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3D Analysis

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Hemant Vadalkar [Wednesday, January 30, 2002 7:52 PM]

Dear Friends / Colleagues / Fellow engineers,

I am happy to be with you all in this e-conference. I am putting up my thoughts for discussion. With the available software and hardware, it is possible to carry out proper 3-D analysis of the structure for Earthquake loads. Some points to be kept in mind while preparing the computer analysis model.
1) Only 3-D space frame model should be used for analysis, as 2-D (Plane frame) model can not take into account the tensional effects.
2) All the stiffness of columns, walls and beams should be correctly modeled. If required, infill walls can be modeled using diagonal members.
3) Many times, space frame analysis is carried out considering beam and column framing without accounting slab stiffness. Diaphragm action of slab in its plane should be considered in the model to ensure correct lateral load distribution in columns and shear walls.

This can be achieved in various ways.
a) Use plate elements to model slab
b) Use diagonal bracing members in plan with truss properties per slab panel.
c) Use master and slave option - User should be careful in selecting the master joint location. Each floor should have at least one master joint. Master joint should be close to centre of mass for that particular floor.

d) Provide high value of M.I. for all beams about the vertical axis considering slab as a flange.
4) Response spectrum analysis gives absolute values of forces and moments. One should be careful about the sign (+ and -) to be attached while using it in load combinations.
If you are using STAAD, the BMD for response spectrum case does not change the sign at the midspan of beam as all the values are positive. Thus, beam and column support moments can be obtained correctly by using + and - sign in load combinations but the values at midspan of beams can not be directly used in design as it is also getting added and subtracted. In reality, for lateral load case, the midspan moment in beams is nearly zero. One should be careful about it.

With thanks and regards.
Hemant Vadalkar

Dipak Shah [Thursday, January 31, 2002 7:42 PM]

Hello Friends,
Namskar

I have read the book "Three Dimensional Static and Dynamic Analysis of Structures by Dr. Edward L. Wilson, Professor Emeritus, University of California, Berkeley " & is extremely useful to understand fundamentals of Earthquake Analysis. SUMMARY in Prof. Emeritus words "After being associated with the three dimensional dynamic analysis and design of a large number of structures during the past 40 years author would like to take this opportunity to offer some constructive comments on the lateral load requirements of the current code.[UBC] First: the use of the "dynamic base shear" as a significant indication of the response of a structure may be conservative. An examination of the modal base shears and overturning moments clearly indicates that base shear associated with the shorter periods produce relatively small overturning moments. Therefore, a dynamic analysis. Which will higher mode response, will always produce a larger dynamic base shear relative to the dynamic overturning moment. Since the code allows all results to be scaled by the ratio of dynamic base shear to the static design base shear, the dynamic overturning moments can be significantly less than the results of a simple static code analysis. A scale factor based on the ration of the 'static design overturning moment" to the "dynamic overturning moment" would be far more logical. The static overturning moment can be calculated by using the static vertical distribution of the design base shear which is currently suggested in the code.

Second: for irregular structures, the use of the terminology "period (or mode shape) in the direction under consideration" must be discontinued. The stiffness and mass properties of the structure define the direction of all three dimensional mode shape.
The term "principal direction" should not be used it is clearly and uniquely defined.
Third: the scaling of the results of a dynamic analysis should be re-examined. the use of site-dependent spectra is encouraged.

Finally: it is not necessary to distinguish between regular and irregular structures when a three dimensional dynamic analysis is conducted. If an accurate three dimensional computer models is created, the vertical and horizontal irregularities and known eccentricities of stiffness and mass will cause the displacement and rotational components of the mode shapes to be coupled. A three dimensional dynamic analysis, based on these coupled mode shapes, will produce a far more complex response with larger forces than the response of a regular structure. It is possible to predict the dynamic force distribution in a very irregular structure with the same degree for a accuracy and reliability as the evaluation of the force distribution in a very regular structure. Consequently, if the design of an irregular structure is based on a realistic dynamic force distribution, three is no logical reason to expect that it will be any less earthquake resistant than a regular structure which was designed using the same dynamic loading. A reason why irregular structures have a documented record of poor performance during earthquake is that their designs were often based on approximate two dimensional static analyses.

One major advantage of the modeling method presented in this chapter is that one set of dynamic design forces, including the effects of accidental torsion, is produced with one computer run. Of greater significance, however, is the resulting structural design has equal resistance to seismic motions from all possible directions."

