

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

In the Matter of

LOUISIANA POWER AND LIGHT COMPANY

(Waterford Steam Electric Station,
Unit 3)

Docket No. 50-382

AFFIDAVIT OF MORRIS REICH,
CHARLES A. MILLER, AND CARL J. COSTANTINO

Q.1. Please state your names, titles and by whom you are employed.

A.1(a). My name is Morris Reich. I am employed as Head of the Structural Analysis Division, Department of Nuclear Energy, Brookhaven National Laboratory, Upton, NY. A statement of my professional qualifications is attached.

A.1(b). My name is Charles A. Miller. I am employed as Professor of Civil Engineering and Director of the Materials Testing Laboratory, Department of Civil Engineering, The City College of the City University of New York. A statement of my professional qualifications is attached.

A.1(c). My name is Carl J. Costantino. I am employed as Professor of Civil Engineering and Director of the Soil Mechanics Laboratory, Department of Civil Engineering, The City College of the City University of New York. A statement of my professional qualifications is attached.

8409040204 840828
PDR ADOCK 05000382
PDR

Q.2. What is the purpose of this affidavit?

A.2. The purpose of this affidavit is to provide a summary of our evaluation and conclusions as to the safety significance of the concrete cracking that has been observed in the foundation base mat at Waterford Steam Electric Station, Unit 3.

Q.3. Please describe your involvement with these issues.

A.3. The Structural Analysis Division of the Department of Nuclear Energy, Brookhaven National Laboratory (BNL), was requested by the NRC Staff to review various design issues related to the Waterford foundation base mat and to provide its conclusions as to the adequacy and structural integrity of the base mat. BNL's efforts were directed by Dr. Morris Reich and received technical assistance from Drs. Costantino and Miller, whose services were provided under contract to BNL. The other members of the BNL team were A.J. Philippacopoulos, S. K. Sharma and P. C. Wang; the professional qualifications of these individuals are attached to this affidavit as Attachment 1.

Our involvement with these issues commenced in March 1984 and has continued to the present. During this period, we met and consulted with members of the NRC Staff on numerous occasions; reviewed several reports prepared by the Applicant's consultant, Harstead Engineering Associates, Inc.; met with and obtained further information from the Applicant and its architect-engineer, EBASCO; and visually examined the cracks and water seepage. On July 18, 1984, we issued a report which provided a detailed description of our analyses and conclusions concerning the Waterford foundation base mat, entitled "Review of Waterford III Basement

Analysis" ("BNL Report"); on information and belief, this report was provided to the Atomic Safety and Licensing Appeal Board on July 25, 1984.

On July 31, 1984, following the issuance of the BNL Report, we traveled to the Waterford site to meet with the Applicant and its consultant, Muenow Associates, which has been conducting non-destructive testing of the foundation base mat, and received an explanation of the preliminary results of the NDT program. Based upon our understanding of these preliminary results, as represented to us by the Applicant and Muenow Associates, we have prepared an "Addendum" to the BNL Report of July 18, 1984, which provides further information and confirms the initial conclusions presented in the BNL Report. This Addendum, dated August 3, 1984, is attached to this Affidavit as Attachment 2.

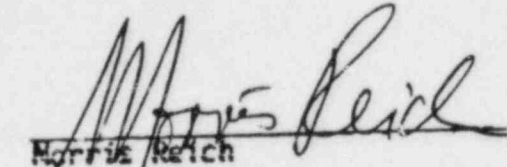
Q.4. Does the BNL Report dated July 18, 1984, as supplemented by the Addendum dated August 3, 1984, provide a true and accurate representation of your views concerning the adequacy and structural integrity of the Waterford foundation base mat?

A.4. Yes.

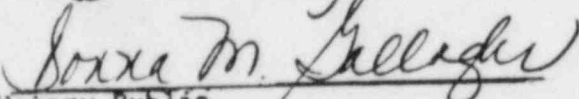
Q.5. What is your conclusion relative to the adequacy and structural integrity of the Waterford foundation base mat?

