Nondestructive Evaluation of Reinforced Concrete Columns with Steel Jackets

Research Proposal Submitted to

California Department of Transportation

Submitted By
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Director of the Structural Testing Lab

Department of Civil & Geomatics Engineering & Construction
California State University, Fresno

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Executive Summary

This proposal is intended to develop a portable device to be used to assess the integrity of steel jacketed concrete columns after seismic events. The first phase of this project will demonstrate the use of ultra-seismic test (UST) method to assess the damage and will establish the criteria of damage detection. The second phase will then follow to develop a portable efficient device most suitable for this specific application. It will also include training of Caltrans technicians to use the developed device.

Upon the completion of the project, the damage detection will be implemented in the following manner; first the UST device will be used to detect fracture zones. Once a fracture zone is identified, the steel jacket is to be removed and the crossmedium tomographic imaging (CT) technique can be used for three-dimensional volumetric definition of the defective zones for remedial planning. In addition, the Ground Penetrating Radar (GPR) technique may also be used to assess the condition of the rebar cage by identifying steel member buckling of the vertical bars and the stirrups openings. Both CT and GPR techniques can also be used to assess damages in columns without steel jacket even if they are wrapped with composite jackets. This project will also include the demonstration and criteria establishment of using CT and GPR techniques after removing the steel jacket, thus covering all possible scenarios.

The proposed procedure to complete the task may be outlined in the following steps:

1. **Phase I:..$140,000**
    a. Construct five sample columns in the structural labs $50,000
    b. Image the five samples using the CT & GPR methods before applying the steel jacket to establish the image before any failure takes place $15,000
    c. Install the steel jackets on all samples
    d. Use the UST method to establish the wave spectrum for healthy columns.................$15,000
    e. Apply cyclic load on the columns to induce different levels of failure, record the corresponding load-deflection curves $15,000
    f. Use the UST method to detect the location of the fracture zone and to establish the wave spectrum for defective columns $20,000
    g. Remove the steel jackets
    h. Image the samples using the CT & GPR methods to establish the images for defective columns $25,000
2. **Phase II:**
    a. Fabricate Ultra-Seismic mobile portable field systems .... $10,000 per system
    b. Train Caltrans Technicians on how to perform the UST, CT and GPR tests .... $100 per hour

1. Introduction

Bridge columns built long time ago were constructed according to the old design criteria, which did not mandate spiral or closed stirrups, or require adequate rebar splices. Such columns lack sufficient confinements to keep the steel reinforcement from buckling. Following research studies, it was decided to retrofit these columns using steel jackets to provide the required confinements. It is not possible to inspect these columns after major seismic events because of the steel jacket. Thus, a new technology to assess the damages in these columns is necessary.

2. Research Approach

This research study will primarily focus on the development of the ultra-seismic test (UST) method for identifying fracture zones in steel jacketed concrete columns. In Section 3, the UST method is described followed by a data example.

Once a fracture zone is identified by the UST method, the crossmedium tomographic imaging (CT) technique can be used for three-dimensional volumetric definition of the defect zones for remedial planning. However, transmission of high frequency (20-40 kHz) acoustic energy through steel jacketed columns is a challenging task. Section 4, describes the research effort for the transmission and the detection of acoustic energy through steel jackets concrete columns.

Crossmedium tomography can easily be used for three-dimensional defect characterization in reinforced concrete columns after the steel jacket is removed. Section 5 describes conducting three-dimensional tomography surveys on columns containing defects after the application of seismic load and after the removal of the steel jacket. Section 6 also describes the use of Ground Penetrating Radar (GPR) technology for identifying rebar and circular stirrups buckling and bending—including data examples. Finally, in Section 7, the cost of fabricating UST field units is discussed.

3. Demonstration and Criteria Establishment Of The Ultra-Seismic Test Method For The Steel Jacketed Concrete Columns

The ultra-seismic test was introduced for nondestructive evaluating (NDE) of complex civil structures such as bridges, buildings, and dams. This method can also be used to determine the unknown depth of a foundation or the presence of significant flaws within a structural element.

3.1 Testing Procedure

The ultra-seismic test method uses multiple channel recording of acoustic data followed by computer processing techniques adapted from the seismic exploration method. Seismogram records are collected by using an impulse hammer as the source and accelerometers as receivers that are mounted on the surface or side of the accessible structure element at intervals of 1 ft or less. The structure element itself is used as the medium for the transmission of the seismic energy. All types of wave modes traveling down or reflected back are recorded by this method as shown in Figure (1).

