Referências bibliográficas

Alarcon-Guzman, A.; Leonards, G.A.; Chameau, J.L. Undrained monotonic and cyclic strength of sand, **Journal of the Geotechnical Engineering Division**, **ASCE**, volume 114, n. 10, p. 1089-1108, 1988.

Alonso, E.E.; Gens, A.; Hight D.W. Special problems of soil: general report, Proc. 9th Euro. **Conf. Int. Soc. Soil Mech. Found. Eng.**, Dublin, 1987.

Alonso, E.E.; Gens, A.; Josa A. A constitutive model for partially saturated soils. **Géotechnique**, n. 40, volume 3, p. 405–30, 1990.

Al-Tabbaa, A.; Wood, D.M. An experimentally based 'bubble' model for clay. Numerical Methods in Geomechanics NUMOG III, Pietruszczak, S. and Pande, G.N., (Eds.), **Elsevier Applied Science**, Amsterdam, p. 91-99, 1989.

Andersen, A.; Bjerrum, L. Slides in Subaqueous slopes in loose sand and silty, Publication 81, **Norwegian Geotechnical Institute**, Oslo, p. 1-9, 1968.

Andrews, D.C.A.; Martin, G.R. Criteria for Liquefaction of Silty Soils, Proceedings, **12th World Conference on Earthquake Engineering**, Auckland, New Zealand, 2000.

Astarita, G.; Marrucci, G. Principles of Non-Newtonian Fluid Mechanics, **McGraw-Hill**, Great Britain, 1974.

Aubry, D.; Hujeux, J.C.; Lassoudi, F.; Meimon, Y. A double Memory Model with Multiple Mechanisms for Cyclic Soil Behaviour. Int. Symp. Num. Models in Geomechanics, Dungar, R.; Pande, G. N.; Studer, J. A. (Eds.), **Balkema**, Rotterdam, 1982.

Bahda, F.; Pastor, M.; Saiita, A. A double hardening model based on generalized plasticity and state parameters for cyclic loading of sands. In K. Pietruszczak; Pande (Eds.), Numerical Models in Geomechanics, **Balkema**, Rotterdam, 1997.

Bardet, J.P. Hypoplastic model for sands, **Journal of Engineering Mechanics Division**, **ASCE**, volume 116, n. 9, p. 1973-1994, 1990.

Bastian, P. Numerical Computation of Multiphase Flows in Porous Media, **Habilitationsschrift**, Christian-Albrechts-Universität zu Kiel, 1999.

Bathe, K.J. Finite element procedures, **Prentice-Hall International Editions**, New Jersey, 1996.

Bazant, Z.P.; Krizet, R.J. Endochronic Constitutive Law for Liquefaction of Sand, **Journal of Engineering Mechanics Division**, **ASCE**, volume 102, n. EM2, p. 225-238, 1976.

Bear, J. Dynamic of fluids in porous media, **Dover publications Inc**., New York, 1972.

Bear, J.; Bachmat, Y. Introduction to Modeling of Transport Phenomena in Porous Media, **Kluwer Academic Publishers**, 1991.

Bear, J.; Corapcioglu, M.Y.; Balakrishna, J. Modeling of centrifugal filtration in unsaturated deformable porous media, **Adv. Water Resour**., volume 7, p. 150-167, 1984.

Beaty, M.H.; Byrne, P.M. An effective stress model for predicting liquefaction behavior of sand. Proc., Specialty Conf., Geotechnical Earthquake Engineering and Soil Dynamics III, Seatle, **ASCE** G.S.P No. 75, volume 1, 766-777, 1998.

Been, K.; Crooks, J.H.A.; Becker, D.E.; Jefferies, M.G. The Cone penetration test in sands, Part I: States parameter interpretation, **Géotechnique**, volume 36, n. 2, p. 239-249, 1986.

Been, K.; Jefferies, M.G. A state parameter for sands, **Géotechnique**, volume 35, n. 2, p. 99-112, 1985.

Been, K.; Jefferies, M.G.; Crooks, J.H.A.; Rothenburg, L. The Cone penetration test in sands, Part II: General inference of states, **Géotechnique**, volume 37, n. 3, p. 285-300, 1987.

Been, K.; Jefferies, M.G.; Hachey, J. The critical state of sands, **Géotechnique**, volume 41, n. 3, p. 365-381, 1991.

Biot, M.A. Theory of elasticity and consolidation for a porous anisotropic solid, **Journal of Applied Physics**, volume 26, p. 182-185, 1955.

Biot, M.A. Theory of propagation of elastic waves in a fluid saturated porous solid, Part I, Low-Frequency range, **Journal of the Acoustical Society of America**, volume 28, n. 2, p. 168-178, 1956a.

Biot, M.A. Theory of propagation of elastic waves in a fluid saturated porous solid, Part II, Higher-Frequency range, **Journal of the Acoustical Society of America**, volume 28, n. 2, p. 179-191, 1956b.

Bird, R.B.; Stewart, W.E.; Lightfoot, E.N. Transport Phenomena, Second Editions, **Wiley**, New York, 2002.

Bishop, A.W.; Blight G.E. Some aspects of effective stress in saturated and partially saturated soils, **Geotechnique**, volume 13, p.177–97, 1963.

Bjerrum, L. Subaqueous Slope Failures in Norwegian fjords, Publication 88, **Norwegian Geotechnical Institute**, Oslo, 1971.

Blázquez, R.; López-Querol, S. Generalized densification law for dry sand subjected to dynamic loading, **Soil dynamics and Earthquake Engineering**, p.888-898, 2006.

Blázquez, R.; Krizek, R.; Bazant, Z. Site dactors controlling liquefaction. **Journal of the Geotechnical Engineering Division**, p. 785-801, 1980.

Bolzon, G.; Schrefler, B.A.; Zienkiewicz, O.C. Elastoplastic soil constitutive laws generalized to partially saturated states, **Geotechnique**, 46, p. 279-89, 1996.

Boukpeti, N.; Drescher, A. Triaxial behavior of refined Superior sand model, **Computers Geotechnics**, volume 26, p. 65-81, 2000.

Bray, J.D.; Augello A.J.; Leonards G.A.; Repetto P.C.; Byrne, R.J. Seismic stability procedures for solid-waste landfills, **International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts**, volume 32, n. 8, 1995.

Bray, J.D.; Sancio, R.B.; Durgunoglu, H.T.; Onalp, A.; Seed, R.B.; Stewart, J.P.; Youd, T.L.; Baturay, M.L.; Cetin, K. O.; Christensen, C.; Karadayilar, T.; Emrem, C. Ground Failure, In: Adapazari, Proceedings of **Earthquake Geotechnical Engineering Satellite Conference of the XVth International Conference on Soil Mechanics & Geotechnical Engineering**, Istanbul, Turkey, August 24-25, 2001.

Broms, B.; Bennermark, H. Free discussion, Proceeding, Geotechnical Conference, volume 2, Oslo, Norway, p. 118-120, 1967.

Byrne, P.M. **Earthquake Induced Damage Mitigation from Soil Liquefaction**. Project Web Site: < http://www.civil.ubc.ca/liquefaction/ >. Acceso em: 2005.

Byrne, P.M.; Roy, D.; Campanella, R.G.; Hughes, J. Predicting liquefaction response of granular soils from pressuremeter tests. In Static and Dynamic Properties of Gravelly Soils: Proceedings of the ASCE National Convention, San Diego, Calif., 23–27 Oct. 1995. Edited by M.D. Evans and R.J. Fragaszy. American Society of Civil Engineers, **Geotechnical Special Publication**, volume 56, pp. 122–135, 1995.

Byrne, P.M.; Seid-Karbasi, M. Seismic Stability of Impoundments, **17th Annual Symposium**, VGS, 2003.

Cárdenas, J.L. Estudo de Modelos Constitutivos para Previsão da Liquefação em Solos sob Carregamento Monotônico. **Dissertação de mestrado**, PUC-Rio, Departamento de Engenharia Civil, 2004.

Cárdenas, J.L.; Fontoura, A.B.; Romanel, C. Um modelo constitutivo hiperbólico para simulação da liquefação estática de solos. In: **XXV Iberian Latin-American Congress on Computational Methods in Engineering**, Recife, 2004.

Carter, J.P.; Booker, J.R.; Wroth, C.P. A Critical State Soil Model for Cyclic Loading. Soil Mechanic - Transient and Cyclic Load, Pande G. N.; Zienkiewicz, O. C. (Eds.), J. **Wiley** & Sons Ltd., p. 219-252, 1982.

Carter, D.P.; Seed, H.B. Liquefaction potential of sand deposits under low levels of excitation, Report UCB/EERC-88/11, **Earthquake Engineering Research Center**, University of California, Berkeley, 309 p., 1988.

Casagrande, A. Characteristic of Cohesionless Soils Affecting the Stability of Slope and Earth Fill, **Journal of the Boston Society of Civil Engineering**, January, p. 13-32, 1936.

Casagrande, A. Liquefaction and Cyclic deformation of Sands - A critical review, Proceeding: **5th Pan-American Conference on Soil Mechanics and Foundation Engineering**, Buenos Aires, Argentina, 1975.

Casagrande, A. On Liquefaction Phenomena, **Geotechnique**, volume XXI, n. 3, p. 197-202, 1971.

Castro, G. Liquefaction and cyclic mobility of saturated sand, **Journal of the Geotechnical Engineering Division**, **ASCE**, volume 101, p. 501-569, 1975.

Castro, G. Liquefaction of sand, **Harvard Soil Mechanic Series 87**, Harvard University, Cambridge, Massachusetts, 1969.

Castro, G.; Poulos, S.J. Factors affecting Liquefaction and Cyclic Mobility, **Journal of the Geotechnical Engineering Division**, ASCE, volume 103, p. 501-516, 1977.

Chan, A.H.C. A Unified Finite Element Solution to Static and Dynamic Geomechanics Problems. **Ph. D. Thesis**, University College of Swansea, 1988.

Chan, A.H.C. User Manual for DIANA SWANDYNE-II, School of Civil Engineering, **University of Birmingham**, December, 1995.

Chan, A.H.C.; Famiyesin O.O.; Wood D.M. A Fully Explicit u-w Scheme for Dynamic Soil and Pore Fluid Interaction, **APCOM Hong Kong**, 11-13 Dec., 1, 881-887, 1991.

Chang, K.T. An Analysis of Damage of Slope Sliding by Earthquake on the Paiho Main Dam and its Earthquake Strengthening. Tseng-Hua Design Section. **Dept. of Earthquake Resistant design and Flood Control Command of Miyna Reservoir**, Peoples Republic of China, 1978.

Chen, Z.; Huan G.; Ma, Y. Computational Methods for Multiphase Flows in Porous Media, **Sian**, 2006.

Chopra, A.K. Earthquake Response of Earth Dams, **Journal of the Soil Mechanics and Foundation Division**, **ASCE**, volume 93, n. SM2, March 1967.

Clough, R.W.; Chopra, A.K. Earthquake Stress Analysis in Earth Dams, **Journal of the Engineering Mechanical Division**, **ASCE**, volume 92, n. EM2, p. 197-212, April 1966.

Collins, I.F.; Kelly, P.A. A thermomechanical analysis of a family of soil models, **Geotechnique**, volume 52, n. 7, p. 507-518, 2002.

Conlon, R. Landslides at Toulnustouc River, Quebec, **Canadian Geotechnical Journal**, volume 3, n. 3, p. 113-144, 1966.

Cook, R.; Malkus, D.; Plesha, M. Concepts and applications of finite element analysis, Third Edition, **Wiley**, New York, 1989.

Cornforth, D.H.; Worth, E.G.; Wright, W.L. Observation and analysis of a flow slide in sand fill, In British Geotechnical Society, Field Instrumentation in Geotechnical Engineering, **Wiley**, New York, p. 136-151, 1975.

Coulter, M.; Migliaccio, L. Effects of the Earthquakes of March 27, 1964 at Valdez, Alaska. Professional paper 542-C, **U.S. Geological Survey**, U.S. Department of the interior, Washington, D. C., 1966.

Cuéllar,V. Rearrangement measure theory applied to dynamic behavior of sand, **Ph.D. dissertation**, Civil Engineering Department, Northwestern University, Evanston, Illinois, 1974.

Cuéllar, V.; Bazant, Z.P.; Krizek, R.J.; Silver, M.L. Densification and Hysteresis of Sand under Cyclic Shear, **Journal of the Geotechnical Engineering Division**, **ASCE**, volume 103, n. GT5, p. 399-416, 1977.

Cundall, P.A.; Board, M. A MicroComputer Program for Modeling LargeStrain Plasticity Problems, Proceedings, **6th International Conference on Numerical Methods in Geomechanics**, Innsbruck Austria, p. 2101-2108, April, 1988.

Dafalias, Y.F.; Hermann, L.R. Bounding surface plasticity. II: Application to isotropic cohesive soils, **Journal of Engineering Mechanics**, volume 112, n. 12, p. 1263-1291, 1986.

Dafalias, Y.F.; Popov, E.P. Model of nonlinearly hardening materials for complex loading. **Acta Mechanica**, volume 21, n. 3, p. 173-192, 1975.

Darcy, H. Les Fontaines Publiques de la Ville de Dijon, **Dalmont**, Paris, 1856.

Darve, F.; Dendani, H. An incrementally non-linear constitutive relation and its predictions. In Saada & Biachini (Eds.), Proceeding of the International Workshop on Constitutive Equations for Granular Non-Cohesive Soils, p.237-254, **Balkema**, Rotterdam, 1988.

Darve, F.; Dendani, H.; Chau, B. Different classes of constitutive equations and their characteristics. In Saada & Biachini (Eds.), Proceedings of the International Workshop on Constitutive Equations for Granular Non-Cohesive Soils, p. 11-17, **Balkema**, Rotterdam, 1988.

Di Prisco, C.; Nova, R.; Lanier, J. A Mixed Isotropic Kinematic Hardening Constitutive Law for Sand. Modern Approaches to Plasticity, Kolymbras, D. (Ed.), **Balkema**, Rotterdam, p. 83-124, 1993.

Dibaj, M.; Penzien, J. Dynamic Response of Earth Dams to Traveling Seismic Waves, Report Nº. TE-67-3, **Soil Mechanics and Bituminous Materials Research Laboratory**, University of California, Berkeley, California, Aug. 1967a.

Dibaj, M.; Penzien, J. Nonlinear seismic response of earth structures, Report No. EERC-69/2, **Earthquake Engineering Research Center**, University of California, Berkeley, 1969.

Douglas, B.J.; Olsen, R.S. Soil classification using electric cone penetrometer, Cone Penetration Testing and Experience, Proceedings: **ASCE National Convention, American Society of Civil Engineers**, p. 209-227, St. Louis, 1981.

Drnevich, V.P. Effect of strain on the dynamic properties of sand, **Ph. D. Thesis**, **University of Michigan**, Ann arbor, Michigan, 1967.

Drucker, D. A more fundamental Approach to Plastic Stress-Strain Relations. **1st U.S. Congress of Applied Mechanics**, New York: ASME, p.487-491, 1952.

Drucker, D.; Prager, W. Soil mechanics and Plastic analysis or limit design, **Quartterly Applied Mathematic**, volume 10, p. 57–165, 1952.

Durham, G.N.; Townsend F.C. Effect of Relative Density on the Liquefaction Susceptibility of a fine sand under Controlled-Stress Loading, Evaluation of relative density and its role in geotechnical projects involving Cohesionless soils, Proceeding: 75th annual Meeting American Society for Testing and Materials, Los Angeles, California, 25-30 June 1972, **ASTM Special Technical Publication 523**, Selig E.T & Ladd R.S. (Eds.), Baltimore, 1973.

Eckersley, J.D. Flowslides in stockpiled coal, **Engineering Geology**, volume, 22, p. 13-22, 1985.

Evans, M.D.; Seed, H.B. Undrained Cyclic Triaxial testing of gravels: the effect of membrane compliance, Repot UBS/EERC-87/08, **Earthquake Engineering Research Center**, University of California, Berkeley, 1987.

Fellenius, B. The landslide at Guntorp, **Géotechnique**, volume 5, n. 1, p. 120-125, 1953.

Finn, W.D.L. Evaluation of Liquefaction Potential, **Soil Dynamics and Geotechnical Earthquake Engineering**, Seco e Pinto (Ed.), Balkema, p.127-157, 1993.

Finn, W.D.L.; Khanna, J. Dynamic Response of Earth Dams, Transactions, **Ninth International Congress on Large Dams**, volume IV, Istanbul, 1967.

Finn, W.D.L.; Ledbetter, R.H.; Wu, G. Liquefaction in silty soils: design and analysis, ground failures under seismic conditions, **Geotechnical Special Publication**, volume 44, ASCE, New York, p. 51-76, 1994.

Finn, W.D.L.; Lee M.K.W.; Martin G.R. An effective stress model for liquefaction, **Journal of the Geotechnical Engineering Division**, **ASCE**, volume 103, n. GT6, p.517-33, 1977.

Finn, W.D.L.; Yogendrakumar, M. TARA3FL: Program for Analysis of Liquefaction Induced Flow Deformations, **Department of Civil Engineering**, University of British Columbia, Canada, 1989.

Finn, W.D.L.; Yogendrakumar, M.; Yoshida, N.; Yoshida, H. TARA-3: A program to compute the response of 2-D embankments and soil-structure interaction systems to seismic loadings, Department of Civil Engineering, **University of British Columbia**, Canada, 1986.

Fox, R.W.; McDonald, A.T. Introdução à Mecânica dos Fluidos, **LTC**, Rio de Janeiro, 2001.

Frossard, E. Une equation d’ecoulement simple pour less materiaux granularies, **Géotechnique**, volume 33, n. 1, p. 21-29, 1983.

Fukutake, K.; Ohtsuki, A. Three-dimensional liquefaction analysis of partially improved ground. Proceedings of the **First International Conference on Earthquake Geotechnical Engineering**. Japan, p. 863–68, 1995.

Gazetas, G.; Dakoulas P. Seismic Analysis and Design of Rockfill Dams: State of the Art", **Soil Dynamics & Earthquake Engineering**, volume 11, n. 1, p. 27-61, 1992.

Ghaboussi, J.; Momen, H. Plasticity model for cyclic behavior of sands, Proceedings, **3rd International Conference on Numerical Methods in Geomechanics**, Aache, volume, 1, p. 423-434, 1979.

Ghaboussi, J.; Momen, H. Modeling and Analysis of Cyclic Behavior of Sands. Soil Mechanic - Transient and Cyclic Load. Pande G. N.; Zienkiewicz, O. C. (Eds.), **J. Wiley & Sons Ltd**., p. 313-342, 1982.