A.5. Based upon the analysis which we have conducted and the information provided by the Applicant and EBASCO, it is our conclusion that the safety margins in the design of the mat are adequate, and that the concrete cracks in the base mat, as well as the cracks in certain vertical walls standing on the base mat, do not present a significant

issue affecting the safety of the Waterford facility. We have, however, recommended that certain detailed confirmatory calculations be performed, although we do not anticipate that these analyses will lead to any substantially different results, and we have recommended that a surveillance program be initiated to monitor the cracks. Detailed explanations of the bases for these conclusions may be found in the BNL Report of July 18, 1984 and the Addendum of August 3, 1984.


Morris Reich

Subscribed and sworn to before me
this 3 day of August 1984

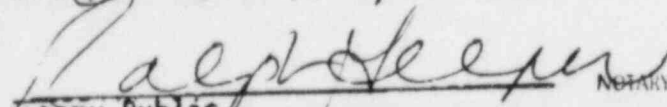

Notary Public

DONNA M. GALLAGHER
NOTARY PUBLIC, State of New York
No. 4777833, Suffolk County
Term Expires March 30, 1985

My Commission expires: Mar. 30, 1985


Charles A. Miller

Subscribed and sworn to before me
this 6 day of August 1984



Notary Public

RALPH GELPER
NOTARY PUBLIC, State of New York
No. 41-1400538
Qualified in Rockland County
Term Expires March 30, 1985

My Commission expires: _____


Carl J. Costantino

Subscribed and sworn to before me
this 6 day of August 1984


Notary Public

RALPH GELPER
NOTARY PUBLIC, State of New York
No. 41-1400538
Qualified in Rockland County
Term Expires March 30, 1985

My Commission expires: 1 _____

Morris Reich

Position:

Head, Structural Analysis Division
Department of Nuclear Energy
Brookhaven National Laboratory

Special Fields:

Over twenty years of extensive management experience in the utilization and development of nuclear energy systems and related technology. Some of the items worked on includes; structural design and safety evaluations of fission, advanced fission, fusion reactors, geothermal and conventional power plants, coal mine tunnels, underground support systems, complex radar support systems, and bridge and highway structures; extensive work in the development of structural finite element techniques, fracture mechanics techniques, and dynamic response methods; recent work includes development of risk and reliability analysis methods for design of engineering structures and systems.

Member - Editorial Board of Journal of Nuclear Engineering and Design, North Holland Publishing Company.

Consultant - Advisory Committee on Reactor Safeguards (ACRS) of the United States Nuclear Regulatory Commission, 1977 - 79.

Board Member of the International Association for Structural Mechanics in Reactor Technology.

Division/Session Chairman
and/or Invited Speaker

Chairman and Invited Speaker - Session - M5, Structural Systems/Component Reliability, 7th International Conference on Structural Mechanics in Reactor Technology, Chicago, IL, 1983.

Invited Speaker - Session - M7, Probabilistic Risk Assessment, 7th International Conference on Structural Mechanics in Reactor Technology, Chicago, IL, 1983.

Division Chairman - 5th International Conference on Structural Mechanics in Reactor Technology, Berlin, Germany, 1979.

Chairman Session - (H3) Structural Analysis of Pre-Stressed Concrete Reactor Vessels II, 4th International Conference on Structural Mechanics in Reactor Technology, San Francisco, CA, August, 1977.

Division/Session Chairman
and/or Invited Speaker (Cont'd)

Co-Chairman - Structural Dynamics II, International Meeting on Fast Reactor Safety and Related Physics, American Nuclear Society and European Society, Chicago, IL, October 1976.

Invited Speaker - Structural Problems of Fusion Power, Session NP, 4th International Conference on Structural Mechanics in Reactor Technology, San Francisco, CA, August 1977.