Bye & Good Night,
Dipak Shah

Jitendra K Bothara [Friday, February 01, 2002 12:11 AM]

Dear Sir/ Madam,

I also agree with the dangers and potential consequences expressed by Dr. S. R. Satish Kumar. Earthquake resistant design, use of powerful 3-dimentional software has become a fashion and short cut without going into the basics of the philosophy/ uncertainty associated. It seems that, the enormous approximations involved in seismic design are perhaps becoming less appreciated, rather than more, as sophisticated analytical techniques accepted into common design practice. Unfortunately, many of we are living in false faith that computer and powerful software and "accurate" analysis gives very accurate design without understanding how many rounding/ approximations are done in the loading coefficient and how much approximate we are. It might be rude to say, in our part of the world (Nepal, India etc), an engineer just graduated from a university can work as an independent design engineer and learns by making mistakes. Very few of us might have been very lucky to have supervision of seniors. Further, we do not have any system of peer review. Where as in developed world (as far as I know), they have to work under senior engineer for few years and then need to pass an exam to work as independent professional engineer.. Following is in response of Hemant Vadalkar

1) Only 3-D space frame model should be used for analysis, as 2-D (Plane frame) model can not take into account the tensional effects.
Jitendra's response: of course 3-D model analysis is useful in structures with unusual or irregular shape, it is doubtful that it produces better results than those obtained from simpler methods. The myth is that the refinement of analysis procedure produces more 'accurate' results (what about loads and changing stiffness?). Further, there is enough possibility of crept in mistakes (seeing the involvement of fresh engineers without any supervision) in

input. It is too difficult then to find them out and can lead to disaster. Where as simple systems are more in control and easy to understand. As expressed by Dr. SR Satish Kumar, I have found people who do not well understand superposition of BM due to vertical and lateral load and reversibility of lateral load, do proud they use 3-D software. I am not at all against use of computer but its misuse.

2) All the stiffness of columns, walls and beams should be correctly modeled. If required, infill walls can be modeled using diagonal members. Jitendra's response: When we say "correct" stiffness, which stiffness we are talking about: elastic or inelastic? After few 'good' shocks, members would crack, reinforcement would go stain hardening and then the member and global stiffness of the building will be quite different than the elastic one and hence the time period and structural behavior. Even if we talk of elastic regime, our stiffness calculation is based on gross section only where as it is function of section and axial load on it as well.

Following paper presents some of the fallacies of earthquake resistant design: Priestley, M. J. N., 1995, Myths and Fallacies in Earthquake Engineering-Conflict between Design and Reality, Recent Developments in Lateral Force Transfer in Buildings (Thomas Paulay Symposium), ACI, SP-157, Michigan, USA. I still think, for normal RC building few extra stirrups well anchored in core, well anchored beam/ column L-bars and other aspects of good detailing will help much more for survival of the building then "very accurate" analysis and design. I would like to listen your comments.

Regards,
Jitendra K Bothara

Dipal N. Oza [Tuesday, February 05, 2002 6:11 PM]

Dear fellow Engineers,

Firstly, I appreciate the initiative taken by NICEE and also great efforts by the organisers.

My query is related to analysis aspect of the earthquake engineering.

The case is, the analysis model consists of different materials (which has different damping coefficient values), say concrete and steel and analysis is to be carried out using Response spectrum method of modal combinations. Such a case is encountered in practice, when foundation part is also required to be modeled along with supported structure or equipment (or part of the structure is of steel and part is of concrete).

However, the analysis packages like STAAD allow use of different spectra for different directions but not the different spectra (based on damping coefficient for different) for different members.

I desire to have more information on this subject (covering following points):
1) Which industry supported and easily available standard analysis softwares can tackle this.
2) If we try to solve this problem using higher spectra values (for lower damping

coefficient), what will be the amount of conservation I shall have in my design as compared to actual values for the same structure.

Looking forward for expert views and knowledge sharing.

Thanks and regards,
Dipal N. Oza

Dipal N. Oza [Tuesday, February 05, 2002 7:38 PM]

Note: Dear Moderator,

There was a mistake in my earlier mail, whereas, response spectrum method was inadvertently mentioned as model combination method and subject referred to SRSS method instead of Response Spectrum method. You are requested to forward following corrected mail again. Inconvenience is greatly regretted.

Regards,
Dipal N. Oza

Rajendra Raut [Tuesday, February 05, 2002 1:54 PM]

Congratulations and thanks to Dr.Sh.SKJ, Dr.Sh.CVRM and organiser' e-conf, this is dream –true opportunity for discussion & made available to everyone.

Request to clear my doubts in following description.

COMPLEX STRUCTURE AND 100+30%RULE:

For complex structure Lateral design load resisting elements are at arbitrary angle(non-orthogonal) with respect to user defined system.

Various building codes recommend to apply 100% design lateral load and 30% in orthogonal directions.

The direction of Design Basis Earthquake (DBE) corresponds to MCE due to seismic motions in complex structure, which produces max. Stresses in element (sigmamax=P/A+My/Zy+Mz/Zz) at arbitrary angle using 100+30% rule with user reference system.

This rule 100+30% does it happens to underestimate design forces with user reference system?

How to achieve resistance of structure for DBE in complex structures and study effect of rational design forces generated at arbitrary elements?

I would like to know, implementation of 100+30% rule with SRSS & CQC methods in arbitrary reference system for various modal combinations.

Regards
RAJENDRA RAUT

N. Subramanian [Tuesday, February 05, 2002 7:55 PM]

I would like to appreciate Prof. S. K. Jain and his team for organising this novel e-conferences on this important topic. I have been following most of the emails and find them to be educative, informative and interesting. I have the following points to make.