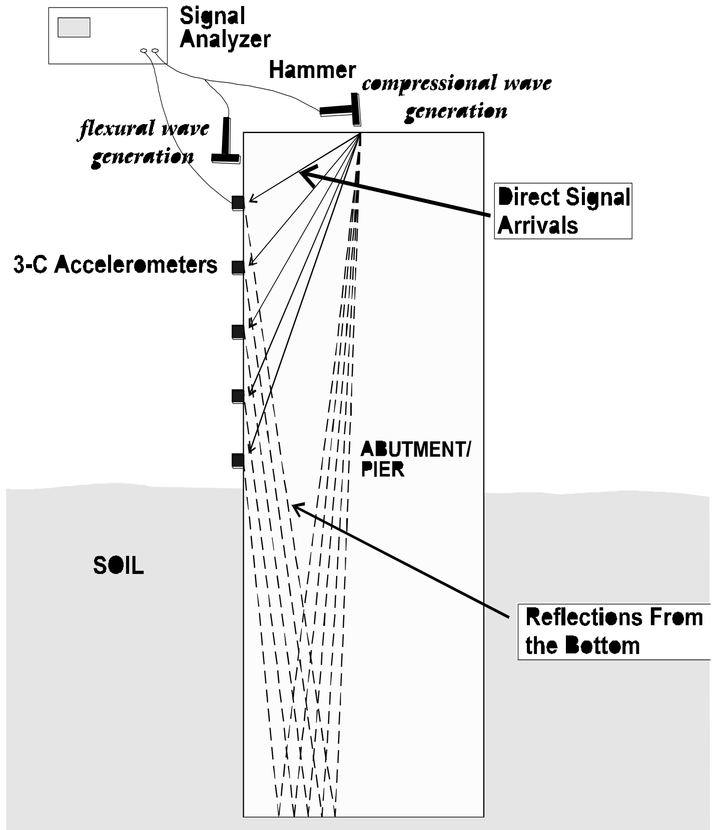

Figure (1)

For a one-dimensional imaging, a variant of UST—known as the Vertical Profiling (VP) technique—is used. In this technique, the structural element is hit from the top or from the bottom and the ensuing wave motion is recorded at regular intervals along the length of the structure. The Vertical Profile (VP) data records are used to differentiate downgoing from the upgoing events based on their characteristic time moveout and accurately measure their velocity.

3.2 Advantages of the UST Method

- Can be used for obtaining two-dimensional reflection images from complex structures, such as bridge columns and abutments, buildings, and dam
- Uses well-proven processing techniques developed in the seismic exploration method
- Multiple-channel recording allows for differentiation of bottom echoes from other complex structures

3.3 Data Examples for the UST Method

The data shown in Figure (2) are (filtered and amplified) seismic records obtained from accelerometer receiver attached to the side of a bridge column in response of horizontal impact of a 3-lb hammer struck at the top of the beam near the bridge deck. Each trace location corresponds to different survey location with Trace 2 indicating 1 ft and Trace 22 indicating 21 ft below the source location. Two *series* of seismic events are observed from this dataset including a downgoing flexural wave event, with a positive travel time moveout, and an upgoing flexural wave event (reflection from the bottom of the foundation) with a negative travel time moveout. Gross fracture zones within the bridge column will act as an impedance boundary that can be identified as events ending in the downgoing data stream with negative slopes.

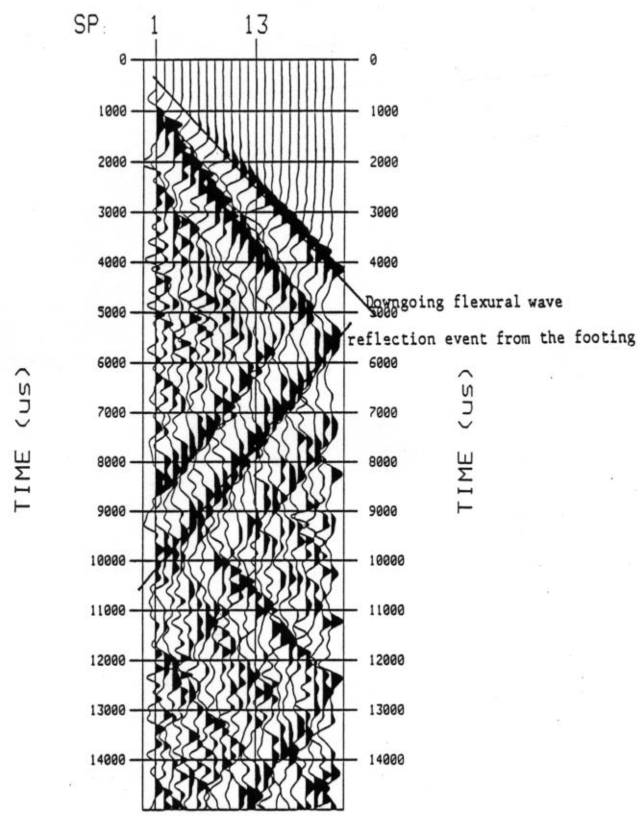

Figure (2)

3.4 Research Needs

The data example shown in Section 3.3 is from a concrete bridge column without a steel jacket. The presence of a steel jacket will result in strong primary downgoing and strong primary upgoing waveforms to also be present in the seismic record (with different time moveouts). Therefore, the recorded data needs to be filtered using multi-channel digital data processing techniques adapted from geophysical exploration (like f-k and median velocity filtering techniques) to differentiate between the concrete and steel waveform arrivals.

Laboratory data will be collected using different data acquisition geometries including stationary receiver and moving source versus stationary source and moving receiver to investigate data quality due to receiver coupling differences. Different source locations from the top of the column or from a small section in direct contact with the concrete column will also be investigated in this research.

