Discussion

Objekttyp: **Group**

Zeitschrift: **IABSE reports of the working commissions = Rapports des commissions de travail AIPC = IVBH Berichte der Arbeitskommissionen**

Band (Jahr): **30 (1978)**

PDF erstellt am: **23.05.2024**

1st Session: DESIGN CRITERIA FOR STRUCTURES IN SEISMIC ZONES

DISCUSSION

Paper 1/2 R. W. CLOUGH, A. A. HUCKELBRIDGE - USA
"Column Uplift During Seismic Response of Buildings"

LANE

I see that your shaking table was able to produce both horizontal and vertical vibrations. I would like to ask whether the combination of some vertical and some horizontal was tending to give a worse effect than either the one or the other.

CLOUGH

That is a very good question. We tested this structure with the horizontal input component only in part of the tests, and with the combination of horizontal and vertical in part of the tests. We found in this test, as we have found in many other tests, that the vertical component has very little significance; it made very little difference in the kind of results that were measured. I would say that this conclusion is typical for building type constructions.

If there is no other comment at all, I will make one comment myself. In response to the note that I was not speaking about finite elements, I will mention that I became an experimentalist again about six years ago. At that time I concluded that we know very well how to calculate the response of structures; much better than we knew how to specify the material behaviour and the non-linear characteristics of the structural system. I think we need much more experimental information to verify these aspects of the numerical analysis procedures.

WOLF

We have done some work on nuclear power plants which also have this capacity to uplift. Uplift can cause the mode with the largest product of spectral acceleration and participation factor to be shifted from the first to a higher one. This can lead to high frequency response not present if lifting-off is prevented (in-structure response spectra). Was this low amplitude but high frequency vibration visible and measured or was it damped out?

CLOUGH

I would like to answer the question first by differing with you on the point of view of modal frequencies. You indicated that the fundamental mode frequency is increased during uplift. This is a point of view, of course. My opinion is that the fundamental mode during uplift is the rocking mode and that its frequency is reduced from the value of the fundamental mode frequency before uplift takes place. The uplift mode you are referring to has the next higher frequency, the one involving straining of the system. Of course the system does develop, or continues to develop, these higher mode frequencies after uplift takes place. But in our experiment we didn't find any increase of intensity of those higher frequency components. What we call the second mode frequency without uplift, and what we continue to call the second mode frequency after uplift is evident in the records, it can be observed but with no increase of intensity after uplifting occurs.

CLOUGH (answer to questions by PETROVSKI)

There are several comments I would make in response to your questions. First of all, in our concept of this uplifting mechanism, we are not proposing that the footings, the concrete part of the system, be uplifted. We are proposing that the steel columns be allowed to separate from the concrete footing, so that the footing continues to maintain contact with the soil, and it is only the steel portion in our structure which is uplifted. I do not expect any significant amplification of the soil stresses because of the uplifting phenomenon; in fact, I would expect that the soil stresses would be reduced, just as the column stresses are reduced.

The other comment I wish to make is that I think the structure should be designed so that uplifting does not occur during a typical design earthquake. A typical building code loading should not produce uplift, but because we recognize that significant earthquakes (like the maximum expectable earthquake) are much greater than the typical design requirements, we feel that the building should be permitted to have uplift during this extremely severe excitation. The amount of uplift that occurs will not be great. Loss of stability in the sense of overturning is not a problem because the amount of horizontal ground displacement is not sufficient to cause overturning.

MARINAKIS

Did you take into consideration the subsidence of the footing owing to pressure in the soil, in the foundation material?

CLOUGH

The test we performed simulated an essentially rock-type foundation. There is no foundation flexibility contained in our test system. If there were significant foundation flexibility, so that soil-structure interaction would be a factor in the response, then of course that should be included in the analysis. But I think the uplifting behaviour could still be calculated by the same procedure we used, and the net effect, I think, would be essentially the same.

YÜZÜGÜLLÜ

Prof. Clough, I have a small question about the type of material considered. The example you have given is a steel building, and the foundation is also steel. Have you ever thought of a reinforced concrete footing or other types of foundation?