Invited Speaker - Safety Considerations of PCRV's American Nuclear Society Meeting, San Francisco, CA, November 1975.

Edited; Special Issue on Fusion, Vol. 58, (1980), Nuclear Engineering and Design, North Holland Publishing Company, Amsterdam, Netherlands.

Edited; Structural Analysis Needs for Magnetic Fusion Energy Superconducting Magnets, published by ERDA, CONF-760984-1976.

Education:

City College of New York, B.S.M.E., June 1961

City College of New York, M.S.M.E., June 1963

Polytechnic Institute of Brooklyn, Mechanical Engineering, June 1972

Polytechnic Institute of Brooklyn, Mechanical Engineering, Ph.D., Summer 1974

Dr. Reich joined Brookhaven National Laboratory in 1962 as a member of the Mechanical Engineering Division. His early assignments included project work at the newly designed High Flux Beam Reactor (HFBR). Later, he was appointed Chief Mechanical Engineer of the Pulsed Fast Reactor Project.

Since forming the Structural Analysis Group (about seven years ago), he has participated and directed a host of activities for the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE - formerly ERDA), the Federal Highway Administration, the U.S. Bureau of Mines, the Office of Saline Water and the Department of Defense. As Head of the Structural Analysis Group, he supervises Senior Engineers and scientists in the development of complex structural analysis and probabilistic methods and their application to evaluations of structural components and systems used in water-cooled reactors (LWR's and BWR's), Liquid Metal Fast Breeder Reactors (LMFBR's), High Temperature Gas-Cooled Reactors (HTGR's), and Controlled Thermomuclear Reactors (CTR's). His activities involving evaluations of static, dynamic, elastic, elastic-plastic small and large deformations, as well as large strains, liner and ductile.

fracture mechanics, creep, fatigue, creep-fatigue interaction, linear and nonlinear seismic response, soil structure interaction, and combined structural-probabilistic analysis, etc. for reactor vessels, steam generators, piping systems, core and core components, prestressed concrete reactor vessels (PCRVS), containment structures, fusion magnet structures and systems, blanket, and other general power plant components, are well documented in literature.

Similarly, he has participated and directed research for the Bureau of Mines, dealing with the design and evaluation of coal mine underground support systems, and development methods and the structural response evaluation of anisotropic layered media; has worked on various schemes for new types of desalinization plants for the Office of Saline Water; has participated in structural evaluations and designs involving new highway bridge-decks airport runways, and general bridge designs utilizing prestressed and/or post-tensioned polymer concrete for the Federal Highway Administration; developed and designed equipment for geothermal power plant use for Department of Energy; evaluated various sophisticated equipment for Department of Defense.

As Division Head, he is in charge of developing the division's research programs and in obtaining the funding for all proposed work. He maintains a close liaison with various research funding organizations as well as professional organizations involved with structural, mechanical and nuclear engineering research.