4. Research On Ways To Penetrate And Obtain Discernible High Frequency Data Through Steel Jacketed Reinforced Concrete Columns

Ounce a fracture zone is identified by the UST method, three-dimensional crossmedium tomographic imaging technique can be used for volumetric definition of the fracture zone for immediate remediation. However, crossmedium tomography, in this application, requires the transmission of high frequency acoustic energy (in range of 30-60 kHz) through steel-jacketed concrete columns which is a challenging task. Nevertheless, if the steel jackets is removed around a suspected defect zone (as identified by the ultraseismic testing), crossmedium tomography can easily be performed using off-the-shelf equipment as shown in Section 5.

Before a seismic load is applied to a column, it is planed to use a high frequency impulsive pinger source struck on one side of a steel-jacketed column and record acoustic energy from a high frequency accelerometer attached to the opposite side of the column. In this research, we plan to examine the capabilities of this high frequency pinger source in obtaining discernible acoustic data that can be used in crossmedium tomography application without the requirements of steel jacket removal.

5. Imaging Of Defects And Rebar After The Removal Of Steel Jackets

After the identification of a fracture zone by the UST method, the steel jacket can be removed and two imaging techniques of crossmedium tomography and ground penetrating radar (GPR) methods can used for defect characterization. Tomography is effective for three-dimensional imaging of the fracture zones and their volumetric definition. GPR is used in assessing the condition of the rebar cage by identifying steel member buckling of the vertical bars or the stirrups, as described below.

5.1 Crossmedium Tomographic Imaging

Tomography is an inversion procedure that provides for two- or three-dimensional velocity (or attenuation) images between test holes (crosshole tomography) or structural surfaces (crossmedium tomography) from the observation of transmitted first arrival energy. This method can be used for imaging underground structures as well as delineating internal flaws in man-made structures; such as buildings, bridges, slurry diaphragm walls, and dams.

5.2 Testing Procedure

As shown in Figure (3), Tomography data collection involves in scanning the region of interest with many combinations of source and receiver depth locations. Typical field operation consists of holding the receiver tool at the bottom of one hole/surface and moving the source tool systematically in the opposite hole/surface from bottom to the top. The receiver is then moved to the next depth location and the test procedure is repeated until all possible source-receiver combinations are incorporated.

5.3 Theoretical Approach

In the tomographic inversion technique, the acoustic wavefield is initially propagated through a presumed theoretical model and a set of travel times are obtained by ray-tracing (forward modeling). The travel time equations are then inverted iteratively in order to reduce the root mean square (RMS) error between the observed and computed travel times. The inversion results can be used for imaging the velocity (travel time tomography) and attenuation (amplitude tomography) distribution between boreholes.

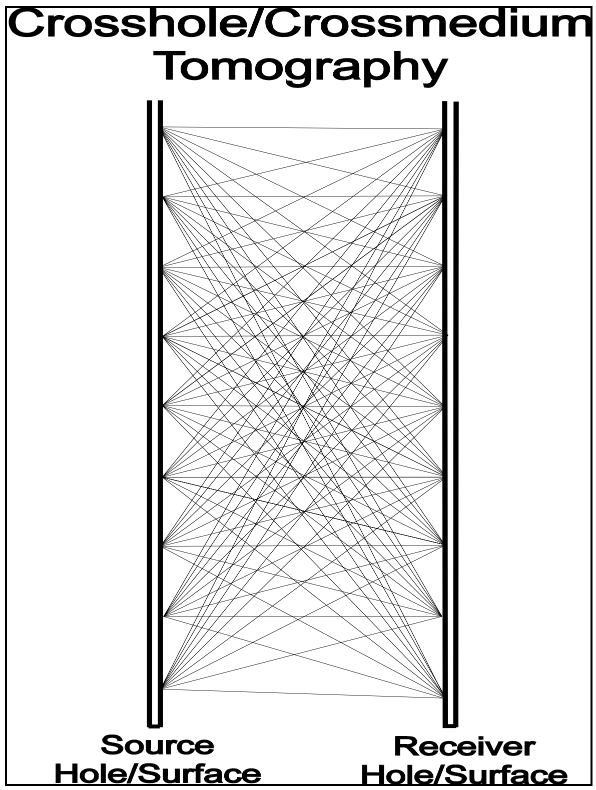

Figure (3)

5.4 Advantages of Tomography

- Provides for a 2-D or a 3-D image of a defect or a target zone between test holes/surfaces
- Can be used in before and after surveys for monitoring fluid injections between test holes or for assessing the effectiveness of soil improvement techniques for geotechnical studies
- Attenuation tomography can be used for the delineating fracture zones

5.5 Data Examples for the Tomographic Imaging Method

Figure (4) indicates a three-dimensional <u>crosshole</u> tomographic image obtained from a drilled shaft foundation in Nevada. The shaft has a length of 7 m (23 ft) and contains three (3) 2-inch I.D. steel tubes attached to the rebar cage. The 3-D image was obtained by combining three 2-D tomographic surveys conducted between the 3 access tubes. The velocity contours indicate differential curing of concrete with faster curing time for the side of the shaft facing the river. Otherwise, the shaft is sound. In this research for the FHWA, the digital *PILELOG*$_S$ system was used (developed in cooperation with Mount Sopris Instruments and sold internationally) to collect tomographic dataset between the access tubes. Similar images will be obtained using crossmedium tomographic method obtained from opposite sides of bridge columns.