Ghaboussi, J.; Wilson, E. Variational formulation of dynamics of fluid-saturated porous elastic solids, **Journal Engineering Mechanics Division**, volume 98, p. 947-963, 1972.

Gudehus, G. A comprehensive constitutive equation for granular materials. **Soils and Foundations**, volume 36, n. 1, p. 1-12, 1996.

Gutierrez, M.; Verdugo, R. Analysis of flow and liquefaction of sand via a simple model, Earthquake Geotechnical Engineering. In: Ishihara, K. (Ed.), **Balkema**, Rotterdam, p. 893-898, 1995.

Haigh, S. Class A prediction of centrifuge test 1, Mitigation of damage from soil liquefaction, **Cambridge University**, UK, February 14, 2002.

Hanzawa, H.; Itoh, Y.; Suzuki, K. Shear characteristics of a quick sand in the Arabian Gulf. **Soil and Foundation**, volume 19, n. 4, p. 2071-2095, 1979.

Hardy, S. The implementation and application of dynamic finite element analysis to geotechnical problems, **Ph. D. Thesis**, **Imperial College**, London. 2003.

Hashiguchi, K. Subloading surface model in unconventional plasticity, **International Journal of Solids and Structures**, volume 25, n. 8, p. 917-945, 1989.

Hashiguchi, K.; Ueno, M. Elastoplastic constitutive laws of granular materials. Constitutive equations of Soils, Proceeding, **9 International Conference on Soil Mechanics and Foundation engineering**. Special Session 9, JSSMFE, Muruyama, S., Schofield, A.N. (Eds.), Tokyo, p. 73-82, 1977.

Hazen, A. Hydraulic Fill Dams. **ASCE Transactions**, volume 83, p. 1713-1745, 1920.

Herle, I.; Gudehus, G. Determination of parameters of a hypoplastic constitutive model from properties of grain assemblies, **Mechanics of cohesive frictional materials**, volume 4, n. 5, p.461-486, 1999.

Hinton, E.; Rock, T.; Zienkiewicz, O.C. A note on mass lumping and related processes in the finite element method, **Earthquake Engineering and Structures Dynamics**, volume 4, p. 245–249, 1976.

Hirai, H. An Elastoplastic Constitutive Model for Cyclic Behaviour of Sands, **International Journal for Numerical and Analytical Methods in Geomechanics**, volume 11, p. 503-520, 1987.

Hryciw, R.D.; Vitton, S.; Thomann, T.G. Liquefaction and flow failure during seismic exploration, **Journal of the Geotechnical Engineering Division**, **ASCE**, volume 116, n.12, p. 1881-1889, 1990.

Huang, M.; Zienkiewicz, O.C. New unconditionally stable staggered solution procedures for coupled soil-pore fluid dynamic problems. **Int J Numer Meth Eng**, volume 43, p. 1029–52, 1998.

Hudson, M., Idriss, I.M., Beikae, M. QUAD4M: A computer program to evaluate the seismic response of soil structures using finite element procedures and incorporating a compliant base, **Center for Geotechnical Modeling**, University of California, Davis, 1994.

Hughes, T.J.R. The Finite Element Method – Linear static and dynamic finite element analysis, **Prentice-Hall International Editions**, 1987.

Hughes, T.J.R.; Belytschko, T. A Précis of Developments in Computational Methods for Transient Analysis, **Journal of Applied Mechanics**, volume 50, p.1033-1041, 1983.

Hyodo, M.; Tanimizu, H.; Yasufuku, N.; Murata, H. Undrained cyclic and monotonic triaxial behaviour of saturated loose sand, **Soils and Foundations**, volume 34, n. 1, p. 19-32, 1994.

Idriss, I.M. Finite Element Analysis for the Seismic Response of Earth Banks, **Journal of the Soil Mechanics and Foundation Division**, **ASCE**, volume 94, n. SM3, p. 617-636, May 1968.

Idriss, I.M.; Lysmer, J.; Hwang, R.; Seed, H.B. QUAD-4: A Computer Program for Evaluating the Seismic Response of Soil Structures by Variable Damping Finite Element Procedures, Report No. EERC-73/16, **Earthquake Engineering Research Center**, University of California, Berkeley, CA, 1973.

Idriss, I.M.; Seed, H.B. Response of Horizontal Soil Layer during Earthquakes, **Soil Mechanics and Bituminous Materials Research Laboratory**, Aug. 1967.

Idriss, I.M.; Seed, H.B. Seismic Response of Horizontal Soil Layers, **Journal of the Soil Mechanics and Foundations Division**, **ASCE**, volume 94, n. SM4, p. 1003-1030, July 1968.

Idriss, I.M.; Sun, J.I. SHAKE91: A Computer Program for Conducting Equivalent Linear Seismic Response Analyses of Horizontally Layered Soil Deposits, **Center for Geotechnical Modeling**, Department of Civil and Environmental Engineering, University of California, Davis, November. 1992.

Ishihara, K. Liquefaction and flow failure during earthquakes, **Géotechnique**, volume 43, n. 3, p. 351-415, 1993.

Ishihara, K. Post-earthquake failure of a tailing dam due to liquefaction of de pound deposit. Proceedings, **International Conference on the case Histories in Geotechnical Engineering**, University of Missouri, St. Louis, volume 1, p. 1129-1143, 1984.

Ishihara, K. Soil Behaviour in Earthquake Geotechnics, **Clarendon Press**, Oxford, 1995.

Ishihara, K. Stability of Natural Deposits during Earthquakes. Proceedings, **11th International Conference on Soil Mechanics and Foundation Engineering**, San Francisco, volume 1, p. 321-376, 1985.

Ishihara, K.; Okoda, S. Effects of large preshearing in cyclic behavior of sand. **Soils and Foundations**, volume 22, p.109-125, 1982.

Ishihara, K.; Tatsuoka, F.; Yasuda, S. Undrained deformation and liquefaction of sand under cyclic stresses reversing direction, **Soils and Foundations**, volume 15, n. 1, p. 29-44, 1975.

Ishihara, K.; Towhata, I. Dynamic response analysis of level ground based on the effective stress method. In: Pande GN, Zienkiewicz O.C, editors. Soil mechanics-transient and cyclic loads. New York: **Wiley**, Chapter 7, 1982.

Itasca Consulting Group. Fast Lagrangian Analysis of Continua (FLAC) User's Guide, Version 5, **Itasca Consulting Group Inc**, Minneapolis, Minnesota, USA, 2005.

Iwan, W.D. On a class of models for the yielding behavior of continuous and composite systems. **J. Applied Mechanics**, volume 34, p.612-617, 1967.

Jafari, A.; Popescu, R. Class A Prediction of the First Centrifuge Test, **Memorial University of Newfoundland**, March, 2004.

Jakobsen, B. The landslide at Surte on the Gota River, September 29, 1952. Proceeding, **Royal Swedish Geotechnical Institute**, Stockholm, 1952.

Jefferies, M.G. Nor–sand: a simple critical state model for sand. **Géotechnique**, volume 43, n. 1, p. 91-103, 1993.

Jefferies, M.G.; Been, K. Soil liquefaction - A critical state approach, **Taylor & Francis**, 2006.

Jennings, P.C. The failure of a slimes dam at Bafokeng, **Civil Engineering in South Africa**, volume, 6, p. 135-140, 1979.

Jeremic, B.; Yang, Z.; Cheng, Z.; Jie, G.; Sett, K.; Taiebat, M.; Preisig, M. Computational Geomechanics: Inelastic Finite Elements for Pressure Sensitive Materials, **Lecture Notes**, Department of Civil and Environmental Engineering, University of California, Davis, 2006.

Kagawa, T.; Kraft, L.M. Modelling the liquefaction process, **J Geotech Engng Div**, **ASCE**, volume 107, n. GT12, p.1593-607, 1981.

Katona, M.G. A general family of single-step methods for numerical time integration of structural dynamic equations, **NUMETA 85**, volume 1, p.213-225, 1985.

Katona, M.G.; Zienkiewicz, O.C. A unified set of single step algorithms Part 3: The Beta-m method, a generalisation of the Newmark scheme**, Int. J. Num. Meth. Eng**., 21, 1345-1359, 1985.

Kavazanjian, E.; Matasovic, N; Hadj-Hamou, T.; Sabatini, P.J. Geotechnical Earthquake Engineering for Highways: Volume I – Design Principles, Report N. FHWA-SA-97-077, **U.S. Department of Transportation, Federal Highway Administration**, Washington DC, 163 p., 1997.

Kawai, T. Summary Report on the Development of the Computer Program: DIANA-Dynamic Interaction Approach and Non-Linear Analysis, **Science University of Tokyo**, 1985.

Kawasumi, H. (Editor-in-Chief). General Report on the Niigata Earthquake of 1964, **Tokyo Electrical Engineering College Press**, Tokyo, Japan, 1968.

Keefer, D. Landslides caused by earthquakes. **Geological Society of America Bulletin**, volume 95, n. 2, p. 406-421, 1984.

Khoei, A.R.; Azami, A.R.; Haeri, S.M. Implementation of plasticity based models in dynamic analysis of earth and rockfill dams: A comparison of Pastor–Zienkiewicz and cap models, **Computers and Geotechnics**, volume 31, n. 5, p. 384-409, 2004.

Kiku, H.; Tsujino S. Post liquefaction characteristics of sand. Proceedings of the **11th World Conference on Earthquake Engineering**, Paper No. 1088, 1996.

Kleiner, D.E. Design and construction of an embankment dam to impound gypsum wasted. Proceeding, **12th International Congress on Large Dams, International Commission on Large Dams**, Mexico City, p. 235-249, 1976.

Koppejan, A.W.; Wamelan, B.M.; Weinberg, L.J. Coastal flowslides in the Dutch Province of Zeeland, Proceeding, **2nd International Conference on Soil Mechanic and Foundation Engineering**, volume 5, p. 89-96,1948.

Kramer, S.L. Geotechnical Earthquake Engineering, **Prentice Hall**, 1996.

Kramer, S.L.; Seed, H.B. Initiation of soil liquefaction under static loading condition, **Journal of the Geotechnical Engineering Division**, **ASCE**, volume 114, n.4, p. 412-430, 1988.

Krieg, R. D. Practical 2 surface plasticity theory, **Journal of Applied Mechanics-Transactions of the ASME**, volume 42, n. 3, p. 641-646, 1975.

Lade, P.V.; Yamamuro, J.A. Effects of non-plastic fines on static liquefaction of sands, **Canadian Geotechnical Journal**, volume 34, p. 918-928, 1997.

Lade, P.V.; Yamamuro J.A. Physics and Mechanics of Soil Liquefaction, **Balkema**, Rotterdam, 1999.

Lee, M.K.W.; Finn, W.D.L. DESRA-2: Dynamic effective stress response analysis of soil deposits with energy transmitting boundary including assessment of liquefaction potential. Soil Mechanics Series No. 36, **Department of Civil Engineering**, University of British Columbia, Vancouver, Canada, 1978.

Leung, K.H. Earthquake response of saturated soils and liquefaction, **PhD. Dissertation**, **University Collage of Swansea**, Wales, 1984.

Lewis, R.W.; Schrefler, B.A. The Finite element method in the deformation and consolidation of Porous Media, **Wiley**, Chichester, 1987.

Lewis, R.W.; Schrefler, B.A. The Finite Element Method in the Static and Dynamic Deformation and Consolidation of Porous Media. **Wiley**, Chichester, 1998.

Li, X.; Zienkiewicz, O.C. Multiphase flow in deforming porous media and finite element solution, **Computers & Structures**, volume 45, n. 2, p. 211-27, 1992.

Liakopoulos, A.C. Transient flow through unsaturated porous media, D. Eng. Dissertation, **University of California**, Berkeley, USA, 1965.

Liao, S.S.C.; Whitman, R.V. Overburden Correction Factor for SPT in Sand, **Journal of Geotechnical Engineering**, volume 112, n. 3, p. 373-377, 1986.

Ling, H.I.; Liu, H. Pressure-level dependency and densification behavior of sand through generalized plasticity model. **J. Eng. Mech.**, volume 129, n. 8, p. 851-860, 2003.

Liyanapathirana, D.S.; Poulos, H.G. A numerical model for dynamic soil liquefaction analysis, **Soil Dynamics and Earthquake Engineering**, volume 22, p.1007-1015, 2002.

Lloret, A.; Alonso, E.E. Consolidation of unsaturated soils including swelling and collapse behaviour, **Géotechnique**, volume 30, p. 449-447, 1980.

López-Querol, S.; Blázquez, R. Liquefaction and cyclic mobility model for saturated granular media. **International Journal for Numerical and Analytical Methods in Geomechanics**, volume 30, n. 5, p. 413-439, 2006.

Lysmer, J.; Udaka, T.; Tsai, C.F.; Seed, H.B. FLUSH: A computer program for approximate 3-D analysis of soil-structure interaction problems. Report No. EERC-75/30, **Earthquake Engineering Research Center**, University of California, Berkeley, CA, 1975.

Makdisi, F.I.; Seed, H.B. Simplified procedure for estimating dam and embankment earthquake-induced deformations, **Journal of the Geotechnical Engineering Division**, **ASCE**, volume 104, n. GT7, p. 849-867, 1978.

Malvern, L.E. Introduction to the Mechanics of a Continuous Medium, **Prentice Hall Inc**., Englewood Cliffs, 1969.

Marcuson III, W.F.; Hynes-Griffin, M.E.; Franklin, A.G. Seismic Design and Analysis of Embankment Dams: The State of Practice, The Donald M. Burmister Lecture, **Department of Civil Engineering and Engineering Mechanics Columbia University**, October, 2007.

Martin, G.R.; Finn, W.D.L.; Seed, H.B. Fundamentals of liquefactions under cyclic loading. **Journal of the Geotechnical Engineering Division**, **ASCE**, volume 101, n. GT5, p. 423-438, 1975.

Martin, G.R.; Lew, M., (Eds.). Recommended Procedures for Implementation of DMG Special Publication 117: **Guidelines for Analyzing and Mitigating Liquefaction Hazards in California**, Southern California Earthquake Center, Univ. of Southern California, March 1999.

Masing, G. Eigenspannungen und verfertigung beim messing. Proceeding, **2nd International Congress on applied mechanics**, Zurich, 1926.

Middlebrooks, T.A. Fort Peck Slide, ASCE **Transactions**, volume 107, p. 723-742, 1942.

Mitchell, D.E. Liquefaction slides in hydraulically placed sands. Proceeding, **4th International Symposium on Landslides**, Toronto, 1984.

Mononobe, N. Design of Aseismic Gravity Wall, Report of Kwanto Earthquake Damages of 1923, **Japan Society of Civil Engineering**, volume 3, 1925.

Mroz, Z. On the description of anisotropic work hardening, **J. Mechanics and Physics of Solids**, volume 15, p. 163-175, 1967.

Mroz, Z.; Norris, V.A.; Zienkiewicz, O.C. An anisotropic hardening model for Soils and its application to Cyclic Loading, **Int, J. Num, Geomech**., volume 2, p.203-221, 1978.

Mroz, Z.; Norris, V.A.; Zienkiewicz, O.C. An anisotropic, critical state model for soils subject to cyclic loading, **Géotechnique**, volume 31, n. 4, p. 451-469, 1981.

Mroz, Z.; Zienkiewicz, O.C. An anisotropic critical state model for soils subject to cyclic loading, **Geotechnique**, volume 31, p.451-469, 1981.

Muraleetharan, K.K; Mish, K.D.; Arulanandan, K. A fully-coupled nonlinear dynamic analysis procedure and its verification using centrifuge test results. **Int J Numer Anal Meth Geomech.**, volume 18, p. 305–24, 1994.

Naesgaard, E.; Byrne, P.M. Class A Prediction of Centrifuge Test 1, Liquefaction Mitigation Project, **University of British Columbia**, April 13, 2004.

Narasimhan, T.N.; Witherspoon, P.A. Numerical model for saturated-unsaturated flow in deformable porous media 3. Applications, **Water Resources Res**., 14, p. 1017-1034, 1978.

Neuman, S.P. Galerkin approach to saturated-unsaturated flow in porous media in Finite Elements in fluids, **Wiley**, London, 1975.

Newmark, N.M. A method of computation for structural dynamics, Proc. **ASCE**, volume 8, p.67-94, 1959.

Newmark, N.M. Effects of earthquakes on dams and embankments, **Geotechnique**, volume 115, n. 2, p. 139-160, 1965.

Niemunis, A. Extended Hypoplastic Models for Soils. Technical Report 34, **Politechnika Gdanska**, 2003.

Nova, R. A constitutive Model for Soil under Monotonic and Cyclic Loading. Soil Mechanic - Transient and Cyclic Load. Pande G. N.; Zienkiewicz, O. C. (Eds.), **J. Wiley & Sons Ltd.**, p. 343-373, 1982.

Nova, R. On the Hardening of soil. **Arch. Mech**., volume 29(3), p. 445-458, 1977.

Nova, R.; Hueckel, T. An engineering theory of soil behaviour in unloading and reloading, **Meccanica**, volume 16, n. 1981.

Nova, R.; Wood, D.M. A constitutive model for sand in triaxial compression, **International Journal for Numerical and Analytical Methods in Geomechanics**, volume 3, p. 255-278, 1979.

Olson, S.M.; Stark, T.D.; Walton, W.H.; Castro, G. 1907 static liquefaction flow failure of the north dike of Wachusett Dam, **Journal of the Geotechnical and Geoenvironmental Engineering**, volume 126, n. 12, p.1184-1193, December 2000.

Pande, G.; Zienkiewicz, O.C. (Eds.). Soil Mechanics – Transient and Cyclic Loads, Chichester and New York. **Wiley**, 1982.

Parmelee, R.A.; Penzien, J.; Scheffey, C.F.; Seed, H.B.; Thiers, G.R. Seismic Effects on Structures Supported on Piles Extending Through Deep Sensitive Clays. Report Nº. 64-2, **Institute of Engineering Research**, University of California, Berkeley, 1964.

Parra-Colmenares, E.J. Numerical Modeling of liquefaction and Lateral Ground Deformation Including Cyclic Mobility and Dilation Response in Soil Systems. **PhD Thesis**, Rensselaer Polytechnic Institute, Troy, New York, 1996.

Pastor, M.; Chan, A.H.C.; Zienkiewicz, O.C. Constitutive Model and Numerical Modelling of Liquefaction, *In:* Modeling in Geomechanic, Zaman, M., Gioda, G. & Booker, J. (Eds.), **Wiley**, p. 91-128, 2000.