Journal Publications

1. "Analysis of Bridge Decks Using Poly-Impregnated Concrete", M. Reich and E. Koplik, Pub. SP. 40, American Concrete Inst. (ACI) 1973.
2. "Finite-Element Analysis of Structural Response of Superconducting Magnets for a Fusion Reactor", M. Reich, T.Y. Chang, S. Prachuktam and J. Powell, Paper M 2/9, proceedings of the 3rd International Conference on Structural Mechanics in Reactor Technology, London, England, Sept. 1975.
3. "Determination of Burst Pressures for Cracked Steam Generator Tubes", M. Reich and T.Y. Chang, ASME Paper 77 PVP-31, proceedings of the ASME Energy Tech. Conf., Houston, TX, Sept. 1977.
4. "Inelastic Analysis of Finite Length and Depth Cracked Tubes", M. Reich, S. Prachuktam and D. Gardner, Paper F 7/4, proceedings of the 4th Intl. Conf. on Structural Mechanics in Reactor Technology, San Francisco, CA, Aug. 1977.
5. "Three-Dimensional Nonlinear Failure Analysis for PCRV's and Containment Structures", M. Reich and J.J. Connor, Paper H 2/1, proceedings of the 4th International Conf. on Structural Mechanics in Reactor Technology, San Francisco, CA, Aug. 1977.
6. "Effect of Clearance and Distribution of Mass on the Dynamic Response of an HTGR Core", M. Reich and B. Koplik, Paper K 7/3, proceedings of the 4th International Conf. on Structural Mechanics in Reactor Technology, San Francisco, CA, Aug. 1977.
7. "Structural Aspects of Superconductivity Fusion Magnets", M. Reich, J. Lehner and J. Powell, Paper 1.55, proceedings of the World Electro-technical Congress, Moscow, USSR, June 1977.
8. "Cyclic Behavior of Seized Steam Generator Tubes", M. Reich and S. Prachuktam, ASME/CSME Vessel and Piping Conference, Montreal, Canada, June 1978.
9. "Failure Analysis of Steam Generator Tubes in Dented and Wastage Configuration", M. Reich, S. Prachuktam and T.Y. Chang, Journal of Pressure Vessel Technology Trans. ASME, Vol. 100, No. 4, 1978.
10. "Compilation of References, Data Sources and Analysis Methods for LMFBR Primary Piping System Components", M. Reich and E.P. Esztergar, Nuclear Engineering and Design, Vol. 50, No. 2, Oct. 1978.
11. "Application of Fracture Mechanics Methods in Safety Analysis of Piping Components in Subcreep and Creep Regions", M. Reich, E.P. Esztergar, E.C. Ellison, R. Erdogan, T.F.G. Spence and C. Wells, Nuclear Engineering and Design, Vol. 51, No. 2, Jan. 1979.

Journal Publications (Cont'd)

12. "Concepts for Benchmark Problem Development for Fracture Mechanics Application in Safety Evaluation of Nuclear Piping in Sub-Creep Service", M. Reich and E.P. Esztergar, Nuclear Engineering and Design, Vol. 51, No. 2, January 1979.
13. "Nonlinear Response to Multiple Decaying Sine Waves", B. Koplik, M. Reich and J. Curreri, Paper M10/7, proceedings of the 5th International Conference on Structural Mechanics in Reactor Technology, Berlin, August 1979.
14. "Existing and Future Structural Analysis Techniques and Their Application to Superconducting Magnets", M. Reich, N2/1-1, proceedings of the 5th International Conference on Structural Mechanics in Reactor Technology, Berlin, August 1979.
15. "Generic Structural Mechanics Aspects of Fusion Magnet Systems", M. Reich and J.R. Powell, Nuclear Engineering and Design, Vol. 58, No. 2, 1980.
16. "Non-linear Dynamic Response of a Multi-Mass System with Gaps", M. Reich, and B. Koplik, proceedings of the 47th Shock and Vibration Symposium, Albuquerque, N.M., October 1976.
17. "Reliability Assessment of Nuclear Structural Systems", M. Reich, and H. Hwang, Paper M/5/1, proceedings of the 7th International Conference on Structural Mechanics in Reactor Technology Chicago, IL, August 1983.
18. "The Brookhaven High Flux Beam Reactor Fast Chopper Facility", R.E. Chrien and M. Reich, Nuclear Instruments and Methods, Vol. 53, No. 1, pp. 93-107, 1967.
19. "Assessment of Nonlinear Structural Finite Element Program: NONSAP for Inelastic Analysis", T.Y. Chang, S. Prachuktam and M. Reich, ASME paper 77-PVP-10, ASME Energy Conference, Houston, Texas, September 1977.
20. "Three-Dimensional Inelastic Evaluation of Controlled Magnetic Fusion Energy Reactor Magnet", J. Lehner, M. Reich and J. Powell, Paper L5/4, proceedings of the 4th International Conference on Structural Mechanics in Reactor Technology, San Francisco, CA, August 1977.
21. "Nonlinear Analysis of a Superconducting Magnet of a Fusion Reactor", T.Y. Chang, H. Suzuki and M. Reich, Paper L5/3, proceedings of the 4th International Conference on Structural Mechanics in Reactor Technology, San Francisco, CA, August 1977.
22. "Safety and Reliability Aspects of Superconducting Magnets for Thermo-nuclear Power Reactors", J. Powell, S.Y. Hsieh and M. Reich, Paper 1.54, proceedings of the World Electrotechnical Congress, Moscow, USSR, June 1977.