CLOUGH

As I mentioned earlier, we assumed that our steel frame building would be designed to uplift from a concrete foundation system. The steel flexure plate of the column base should be bolted directly to the concrete footing system in a typical installation. Now the question of providing a similar uplifting capability in a concrete frame building is very important. I believe a column base device of the same general type we have used could be developed for a concrete structure, and I think in the case of concrete it might have even more important advantages than in the case of steel.

Paper 1/3 M. CELEBI, M. ERDIK, O. YÜZÜGÜLLÜ - Turkey
"Effect of Construction Joints on Vibrations of Structures"

THÜRLIMANN

A first question: could you make a sketch of how the construction joints really look, whether there is complete separation or some interlock?

YÜZÜGÜLLÜ

The usual practice in Turkey is to provide some distance, about 5 or 10 cm, and to put some styrofoam to separate the building. But unfortunately, because of bad construction practice, some reinforcement continues and some concrete pieces are squeezed in between. Actually, if a proper construction practice is followed, those problems are not going to rise.

CLOUGH

I would like to ask the same question Prof. Thürlimann asked about construction joints. We had the same type of experience in a building test program in Berkeley, in which the construction joint in that case was a total separation between two buildings. Only horizontal sliding steel plates were provided at each floor in the connecting hallways. These were completely separate, resting on the adjacent floor slabs. This is a very small connection, and dynamically we could observe relative motions taking place across the joint; but we still found that there was enough force transmitted through that type of connection to cause horizontal coupling of the building vibrations.

YÜZÜGÜLLÜ

I agree with that. We observed a construction joint about 20 cm, but in some of the floors people forgot about the reinforcement or something, even one or two pieces of wood. Thus even small details may induce vibration.

PETROVSKI

There is one thing not to be forgotten, a small point. First these types of tests are done for the level of excitation meant to be minus or g, and we have to be careful in drawing final conclusions.

YÜZÜGÜLLÜ

May I say a few things about that. Although the power we could create with the vibration generator was not so much, we could shear off the irregularities. As one expects since the buildings are of similar type, this shearing force may be in phase and it might not rupture the building, so the two buildings may vibrate in the same direction. It is very hard to shear off the construction joint, except of course in a real earthquake. Then, a construction joint might work properly.

Paper 1/6 E. GRANDORI, G. GRANDORI, V. PETRINI - Italy
"Engineering Decisions and Seismic Risk Prevention"

GROSSMAYER

What is the reliability of the magnitude-frequency relationship particularly in the high magnitude range? Did the recent events in Italy change this relationship which, in contrast to your presentation, may have a significant influence on other kinds of investigations, as for example the development of a seismic risk map?

GRANDORI

We are planning to check our calculation model as regards this influence. This must be done in well-documented zones, with instrumental measures of large values of magnitude. This is in fact the objective difficulty and I do not know now what is the reliability of magnitude-frequency laws. We are only trying to see if the choice of this law is a critical choice for our calculations; or is there are more important uncertainties in the rest of the model. This is the point at which we are now.

Paper 1/7 G. C. DELFOSSE - France

"The GAPEC System: A New Aseismic Building Method Founded on Old Principles"

FISCHER

If you construct a building on these isolators, is it also rigid enough for other horizontal forces like for wind?

DELFOSSE

Yes, of course.

CLOUGH

The concept of the very soft isolator is of course as old as earthquake engineering and has been stressed in many papers. The particular application with rubber bearings is a new detail, but the basic problem of all "soft story" systems is the extreme flexibility of the system under all loading conditions. None of your results indicated the displacement amplitude of the structure under seismic excitation. In addition, of course, wind excitation will also produce significant response, and the amplitude of the displacements has been one of the main difficulties with the use of the soft first-storey concept. I would like your comments on what are the calculated deflections in the examples you indicated.

