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DIFFERENCES AND CONSTRUCTIONAL MEASURES IN ASEISMIC DESIGNS OF TALL BUILDINGS

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SUMMARY

Comparing the aseismic structure designs of 138 tall buildings in China with those of 178 tall buildings in Japan, the paper illustrates the differenecs in structure designs, and emphasises The important role of Constructional measures in designs.

DIFFERENCES IN ASEISMIC DESIGNS

Every structure designer hopes that he or she can design buildings with adequat earthquake resistant behavior and less cost, many designers try their best to creat new ideas under their design codes and they have done very good jobs. But we find that the differences between designs of different designers are obvious. Even designers follow the same code to design structure of buildings in the same area, the results may be quite different. Some of these buildings are earthquake resistant, but some others are not because of diversity of problems. These differences lie in the non-coincidence of seismic coefficient in code with the seismie coefficient in real earthquake; the difference between assumed conditions and real conditions; the difference between the quality requirements proposed by designers and the real results performed by builders; and also lie in the influence of society and the difference of designers as different individuls.

The auther investigated one hundred and thirty eight 12-62 storied tall buildings in china and collected information about aseismic designs of one hundred and seventy eight tall buildings over 60 stories in Japan. From preliminary aualysis, we can see the differences and hope the paper can be useful for further investigation.

1. Structure system

Considering the variety of stories, heights and types of buildings, the designers will choose different structure systems which, in some extent, defermine the rigidity and the aseismic behavior of the buildings.

The structure systems used in the 138 tall buildings in China are shown in table 1.

Table 1

	A	B	C	D	E	F
12-24 stories	1	6	51	23	3	8
25-62 stories	0	1	16	5	7	17
total	1	7	67	28	10	25
percentage	0.7	5.1	49	20	18	7.2

Here, A---Flat slab structure
B---Framed structure
C---Frame wall structure
D---Shear wall structure
E---Partially frame supported structure
F---Tube structure

2. The period of natural vibration

Because of different structure system and different form and amount of lateral force resisting elements, the periods of natural vibration of buildings are quite different. Figure 1 shows the distribution of the periods of natural vibration of the 138 buildings in china.

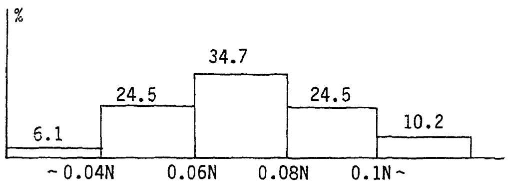

Fig.1 the distribution of the periods of natural vibration (in China)

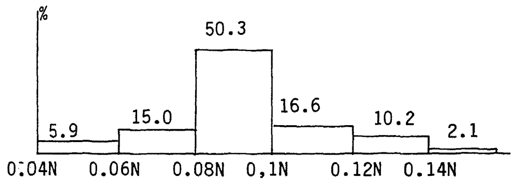

Fig.2 the distribution of the periods of natural vibration (in Japan)

From Fig.1 we can see the periods of the structures below T=0.08N account for 65.3%, while those below T=0.06N account for 30.6%. Most of them close to the empirical formula, but some are smaller (0.024N), some others are bigger (0.19N). In the 178 tall buildings in Japan, the distribution of the periods of natural vibration is shown in Fig 2.

From the figure we can see the regidities of most structures are close to each other, and the rigidities of the buildings are lower than those of the buildings in China. The corresponding earthquake action will be also lower.

3. The story-loads of the buildings

The story-load of building (the average weight per M^2 of the building) mainly depends on the structure system and the building material adopted. The story-load of the building determines the earthquake force and the weight which must be supported by the foundation. So there is a very close relation between the story-loads of building and its aseismic capability. The distribution of the story-loads of the 138 buildings in China is shown in Fig.3.