Journal Publications (Cont'd)

23. "Failure Analysis of Tubes with Wastages", S. Prachuktam, M. Reich and J. Ragan, ASME Paper 79-PVP-113, proceedings of the Pressure Vessel and Piping Conference, San Francisco, CA, June 1979.
24. "A Finite Element Model for Elastic and Slip Responses of Fusion Magnets", T.Y. Chang and M. Reich, Journal of Pressure Vessel Technology, Vol. 102, May 1980.
25. "A Three Dimensional Test Program for Nonlinear Behavior of an HTGR Core", J. Curreri, M. Reich, B. Koplik, P. Bezler and M. Subudhi, Paper K12/1, proceedings of the 5th International Conference on Structural Mechanics in Reactor Technology, Berlin, August 1979.
26. "A Review of Structural Mechanics Aspects of Fusion Blankets", J.R. Powell and M. Reich, Nuclear Engineering and Design, Vol. 58, No. 2, 1980.
27. "Finite Element Based Random Vibration Analysis of Nuclear Structures Under Seismic Loading", T. Kako, M. Shinozuka, H. Hwang, and M. Reich, Paper K 7/2, proceedings of the 7th International Conference on Structural Mechanics in Reactor Technology, Chicago, IL, August 1983.
28. "Development of a Reliability Analysis Method for Category I Structures", M. Shinozuka, T. Kako, H. Hwang and M. Reich, Paper M5/3, proceedings of the 7th International Conference on Structural Mechanics in Reactor Technology, Chicago, IL, August 1980.
29. "Estimation of Structural Reliability Under Combined Loads", M. Shinozuka, T. Kako, H. Hwang, P. Brown and M. Reich, Paper M 2/3, proceedings of the 7th International Conference on Structural Mechanics in Reactor Technology, Chicago, IL, 1983.
30. "Computer Technology in Fusion Reactor Research", T.Y. Chang, H. Suzuki and M. Reich, ASME Publication, PVP-PB-031, 1978.
31. "Thermal and Structural Design Aspects of Heat Temperature Blankets for Fusion SYN Fuel Production", J.R. Powell, J.A. Fillo and M. Reich, Paper N 2/4, proceedings of the 6th International Conference on Structural Mechanics in Reactor Technology, Paris, France, August 1981.
32. "Evaluation of Concurrent Peak Responses", P.C. Wang, J. Curreri, and M. Reich, Paper M 2/4, proceedings of the 7th International Conference on Structural Mechanics in Reactor Technology, Chicago, IL, August 1983.

