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Comments and Reply

Dr. D.K. Paul, Deptt. of Earthquake Engg.,University of Roorkee, Roorkee raised some Comments on the paper entitled "Nonlinear Seismic Response of Reinforced Concrete Stack Like Structures" by Dr. Manoj K. Maiti and Dr. Alok Goyal, Deptt. of Civil Engg.,IIT, Bombay (published in ISET Bulletin Vo. 33 No. 2, pp. 195-213). The Comments and replies of the authors are published here for the sake of interested readers.

Comment

The claim in the conclusion that r.c.c. stack can sustain a severe strong ground motion without total collapse is possibly due to the deficiency in numerical modeling of the chimney itself. If a section of a cantilever structure undergo yielding under reversal type of loading, then the section should behave like a hinge. A cantilever structure supported on hinge is an unstable system and analysis should be able to capture this in numerical modeling.

Authors' Reply

In the present formulation, each strip of concrete and each bar of reinforcement is idealized separately. Yielding of a reinforcing bar at a section does not mean that the plastic hinge has formed at that section and the entire structure is unstable For plastic hinge formation, a significant part of the section should yield, otherwise the system remains stable.

Comment

The modeling of the chimney by beam elements seem to be inadequate for otherwise very sophisticated analysis. Shell elements should have been preferred over the beam elements in order to capture better nonlinear behaviour under radial, circumferential and axial stresses.

Authors' Reply

Because of large height to diameter ratio in chimneys (H/D > 12), the bending behaviour is dominant and section deformations are negligible. The design procedures for reinforced concrete chimneys are based on shear force and bending moments, and not on radial and circumferential stresses. The circumferential stresses are important in steel chimneys where failure is due to local buckling. The authors are not aware of references where shell elements have been used for the analysis and design of reinforced concrete chimneys, and beam elements have not been found to be suitable.

Comment

The assumption that failure of stack is due to crushing of concrete only and not also due to buckling (buckling of exposed steel after the concrete crushes) is not appropriate and it is one of the limitation of modeling which can also be attributed for not able to capture the mechanism.

Authors' Reply

The concept of closely spaced stirrups in earthquake resistant design and detailing is to avoid premature buckling of reinforcing bars and to provide confinement so that sufficient curvature ductility is available. Kindly refer to the following statement of the paper (Pg. 196) :
"The stack cross-sections are provided with two rings of longitudinal reinforcements and cages of circumferential reinforcement placed near both the inside and outside faces of the section (Fig. 1). It is assumed that **the bar sizes and spacing of circumferential steel, selected in detailing,** are appropriate 1) to prevent premature buckling of the longitudinal reinforcement, and 2) to provide sufficient shear resistance so that the collapse of the stack is due to crushing of concrete in primary stress arising from axial load and flexure."

Comment

The cross-section of the structure will be subjected to compressive and tensile stresses under the action of alternating bending moment. How the modeling of reinforced concrete under tensile stress has been considered ? The detail is not available in the paper. Figure 3 only shows stress-strain relationship under compressive forces only.

Authors' Reply

"Concrete is assumed to have no tensile strength" (Pg 200 after equation (8)).

Comment

How the once yielded section is modeled under compressive and tensile forces ? How the progressive yielding of the section is taken into account under sustained earthquake loading ? It is important to evaluate the ductility requirement of the yielded zones to see whether the required ductility can be really achieved or not.

Authors' Reply

"For evaluating the element matrices the cross-section is discretized into a number of strips parallel to the neutral axis (Fig. 2). For each strip of concrete, stress at any instant of time is computed according to the strain at the centroid of the strip using the cyclic stress-strain relationship of concrete. Similarly, each reinforcing bar is idealized independently and the stress in each reinforcing bar is computed according to the strain at its centroid using the cyclic stress-strain curve for reinforcing steel". (Pg. 200 after equation (7)).

Based on the current state of stress in a section, the force displacement relationships are established at each instant of time. For analysis, it is assumed that the sections have sufficient curvature ductility. However, the final objective is to evaluate the actual seismic resistance of reinforced concrete stacks in terms of overall displacement ductility factors, and what will the curvature ductility factor demand. This part of the work has been accepted for publication in the Journal of Earthquake Engineering & Structural Dynamics, and is likely to appear in June 1997.

Comment

The importance of geometric non-linearity on the response evaluation of chimney is not highlighted. How important is the contribution of geometric nonlinearity in the total response of chimney ?

Authors' Reply

The effects of geometric nonlinearity in the response evaluation of chimneys have been included in the analysis. The effects were found to be small, and their importance in the response is only of academic interest. The developed procedure is not intended for practicing engineers for the design of a chimney, but to evolve simplified code procedures and their evaluation.

Comment

What is the maximum compressive strain for concrete that has been taken for the F_c factor. The value of F_c is not reported.

Authors' Reply

The value of F_c is a function of ε_{cm} [Equation (9)] the maximum compressive strain attained at each intant of time. ε_{cm} varies between ε_{cy} and ε_{cu}

Comment

The value of $\varepsilon_{cu} = 0.005$ has been taken in the numerical example (page 12). Normally for concrete this value ranges from 0.0035 to 0.004. This may also be the reason that the chimney does not show the mechanism. The value of $\varepsilon_{su} = 0.0$ is grossly unrealistic (page 14). This means there is no ductility available in the steel which is contrary to the conclusion drawn that the stack can be designed for ductile behaviour.

Authors' Reply

"The linear softening branch is defined by an ultimate compressive strain ε_{cu} and a corresponding stress of 0.2 σ_{cy} ". on (page 200 after equation (8)).

The strains in concrete are limited to values of 0.0035 or 0.004 when the corresponding stress is taken 0.446 σ_{cy} , for example in IS 456-1978. This is well documented that concrete can sustain strains higher than 0.005 but only at lower stress level. The authors are grateful to Prof. Paul for pointing out the typographical mistake. The value of ε_{su} = 0.1 has been taken and not 0.0.

Comment

First three deformed shapes do not agree with the following statement. "The displaced shape of the stack at different instants of time (where maximum top displacement occurs) have been plotted in Fig. 7 along with ground displacement at each instant" (page 208).

Authors' Reply

The maximum top displacement occurs only at one instant of time (t = 4.7 sec.). The other displaced shapes have been presented only to demonstrate how the response builds up, and how the system recovers even after partial yielding of the reinforcement (or section).