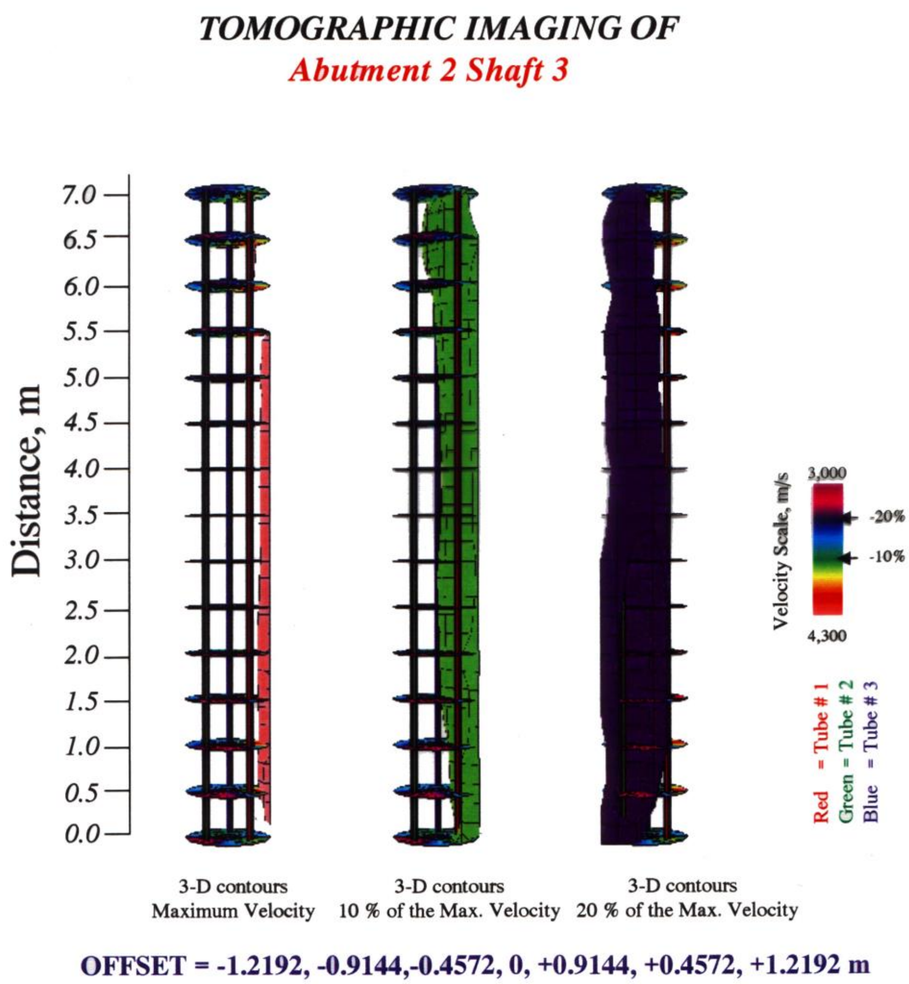

Figure (4)

6. Ground Penetrating Radar (GPR) Method

In the Ground Penetrating Radar (GPR) method, radio frequencies are transmitted into a test medium to image a target of interest. GPR has been used for mapping underground structures, detecting utilities, as well as detecting voids, defects, rebar, and subgrade condition in the civil structures.

6.1 *Testing Procedure*

GPR surveys can be run from the surface of the ground, back of a slow-moving vehicle, or from a borehole. GPR can be used in nondestructive testing (NDT) studies by obtaining data from the exposed surface of the civil structures for the detection of rebar, voids, and delaminations.

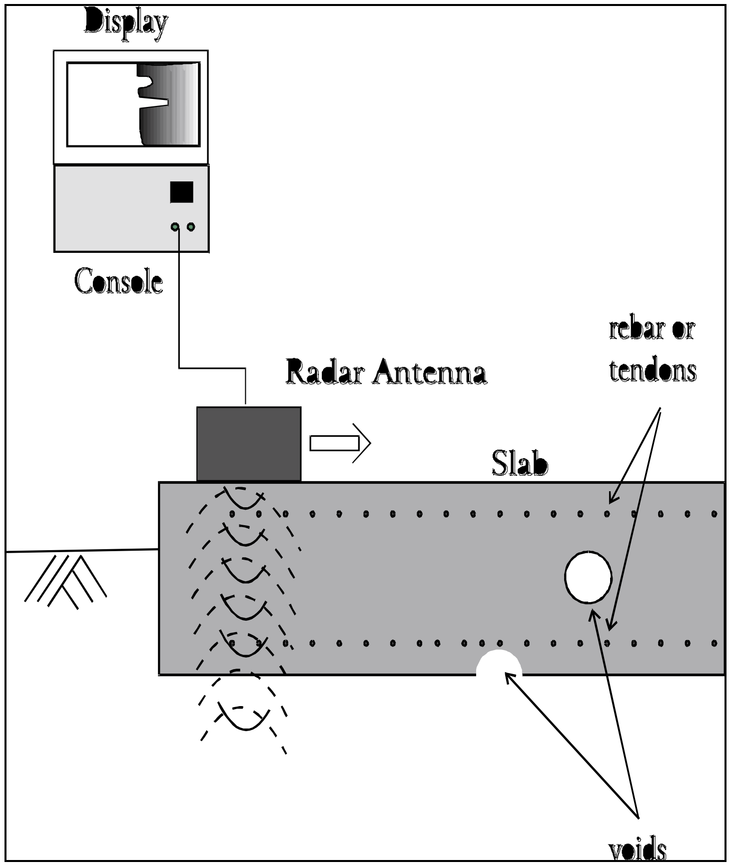

Figure (5)