Pastor, M.; Zienkiewicz, O.C. A generalized plasticity hierarchical model for sand under monotonic and cyclic loading, Proceeding: 2nd Int. Conf. Numerical Models in Geomechanics, Ghent (Belgium), 31 March - 4 April, In: Pande, G.N. & Van Impe, W. F. (Eds.), **Jackson and Son**, p. 131-150, 1986.

Pastor, M.; Zienkiewicz, O.C.; Chan, A.H.C. Generalized Plasticity Model for Three Dimensional Sand Behaviour. Technical Report 596, **Institute for Numerical Methods in Engineering**, Department of Civil Engineering, University College of Swansea, 1987.

Pastor, M.; Zienkiewicz, O.C.; Chan, A.H.C. Generalized Plasticity and the Modeling of Soil Behavior. **International Journal for Numerical and Analytical Methods in Geomechanics**, volume 14, n. 3, p. 151-190, 1990.

Pastor, M.; Zienkiewicz, O.C.; Leung, K.H. Simple-model for transient soil loading in earthquake analysis. II: Non-associative models for sands.

International Journal for Numerical and Analytical Methods in Geomechanics, volume 9, n. 5, p. 477-498, 1985.

Pastor, M.; Zienkiewicz, O.C.; Li, T.; Xiaoquing, L.; Fernández-Merodo, J.A.; Mira, P. Modelización del Comportamiento Sísmico de Geoestructuras, **Física de la tierra**, Servicio de Publicaciones de la Universidad Complutense de Madrid, n. 11, p. 175-201, 1999.

Pastor, M.; Zienkiewicz, O.C.; Xu, G.D.; Peraire, J. Modeling of sand behavior: Cyclic loading, anisotropy and localization, Modern approaches to plasticity, D. Kolymbas, ed., **Elsevier**, New York, p. 469–492, 1993.

Penzien, J.; Scheffey, C.F.; Parmelee, R.A. Seismic Analysis of Bridges on Long Piles. **Journal of the Engineering Mechanics Division**, **ASCE**, volume 90, n. EM3, p. 223-254, June 1964.

Poulos, S.J. The Steady State of Deformation, **Journal of the Geotechnical Engineering Division, ASCE**, volume 107, n. GT5, p. 553-562, May 1981.

Pradhan, T.B.S. The behavior of sand subjected to monotonic and cyclic loadings, **Ph. D. Thesis**, Kyoto University, Japan, 1989.

Prakash, S. Soil Dynamics, **McGraw-Hill Book Co**., New York, 1981.

Prevost, J.H. A simple plasticity theory for frictional cohesionless soils, **Soil Dynamics and Earthquake Engineering**, volume 4, p.9–17, 1985.

Prevost, J.H. DYNAFLOW: A Nonlinear Transient Finite Element Analysis Program, Princeton University, **Department of Civil Engineering**, Princeton, New Jersey, 1981.

Prévost, J.H. Mathematical Modeling of Monotonic and Cyclic Undrained Clay behavior, **International Journal of Numerical Analysis Methods in Geomechanics**, volume 1, n. 2, p. 195-216, 1977.

Prévost, J.H. Mechanics of Continuous Porous Media, **International Journal of Engineering Science**, volume 18, n. 5, 1980, p. 787-800, 1980.

Prévost, J.H. Nonlinear Dynamic Response Analysis of Soil and Soil-structure Interacting Systems, Soil Dynamics and Geotechnical Earthquake Engineering, In: Sêco e Pinto (Ed.), **Balkema**, Rotterdam, p. 49-126, 1993.

Prevost, J.H. Wave propagation in fluid-saturated porous media - An efficient finite element procedure, **Soil Dynamics and Earthquake Engineering**, volume 4, n. 4, p. 183-202, 1985.

Prevost, J.H.; Hoeg, K. Effective stress-strain-strength model for soils, **Journal of Geotechnical Engineering**, volume 101(3), p. 257-288, 1975.

Puebla, H. A constitutive model for sand analysis of the CANLEX embankment, **PhD Thesis**, University of British Columbia, Vancouver, Canada; 1999.

Puri, V.K.; Das, B.; Prakash, S. Liquefaction of Silty Soils, **International Journal of Offshore and Polar Engineering**, volume 6, n. 4, 1996.

Rauch, A.F. EPOLLS: An Empirical Method for Predicting Surface Displacements Due to Liquefaction-Induced Lateral Spreading in Earthquakes, **Ph. D. Thesis**, Virginia Polytechnic Institute, May 1997.

Riemer, M.F.; Seed, R.B. Observed effects of testing conditions on the residual strengths of loose, saturated sands at large strains, *Proceedings*, 4th Japan-U.S. Workshop on Earthquake Resistant Design of Lifeline Facilities and countermeasures for soil liquefaction, *In* M. Hamada and T.D. O'Rourke (Eds.), Technical Report NCEER-92-0019, **National Center for Earthquake Engineering Research**, Buffalo, New York, volume 1, p. 223-238, 1992.

Robertson, P.K. Soil classification using the cone penetration test, **Canadian Geotechnical Journal**, volume 27, p. 151-158, 1990.

Robertson, P.K.; Wride, C.E. Evaluating cyclic liquefaction Potential using the cone penetration test, **Canadian Geotechnical Journal**, volume 35, n. 3, p. 442–459, 1998.

Romano, M. A continuum theory for granular media with a critical state, **Acta Mechanica**, n. 20, p. 1011-1028, 1974.

Roscoe, K.H.; Burland, J.B. On Generalized Stress-Strain Behavior of Wet Clay, *In* Engineering Plasticity, Heyman, J. & Leckie, F.A. (Eds.), **Cambridge University Press**, p. 535-609, 1968.

Roscoe, K.H.; Schofield, A.N.; Wroth C.P. On the Yielding of Soils, **Géotechnique**, volume 8 (1), p. 22-53, 1958.

Ross, G.; Seed, H.B.; Migliaccio, R. Bridge foundations in Alaska Earthquake. **Journal of Soil Mechanics and Foundations Division**, ASME, volume 95, SM4, p. 1007-1036, 1969.

Safai, N.M.; Pinder, G.F. Vertical and horizontal land deformation in a desaturating porous medium, **Adv. Water Resources**, volume 2, p.19-25, 1979.

Sancio, R.B.; Bray, J.D.; Riemer, M.F.; Durgunoglu, H.T. An Assessment of the Liquefaction Susceptibility of Adapazari Silt. Paper 172, Proceedings, **Pacific Conference on Earthquake Engineering**, , New Zealand, 2003.

Sancio, R.B.; Bray, J.D.; Stewart, J.P.; Youd, T.L.; Durgunoglu, H.T.; Onalp, A.; Seed, R.B.; Christensen, C.; Baturay, M.B.; Karadayilar, T. Correlation between ground failure and soil condition in Adapazari, Turkey. **Soil Dynamics and Earthquake Engineering**, volume 22, p. 1093-1102, 2002.

Sandhu, R.S.; Pister, K.S. A Variational Principle for Linear, Coupled Field Problems in Continuum Mechanics, **International Journal of Science**, volume 8, p.989-999, 1970.

Sassa, S.; Sekiguchi, H. Analysis of waved-induced liquefaction of sand beds, **Geotechnique**, 51~2!, p. 115–126, 2001.

Schnabel, P.B.; Lysmer, J.; Seed, H.B. SHAKE: A computer program for earthquake response analysis of horizontally-layered sites, Report No. EERC-72/12. **Earthquake Engineering Research Center**, University of California, Berkeley, CA, 1972.

Schofield, A.N.; Wroth, C.P. Critical State soil Mechanics, **McGraw-Hill**, London, 1968.

Schrefler, B.A. Multifield problems, Encyclopedia of computational Mechanics, In: Stein, E., de Borst, R. & Hughes, T.J.R. (Eds.), Volume 2: Solids and Structures, **Wiley**, Chichester, p. 575-693, 2004.

Schrefler, B.A.; Zhan, X. A fully coupled model for waterflow and airflow in deformable porous media, **Water Resources Res**., volume 29, n. 1, p. 155-167, 1993.

Seed, H.B. Considerations in the earthquake-resistant design of earth and rockfill dams, **Geotechnique**, volume 29(3), p. 215-263, 1979.

Seed, H.B. Evaluation of Soil liquefaction Effects on Level Ground during Earthquakes, Liquefaction Problems in Geotechnical Engineering, **ASCE National Convention**, Philadelphia, p. 1-104, 1976.

Seed, R.B.; Cetin, K.O.; Moss, R.E.S.; Kammerer, A.M.; Wu, J.; Pestana, J.M.; Riemer, M.F.; Sancio, R.B.; Bray, J.D.; Kayen, R.E.; Faris, A. Recent Advances in Soil Liquefaction Engineering: a unified and consistent Framework, Report No. EERC-2003/06, **Earthquake Engineering Research Center**, University of California, Berkeley, December 2003.

Seed, H.B.; Idriss, I.M. Soil Moduli and Damping Factors for Dynamic Response Analysis, Report No. EERC-70/10, **Earthquake Engineering Research Center**, University of California, Berkeley, December 1970.

Seed, H.B.; Idriss, I.M. Simplified Procedure for Evaluating Soil Liquefaction Potential, **Journal of the Soil Mechanics and Foundations Division**, ASCE, volume 97, n. SM9, pp. 1249-1273, 1971.

Seed, H.B.; Idriss, I.M. Ground motion and soil liquefaction during earthquakes, Monograph, **Earthquake Engineering Research Institute**, Oakland, California, 1982.

Seed, H.B.; Lee, K.L. Liquefaction of saturated sands during cyclic loading, **Journal of the Soil Mech. and Foundations Division, ASCE**, volume 92, n. SM6, p. 105-134, 1966.

Seed, H.B.; Lee, K.L.; Idriss, I.M.; Makdisi, F.U. Analyses of slides in the San Fernando during the earthquake of February 9, 1971, Report No. EERC-73/2, **Earthquake Engineering Research Center**, University of California, Berkeley, CA, 1973.

Seed, H.B.; Lee, K.L.; Idriss, I.M.; Makdisi, F.U. The slides in the San Fernando dams during the earthquake of February 9, 1971, **Journal of the Geotechnical Engineering Division**, ASCE, volume 101, n. GT7, p. 651-689, 1975a.

Seed, H.B.; Lee, K.L.; Idriss, I.M.; Makdisi, F.U. Dynamic analyses of the slide in the lower San Fernando dams during the earthquake of February 9, 1971, **Journal of the Geotechnical Engineering Division**, ASCE, volume 101, n. GT9, p. 889-911, 1975b.

Seed, H.B; Martin, P.P.; Lysmer, J. Pore-water pressure changes during soil liquefaction, **Journal of the Geotechnical Engineering Division**, **ASCE**;, volume 102, n. GT4, p.323-346, 1976.

Sheriff, M.A.; Ishibashi, I.; Tsuchiya, C. Pore pressure prediction during earthquake loadings, **Soils Foundations**, JSSMFE, 18(4), p.19-30, 1978.

Siddharthan, R.; Finn, W.D.L. TARA-2: Two dimensional nonlinear static and dynamic response analysis, **Soil Dynamic Group**, University of British Columbia, Vancouver, Canada, 1982.

Singh, S. Liquefaction Characteristics of Silts, **Session on Ground Failures under Seismic Conditions**, Proceeding: ASCE National Convention, Special Publication No. 44, p. 105-116, 1994.

Sladen, J.A. Problems with interpretation of sand states from cone penetration test. **Géotechnique**, volume 39, n. 2, p. 323-332, 1985.

Sladen, J.A.; D`Hollander, R.D.; Krahn, J. The liquefaction of sands, A Collapse surface approach, **Canadian Geotechnical Journal**, volume 22, n. 1, p. 11-27, 1985.

Slattery, J.C. Advanced Transport Phenomena, **Cambridge University Press**, Cambridge, 1999.

Streeter, V.L. Mecânica dos Fluidos, **McGraw Hill do Brasil**, 1974.

Terzaghi, K. The shearing resistance of saturated soils, Proc. 1st Int. Conf Soil Mech. and Found. Eng., **Harvard**, volume 1, p.54-56, 1936.

Troncoso, J.H. Failure Risks of Abandoned Tailings Dams. Proc. **Int. Sym. On Safety and Rehabilitation of Tailings Dams**, International Commission on Large Dams, Paris, p. 82-89, 1990.

Troncoso, J.H.; Verdugo, R. Silt Content and Dynamic behavior of Tailing Sands, **11th International Conference on Soil Mechanics and Foundation Engineering**, volume 3, San Francisco, 1985.

Vaid, Y.P.; Chern, J.C. Cyclic and monotonic undrained response of saturated sands, **Advances in the Art of Testing Soils under Cyclic Conditions**, ASCE, p. 120-147, 1985.

Vaid, Y.P.; Chern, J.C. Effect of static shear on resistance of liquefaction, **Soils and Foundations**, volume 23, n.1, p. 47-60, 1983.

Vaid, Y.P.; Chung, E.K.F.; Kuerbis, R.H. Stress Path and Steady, **Canadian Geotechnical Journal**, volume 27, n. 1, p. 1-7, 1990.

Vaid, Y.P.; Thomas, J. Liquefaction and post liquefaction behavior of sand, **Journal of the Geotechnical Engineering Division, ASCE**, 121, n. 2, p. 163-173, 1995.

Valanis, K.C. A theory of viscoplasticity without a yield surface, **Archivum Mechaniki Stosowanej,** volume 23, n. 4, p. 517-33, 1971.

Van Genuchten, M.T.; Pinder, G.F.; Saukin W.P. Modeling of leachate and soil interactions in an aquifer – EPA-600/9-77-026, **Proc. 3rd Annual Municipal Solid Waste Res. Symp.**, 95-103, 1977.

Wang, W. Some Finding in Soil Liquefaction, **Water Conservancy and Hydroelectric Power Scientific Research Institute**, Beijing, China, 1979.

Wang, Z.L.; Dafalias, Y.F.; Shen, E.K. Bounding surface hypoplasticity model for sand, **Journal of the Engineering Mechanical Division**, **ASCE**, volume, n. 5, p.983–1001, 1990.

Wong, R.T.; Seed, H.B.; Chan, C.K. Liquefaction of gravely soil under cyclic loading condition, **Journal of the Geotechnical Engineering Division, ASCE**, volume 101, n. GT6, p. 571-583, 1975.

Wong, W. Earthquake damage to earth dams and levees in relation to soil liquefaction and weakness in soft clays, Proceedings, **International Conference on Case Histories in Geotechnical Engineering**, volume 1, p. 511-521,1984.

Wood, D.M. Soil Behavior and Critical State Soil Mechanics. **Cambridge University Press**, 1990.

Xie, Y.M. Finite element solution and adaptative analysis for static and dynamics problems of saturated - unsaturated porous media. **Ph. D. Thesis**, **University College of Swansea**, 1990.

Yamamuro, J.A.; Covert K.M. Monotonic and cyclic liquefaction of very loose sands with high silt content, **Journal of Geotechnical and Geoenvironmental Engineering**, volume 127, n. 4, p. 314-324, 2001.

Yamamuro, J.A.; Lade, P.V. Static Liquefaction of Very Loose Sands, **Canadian Geotechnical Journal**, volume 34, p. 905-917, 1997.

Yang, C.; Cui, Y.J.; Pereira, J.M.; Huang, M.S. A constitutive model for unsaturated cemented soils under cyclic loading. Comput. Geotech., 2008.

Yegian, M.K.; Gharaman, V.G.; Harutiunyan, R.N. Liquefaction an Embankment Failure Case Histories, 1988 Armenai Earthquake, **Journal of the Geotechnical Engineering Division, ASCE**, volume 120, n.3, p. 581-596, 1994.

Youd, T.L.; Harp, E.L.; Keefer, D.K.; Wilson, R.C. The Borah Peak, Idaho earthquake of October 28, 1983 – Liquefaction, **Earthquake Spectra**, volume 2, n. 11, p. 1374-1392, 1985.

Youd, T.L.; Idriss, I.M.; Andrus, R.D.; Arango, I.; Castro, G.; Christian, J.T.; Dobry, R.; Finn, W.D.L.; Harder, L.F. Jr.; Hynes, M.E.; Ishihara, K.; Koester, J. P.; Liao, S.S.C.; Marcuson III, W.F.; Martin, G.R.; Mitchell, J.K.; Moriwaki, Y.; Power, M.S.; Robertson, P.K.; Seed, R.B.; Stokoe, K.H.II. Summary Report, *Proceedings*, **NCEER Workshop on Evaluation of Liquefaction Resistance of Soils**, National Center for Earthquake Engineering Research Technical, Report NCEER-97-0022, p. 1-40, 1997.

Youd, T.L.; Idriss, I.M.; Andrus, R.D.; Arango, I.; Castro, G.; Christian, J.T.; Dobry, R.; Finn, W.D.L.; Harder, L.F. Jr.; Hynes, M.E.; Ishihara, K.; Koester, J. P.; Liao, S.S.C.; Marcuson III, W.F.; Martin, G.R.; Mitchell, J.K.; Moriwaki, Y.; Power, M.S.; Robertson, P.K.; Seed, R.B.; Stokoe, K.H.II. Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils.

Journal of Geotechnical and Geoenvironmental Engineering, volume 124, n. 10, 2001.

Zhang, H.W.; Santagiuliana, R.; Schrefler, B.A. Implicit integration algorithm for numerical Solution of partially saturated soils with an Enhanced generalized plasticity constitutive model. VIII International Conference on Computational Plasticity, COMPLAS VIII, E. Oñate, E. & Owen, D. R. J. (Eds.), **CIMNE**, Barcelona, 2005.

Zienkiewicz, O.C.; Chan, A.H.C.; Pastor, M.; Paul, D.K.; Shiomi, T. Static and dynamic behaviour of soils: a rational approach to quantitative solutions: Part I - fully saturated problems, Proceeding: **Royal Society**, Series A, 429, p. 285-309, 1990.

Zienkiewicz, O.C.; Chan, A.H.C.; Pastor, M.; Schrefler, B.A.; Shiomi, T. Computational Geomechanics: with Special Reference to Earthquake Engineering. **Wiley**, New York, 1999.

Zienkiewicz, O.C.; Chang, C.T.; Bettes, P. Drained, Undrained, Consolidation dynamic behavior assumptions in soils, **Geotechnique**, volume 30, p. 385-395, 1980.