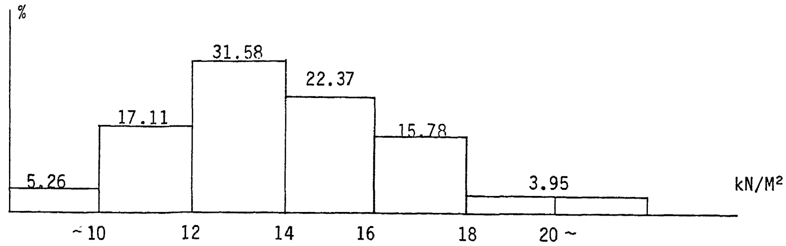

Fig.3 the distribution of story-loads

The buildings with story-load above 14kN/M² account for 46.05%. The buildings with story-loads below 10kN/M² are all of steel structure. Even reinforced concrete structure, there are 50% of the buildings have their story-loads above 14kN/M². The havier is the story-load, the bigger is the earthquake force. Therefore the material which used in the structure will be much considerable.

4. Base shear factor

The base shear factor $C_o = \Sigma Q / \Sigma W$ is the ratio of the total shear force at the foundation of the building and the total weight of the building. It shows the capability of the building to withstand earthquake. Fig.4 shows The distribution of C_o factor of the tall buildings in China when the earthquake acclamations are from 200-250gal.

In China all designers are following the unified code of the country However, there exist many indefinite factors affecting personal judgement of designers, so the earthquake forces differ greatly.In contrast,the values C_o of the tall buildings in Japan are much closer to erch other (see Fig.5) The values C_o between 0.10-0.25 account for 86.4%, and most of them are between 0.15-0.20, which agree with the requirement of the national code.

As there are differences of earthquake intensities and some other conditions between China and Japan,the values of earthquake force are quite different between the two countries. According to Fig.4 and 5, the weighted means of C_o are respectively 0.0469 (China) and 0.1824 (Japan): the difference is as big as 3.89 times.

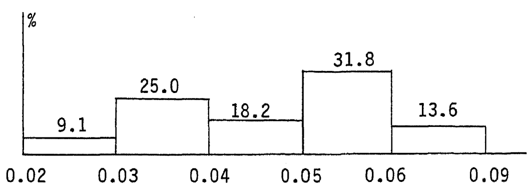

Fig.4 the distribution of values C_o (in China)

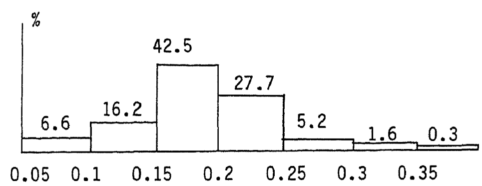

Fig.5 the distribution of values C_o (in Japan)

5. Angular story displacement

The angular story displacement δ/h (δ is the displacement of stories, h is the story hight) is an important indicatrix which illustrates the rigidity of the strucfure. Every country's code includes the requirement of the lowest limit, however,there exists big difference in values. Fig.6 shows the distribution of the angular displacements of the designs of tall buildings in China when the earthquake accelarations are considered as 200-250gal.

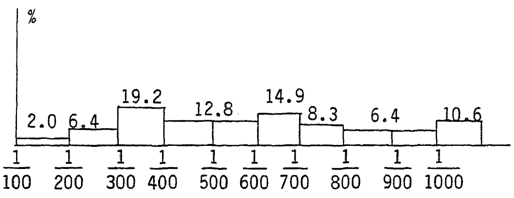

Fig.6 the distribution of angular story displacements (in China)

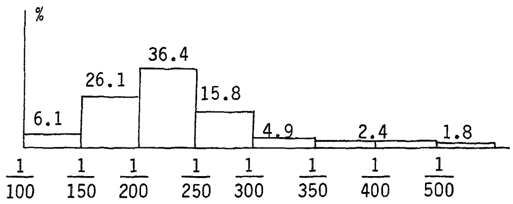

Fig.7 the distribution of angular story displacements (in Japan)

In Fig.6 we can see the obvious difference of the values. Some of them are much lower than the limited values given in the code, while some others are much higher than the limit value. The distribution of δ/h of tall buildings in Japan in the same condition of 200-250gal is shown Fig.5.The angular displacements which are about 1/150-1/300 (Quite close to 1/200 which is the limit value in Japanese code) account for 78.3%.

