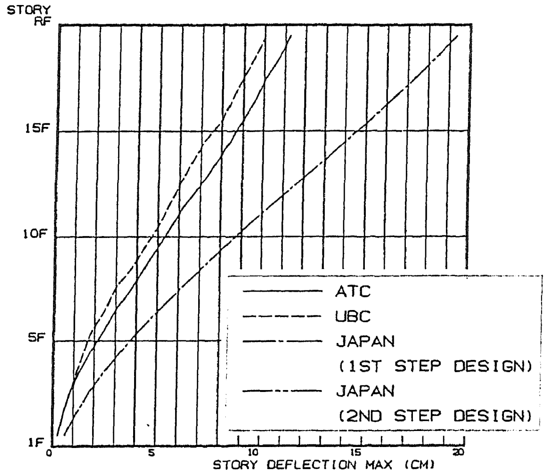


Fig-4 Deflection due to Design Shear

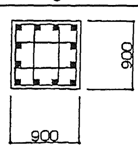
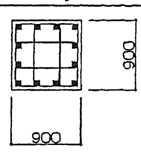
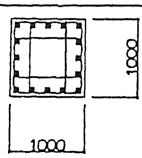
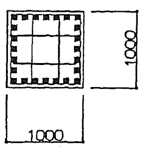
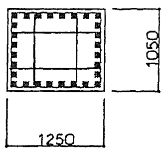
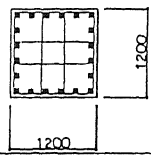
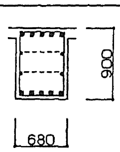
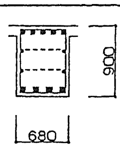
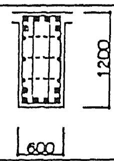
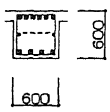
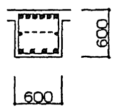
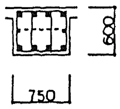
	ATC 3-06	UBC 1982	Japanese Code
C4			
LONGITUDINAL BAR	12-#11	12-#11	16-D38
HOOP TIE	4-#5@120	4-#5@80	4-D16@100
C2			
LONGITUDINAL BAR	24-#11	28-#18	20-D41
HOOP TIE	4-#4@300	4-#4@300	4-D16@100
G6			
LONGITUDINAL REINFORCEMENT TOP	5-#10	4-#11,1-#9	6-D41
LONGITUDINAL REINFORCEMENT BOTTOM	2-#10,2-#9	5-#9	6-D41
STIRRUP	2-#4@200	2-#4@200	4-D16@200
G3			
LONGITUDINAL REINFORCEMENT TOP	4-#11,2-#9	5-#11,1-#9	4-D41
LONGITUDINAL REINFORCEMENT BOTTOM	2-#10,2-#8	3-#10,1-#9	4-D41
STIRRUP	2-#4@150	2-#4@100	4-D16@200

Fig-5 Dimensions of Columns & Girders

CONCLUSIONS

From the comparison of these designs, the following observations can be made. Hereinafter, ATC means the design based on ATC 3-06, UBC means the design based on UBC 1982, and JPN means the design based on the Japanese Building Standard Law.

- The quality of materials used is nearly equal. The differences are that light weight concrete is used in ATC and UBC for the middle stories, but regular weight concrete is used in JPN, and that the yielding strength of reinforcing bars in ATC and UBC is slightly higher than in JPN.
- Vertical loading conditions are nearly equal.
- The values of seismic load in ATC are slightly larger than those in UBC, on the other hand in JPN they are about 3.0 times larger than ATC or UBC. (See Fig 3.)
- The designed dimensions of JPN members are larger than those in ATC and UBC. The differences in columns are small and in depth of beams are large. The quantity of longitudinal and shear reinforcing bars in JPN is 2~3 times that in ATC, except for the longitudinal reinforcement in interior frame columns. (See Fig. 5.)
- The quantity of building materials is nearly equal in ATC and UBC except for reinforcing bar, and is much larger in JPN than in ATC or UBC. Concrete volume in JPN is 1.3 times that in ATC; reinforcing bar weight is 2.4 times; and reinforcement weight per concrete volume is 2.0 times.

The differences in the results of the designs is not so large as that suggested by the seismic load differences. The reasons is assumed to be as follows:

- In JPN, strength reduction factor ϕ is not considered. Contrary to this, yield strength in reinforcing bar is taken as 1.1 times the nominal value.
- In JPN, interior frames are also utilized to resist the large lateral force.
- In ATC and UBC, bi-axial action of seismic lateral load is considered. However, in JPN, only some margin is given to corner columns and there is no distinct provision for bi-axial effect.

Apparent differences are found in the following items:

- Beam depth in JPN is greater than that in ATC due to the increased seismic load. On the other hand, bending strength of columns is large due to the existence of axial compression and the difference in column cross sections is not so large.
- In JPN, much more shear reinforcement than that in ATC and UBC is provided to avoid shear failure.

REFERENCES

1. Proceedings of Second U.S.-Japan Workshop on Improvement of Seismic Design and Construction Practices, August 5-7, 1986; ATC 15-1
2. Amended ATC 3-06; Tentative Provisions for the Development of Seismic Regulations for Buildings
3. Uniform Building Code 1982
4. New Aseismic Design Method in Japan 1985, by Y. ISHIYAMA