6.2 *Theoretical Approach*

In the GPR method, a radio frequency signal is transmitted into the subsurface and reflection echoes are recorded. The radar signal is propagated as an electromagnetic wave (displacement currents) in response to the applied electric field. Reflections occur at interfaces with a contrast in dielectric properties. GPR results are very site specific because of the limited depth of penetration of radar in conductive environments, such as in salt water and water-saturated clay.

6.3 *Advantages of GPR*

- GPR can determine pavement thickness (asphalt and concrete), detect voids underneath the pavement, detect both metallic and nonmetallic rebar, find the extent of rebar corrosion and roadbed slumping, and examine base course thickness and layering

- Fast and non-intrusive field operation, thereby allowing for a quick condition assessment of a test structure. Rapid GPR surveys can be run from radar antennas attached to the back of a slow-moving vehicle
- Borehole radar are used to obtain a side image of foundations and determine their depth

6.4 Example of GPR Data

The 1200x1200 mm image shown in Figure (6) was taken from a flat concrete pad outdoors, in the United Kingdom. It clearly shows two distinct, partially overlapping rebar mats, starting at a depth of 60 mm, going down to 150 mm (courtesy of the Sensors and Software, Inc.). Research is needed to adapt this technology for rebar imaging from flat slabs to cylindrical concrete columns.

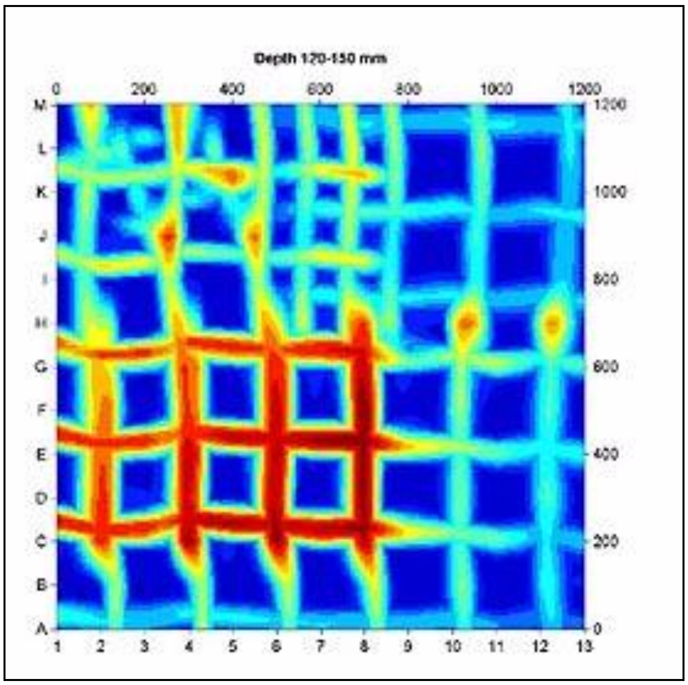

Figure (6)

7. Fabrication Of Ultra-Seismic Field Systems

If desired, compact hand-held ultra-seismic field systems will be fabricated for use by the CALTRANS field personnel. These systems will be designed to be portable and provide rapid turn around of the results in the field. The units will consist of the following components:

a) One battery operated low impedance seismic accelerometer with coaxial cable;
b) One impulsive seismic source with trigger device;
c) Data acquisition box computerized screen containing A/D card, filter/amplifiers, real time data acquisition software, digital data processing software and printing capabilities. Depending on the design element of the data acquisition box and printer capabilities, the price of 1-3 units are expected to range between $10,000-$14,000 per unit. This price is expected to be below $10,000 per unit if greater than 5 units are ordered.

Appendix I

CURRICULUM VITAE

Al Zeiny, Ph.D., P.E

EDUCATION:

- **Ph.D. in Civil Engineering**, December 1992 - September 1995
  University of California, Irvine, Concentration on Structures.
- **Core Courses in Information and Computer Science**, September 1992 -
  University of California, Irvine.
- **M.Sc. in Civil Engineering**, September 1991 - December 1992
  University of California, Irvine, Concentration on Structures.
- **M.Sc. Courses in Civil Engineering**, September 1990 - June 1991, CU
- **B.Sc. in Civil Engingeering with honor**, September 1984 - August 1989, CU

EMPLOYMENT HISTORY:

- **California State University, Fresno**, *August 1997 - Present*
  Faculty, Department of Civil & Geomatics Engineering & Construction
  California State University, Fresno, CA 93740-8030.
- **Brooks-Ransom Associates**, *May 2001 - Present*
  7415 North Palm, Suite 100, Fresno, CA 93711
  Position: Part Time Structural Engineer.
- **Engineering Designs**, *March 1998 - May 2001*
  5155 N 1st St, Fresno, CA 93710-7805
  Position: Part Time Structural Engineer.
- **HARZA Consulting Engineers and Scientists**
  September 1995 - August 1997
  825 Colorado Boulevard, Los Angeles, CA 90041
  Position: Structural Engineer, Earthquake Sciences and Engineering Division
- **University of California, Irvine**, *September 1991 - December 1995*
  Department of Civil and Environmental Engineering, Irvine, CA 92697
  Positions: Instructor, Teaching and Research Assistant, and Research Project Engineer
- **GOHBPR**, *November 1990 - September 1991*
  Position: Research Assistant
  ACE, August 1989 - November 1990, Position: Structural Engineer

RESEARCH INTERESTS:

Structural Engineering Analysis, Laboratory Testing and Non-destructive testing. Specializing in Nonlinear Finite Element Analysis, Structural Dynamics and Fluid-Structure Interaction Problems

FUNDED RESEARCH PROJECTS:

($80,000)

Seismic Evaluation of the Performance of Retrofitted and Repaired Brick Walls by Means of Expansive Epoxy Injection:
March 1998 - August 2000
A pioneer technique to repair unreinforced masonry walls cracked during past seismic events, or to retrofit existing brick walls to meet the current code requirements, is proposed to be subjected to experimental

investigation. Such walls are very common in historical buildings, such as the Los Angeles City Hall and the Alameda City Hall. The walls are injected by ceramic foaming material developed by Delta Plastics Company. After the material is shot into walls, it expands, bonds and hardens like rock. This injection technique does not affect the appearance of these historical walls and consequently it preserves their historical value. The use of Carbon fiber does not have this advantage. It is proposed to test the seismic performance and ductility of the plain brick walls first. These broken walls will then be repaired using the Ceramic Foam and tested. In addition, strengthened unbroken walls with Ceramic Foam and composite Carbon Fiber material will be tested. Performance of all walls will be studied and compared to prove the effectiveness of the Ceramic Foam material in the retrofitting and repairing of walls.

SUBMITTED RESEARCH PROPOSALS:

- **Development of Practical Design Guidelines for Unanchored Liquid Storage Tanks:**
  Research Proposal Written to NSF, November 1998.
- **Survivability Assessment of Current Aircraft Designs Using State-of-the-Art Technologies in Hydrodynamic Ram and Fuselage Decompression Analyses:**
  Research Proposal Written to Northrop Grumman Corporation, October 1998.

RESEARCH Proposals UNDER PREPARATION:

- **Finite Element Analysis of the Facial Skin:**
  The purpose of this research is to use modern numerical analysis techniques to model the biological and mechanical properties of the human face. It is an interdisciplinary project involving engineering science, computer graphics, and biology. This project will produce a software package that is capable of inputting the shape of a face, and then manipulating that face to simulate the effects of reconstructive surgery on the shape of the face.
- **Pseudo Dynamic Testing Using Active Displacement Control Techniques:**
  The proposal will deal with the development of active algorithm to control the displacement of tested specimens. The input for the algorithm will be the magnitude of loads measured from the loading cells during the test, as well as the target ground motion. The output of the algorithm will be the displacement that should be applied on the specimen using the actuators to produce the same forces developed during a real life seismic event.

INDUSTRIAL AND RESEARCH EXPERIENCE HIGHLIGHTS:

- Building a nonlinear Finite Element program capable of modeling curved shells with material and geometric nonlinearities, fluids with the nonlinear sloshing phenomenon and nonlinear fluid-structure interaction, and performs general contact analysis. The program is used to analyze and develop design guidelines for liquid storage tanks
- Enhancing a nonlinear Finite Element program to model concrete

plasticity, composite effect and cracking using the concepts of fracture mechanics

- Nonlinear time history analysis of Big Tujunga Concrete arch dam using the finite element method. Nonlinearities arise due to concrete cracking and opening of joints
- Project engineer on Caltrans project "Retrofit, Repair and Testing of Bridge Pier Walls". Duties included lab testing and supporting analyses
- Author of structural finite element program to analyze static, moving and seismic loads on the Getty Museum floors. Loads include moving fork lifts, heavy statues and displays. Program written in the C language
- Structural Design of Commercial Buildings
- Performed seismic analysis of four 40 ft. wide by 30 ft. high spillway radial steel gates at Big Creek No. 7 Dam, and one 15 ft. wide by 8 ft. high radial spillway gate at Vermillion Dam to determine gate's structural integrity.
- Performed condition assessment of the equipment and structural analysis of each gate including finite element analyses.
- Vulnerability analysis of power transformers and bushings using Finite Element.
- Vulnerability analysis of Rockwell large steel building (250,000~ft^2) with gypsum concrete diaphragm.
- Structural evaluation of Memphis Company LNG tanks, and INTEVEP oil storage tanks.
- Time history analysis of Dames & Moore MFHT unanchored liquid storage tanks. MFHT tanks are supported on building floors and used to store nuclear waste materials.
- Building data base for California faults and adapting seismic risk analysis programs.
- Project management and scheduling using Primavera systems.
- Layout and design of the 20,000 feet-long Santa Ana River pipeline and supporting structures.
- Structural engineer on the analysis and design of steel and concrete structures, bridges and
various types of foundations

HONORS:

- Dissertation fellowship, 1995, University of California, Irvine.
- Institute Merit Scholarship, 1984-1989.