Zienkiewicz, O.C.; Leung, K.H.; Chang, C.T. Liquefaction and Permanent Deformation under Dynamic Conditions - Numerical Solution and Constitutive Relations, Soil Mechanic – Transient and Cyclic Load. Pande, G.N. & Zienkiewicz, O.C. (Eds.), **J. Wiley & Sons Ltd.**, 1982.

Zienkiewicz, O.C.; Leung, K.H.; Pastor, M. Simple model for transient soil loading in earthquake analysis. Part I. Basic model and its application, **International Journal for Numerical and Analytical Methods in Geomechanics,** volume 9, p. 453-476, 1985.

Zienkiewicz, O.C.; Morgan, K. Finite Elements and Approximations, **Wiley & Sons**, 1983.

Zienkiewicz, O.C.; Mroz, Z. Generalised Plasticity Formulation and Applications to Geomechanics, **Mechanics of Engineering Materials**, *In*: Desai, C.S. & Gallagher, R.H. (Eds.), **J. Wiley & Sons**, Chichester, p. 655-679, 1984.

Zienkiewicz, O.C.; Naylor, D.J. The adaptation of critical state soil mechanic for uses in element finite, Proceeding of the Roscoe Memorial Symposium, Cambridge University - Stress Strain Behaviour of Soils, Parry, R. H. (Ed.), **G. T. Foulis & Co. Ltd**, p. 537-547, 1971.

Zienkiewicz, O.C.; Nithiarasu, P.; Taylor, R.L. Finite Element Method for Fluid Dynamics, **Butterworth-Heinemann**, 2006.

Zienkiewicz, O.C.; Pande, G.N. Some useful forms of isotropic yield surfaces for soil and rock mechanics, in Finite Elements in Geomechanics, G. Gudehus (Ed.), **Wiley**, Chapter 5, p. 179-190, 1977.

Zienkiewicz, O.C.; Pastor, M. A General Model for Sand Soil Behaviour. Technical Report 569, **Institute for Numerical Methods in Engineering**, Department of Civil Engineering, University College of Swansea, 1986.

Zienkiewicz, O.C.; Shiomi, T. Dynamic behavior of saturated porous media; the generalized Biot formulation and its numerical solution, **International Journal for Numerical and Analytical Methods in Geomechanics**, volume 8, p. 71-96, 1984.

Zienkiewicz, O.C.; Xie Y.M.; Schrefler, B.A.; Ledesma, A.; Bicanic, N. Static and dynamic behavior of soils: A rational approach to quantitative solution. II. Semi-saturated problems, **Proc R Soc Lond**, p.311–21, 1990b.

Anexo A
Método simplificado para avaliação do potencial da liquefação de solos.

Um método simplificado para determinar o potencial da liquefação de solos, proposto por Seed e Idriss [Seed, H.B. & Idriss, I.M., 1971] e aperfeiçoado por diversos autores ([Finn, W.D.L., 1993], [Youd, T.L., et al., 2001], [Seed, R.B., et al., 2003]) consiste em verificar em determinada profundidade se as tensões geradas pelo carregamento sísmico excedem à resistência ao cisalhamento do solo na condição residual.

Este critério de análise permite estabelecer um fator de segurança contra a liquefação, FS, definido por

$$\mathrm{FS} = \frac{\mathrm{CRR}}{\mathrm{CSR}} \qquad \text{(Eq. A.1)}$$

onde CRR é a razão de resistência cíclica na liquefação (*Cyclic Resistance Ratio*) e CSR a razão de tensão cíclica gerado pelo terremoto de projeto (*Cyclic Stress Ratio*). Se o fator de segurança for menor que a unidade ($\mathrm{FS} < 1$), então a liquefação deve ocorrer.

A razão de resistência cíclica, CRR, é determinada da figura A.1 [Seed, R.B., et al., 2003], onde o número de golpes corrigidos do ensaio SPT, $(N_1)_{60}$, é estimado pela relação

$$(N_1)_{60} = (N)_{60} \cdot C_N \qquad \text{(Eq. A.2)}$$

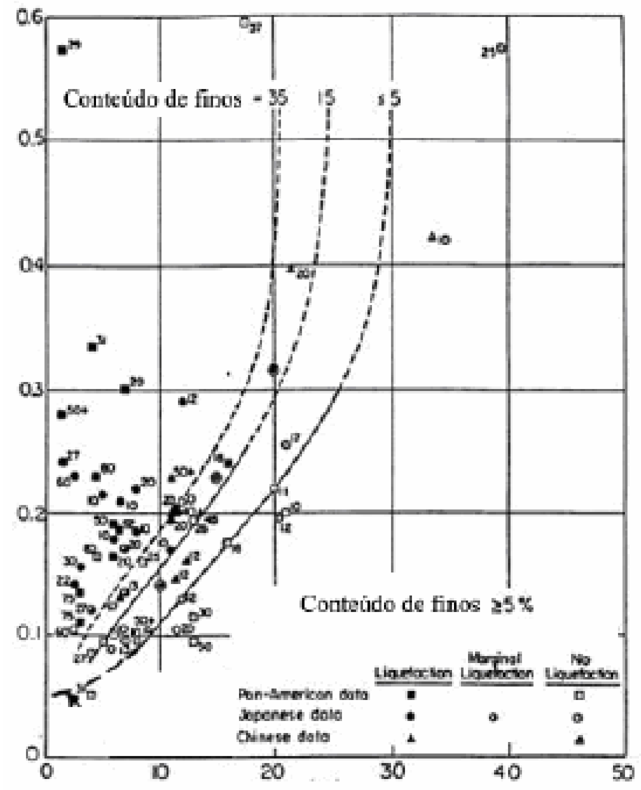
onde C_N é um fator de correção e $(N)_{60}$ o número de golpes do ensaio SPT.

Liao e Whitman [Liao, S.S.C. & Whitman, R.V., 1986] sugerem a seguinte equação para este fator de correção,

$$C_N = \frac{1}{\sqrt{\sigma'_{v0}}} \qquad \text{(Eq. A.3)}$$

onde σ'_{v0} é a tensão vertical efetiva inicial expressa em kgf/cm^2. Outras correlações similares para cálculo de C_N podem ser encontradas na literatura ([Youd, T.L., et al., 2001], [Seed, R.B., et al., 2003]).

CRR



Numero de golpes corrigidos do ensaio SPT, $(N_1)_{60}$.

Figura A.1 Razão de resistência cíclica (CRR) versus número de golpes corrigidos do ensaio SPT, $(N_1)_{60}$, *para terremotos com magnitude igual a 7,5* [Youd, T.L., et al., 2001].

A razão de tensão cíclica, CSR, é expressa por

$$CSR = CSR_{eq\,Mw=7,5} / DWF_M / K_\sigma \qquad \text{(Eq. A.4)}$$

onde $CSR_{eq\,Mw=7,5}$ é a razão de tensão cíclica equivalente correspondente a um terremoto de magnitude (M_W) igual a 7,5; DWF_M o fator de correção da magnitude do terremoto (*Magnitude-Correlated Duration Weighting Factor*) e K_σ o fator de correção da tensão vertical efetiva. As figuras A.2 e A.3 são utilizadas para a determinação de DWF_M e K_σ, respectivamente. Kramer [Kramer, S.L., 1996] recomenda também a utilização da tabela A.1 para a estimativa do fator de correção da magnitude do sismo.

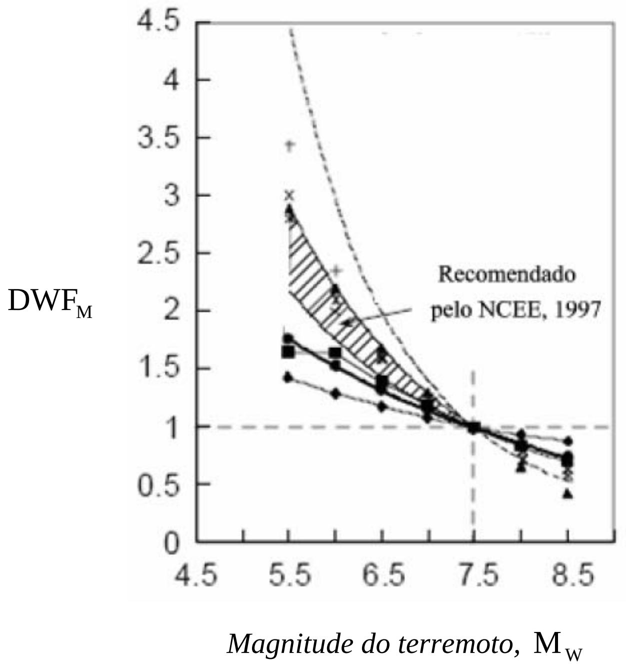


Figura A.2 Fator de correção da magnitude do terremoto [Seed, R.B., et al., 2003].

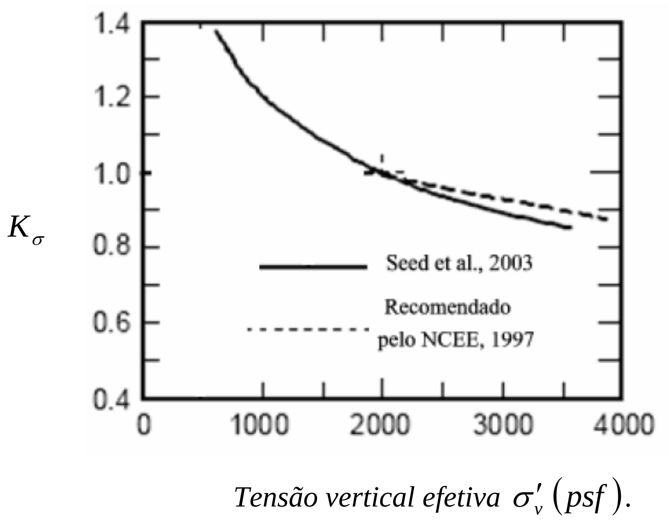


Figura A.3 Fator de correção devido à tensão inicial de cisalhamento [Seed, R.B., et al., 2003].

A razão de tensão cíclica equivalente com $M_W = 7{,}5$, $CSR_{eq\,Mw=7{,}5}$, pode ser escrita como

$$CSR_{eq\,Mw=7{,}5} = 0{,}65 CSR_{max\;Mw=7{,}5} \qquad \text{(Eq. A.5)}$$

com

$$CSR_{eq\,Mw=7{,}5} = \frac{a_{max}}{\vec{g}}\left(\frac{\sigma_v}{\sigma'_{vo}}\right) r_d \qquad \text{(Eq. A.6)}$$

onde $\mathrm{CSR}_{\max\ \mathrm{Mw}=7,5}$ é a razão de tensão cíclica máxima com $\mathrm{M_W} = 7{,}5$; $a_{\max}$ a aceleração horizontal máxima do terremoto na superfície; $\vec{g}$ a aceleração da gravidade; r_d um fator de redução da tensão cíclica devido à profundidade; σ_v a tensão total vertical e σ'_{v0} a tensão vertical efetiva inicial.

De acordo com Finn [Finn, W.D.L., 1993], na prática japonesa o fator de redução de tensão devido à profundidade é frequentemente aproximado pela seguinte correlação

$$r_d = 1 - 0{,}0015\, z \qquad \text{(Eq. A.7)}$$

onde z indica a profundidade do terreno em metros. Youd e colaboradores [Youd, T.L., et al., 2001] recomendam a utilização da figura A.4 para determinação do fator de redução da tensão cíclica devido à profundidade.

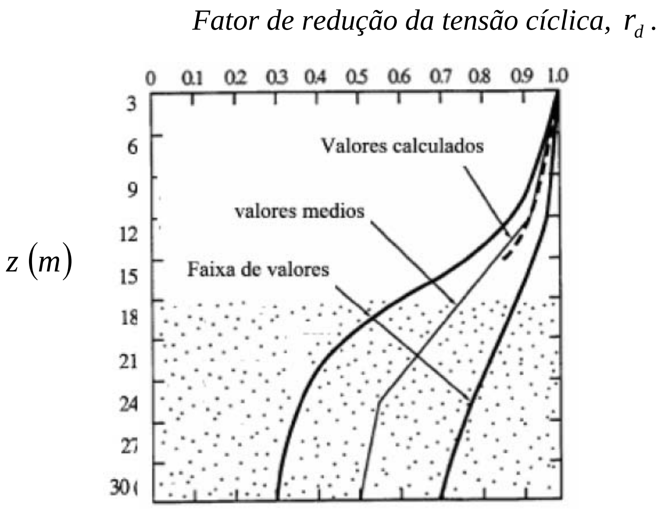


Figura A.4 Fator de redução da tensão cíclica devido à profundidade [Youd, T.L., et al., 2001].

Tabela A.1 Fator de correção da magnitude do sismo [Kramer, S.L., 1996].

Magnitude do terremoto, $\mathrm{M_W}$	Fator de correção, $\mathrm{DWF_M}$
$5\frac{1}{4}$	1.50
5	1,32
$6\frac{3}{4}$	1,13
$7\frac{1}{2}$	1,00
$8\frac{1}{2}$	0,89

Anexo B
Discretizacão das equações fundamentais para a condição não-saturada na forma u-p.

As equações fundamentais em meios porosos saturados na forma **u-w-p** são [Zienkiewicz, O.C., et al., 1999]:

$$\sigma_{ij,j} - \rho\, \ddot{u}_i - \rho_w \underline{\left(\ddot{w}_i + \dot{w}_j \dot{w}_{ij}\right)} + \rho\, b_i = 0 \qquad \text{(Eq. B.1)}$$

$$- p_{w,i} - R_i - \rho_w \ddot{u}_i - \frac{\rho_w}{n} \underline{\left(\ddot{w}_i + \dot{w}_j \dot{w}_{i,j}\right)} + \rho_w b_i = 0 \qquad \text{(Eq. B.2)}$$

$$\dot{w}_{i,i} + \dot{\varepsilon}_{ii} + \frac{n\dot{p}_w}{K_w} + \frac{(1-n)\,\dot{p}_w}{K_s} - \frac{K_T}{K_s}\left(\dot{\varepsilon}_{ii} + \frac{\dot{p}_w}{K_s}\right) + n\frac{\dot{\rho}_w}{\rho_w} + \dot{s}_0 = 0 \qquad \text{(Eq. B.3)}$$

onde as equações B.1 e B.2 representam as equações de movimento para o sistema sólido-fluido e para o fluido respectivamente, e a equação B.3 representa a equação de continuidade do fluido.

Com o objeto de estabelecer as equações fundamentais para descrever o comportamento dinâmico do meio poroso em condição não-saturada (sistema sólido-água-ar) algumas modificações devem ser introduzidas:

- ✓ Os vazios contidos no meio poroso são preenchidos parcialmente por água e parcialmente por ar, resultando

  $$S_{rw} + S_{ra} = 1 \qquad \text{(Eq. B.4)}$$

  onde S_{rw} e S_{ra} é o grau de saturação da água e do ar, respectivamente.

- ✓ A densidade do meio poroso é expressa por

  $$\rho = nS_{rw}\rho_w + nS_{ra}\rho_a + (1-n)\rho_s \qquad \text{(Eq. B.5)}$$

  onde ρ_w, ρ_a e ρ_s são as massas especificas da água, do ar e do sólido respectivamente.

- ✓ A pressão do ar é desconsiderada, i.e. $P_a = 0$ [Zienkiewicz, O.C., et al., 1990b].

- ✓ O principio das tensões efetivas [Terzaghi, K., 1936] pode ser adaptado para solos parcialmente saturados modificando-se a expressão da poropressão de acordo com [Bishop, A.W. & Blight, G.E., 1963],

$$P_{av} = \chi p_w + (1-\chi) P_a \qquad \text{(Eq. B.6)}$$

onde χ é um parâmetro que depende do grau de saturação do sistema. Uma boa aproximação de χ pode ser dada pelo grau de saturação da água, S_{rw}, [Zienkiewicz, O.C., et al., 1999],

$$\chi = S_{rw} \qquad \text{(Eq. B.7)}$$

Desconsiderando-se o valor da pressão do ar ($P_a = 0$). a equação B.6 pode ser aproximada por,

$$p_{av} = S_{rw} p_w \qquad \text{(Eq. B.8)}$$

modificando-se o princípio das tensões efetivas para solos saturados para:

$$\sigma'_{ij} = \sigma_{ij} + \delta_{ij} S_{rw} p_w \qquad \text{(Eq. B.9)}$$

✓ Considerando a permeabilidade dependente do grau de saturação, vem

$$k = k\langle S_{rw} \rangle \qquad \text{(Eq. B.10)}$$

Vários estudos reportados na literatura estabelecem relações entre o grau de saturação, permeabilidade e a poropressão ([Huang, M. & Zienkiewicz O.C., 1998], [Alonso, E.E., et al., 1987], [Bear, J., et al., 1984], [Lloret, A. & Alonso, E.E., 1980], [Safai, N.M. & Pinder, G.F., 1979], [Narasimhan, T.N. & Witherspoon, P.A., 1978], [Van Genuchten, M.T.; Pinder, G.F. & Saukin, W.P., 1977], [Neuman, S.P., 1975], [Liakopoulos, A.C., 1965]).

Levando-se em conta as observações feitas anteriormente para solos não-saturados, as equações B.1, B.2 e B.3 podem então ser modificadas.

A equação de continuidade do fluido (equação B.3) é modificada para,

$$\dot{w}_{i,i} + \dot{\varepsilon}_{ii} + \frac{n}{K_w} S_{rw} \dot{p}_w + \frac{(1-n)}{K_s} S_{rw} \dot{p}_w - \frac{K_T}{K_s}\left(\dot{\varepsilon}_{ii} + \frac{1}{K_s} S_{rw} \dot{p}_w\right) + n\frac{\dot{\rho}_w}{\rho_w} + \dot{s}_0 = 0 \qquad \text{(Eq. B.11)}$$

ou

$$\dot{w}_{i,i} + \tilde{\alpha}\dot{\varepsilon}_{ii} + \frac{\dot{p}_w}{\tilde{Q}^*} + nS_{r\,w}\frac{\dot{\rho}_w}{\rho_w} + \dot{s}_0 = 0 \qquad \text{(Eq. B.12)}$$

onde

$$\frac{1}{\tilde{Q}^*} \equiv S_{r\,w}\left(\frac{n}{K_w} + \frac{\tilde{\alpha} - n}{K_s}\right) + n\frac{\dot{S}_{r\,w}}{\dot{p}_w} \qquad \text{(Eq. B.13)}$$

sendo

$$\tilde{\alpha} = 1 - \frac{K_T}{K_s} \qquad \text{(Eq. B.14)}$$

A definição da compressibilidade equivalente do sistema sólido-agua-ar (condição não-saturada) pode ser expressa como

$$\tilde{C}_T^* \equiv S_{r\,w}\left[nC_w + (\tilde{\alpha} - n)C_s\right] + n\frac{\dot{S}_{r\,w}}{\dot{p}_w} \qquad \text{(Eq. B.15)}$$

onde $\tilde{C}_T^* = 1/\tilde{Q}^*$ é a compressibilidade equivalente do sistema sólido-agua-ar; $C_w = 1/K_w$ a compressibilidade do fluido (água) e $C_s = 1/K_s$ a compressibilidade do sólido. A equação B.15 também pode ser escrita em termos da compressibilidade equivalente do sistema sólido-agua (condição saturada) C_T .

$$\tilde{C}_T^* \equiv S_{r\,w}C_T + n\frac{\dot{S}_{r\,w}}{\dot{p}_w} \qquad \text{(Eq. B.16)}$$

com

$$C_T = nC_w + (\tilde{\alpha} - n)C_s \qquad \text{(Eq. B.17)}$$

No caso das equações B.1 e B.2 a componente de tensão total deve ser substituída em função do princípio das tensões efetivas na condição não-saturada (equacao B.9).