DELFOSSE

In fact, displacements are no longer a problem. For example, for a structure with a 2 second natural period, we can have displacements as large as 50 or 55 cm. We must have isolators which are soft in the horizontal sense but hard in the vertical sense, so that the building moves without rocking. The main problem we solved was to manufacture isolators that would accommodate large displacements. For example, when we test isolators, we can distort them by 400%. That means we can displace one end of the isolator of four times the total thickness of the rubber. So for large buildings we can have isolators 60 cm in diameter, and we can distort the isolators by 1 m 20 cm.

CLOUGH

But there is still one further question. The horizontal displacement relative to the horizontal dimension of the isolator must be a critical factor. You say you could displace it over a meter with a unit which is only half a metre in diametre. Are you going to maintain vertical stability in these conditions?

DELFOSSE

We cannot, 400% is the distorsion at break. We have very high safety factors. In fact, we have a design distorsion of 100% or may be less. It means we have a very large amount of safety in shear.

CLOUGH

Have you studied this stability under large amplitude displacements?

DELFOSSE

Yes, we did large scale experiments.

WOLF

Your process depends very much on the fact that the first mode is basically a straight line; thus hardly leading to any increase in the acceleration along the height of the structure. But for an earthquake input which has a rotational component as happens for non vertically propagating shear waves, the advantages are not so evident. Have you examined what happens in that case?

DELFOSSE

The isolators are designed to prevent coupling between vertical and horizontal motions.

DELFOSSE (answer to questions by PETROVSKI)

By structural system you mean superstructure? We have seen in these studies and research that accelerations are divided by 4 to 7. So if the accelerations are low, structural elements will support these accelerations very easily. There are no problems for structural systems in the sense that there is not relative displacement, but a general displacement of the structure. The problem is accelerations that are applied to these elements, and these accelerations are very low. As we see on the testing models, the structure moves as a single unit and the structural elements are not suffering at all.

The second question for large displacements involved by something like radio waves or long period waves - this question is reflected by the response spectrum. It means that on your response spectrum you have long periods. So we have two possibilities. First we know that we shall have long periods in the response spectrum. In this case, we have to design isolators which will be more flexible so that the natural period of the structure is largely above the dominant period of the ground; we know very well to design such types of isolators. The second possibility is that you do not know that you will have long periods in the response spectrum. In this case isolators will be submitted to larger displacements than designed. But I said a moment ago that we have a factor of safety of 4 for the distorsion of isolators; this factor will be simply reduced to 3 or 2 for example, which is well enough under the worst conditions.

LANE

The large displacements described by the author seem to be additive with several events - particularly with wind induced vibration. Could not arrangements be made for jacking the building back to its original position?

DELFOSSE

It is a perfectly elastic displacement. If you pull, it comes back immediately. Isolators are springs.

GROSSMAYER

If you have such large displacements, do not you have any difficulties with your installations regarding to their connections at the base? So I wonder how you can manage these joints.

DELFOSSE

You must let the necessary clearance between the pipes and the ground or between the adjacent buildings.

CROFTS

I would like to ask some practical questions. Where such systems have been used to isolate buildings from the effect of underground trains, it has normally been assumed that such isolators can become rather rigid and thus less effective in about 20 years, and frequently a provision is made to replace them. I wonder if provision should be made to replace the isolators in this case. The second question is if you have buildings which can articulate in this fashion, with moving joints between buildings, whether special care is necessary to avoid damage between buildings which are moving about in a rather extensive fashion on these special sliding joints.

DELFOSSE

You refer to ageing. In connection with this, we made laboratory tests. We put isolators in a stove for 3, 6, 9 days. These are standard ageing tests. After 3 days in the stove at 100°C temperature, this is equivalent to one century of ageing. After this period they had lost only 15% in strength and then stiffness is only 10% higher. This is due to a special compounding of rubber. In any case, provisions are made to change the isolators, if necessary, by unboltening them from the structure. The second question - we had exactly this problem on this work-site. There were three buildings, one near the other. The clearance was 12 cm between the buildings. There was no problem, because we had designed special flexible seals between the buildings.

