## Summary

## Seismic behaviour of frame structures with unilateral contact conditions

Zervas, P.A., Dipl. Eng.

In the present dissertation the dynamic behaviour of frame structures with unilateral contact conditions is studied. The unilateral contact problem arises when a deformable body is in "ambiguous" contact with a rigid or a deformable support or with another body. The term "ambiguous" means that we do not know a priori which parts of the bodies are in contact, since tensile stresses cannot be transmitted between the bodies and thus the bodies may separate form one another at some parts of the boundaries, under dynamic loading.

This non-linear phenomenon is very important considering the seismic response of structures with unilateral contact conditions between the structure and the ground, if we take into account the possibility of partial uplift of the foundation from the soil. The dynamic response of a structure supported on soil is usually assumed to be the same with the response of a, similarly excited, identical structure firmly bonded to a perfectly rigid soil. For two main reasons, this common simplification may lead to significant errors: a) Most soils are not very stiff and b) actual structures are held in contact with the ground by the force of gravity and not by an adhesive bond. The first sourse of error has been reduced by taking into account foundation flexibility. But the acceptance of a structure firmly bonded with the ground, consider the soil to behave equally in tension and compression. By contrast the soils are capable of supporting compressive stresses but have negligible tensile strength. The base overturning moments of some structures, during strong ground motions may be large enough to cause partial separation (lift-off) from the foundation. This transient uplifting response is highly nonlinear, since changes of the external loadings are not accompanied by proportional changes in other variables.

For the solution of the examined problem, spatial finite element discretization, and also temporal discretization are used. For each time step an elimination technique of the internal degrees of freedom gives rise to a minimum quadratic programming (q.p.) problem on the boundary with respect to the unknown unilateral displacements of the time step under consideration.

The dissertation is divided into six chapters.

In the first chapter the problem is posed and the object of the investigation is explained.

The second chapter includes brief bibliographic reference into papers dealing, firstly, with the dynamic unilateral contact problem for structures supported on soil, secondly, with the general problem of dynamic unilateral contact between elastic bodies, and, finally, with other classes of inequality problems.

In the third chapter a numerical method is presented for the solution of the dynamic unilateral contact-impact problem, between elastic bodies. First a space discretization takes place. Then a time discretization is applied. The implicit and unconditionally stable algorithm proposed by Zienckiewicz, Wood and Taylor [Zie], is used. The unknown unilateral relative displacements are assumed as imposed dislocations on the "unilateral" boundary. Using the "equivalent structural system" the problem is reduced to a quadratic programming problem. A method is presented of imposing the constrained displacements on the boundary, and the numerical calculation of the influence matrix, using Lagrange multipliers. The impact between structure and soil at the contact area is taken into account. Thus for every time step we solve a quadratic programming problem, only for a small number of "unilateral" relative displacements on the boundary. This method can be used for the study of seismic response of actual 3D-structures, with unilateral contact conditions.

In the next chapter the finite element program UniDyn is presented. This program was developed during the elaboration of the dissertation, scoping to realize the numerical method, which was analysed in the previous chapter. We refer to the program capabilities and give logical diagrams and critical information for the program operations. Program UniDyn has the capability to solve 3D-structures, with dynamic excitation, independently of the number of degrees of freedom and the number of the "unilateral" displacements on the soil-structure interface.

In the fifth chapter we present the results from parametric analysis of 2D and 3D-structures with unilateral and bilateral contact conditions. The analysis was performed with the program UniDyn. Firstly, we give general information for the way of imposing unilateral contact conditions, the data of structures and the characteristics of excitations. After that we refer to the common characteristics of all models (time step, damping, impact, convergence of the q.p.p. algorithm). Finally, the results of the parametric analysis are presented in individual sub-chapters.

In chapter six we summarize the conclusions which resulted from the dynamic analysis. It is clear that the structures with unilateral contact conditions, if partial uplift occurs during the dynamic excitation, take special dynamic characteristics, and the responce values could dramatically change from the responce values of the bilateral structures.