A formulação simplificada **u-p**, com a eliminação eliminação da variável $\dot{w}_i$ nas equações acima, pode então ser escrita, na sua forma incremental, para meios porosos não-saturados,

$$\delta\sigma_{ij,j} - \rho\delta\,\ddot{u}_i + \rho\,\delta b_i = 0 \qquad \text{(Eq. B.18)}$$

$$\left(k_{ij}\,(-\delta p_{w,j} - S_{rw}\rho_w \delta\ddot{u}_j + S_{rw}\rho_w \delta b_j)\right)_{,j} + \delta\dot{u}_{i,i} + \frac{\delta\dot{p}_w}{\tilde{Q}^*} = 0 \qquad \text{(Eq. B.19)}$$

com

$$\delta\sigma_{ij} = \delta\sigma'_{ij} - \delta_{ij} S_{rw} \delta p_w \qquad \text{(Eq. B.20)}$$

Com o objetivo de obter a solução numérica das equações governantes, é necessário discretizar estas equações, tanto espacial quanto temporalmente, conservando como variáveis primárias os incrementos de deslocamento nodal do sólido e da poropressão nodal do fluido.

Aplicando-se o método de Galerkin na equação B.18, obtém-se a seguinte equação discretizada a nível local para o sólido:

$$\mathbf{M}\delta\ddot{\bar{\mathbf{u}}} + \mathbf{P}\langle\delta\bar{\mathbf{u}}\rangle - \mathbf{Q}\delta\bar{\mathbf{p}}_w - \delta\bar{\mathbf{f}}^{(s)} = \mathbf{0} \qquad \text{(Eq. B.21)}$$

com

$$\mathbf{M} = \int_\Omega \mathbf{N}^{u^T} \rho\, \mathbf{N}^u \; d\Omega \qquad \text{(Eq. B.22)}$$

$$\mathbf{P}\langle\delta\bar{\mathbf{u}}\rangle = \int_\Omega \mathbf{B}^{u^T} \delta\boldsymbol{\sigma} d\Omega \qquad \text{(Eq. B.23)}$$

$$\mathbf{Q} = \int_\Omega \mathbf{B}^{u^T} S_{rw} \mathbf{m}\, \mathbf{N}^w d\Omega \qquad \text{(Eq. B.24)}$$

$$\delta\bar{\mathbf{f}}^{(s)} = \int_\Omega \mathbf{N}^{u^T} \mathbf{b}\; d\Omega + \int_\Gamma \mathbf{N}^{u^T} \mathbf{t}\; d\Gamma \qquad \text{(Eq. B.25)}$$

De forma similar, considerando-se a equação B.19 resulta a seguinte equação discretizada a nível local para o fluido:

$$\mathbf{Q}^T\; \delta\dot{\bar{\mathbf{u}}} + \mathbf{H}\; \delta\bar{\mathbf{p}}_w + \mathbf{S}\; \delta\dot{\bar{\mathbf{p}}}_w - \delta\bar{\mathbf{f}}^{(w)} = \mathbf{0} \qquad \text{(Eq. B.26)}$$

com

$$\mathbf{H} = \int_\Omega \nabla\mathbf{N}^{w^T} \mathbf{k}\; \nabla\mathbf{N}^w d\Omega \qquad \text{(Eq. B.27)}$$

$$\mathbf{S} = \int_\Omega \mathbf{N}^{w^T} \frac{1}{\tilde{Q}^*} \mathbf{N}^w d\Omega \qquad \text{(Eq. B.28)}$$

$$\delta\bar{\mathbf{f}}^{(w)} = -\int_\Omega \mathbf{N}^{w^T} \nabla^T \left(\mathbf{k}\; S_{rw}\rho_w\, \vec{\mathbf{b}}\right) d\Omega + \int_\Gamma \mathbf{N}^{w^T} \mathbf{q}\; d\,\Gamma \qquad \text{(Eq. B.29)}$$

Combinando as equações B.21 e B.26 para descrever, a nível local, o comportamento dinâmico do elemento acoplado (sólido-água-ar), tem-se

$$\begin{bmatrix} \mathbf{M} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} \end{bmatrix} \begin{Bmatrix} \delta\ddot{\bar{\mathbf{u}}} \\ \delta\ddot{\bar{\mathbf{p}}}_w \end{Bmatrix} + \begin{bmatrix} \mathbf{0} & \mathbf{0} \\ \mathbf{Q}^T & \mathbf{S} \end{bmatrix} \begin{Bmatrix} \delta\dot{\bar{\mathbf{u}}} \\ \delta\dot{\bar{\mathbf{p}}}_w \end{Bmatrix} + \begin{bmatrix} \mathbf{K} & -\mathbf{Q} \\ \mathbf{0} & \mathbf{H} \end{bmatrix} \begin{Bmatrix} \delta\bar{\mathbf{u}} \\ \delta\bar{\mathbf{p}}_w \end{Bmatrix} - \begin{Bmatrix} \delta\bar{\mathbf{f}}^{(s)} \\ \delta\bar{\mathbf{f}}^{(w)} \end{Bmatrix} = \mathbf{0} \qquad \text{(Eq. B.30)}$$

Após o procedimento de montagem dos elementos finitos acoplados, a equação discreta que descreve o comportamento dinamico acoplado sólido-água-ar a nível global (sistema), tem a seguinte forma,

$$\begin{bmatrix} \tilde{\mathbf{M}} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} \end{bmatrix} \begin{Bmatrix} \delta\ddot{\tilde{\mathbf{u}}} \\ \delta\ddot{\tilde{\mathbf{p}}}_w \end{Bmatrix} + \begin{bmatrix} \mathbf{0} & \mathbf{0} \\ \tilde{\mathbf{Q}}^T & \tilde{\mathbf{S}} \end{bmatrix} \begin{Bmatrix} \delta\dot{\tilde{\mathbf{u}}} \\ \delta\dot{\tilde{\mathbf{p}}}_w \end{Bmatrix} + \begin{bmatrix} \tilde{\mathbf{K}} & -\tilde{\mathbf{Q}} \\ \mathbf{0} & \tilde{\mathbf{H}} \end{bmatrix} \begin{Bmatrix} \delta\tilde{\mathbf{u}} \\ \delta\tilde{\mathbf{p}}_w \end{Bmatrix} - \begin{Bmatrix} \delta\tilde{\mathbf{f}}^{(s)} \\ \delta\tilde{\mathbf{f}}^{(w)} \end{Bmatrix} = \mathbf{0} \qquad \text{(Eq. B.31)}$$

O processo de solução numérica se completa com a discretização temporal das componentes da *equação de equilíbrio dinâmico do sistema* (equaçao B.31) no tempo $t + \Delta t$,

$$\tilde{\mathbf{M}}\delta\ddot{\tilde{\mathbf{u}}}_{t+\Delta t} + \tilde{\mathbf{P}}\left\langle \delta\tilde{\mathbf{u}}_{t+\Delta t} \right\rangle - \tilde{\mathbf{Q}}\delta\tilde{\mathbf{p}}_{w\,t+\Delta t} - \delta\tilde{\mathbf{f}}^{(s)}_{t+\Delta t} = \mathbf{0} \qquad \text{(Eq. B.32)}$$

$$\tilde{\mathbf{Q}}\delta\dot{\tilde{\mathbf{u}}}_{t+\Delta t} + \tilde{\mathbf{H}}\delta\tilde{\mathbf{p}}_{w\,t+\Delta t} + \tilde{\mathbf{S}}\delta\dot{\tilde{\mathbf{p}}}_{w\,t+\Delta t} - \delta\tilde{\mathbf{f}}^{(w)}_{t+\Delta t} = \mathbf{0} \qquad \text{(Eq. B.33)}$$

através do método de Newmark Generalizado, $GNij$.

Considerando-se o esquema GN22 para o sólido,

$$\delta\tilde{\mathbf{u}}_{t+\Delta t} = \delta\tilde{\mathbf{u}}_t + \delta\dot{\tilde{\mathbf{u}}}_t\,\Delta t + \frac{1}{2}\delta\ddot{\tilde{\mathbf{u}}}_t\Delta t^2 + \frac{1}{2}\beta_2\left(\delta\ddot{\tilde{\mathbf{u}}}_{t+\Delta t} - \delta\ddot{\tilde{\mathbf{u}}}_t\right)\Delta t^2 \qquad \text{(Eq. B.34)}$$

$$\delta\dot{\tilde{\mathbf{u}}}_{t+\Delta t} = \delta\dot{\tilde{\mathbf{u}}}_t + \delta\ddot{\tilde{\mathbf{u}}}_t\,\Delta t + \beta_1\left(\delta\ddot{\tilde{\mathbf{u}}}_{t+\Delta t} - \delta\ddot{\tilde{\mathbf{u}}}_t\right)\Delta t \qquad \text{(Eq. B.35)}$$

$$\delta\ddot{\tilde{\mathbf{u}}}_{t+\Delta t} = \frac{1}{\beta_1\,\Delta t^2}\left(\delta\tilde{\mathbf{u}}_{t+\Delta t} - \delta\tilde{\mathbf{u}}_t\right) - \frac{1}{\beta_1\,\Delta t}\delta\dot{\tilde{\mathbf{u}}}_t - \left(\frac{1}{2\beta_1} - 1\right)\delta\ddot{\tilde{\mathbf{u}}}_t \qquad \text{(Eq. B.36)}$$

e GN11 para o fluido,

$$\delta\tilde{\mathbf{p}}_{w\,t+\Delta t} = \delta\tilde{\mathbf{p}}_{w\,t} + \delta\dot{\tilde{\mathbf{p}}}_{w\,t}\,\Delta t + \bar{\beta}_1\left(\delta\tilde{\mathbf{p}}_{w\,t+\Delta t} - \delta\tilde{\mathbf{p}}_{w\,t}\right)\Delta t \qquad \text{(Eq. B.37)}$$

$$\delta\dot{\tilde{\mathbf{p}}}_{w\,t+\Delta t} = \delta\dot{\tilde{\mathbf{p}}}_{w\,t} + \frac{\delta\tilde{\mathbf{p}}_{w\,t+\Delta t} - \delta\tilde{\mathbf{p}}_{w\,t}}{\Delta t} \qquad \text{(Eq. B.38)}$$

onde as variáveis no tempo $t+\Delta t$ são quantidades a calcular e as variaveis no tempo t são valores conhecidos ou previamente determinados.

A equação de *equação de equilíbrio dinâmico do sistema* (equação B.31), pode ser escrita de forma equivalente ao *equilíbrio estático*,

$$\overline{\overline{\mathbf{K}}}_S\ \delta\tilde{\mathbf{\Phi}}_{t+\Delta t} = \delta\overline{\overline{\mathbf{f}}}_{S\,t+\Delta t} \qquad \text{(Eq. B.39)}$$

com

$$\overline{\overline{\mathbf{K}}}_S = \begin{bmatrix} \dfrac{1}{\alpha_s \Delta t^2}\tilde{\mathbf{M}} + \dfrac{\beta_s}{\alpha_s \Delta t}\tilde{\mathbf{C}} + \tilde{\mathbf{K}} & -\tilde{\mathbf{Q}} \\ \dfrac{\beta_w}{\alpha_w \Delta t}\tilde{\mathbf{Q}}^T & \dfrac{\beta_w}{\alpha_w \Delta t}\tilde{\mathbf{S}} + \tilde{\mathbf{H}} \end{bmatrix} \qquad \text{(Eq. B.40)}$$

$$\delta\tilde{\mathbf{\Phi}}_{t+\Delta t} = \left\{\delta\tilde{\mathbf{u}}_{t+\Delta t} \quad \delta\tilde{\mathbf{p}}_{w\,t+\Delta t}\right\}^T \qquad \text{(Eq. B.41)}$$

$$\delta\overline{\overline{\mathbf{f}}}_{S\,t+\Delta t} = \left\{\delta\overline{\overline{\mathbf{f}}}^{(s)}_{t+\Delta t} \quad \delta\overline{\overline{\mathbf{f}}}^{(w)}_{t+\Delta t}\right\}^T \qquad \text{(Eq. B.42)}$$

onde

$$\begin{aligned} \delta\overline{\overline{\mathbf{f}}}^{(s)}_{t+\Delta t} &= -\delta\tilde{\mathbf{f}}^{(s)}_{t+\Delta t} + \delta\tilde{\mathbf{f}}^{(s)}_{t} \\ &+ \left(\frac{1}{\alpha_s \Delta t}\delta\dot{\tilde{\mathbf{u}}}_t + \frac{1}{2\alpha_s}\delta\ddot{\tilde{\mathbf{u}}}_t\right)\tilde{\mathbf{M}} \\ &+ \left(\frac{\beta_s}{\alpha_s}\delta\dot{\tilde{\mathbf{u}}}_t + \Delta t\left(\frac{\beta_s}{2\alpha_s} - 1\right)\delta\ddot{\tilde{\mathbf{u}}}_t\right)\tilde{\mathbf{C}} \end{aligned} \qquad \text{(Eq. B.43)}$$

$$\begin{aligned} \delta\overline{\overline{\mathbf{f}}}^{(w)}_{t+\Delta t} &= -\delta\tilde{\mathbf{f}}^{(w)}_{t+\Delta t} + \delta\tilde{\mathbf{f}}^{(w)}_{t} \\ &+ \left(\frac{\beta_s}{\alpha_s}\delta\dot{\tilde{\mathbf{u}}}_t + \Delta t\left(\frac{\beta_s}{2\alpha_s} - 1\right)\delta\ddot{\tilde{\mathbf{u}}}_t\right)\tilde{\mathbf{Q}}^T \\ &+ \left(\frac{\beta_w}{\alpha_w}\delta\dot{\tilde{\mathbf{p}}}_{w\,t}\right)\tilde{\mathbf{S}} \end{aligned} \qquad \text{(Eq. B.44)}$$

A utilização da equação B.39 como procedimento de solução numérica permite a determinação direta das variáveis primárias $\delta\tilde{\mathbf{u}}_{t+\Delta t}$ e $\delta\tilde{\mathbf{p}}_{t+\Delta t}$.

Finalmente, é necessário incorporar na formulação das equações fundamentais discretas relações constitutivas (em termos de tensões efetivas) de modo de obter as equações governantes totalmente discretizadas e prever o comportamento dinâmico de solos não-saturados atraves da sua solução numerica. Neste sentido, uma adaptação da teoria da plasticidade generalizada feita por

[Bolzon, G., et al., 1996] para simulação de carregamentos sob condições parcialmente saturadas, pode ser utilizada. Para o caso de solos cimentados parcialmente saturados, Yang e colaboradores [Yang, C., et al., 2008] formularam também um modelo constitutivo combinando conceitos da teoria da plasticidade generalizada com o modelo BBB (Modelo Básico Barcelona) porposto por Alonso [Alonso, E.E., et al., 1990].

Anexo C
Diagrama de blocos do programa computacional

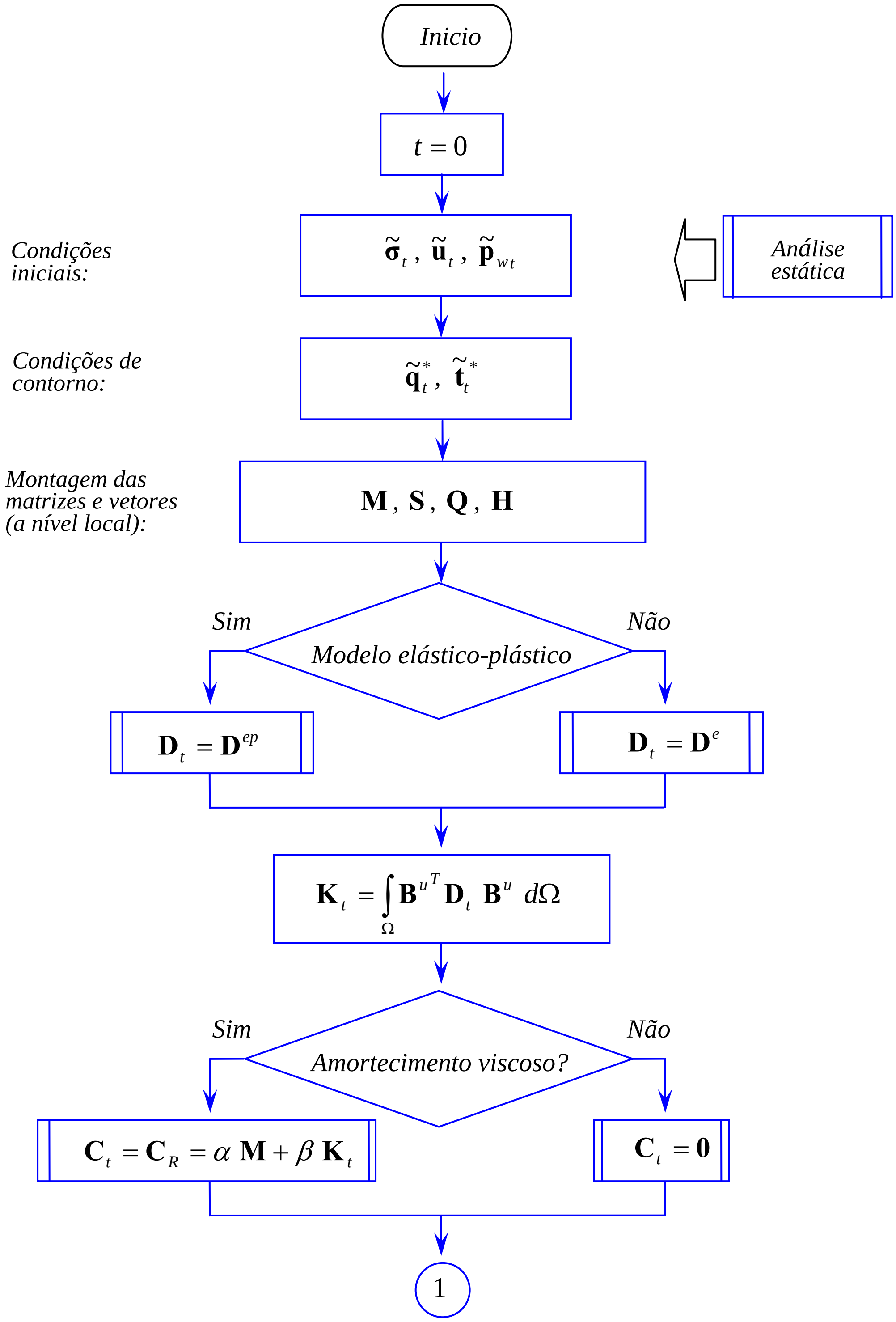


Figura C.1(a) Esquema geral do programa desenvolvido nesta pesquisa.