YÜZÜGÜLLÜ

Leaving aside for the moment the structural behaviour, what would happen to the occupants under such large displacements, I mean if there is a strong wind?

DELFOSSE

For the occupants, as for the structural system, the main thing is acceleration. If you move slowly, you can move a long time, but if you move quickly, you fall, and it is the same thing for buildings or isolators. In our case the displacements are slow, much slower than for buildings without isolators.

HOVE

I wonder if you have studied or tested the use of friction dampers combined in series with the rubber isolators.

DELFOSSE

Dampers is the first idea you have when you work on these problems. When you consider a response spectrum you see that, if you want to have low accelerations, the main thing to do is to increase the natural period. You cannot increase the natural periods with dampers. With dampers you will decrease the amplitude in resonance but not enough to provide such results. If you want to decrease acceleration by a factor of 2, 3, 4 or more, you have to work on the natural periods, and you can increase natural periods only by using springs.

WYLLIE

I would like to bring up another comment on this displacement issue. In a major earthquake, for example in 1906 in San Francisco we had 5 to 7 meters of displacement along the San Andreas Fault. Along either side of the fault, the horizontal ground displacement had to be at least 2.5 to 3.5 meters. For a structure I design in the San Francisco area, I have to anticipate well over 1 meter of ground displacement under a building I am going to design. I have trouble seeing how the building on your isolators is going to follow that large ground displacement.

DELFOSSE

If you have so large displacements, I could say you have not to build in this area. We are working on problems in California for structural equipment and displacements as large as 1 meter and we have designed special isolators for this purpose.

MAZET

To answer questions which have been asked we have brought some photographs and a film which illustrates the use of these dampers or rubber cushions on nuclear plants. We will show you this film if you want and may be try to answer some questions.

CLOUGH

I would like to raise one caution in connection with the results that Prof. Shah's experiments demonstrated. He pointed out extremely large reductions in the forces between the case with and without the isolating devices. But in the case where there were no isolating devices, he was using a structure with a very small fraction of 1% critical damping. The isolator device increased this to may be 5% or 6%. The reduction which is shown in that case is due both to the isolation mechanism and to the increase of damping. Now in a real building, the damping without isolators is much more than a fraction of 1%. So the increase of damping in a real structure will not be as significant as you have demonstrated with Prof. Shah's designs. I think only a part of what he has demonstrated is available as an improvement in a real field condition.

DELFOSSE

I must emphasize that damping has not that effect. It seems a secondary factor in our results, as we can see in the design of typical buildings.

STRATTA

I was just thinking in terms of an earthquake which was going to last for more than a very short period. The concept that you have perhaps may work for a very short period, but it would appear that the only possible structural scheme would be to have a structural floor immediately above the units. In other words, you cannot have a lot of columns of 15 or 20 feet in height, let us say 5 meters. It must be a very short column. Whatever motion you have must certainly be a function of the vertical load on any one unit. Where you have varying vertical loads, you must have varying compensating units. That is number one. Number two as the building tends to overturn, as it tends to have lateral forces applied to the structure above, your lateral motion in each one of these begins to vary. Now if you have varying motion each one of these units is carrying different loads (remember the motion in each one of these bases must remain the same because if the motion tends to change, then your lateral concept is out of the window) so that as you have rotational overturning, as Prof. Clough was saying this morning, and you have an added vertical load, or an increased vertical load on one side and a decreased vertical load on the other side, the lateral motion would tend to be reduced, if in fact the one is the function of the other. So in an earthquake which is going to last, say, 10, 15, 20 seconds, it would appear that this lateral motion is no longer going to be consistent with the base. Have you studied this type of consideration? And what are your conclusions?

DELFOSSE

Yes we have. We are working presently on these elements. We have to do a special design for the isolators, so that we have no rocking. We must not admit rocking.

STRATTA

How do you eliminate rocking?

DELFOSSE

We eliminate rocking in designing the isolators several hundred times stiffer in the vertical sense than in the horizontal one.

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