THE REASONS FOR THE DIFFERENCES

There are three reasons which lead to the differences of the designs. The first one is the incorrect judgement of the seismic coefficient of which earthquake may happen in the area. For example, in 1975 an earthquake the intensity of which was 7.3 happened in Hai Cheng city of China. The buildings which were built without any aseismic requirement damaged seriously. Another example is the earthquake happened in Tangshan in 1976..The earthquake intensity was 7.8. However, the aseismic requirement for the buildings in that area was only for earthquake intensity 4-5..

The second reason is that in the code only the lowest values or a general requirements are given. The reasonable design depends on The experience of designer and his correct way to realize the aseismic purpose, his ability of correctly choosing the structure scheme and deciding the variety of factors beyond the requirement of the code. For instance, the influence of slab on the rigidity of beam. In the case of a 25 storied steel structure,the difference of natural vibration is 0.45 sec. between those considering and not considering the effect of slab. Another example is the effect of non-structure wall on the structure rigidity. It is difficult to estimate exactly the effect of non-structure wall on the rigidity of the whole building because there are many kinds of non-structure walls. In the case of frame structure, considering its effect or not can lead to 100% difference between the two computed periods.

The third reason is that, after the structure was built or withstood earthquake, the structure would be quite different from the original design. For example, the quality of workmanship, the variation of modulus of elasticity of steel concrete, the effect of the deformation of joints on the damping coefficient and so on. The statistics in some reference shows that variations of modulus of elasticity, damping coefficient and the moment of inertia will lead to the difference of response of structure as big as 3.71 times. It is very difficult for designer to make correct judgement about the factors mentioned above.

REMEDY DESIGN DEFECTS BY CONTRUCTIONAL MEASURES

It is difficult to avoid the above mentioned design defects. Many designers recognize clearly that to complete an excellent design the first important tast is to choose reasonable scheme and rational detailing of reinforcement. He will not be satisfied with only structure calculation. In order to choose rational scheme there are a lot of things to do with architects. However, detailing of reinforcement will only depends on the wistom and experience of designer.

1. Rational detailing of reinforcement will make up the difference in aseismic calculation. As mentioned above, the difference in aseismic calculation. As mentioned above, the difference of earthquake forces betwecn the codes of the two countries will be as big as 3.89 times. However, if you design same three storied RC structures according to the codes of the two countries, the difference of resistance of beam and column are only 1.5 times for beam and 2.5 times for column, It is because the codes require necessary constructional measures for beam, column design and reinforcement detailing. Many design exemples show that in almost all frame structurcs below ten stories the actual resistance exceeds the computed resistance.

2. Proper detailing can provide ductility of structure economically and effectively. To warrant adequate ductility depends mainly on proper defailing rather than conputation.

Many earthquake damages show that the ends of beams and columns were damaged frequeancy, and it will lead to the degration of resistarce. Tests illustrated that using closely spaced hoops at plastic hinge regime is very effective for confining concrete, providing the rebar from buckling and providing shearing strength. For example, changing from Φ 10 @ 200 to Φ 10 @ 100 can raise the shearing strength efficiently, but the total amount of reinforcement of beams and columns only crease 1%.

3. Constructional measures can be considered as affection line of defense to prevent buildings from collapse. There is no applicable analytical method which can make building withstand any unexpected earthquake, but it can be done by adequate constructional measures. For instance, in Tang shan sity of China, there was a seven-storied brick structure building, which was designed to withstand earthquake of intensity 6. But at the cross points of the walls some RC columns were arranged. Even though it located near the epicenter of the earthquake, the brick walls were damaged, but the building still stood there.

4. Constructional measure is a design means which may be easily managed by designers. Conceptual design requires richer experiences and clever works of designers. Not all of the designers can do it. But the constructional measures, which obtained from experience or summarized from tests, were usually compiled in handbooks. It only needs designers to use them in their designs correctly to satisfy aseismic requirement. It is easy for designers to understand, even for young engineers.

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