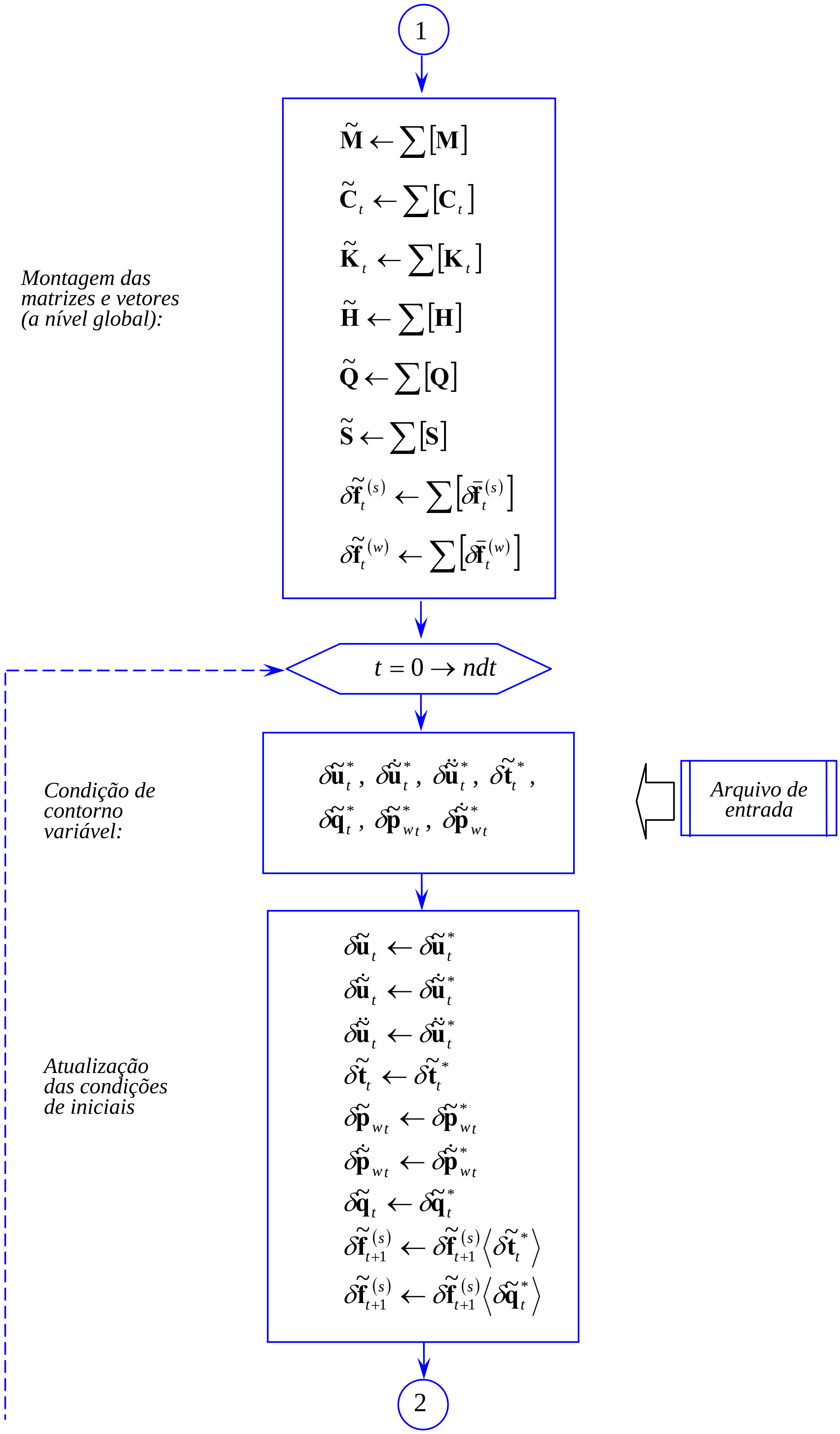


Figura C.1(b) Esquema geral do programa desenvolvido nesta pesquisa.

(2)

Montagem da matriz equivalente do sistema:

$$\overline{\overline{\mathbf{K}}}_{St} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix}$$

$$K_{11} = \frac{1}{\beta_1}\frac{1}{\Delta t^2}\tilde{\mathbf{M}} + \frac{1}{2}\frac{\beta_2}{\beta_1}\frac{1}{\Delta t}\tilde{\mathbf{C}}_t + \tilde{\mathbf{K}}_t$$

$$K_{12} = -\tilde{\mathbf{Q}}$$

$$K_{21} = \overline{\beta}_1 \frac{1}{\Delta t}\tilde{\mathbf{Q}}^T$$

$$K_{22} = \overline{\beta}_1 \frac{1}{\Delta t}\tilde{\mathbf{S}} + \tilde{\mathbf{H}}$$

Montagem do vetor incremento de forca equivalente do sistema:

$$\delta\overline{\mathbf{f}}_{St} = \begin{Bmatrix} \delta\overline{\overline{\mathbf{f}}}^{(s)}_{t+1} \\ \delta\overline{\overline{\mathbf{f}}}^{(w)}_{t+1} \end{Bmatrix}$$

$$\delta\overline{\overline{\mathbf{f}}}^{(s)}_{t+1} = -\delta\tilde{\mathbf{f}}^{(s)}_{t+1} + \delta\tilde{\mathbf{f}}^{(s)}_{t} + a_1\tilde{\mathbf{M}} + a_2\tilde{\mathbf{C}}$$

$$\delta\overline{\overline{\mathbf{f}}}^{(w)}_{t+1} = -\delta\tilde{\mathbf{f}}^{(w)}_{t+1} + \delta\tilde{\mathbf{f}}^{(w)}_{t} + a_3\tilde{\mathbf{Q}}^T + a_4\tilde{\mathbf{S}}$$

$$a_1 = \left(\frac{1}{\beta_1}\frac{1}{\Delta t}\delta\dot{\tilde{\mathbf{u}}}_t + \frac{1}{2\beta_1}\delta\ddot{\tilde{\mathbf{u}}}_t\right)$$

$$a_2 = \left(\frac{1}{2}\frac{\beta_2}{\beta_1}\delta\dot{\tilde{\mathbf{u}}}_t + \Delta t\left(\frac{1}{4}\frac{\beta_2}{\beta_1} - 1\right)\delta\ddot{\tilde{\mathbf{u}}}_t\right)$$

$$a_3 = \left(\frac{1}{2}\frac{\beta_2}{\beta_1}\delta\dot{\tilde{\mathbf{u}}}_t + \Delta t\left(\frac{1}{4}\frac{\beta_2}{\beta_1} - 1\right)\delta\ddot{\tilde{\mathbf{u}}}_t\right)$$

$$a_4 = \left(\overline{\beta}_1\delta\dot{\tilde{\mathbf{p}}}_{wt}\right)$$

(3)

Figura C.1(c) Esquema geral do programa desenvolvido nesta pesquisa.

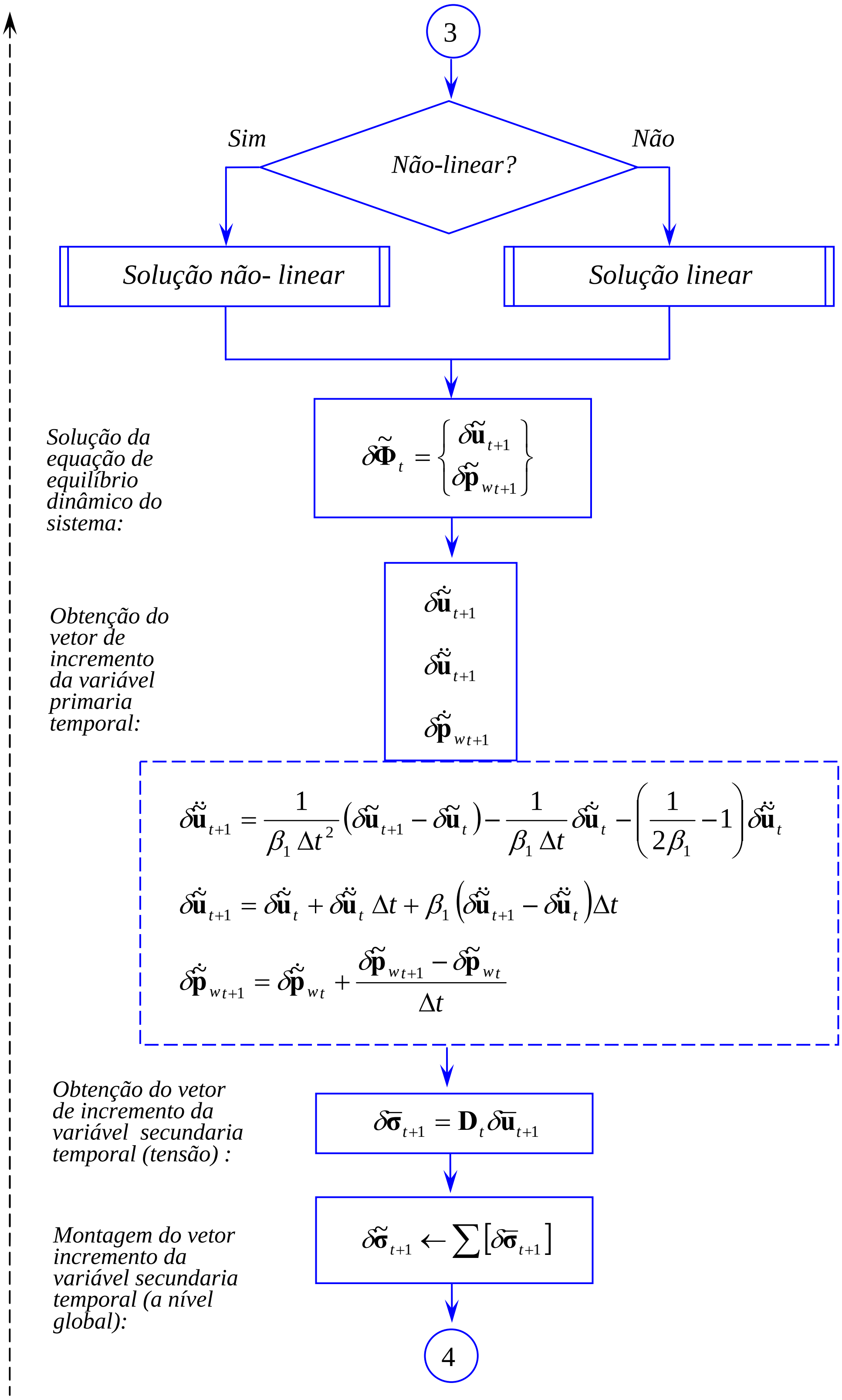


Figura C.1(d) Esquema geral do programa desenvolvido nesta pesquisa.

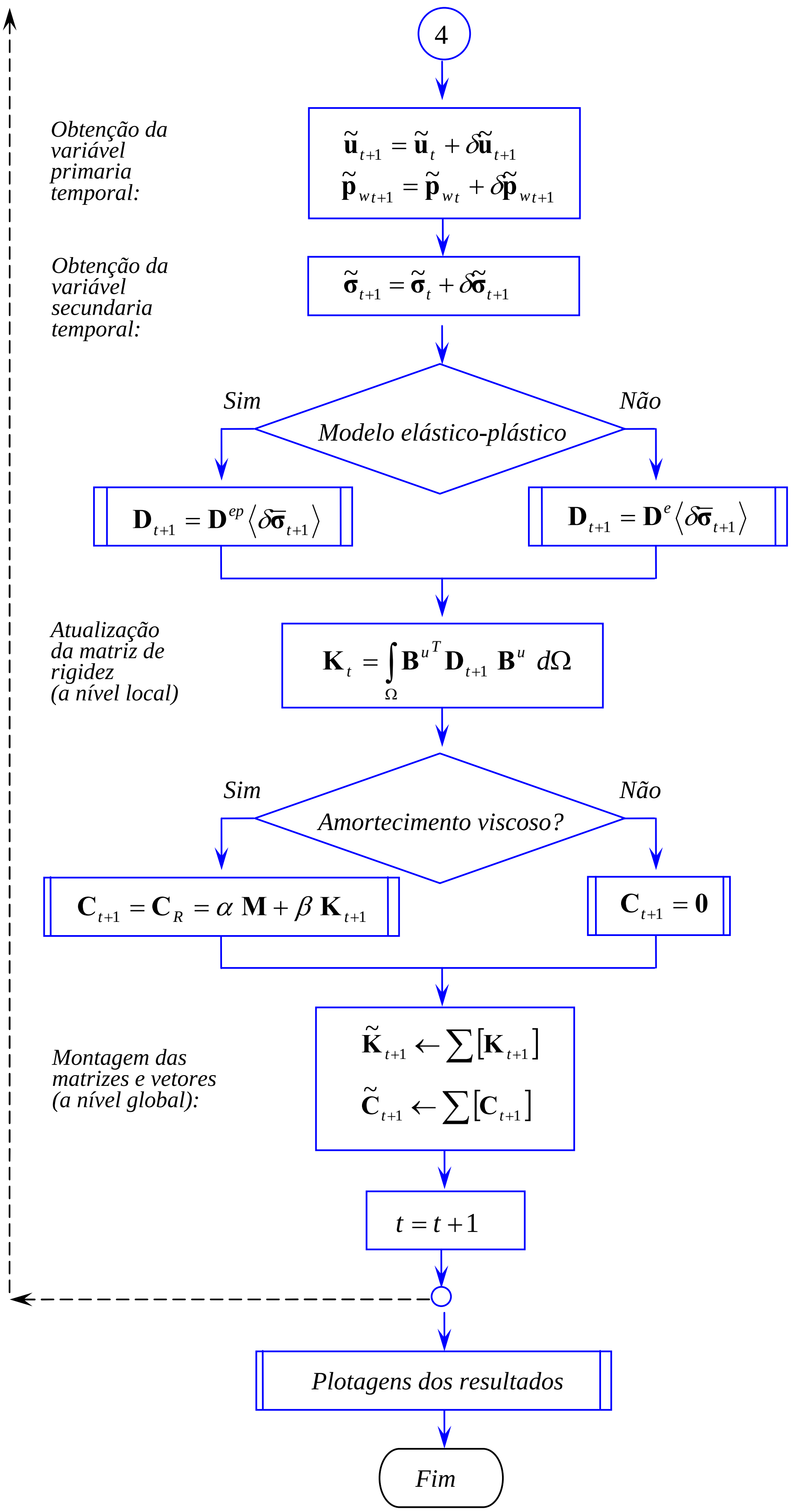


Figura C.1(e) Esquema geral do programa desenvolvido nesta pesquisa.

Apêndices

Apêndice A
Resultados em termos da história dos deslocamentos. Coluna de solo seco. Solução analítica.