Selected NRC and DOE Reports

1. "Integrity of LMFBR Primary Piping: A Preliminary Evaluation", Part I: J.G.Y. Chow, Part II, M. Reich, September 1974, Report No. BNL/FRS-74-2.
2. "Elastic and Inelastic Methods of Piping Systems Analysis: A Primary Review", M. Reich and E. Esztergar, February 1975, Report No. BNL-19768.
3. "Proceedings of the Workshop on Structural Analysis Needs for Magnetic Fusion Energy Superconducting Magnets - A Technical Assessment", M. Reich, J. Lehner, J. Powell and P. Bezler, Eds., held at BNL, September 1976, Report No. CONF-760984.
4. "Piping Benchmark Problems, Dynamic Analysis Uniform Support Motion Response Spectrum Method", P. Bezler, M. Hartzman and M. Reich, August 1980, Report No. NUREG/CR-1677.
5. "Seismic Review Table", M. Subudhi, M. Reich, B. Koplik and J. Lane, April 1980, Report No. NUREG/CR-1429.
6. "Probability Based Load Criteria for Design of Nuclear Structures: A Critical Review of the State of the Art", M. Reich, H. Hwang, Eds., Major Contributors, M. Shinozuka, B. Ellingwood, Contributors, P.C. Wang, C. Meyer, Y.K. Wen, S. Kao, M.L. Shooman and A.J. Philippacopoulos, February 1981, Report No. NUREG/CR-1979.
7. "Dynamic Combinations for Mark II Containment Structures", A.J. Philippacopoulos and M. Reich, February 1981, Report No. NUREG/CR-2039.
8. "Evaluation of Concurrent Peak Response", P.C. Wang, J. Curreri, M. Shooman, Y.K. Wang, A.J. Philippacopoulos, M. Reich and M. Subudhi, May 1982, Report No. NUREG/CR-2685.
9. "Review of Load Combinations for NSSS and BOP Piping and Equipment of Mark III Plants", A.J. Philippacopoulos, M. Reich and P.C. Wang, May 1982, Report No. NUREG/CR-2686.
10. "Independent Seismic Evaluation of the Diablo Canyon Unit 1 Containment Annulus Structure and Selected Piping Systems", A.J. Philippacopoulos, M. Reich, P. Bezler, C. Miller, Y.K. Wang, M. Subudhi, S. Shteyngart and P. Brown, June 1982, Report No. NUREG/CR-2834.
11. "Failure Evaluation of a Reinforced Concrete Mark III Containment Structure Under Uniform Pressure", S. Sharma, M. Reich, T.Y. Chang and S. Shteyngart, September 1982, Report No. NUREG/CR-1967.
12. "Reliability Assessment of Reinforced Concrete Containment Structures", H. Hwang, P. Brown and M. Reich, February 1983, Report No. NUREG/CR-3227.

Selected NRC and DOE Reports (Cont'd)

13. "Probabilistic Models for Materials Used in a Reinforced Concrete Containment", H. Hwang, S. Kao and M. Reich, September 1982, Report No. NUREG/CR-3041.
14. "Seismic and Dynamic Qualification of Safety Related Electrical and Mechanical Equipment in Operating Nuclear Power Plants", J. Curreri, C. Costantino, M. Reich and A.J. Philippacopoulos, April 1983, Report No. NUREG/CR-3266.
15. "Review of Current Analysis Methodology for Reinforced Concrete Structural Evaluations", S. Sharma, M. Reich and T.Y. Chang, April 1983, Report No. NUREG/CR-3284.
16. "Probabilistic Models for Operational and Accidental Loads on Seismic Category I Structures", H. Hwang, P.C. Wang and M. Reich, April 1983, will be published as a NUREG Report.
17. "Analysis of Multi-Dimensional Thermoelastic Dynamic Response of Reactor Fuel Elements", Pulsed Fast Research Reactor Project, M. Reich and B. Koplik, November 1968, Report No. BNL-13311.
18. "Review of Methods and Criteria for Dynamic Combination in Piping Systems", M. Reich, P.C. Wang, J. Curreri, S. Hou, and H. Goradia, March, 1980, Report No. NUREG/CR-1330.

Vita

CHARLES A. MILLER

Professor of Civil Engineering and
Director, Materials Testing Laboratory

Department of Civil Engineering
The City College of the
City University of New York

EXPERIENCE:

a. Teaching:

The City College of the City University of New York	1968-1972 1972-1980 1980-Present	Asst. Prof. Assoc. Prof. Professor
Illinois Institute of Technology	1966-1968	Adj. Asst. Prof.

b. Research:

1957-1968: IIT Research Institute, Chicago, Illinois

From Assistant Research Engineer to Assistant Director
of Mechanics Research Division.