REGISTRATION: Registered Professional Civil Engineer in the State of California

PROFESSIONAL SOCIETIES: Member of American Society of Civil Engineers

COMPUTER SKILLS:

- Experienced in Object-Oriented Fininte Element Development
- Experienced in using the numerical object package DiffPack. The DiffPack object-oriented C++ libraries contain a wide selection of interchangeable and application-independent components, which

facilitate the development of numerical simulations of partial differential equations

- Knowledgeable in Software Engineering, Data Structures, Algorithm Analysis and various Operating Systems
- Capable of programming in many programming language including C, C++, Java, Fortran 2000, Ada, Pascal and Assembly Language
- Proficient in finite element analysis with software packages MARC, ADINA, SAP, ANSYS and COSMOS with special experience in building research oriented Finite Element programs
- Experienced with Unix machines and with wide variety of commercial software.

PERSONAL INFORMATION:

Born on February 15, 1968. Married and have four children

Appendix II

Brief Profile Of Infraseis

InfraSeis, Inc. is a specialized geophysical company dedicated to provide services and products for nondestructive testing and subsurface site characterization to the civil infrastructure industry. InfraSeis has developed state-of-the-art nondestructive system for QA/QC measurement and evaluation of the structural integrity of existing and new foundations. In cooperation with Mount Sopris Instruments, Golden, Colorado, InfraSeis has developed a full-waveform" Crosshole Sonic Logging (CSL) system for logging drilled shaft foundations and slurry walls.

For a description of the company's products and services pertaining to highway engineering problems, please refer to our web site at: *www.infraseis.com*.

II.1 Project and Pertinent Research Experience

InfraSeis has extensive project experience in the areas of deep foundation integrity testing; testing of concrete pavements, floors, and walls for thickness measurement and locating voids, delamination and rebar. State-of-the-art geophysical methods and equipment are applied for site characterization and investigations in locating obstructions along micro-tunnel alignment, determining depth of bedrock, and locating utility pipes or underground storage tanks. To-date, InfraSeis has performed numerous projects to support a wide variety of engineering investigations ranging from non-destructive evaluation (NDE) of engineered structures to subsurface geophysical site characterization. These projects were performed throughout the U.S. for Federal Highways, State Department of Transportations, local municipalities, prime contractors, subcontractors, and engineering consultant companies.

Additionally, InfraSeis has extensive experience in conducting applied research projects for the civil infrastructure industry. As an example of such research work, Mr. Jalinoos has served as a Co-Principal Investigator for the FHWA-sponsored National Cooperative Highway Research Program (NCHRP) research project for "Unknown Bridge Foundation Testing". The NCHRP 21-5 project was conceived to "evaluate, develop, and test concepts, methods and equipment that will allow the determination of subsurface bridge foundation characteristics where information is unavailable, unknown, or uncertain". There are approximately 580,000 highway bridges in the national bridge inventory. For a large number of older, non-federal-aid bridges, their design plans have been lost; and, consequently, no information is available regarding the type, depth, geometry, or material incorporated in the foundations. The current best estimate of the population of bridges over water with unknown foundations is 106,000 with 25,000 of the bridges on-state systems and 81,000 bridges off-state systems. Such foundation type and depth information is needed for performing scour evaluation for each bridge by the state DOT's as required by the Federal Highway Administration (FHWA).

Mr. Jalinoos carried both the literature survey and was principally involved in the performance of the field work for the NCHRP 21-5 project. That study documented the results for i)- three direct acoustic NDT methods applied from the surface of the bridge: sonic echo/impulse response, bending (flexural) wave, and ultra-seismic surface method (developed by Mr. Jalinoos in the course of carrying this research); and ii)- three borehole methods: parallel seismic and borehole sonic methods, and borehole radar; and iii)- one modal vibration method: dynamic foundation response at seven bridges with known foundation characteristics.

Mr. Jalinoos has also served as a Co-Principal investigator in a National Science Foundation sponsored (SBIR) study on ultrasonic crossmedium tomographic imaging of structural concrete. Acoustic tomography was used to image flaws or defects cast-in-place in five concrete walls. The results of this study indicated that travel time tomography was most successful in detecting isolated air-filled voids in concrete. Tomographic imaging was also used to locate honeycombs, simulated open cracks, microcracks, and weak concrete. Because of this study, tomography is now a practical tool for assessing the condition of critical concrete structures with two-sided access, such as bridge columns and decks.

Most recently, InfraSeis has concluded a research study for the Federal Highway Administration (FHWA). This study involved 3-dimensional Crosshole Tomographic (CT) imaging of four drilled shafts with engineered defects at the National Geotechnical Experimentation Site (NGES), University of Massachusetts-Amherst. Each shaft contained four access tubes and 6 tomographic dataset panels were acquired using 4 perimeter panels and 2 diagonal panels. This study was successful in delineating 3-dimensional images of defects inside the rebar cage. It is clear from this study that defects that are situated outside the rebar cage with no intrusion into the test pipes are missed by the CSL and the tomographic imaging techniques. Only single-hole nuclear logging techniques can detect this important class of defects in the drilled shafts. Therefore, an extension to the NGES study is being requested to incorporate three additional geophysical logs including gamma-gamma density logging (GDL), natural gamma logging (NGL), and neutron moisture logging (NML).