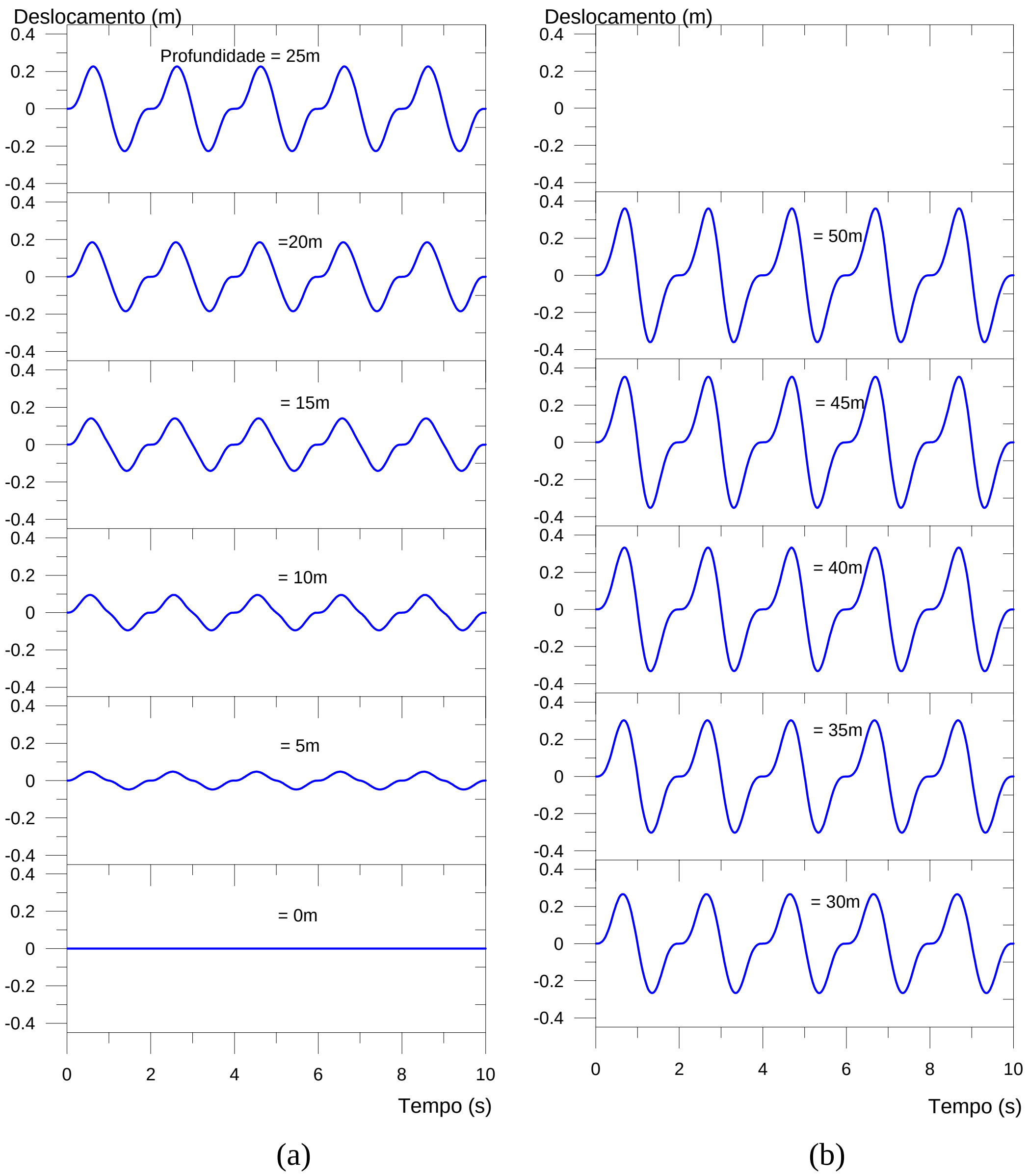
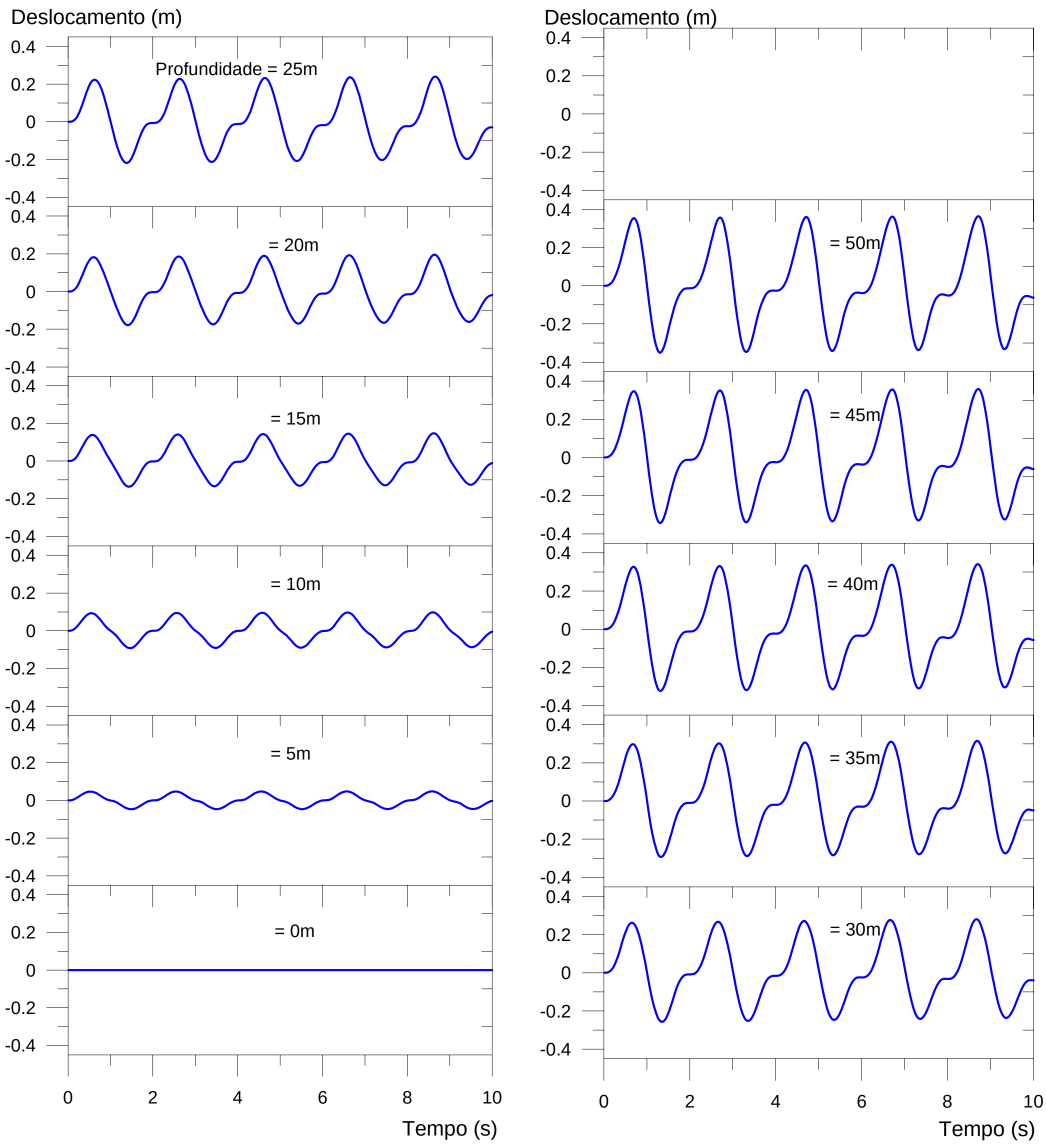


Figura A.1 História dos deslocamentos para a coluna de solo seco. Solução analítica.

Apêndice B
Histórias dos deslocamentos, velocidades e acelerações para a coluna de solo seco. Solução aproximada [FEM].



(a) (b)

Figura B.1 História dos deslocamentos para coluna de solo seco. Solução aproximada MEF.

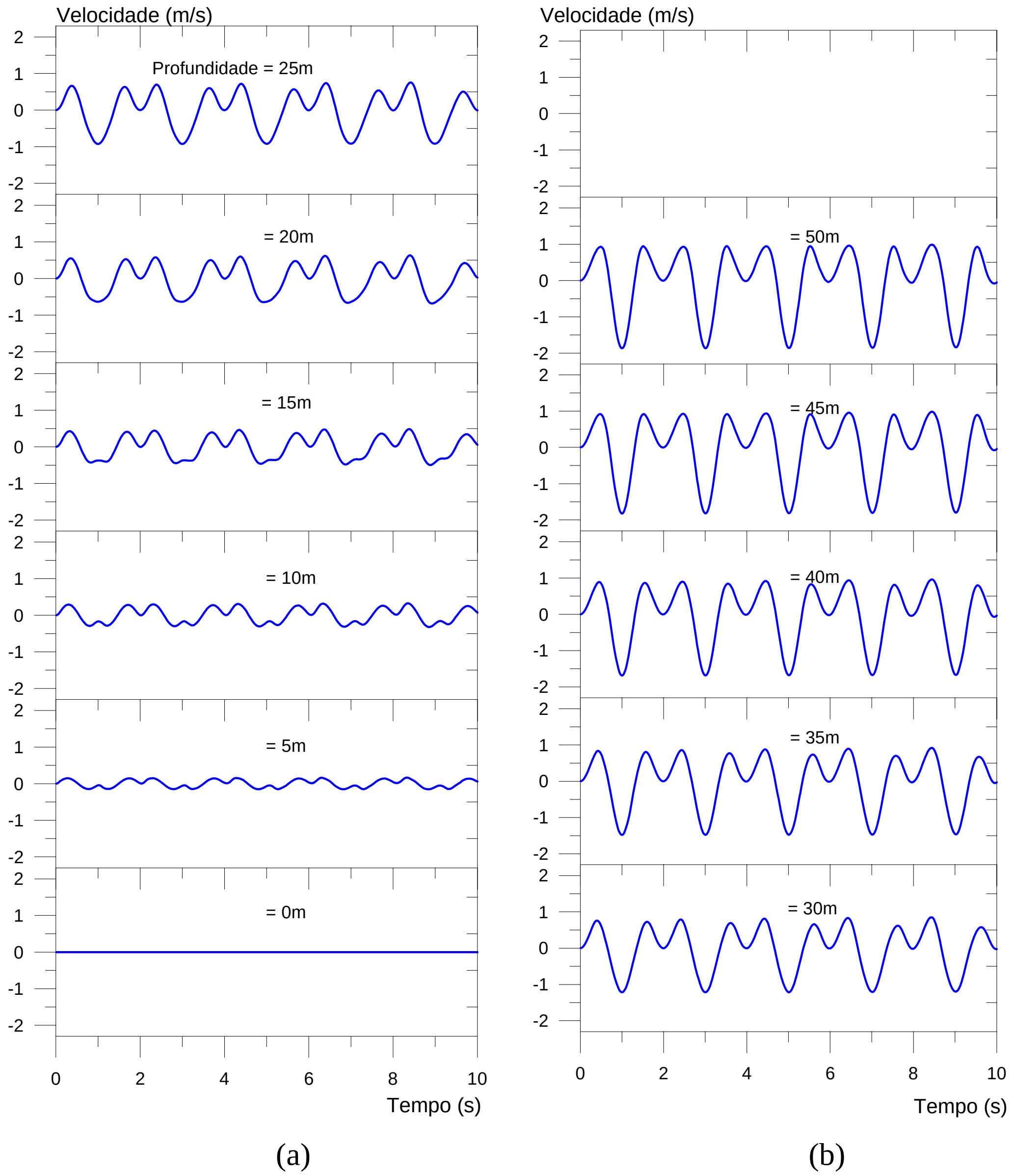
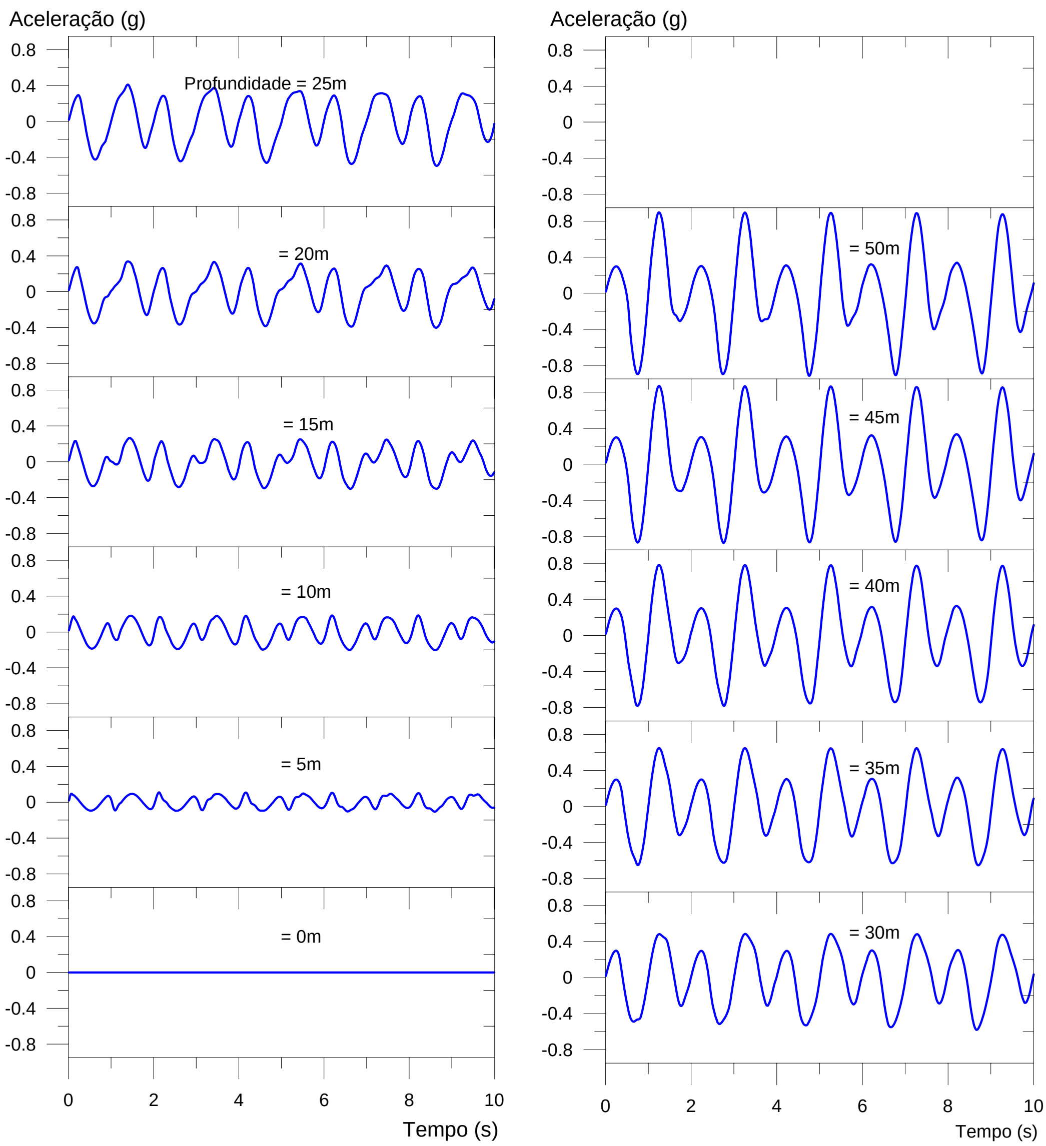


Figura B.2 História das velocidades para coluna de solo seco. Solução aproximada MEF.



(a) (b)

Figura B.3 História das acelerações para coluna de solo seco. Solução aproximada MEF.

Apêndice C
Histórias dos deslocamentos, incrementos de poropressão e de acelerações para coluna de solo saturado. Amplitude da onda excitante 0,35g.

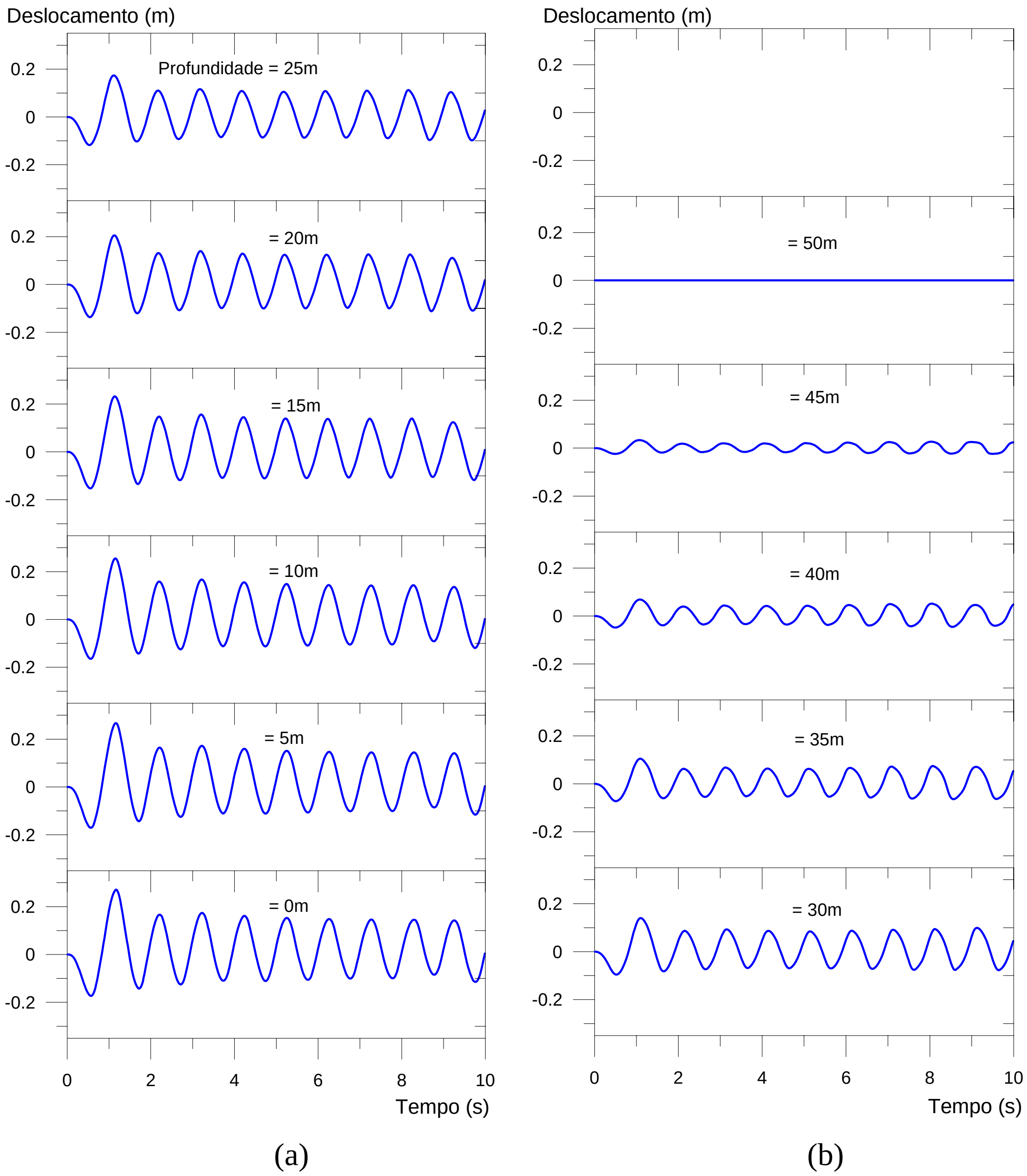
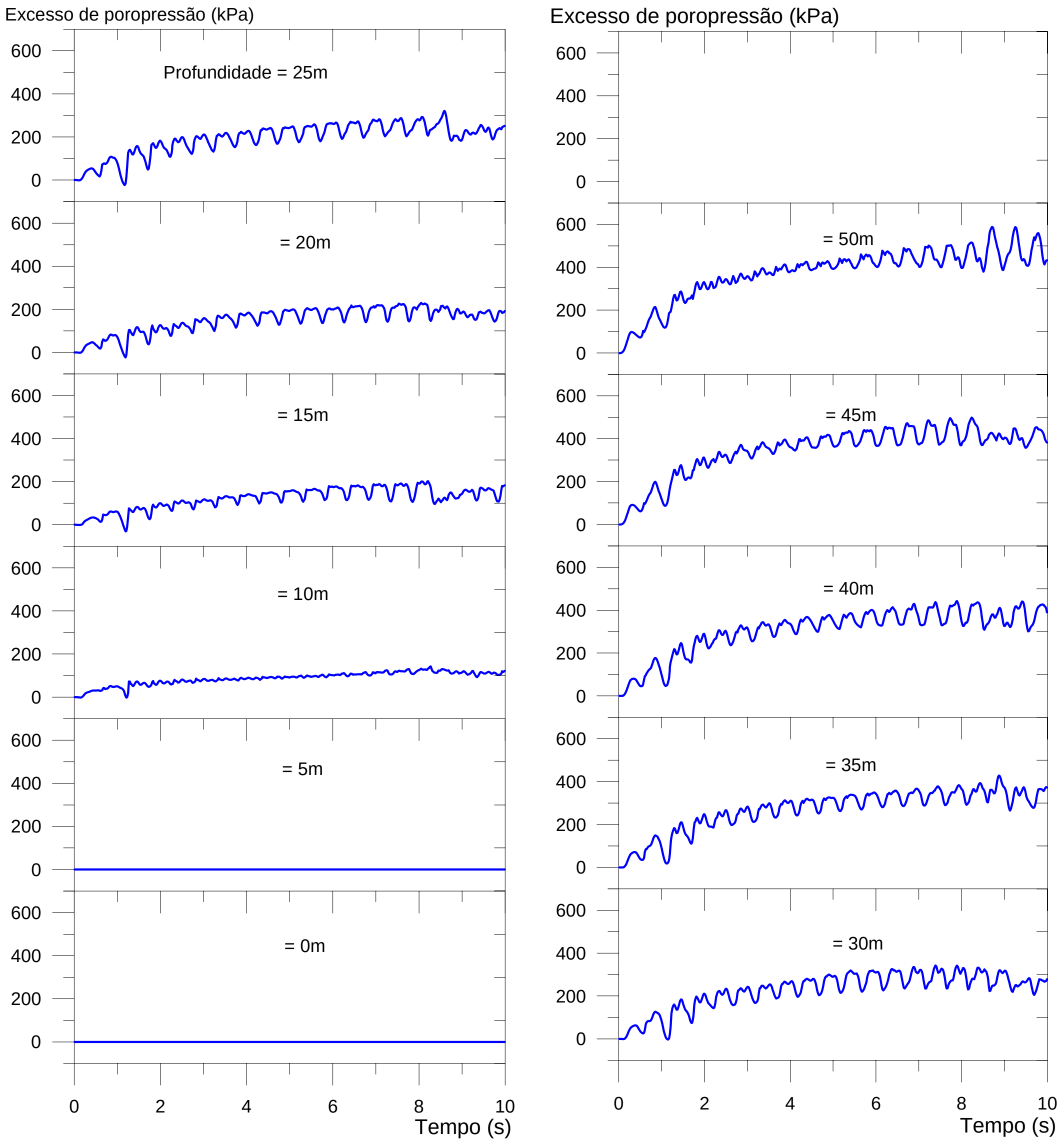


Figura C.1 História dos deslocamentos para coluna de solo saturado. Solução aproximada MEF considerando aceleração horizontal máxima $0{,}35g$.