1. While analysing moment resisting frames, many designers assume that the column is fixed at the top of individual footings. This assumption is valid only for column supported on rigid raft foundation or on individual footings supported by short stiff piles or by basement walls. Foundation supported on deformable soil may have (ex. clay, soft loose sand) considerable rotational flexibility, resulting in column moments in the bottom storey quite different from those resulting from the assumption of a rigid base. In such cases, column base should be modelled by a rotational spring of flexural stiffness KF= KS*IF where KS is the vertical coefficient of subgrade modulus and IF is the second moment of area of the foundation pad. Of course, the safe assumption will be to assume the column as pinned. I would like to know whether any work has been done on the effect of this assumption on the earthquake safety of the building.

2. In many developed countries, soil-structure interaction is taken into account in the analysis by means of horizontal and vertical springs. What will be the effect on the structure, if we don't consider soil structure interaction?

3. Even though we specify ties at column-beam junction, most of the builders do not execute them in practice saying that it is very difficult to implement. We even suggested them to provide 2 U bars which can be tied together. How best it can be implemented in practice? Any suggestion?

4. The American Society of civil Engineers is in the process of bringing out a guideline for the dynamic analysis of latticed antenna towers. It gives details about the earthquake design of such towers.

Dr. N. Subramanian

Stewart Gallocher [Tuesday, February 05, 2002 9:05 PM]

Dear Dipal,

Since you are using a Response Spectrum Method the fundamental mode(s) will probably have steel and concrete members associated with the deformation. Therefore you will probably need to look at using 'Composite Modal Damping' (Try a standard text for information) This method allows the damping level to adjusted for the fundamental modes to be somewhere in between the steel and concrete values - depending on the mode shape. You will also need the damping matrix. Once you calculated the damping value for each mode you will need to create a input spectra with a damping level that varies across the entire frequency range with different levels of damping at each modal frequency. You will also need to know how to generate intermediate values between the steel and concrete Spectra. Seems like a lot of effort.

I'm not sure which packages directly implement this procedure - it may only be packages such as ANSYS and ABACUS. Hope this assists.
Regards
Stewart Gallocher

A.D. Roshan [Wednesday, February 06, 2002 2:32 PM]

This is in response to Mr Dipal N. Oza's mail.

For structures or structural systems that consist of major substructures or components with different damping characteristics composite modal damping values are used (Ref. Cl. 3.1.5.4 of American Society of Civil Engineers Standard 4-98, Seismic Analysis of Safety Related Nuclear Structures and Commentary)

For calculating modal damping value corresponding to jth mode, lamda(j) = phi(j)T * {for i=1 to N, SIGMA [lamda(i)*[k](i)]} phi(j) / omega(j)^2.

where,
phi(j) is the vector corresponding to jth mode shape, normalised with respect to mass matrix, so that (phi)T[M](phi) = [I] lamda(i) is the damping ratio corresponding to ith material/subsystem
[k](i) is the stiffness matrix corresponding to ith material/subsystem omega(j) is the natural circular frequency of jth mode,

This method may be used as long as the resulting lamda (j) is less than 20% critical. The solution of problems where soil structure effects are significant, this method can lead to erroneous results. This 20% cutoff is to prevent under prediction of the response in such cases.
with regards
Roshan A.D.

Anand Ghaisas [Wednesday, February 06, 2002 4:05 PM]

Dear Dipal:

Your problem regarding evaluation of Response of model with two different materials is very common in industrial structures. You may go for a modal damping kind of solution. For this of course you have to resort to use of general purpose FEA package such as ANSYS. Even STARDYNE solution engine of STAADPro may be useful. Using a general purpose package would also be useful to understand node wise mass distribution in different modes and will give a full picture on mass participation, missing mass etc. As a caution you may work out simplified models (Ball-stick type) for comparison to ensure correctness of the FULL FE model.

You may as well go for stage wise Modal Analysis (assuming your steel structure modes are quite flexible as compared to Rigid modes of Concrete) using spectra for different damping. However this will mean that you need to post process the two STAAD runs externally.

Alternatively you may go for a sub-structure analysis if the sub-structuring criteria such as those given by ASCE special publication on Seismic Design of Petrochemical Facilities are satisfied.

The simplest way is to go for a response spectrum with fixed combined damping (which would be obviously in between the two damping.) The value of this damping may be estimated based on the Total Mass proportions of the two materials. With a good engineering judgment on this value you will be well within the desired accuracy.

With Best Wishes
Anand Ghaisas

S.P. Srinivasan [Thursday, February 07, 2002 2:02 PM]

Hello everybody

I agree with Dr. N. Subramaniam that we will get a truer picture of the frame behavior if soil below the footings is suitably idealized using springs.

However I wish to point out that during the 1967 earthquake at Caracas, Venezuela, multistoried buildings at one end of the city suffered severe damage, including some collapses, whereas the multistoried buildings at the other end of the city suffered much less damage. The only difference was in the thickness of soil layer at the two locations. This indicates that to obtain a correct understanding of building behaviour, the entire soil layer below the foundation has to be modelled in the analysis. How can this be done?

Regards
S.P.Srinivasan