II.2 Personnel Qualifications

This research study will be performed by Mr. Frank Jalinoos as the Principal Investigator and Prof. Kanaan Hanna who will oversee the whole project. Mr. Jalinoos has experience in geophysical research and methodology, business development, technical management and consulting. Mr. Jalinoos is one of a few practitioners in the field of the civil infrastructure testing with extensive experience in both civil NDT and advanced geophysical engineering methods. Prof. Hanna brings over 25 years experience in government, consulting industry and academia. Experience in business development and marketing strategy, management, contract negotiation, project planning and implementation, and system engineering. Prof. Hanna has extensive geotechnical engineering experience, R&D, manual/guidebook preparation, and the applications of advanced geophysical imaging technologies for transportation infrastructure systems.

Appendix III

Resume Of Mr. Jalinoos

FRANK JALINOOS, President

EDUCATION

- Ph. D. on hold, Colorado School of Mines, Golden Colorado
- M.S., Geophysical Engineering, Colorado School of Mines, 1984
- B.S., Physics, Connecticut College, 1980

PROFESSIONAL EXPERIENCE

- InfraSeis, Inc., Denver, Colorado
  President, August 1996 - Present
  Responsible for conducting consulting and research services in Nondestructive Testing (NDT) of and subsurface geophysical testing civil infrastructure
- Olson Engineering, Inc., Golden, Colorado
  Senior Geophysicists, August 1992- August 1996
  Nondestructive testing using Sonic Echo Test (SET), Ultra-seismic Test (UST), Crosshole Sonic Logging, Impact Echo Test (IE), Ground Penetrating Radar (GPR), Parallel Seismic (PS), and Spectral Analysis of Surface Wave (SASW) methods. Geophysical testing using Seismic Refraction, Crosshole Seismic, and SASW methods. Research Activities: Co-Principal Investigator in the National Cooperative Highway Research Program (NCHRP) for the determination of unknown depth of bridge foundations. Co-Principal Investigator in National Science Foundation (NSF) project for the tomographic imaging of defects in concrete slabs.
- Production Geophysical Services (PGS), Englewood, Colorado
  Geophysical Consultant, 1990- 1992
  Geophysical consulting and software development in source deconvolution and three component data acquisition and processing in support of petroleum exploration and civil engineering projects.
- Digicon, Inc., Houston, Texas
  Senior Geophysical Programmer, 1988- 1990
  Geophysical software development including tau-p analysis, surface consistent deconvolution and inversion. Software maintenance of Dicgicon's "DISCO" processing package.
- Bolt Technologies, Denver, Colorado
  Research Geophysicists, 1984- 1988
  Geophysical research and program development in surface seismic exploration, three component seismology, and Vertical Seismic Profiling (VSP). Developed travel time tomographic imaging software using ART and SIRT algorithms and curved rays.
- Colorado School of Mines, Golden, Colorado
  Research Assistant, 1981- 1984
  Geophysical research with the Department of Geophysics at CSM

CONSULTING EXPERIENCE

- Drilled Shaft and Pre-cast Pile Integrity Testing: testing structural integrity and defects in deep foundations using Crosshole Sonic Logging (CSL), 3-D tomographic imaging, Gamma-Gamma Density logging and the Sonic Echo Test (SET) techniques.
- Slab and Utility Pipes Integrity Testing: integrity testing of concrete slabs/walls, parking structures and utility pipes using the Impact Echo (IE), Slab Impulse Response, and Ground Penetrating Radar (GPR) test methods.
- Bridge Foundations and Dams Testing: Testing of bridge foundations for integrity and <u>unknown depth</u> using Ultra-seismic Test (UST), Parallel Seismic (PS) test, Borehole Radar (BHR) and cross-borehole 3-D tomographic imaging.
- Subsurface Investigations: Testing of physical properties of soil using shear and compressional wave measurements, 2-D and 3-D tomographic imaging for subsurface investigations using vertical and horizontal borehole. Near surface geophysical surveys for locating utilities, underground storage tanks and unexploded ordinates (UXO) using Ground Penetrating Radar (GPR), and electrical conductivity and DC resistivity. Depth to bedrock and velocity measurements using Seismic Refraction, Spectral Analysis of Surface Wave (SASW), and GPR.

INSTRUMENT DEVELOPMENT AND RESEARCH

Development of a state-of-the-art Crosshole Sonic Logging (CSL) system in cooperation with Mount Sopris Instruments of Golden, Colorado. Research into development of the Ultra-seismic test method with Dr. Alfred H. Balch at Colorado School of Mines.

AFFILIATIONS

- International Association of Foundation Drilling (ADSC, Technical Affiliate)
- Member of Environmental and Engineering Geophysical Society (EEGS, Past Society Liaison Chairman)
- Society of Exploration Geophysicists (SEG)
- Near Surface Group (NSG) of SEGDenver Geophysical Society (DGS)

PUBLICATIONS

<u>Papers:</u>

- "Determination of unknown depth of bridge foundations using nondestructive testing methods", Jalinoos, F., Olson, L.D., Structural Materials Technology, an NDT Conference, San Diego, California, 1996.
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