(a) (b)

Figura C.2 História dos incrementos de poropressão para coluna de solo saturado. Solução aproximada MEF. Aceleração horizontal máxima $0{,}35g$.

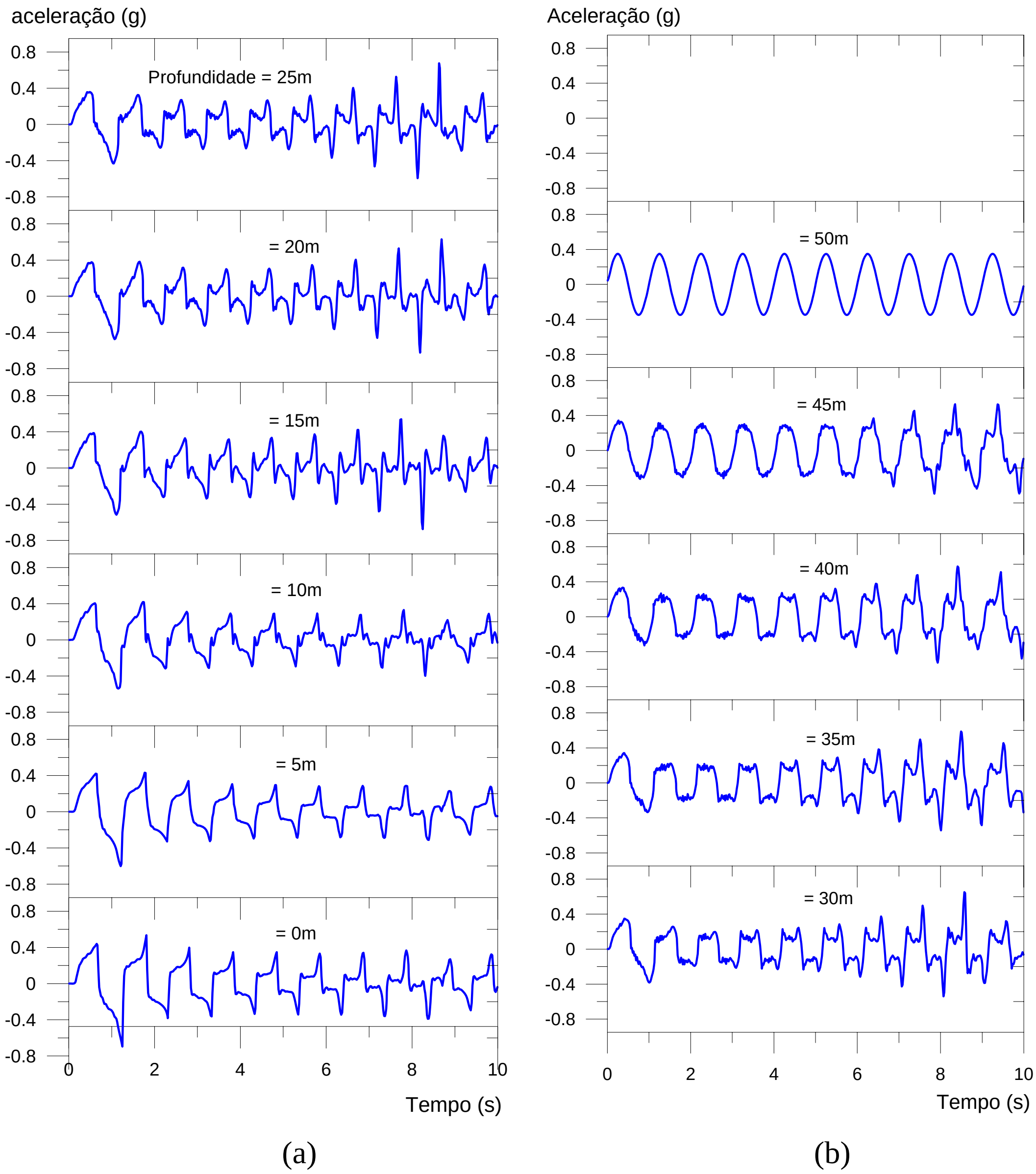


Figura C.3 História das acelerações para coluna de solo saturado. Solução aproximada MEF. Amplitude do registro de aceleração da onda excitante $0{,}35g$.

Apêndice D
Registro dos deslocamentos, incrementos de poropressão e acelerações para coluna de solo saturado. Aceleração horizontal máxima 0,40g.

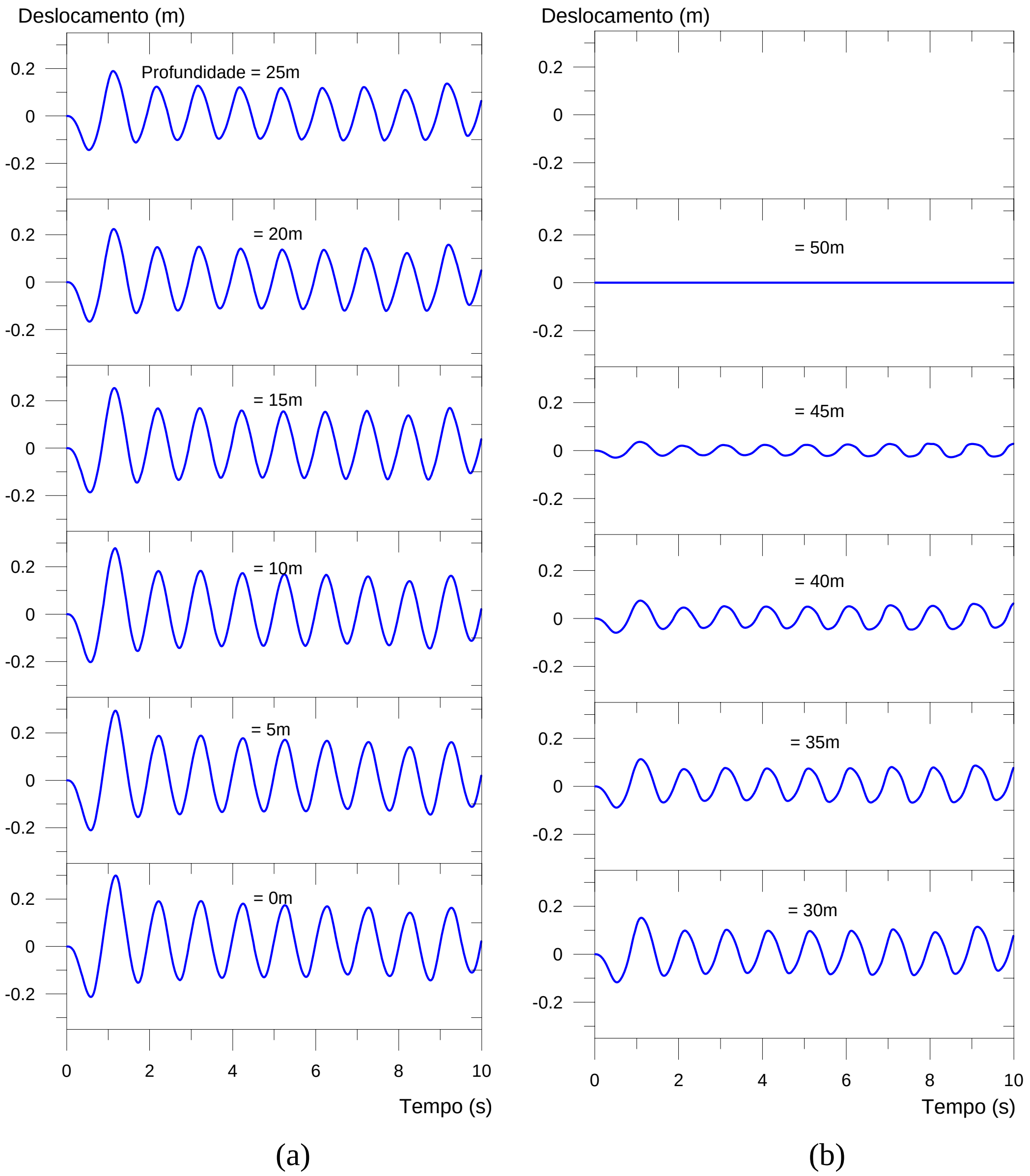


Figura D.1 História dos deslocamentos para coluna de solo saturado. Solução aproximada MEF. Aceleração horizontal máxima $0{,}40g$.

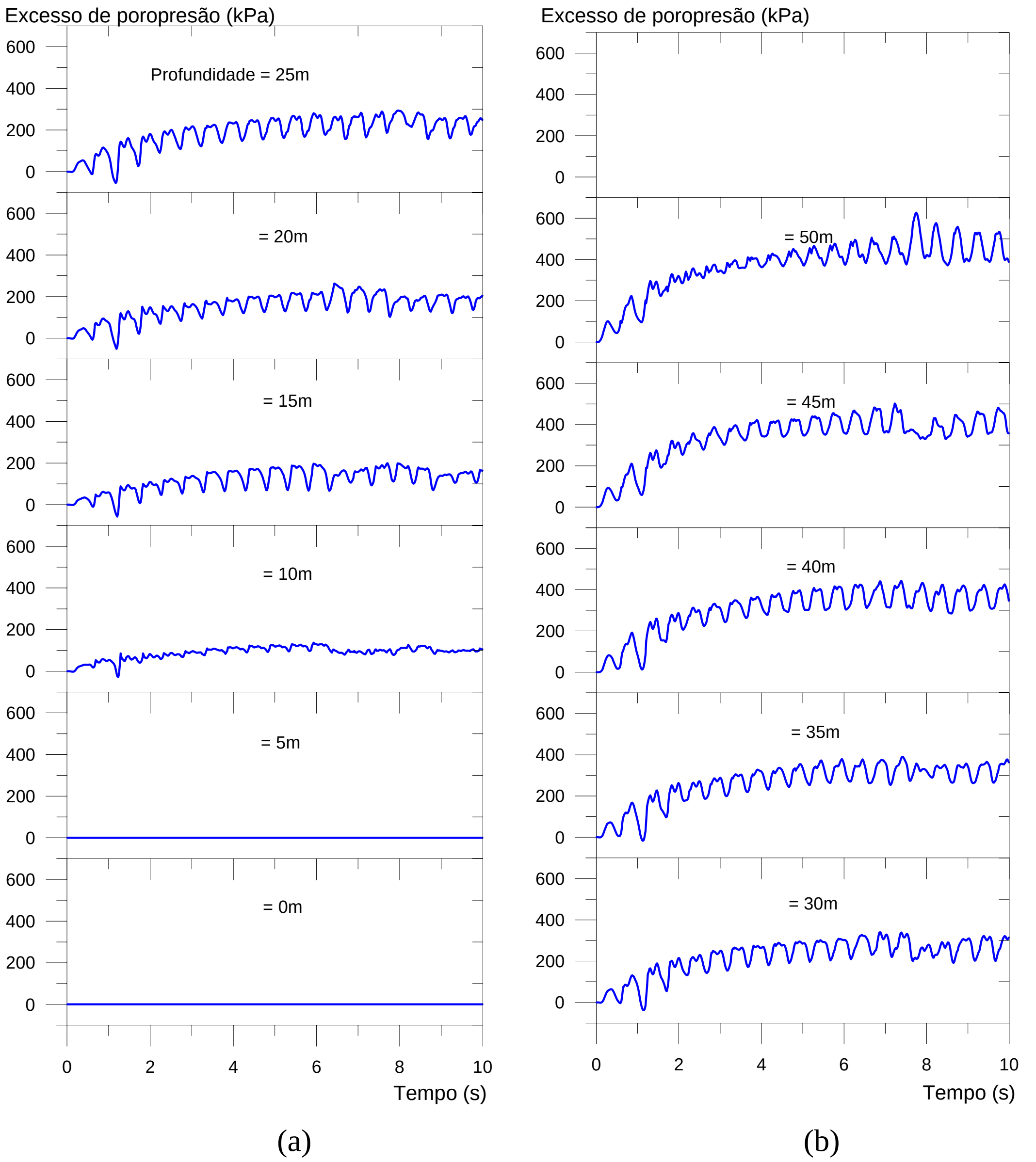


Figura D.2 História dos incremento de poropressão para coluna de solo saturado. Solução aproximada MEF. Aceleração horizontal máxima $0{,}40g$.

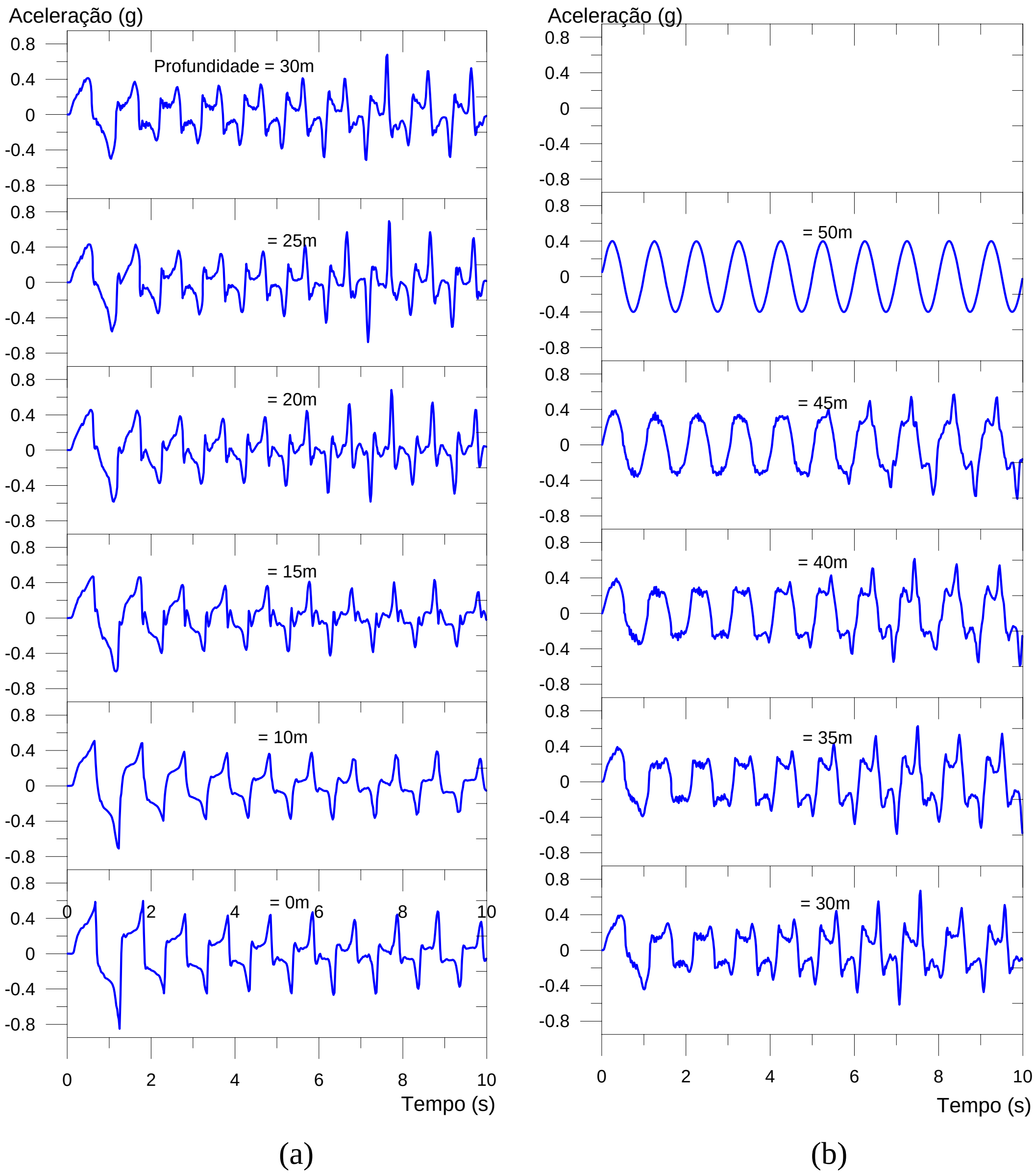


Figura D.3 - História das acelerações para coluna de solo saturado. Solução aproximada MEF. Aceleração horizontal máxima $0{,}40g$.