- Fiscal and technical responsibility for 26 engineers
conducting research for government and industry in all
areas of structural mechanics and design.
- Principal investigator on projects in the following
areas: design study for superhard missile launch
facility; design studies on Titan and Minuteman ground
facilities; design of civil defense shelters; load test
on cylindrical concrete shell roof structure; design of
prestressed concrete rail cars; creep effects in
concrete structural components.
- Participant on studies in the following areas:
response of shell structures; development of computer
programs to analyze static and dynamic response of
structures; stability of shell structures.

1968-Present: Department of Civil Engineering, CCNY

- Experimental and analytical studies of creep effects
in concrete structures.
- Test program to evaluate constitutive relationship
for rock and rock/mortar material used in bridge
abutment.
- Evaluation of fatigue properties in concrete
specimens subjected to biaxial stress states.
- Development of computer codes to evaluate the

response of structures to seismic induced loadings.
- Study of the effect of various reduction methods used in performing dynamic analysis of large structural systems.

c. Consulting:

1953-1954 Engineer with M.W.Kellogg
- Design of concrete and steel structures used in petrochemical plants

1968-1970 Consultant to Ammann and Whitney
- Design of structures used on the Nike weapon system. Principal activities were in the design of shear wall components.

1969-1975 Stressteel Corp.
- Developed computer programs to automate the design of prestressed concrete beams.
- Design of prestressed concrete nuclear power plant containment vessels.

1975-Present Transnuclear Inc.
- Design and preparation of liscensing documents for containers used to ship radioactive waste material.

1970-Present Seismic Consultant for Nuclear Regulatory Commission
- Perform studies relating to soil/structure interaction effects in nuclear power plant structures subjected to earthquake loadings.
- Audit safety reports prepared by utilities seeking to liscense a plant.
- Participate in liscensing hearings on behalf of the NRC staff.

EDUCATION

BCE	1953	Manhattan College
MSCE	1960	Illinois Institute of Technology
PhD	1966	Illinois Institute of Technology,
		thesis dealt with creep effects in concrete structures.

REGISTRATION

Registered Professional Engineer, New York State

SOCIETY MEMBERSHIP

American Society of Civil Engineers
American Concrete Institute
Prestressed Concrete Institute
Sigma Xi
Chi Epsilon
Tau Beta Pi

PUBLICATIONS

- "Dynamic Analysis of Two Hinged Arches", M S Thesis, Illinois Institute of Technology, January 1960.
- "Response of Electronic Equipment To Nuclear Blast", with J.A. Granath, Proc. 29th Symposium on Shock, Vibration and Associated Environments, 1961.
- "Influence Coefficients for Two-Hinged Arches", with S.A. Guralnick, Proc. ASCE, Journal of the Structural Division, August 1962.
- "Dynamic Response of Slab Structures Exhibiting Coulomb Friction to Combined Air and Shock Loading", with E. Sevin and R.R. Robinson, Proc. Symposium on the Use of Computers in Civil Engineering, September 1962.
- "An Investigation of the Behavior of Reinforced Concrete Beams Subjected to Repeated Cycles of Loading", PhD thesis, Illinois Institute of Technology, January 1966.
- "The Response of Plain Concrete to Repeated Loads", with S.A. Guralnick, Proc. RILEM International Symposium on the Effects of Repeated Loading on Materials and Structures, September 1966.
- "The Dynamic Analysis of Non-Orthogonal Grid Systems", with R.E. Kramm, Proc. International Conference on Space Structures, September 1966.
- "Reinforced Concrete Beams Subjected to Repeated Loads", With S.A. Guralnick, Proc. ASCE, Journal of the Structural Division, October 1967.
- "Creep Deformations of Thick Prestressed Rings", Nuclear Engineering and Design (7), 1968.
- "Creep of Reinforced Concrete Beams", Proc. ASCE Joint Speciality Conference on Optimization and Non-Linear Problems, April 1968.
- * "Creep Effects in Continuous Reinforced Concrete Beams", Proc. IADSE Symposium on Design of Concrete

Structures for Creep, Shrinkage, and
Changes, September 1980.

"Creep Deflection of Reinforced Concrete Beams", with
S.A.Guralnick, Proc.ASCE, Journal of the Structural
Division, December 1970.

"Structure-Foundation Interaction of a Nuclear Power
Plant with a Seismic Disturbance", with
C.J.Costantino, Nuclear Engineering and Design, December
1970.

"Redistribution of Internal Forces in Concrete Beams as
a Result of Creep", ACI annual meeting, March 1971.

"Seismic Analysis of Liquid Sodium Storage Tanks", with
C.J.Costantino, Proc.5th World Conference on Earthquake
Engineering, June 1973.

"Rocking Effects in a Nuclear Power Plant Subjected to
a Seismic Disturbance", with C.J.Costantino, Proc.5th
World Conference on Earthquake Engineering, June 1973.

"Influence of Soil-Structure Interaction Parameters on
Floor Response Spectra", with C.J.Costantino, Proc.2nd
Structural Mechanics in Reactor Technology
Conference, September 1973.

"Mesh Size Criteria for Soil Amplification Studies",
with C.J.Costantino and L.Lufrano, Proc.3rd Structural
Mechanics in Reactor Technology Conference, September
1975.

"Facility Design Constraints for Combined Seismic and
Thermal Loading", with C.J.Costantino, Proc.3rd
Structural Mechanics in Reactor Technology Conference,
September 1975.

"Seismic Analysis", with C.J.Costantino, Shock and
Vibration Computer Programs, Reviews and Summaries,
edited by W & B Pilkey, The Shock and Vibration
Information Center, U.S.Department of Defense, 1975.

"Soil-Structure Interaction Parameters from Finite
Element Analysis", with C.J.Costantino and L.Lufrano,
Nuclear Engineering and Design, August 1976.

"Locating Pipe Supports for Combined Thermal and
Seismic Loading", with H.I.Fink, ASME paper 77-PVP-63,
Proc. ASME Energy Technology Conference, June 1977.

"Low Cycle Fatigue Characteristics of Concrete", with

S.Malliaros, Proc. ASCE Spring Convention April 1979.

"Dynamic Reduction of Structural Models", Proc. ASCE, Journal of the Structural Division, October 1980.

"Errors Resulting from Dynamic Reduction", Proc. First International Conference on Computers in Civil Engineering, May 1981.

"An Assessment of Soil-Structure Interaction Effects Based on Simple Models", with A.J.Philippacopoulos, Proc. Seventh SMIRT, August 1983.

"High Soil/Structure Interaction Combined with Low Structural Damping", with C.J.Costantino, and A.J.Philippacopoulos, Proc. Seventh SMIRT, August 1983.

"Errors Resulting from Reduction Methods", with A.J.Philippacopoulos, Proc. Seventh SMIRT, August 1983.

"Analysis Method for the Design of Transport Packaging Shock Absorbing Covers", with D.J.Nolan, and C.Fernandez, Proc. Seventh Transportation of Radioactive Materials (PATRAM), May 1983.

Vita

CARL J. COSTANTINO

Professor of Civil Engineering and
Director, Soil Mechanics Laboratory

Department of Civil Engineering
The City College of the
City University of New York

EXPERIENCE:

a. Teaching:

The City College of the City University of New York	1956 - 1958	Lecturer
	1967 - 1970	Asst. Prof.
	1970 - 1975	Assoc. Prof.
	1975 - to date	Professor
Illinois Institute of Technology	1964 - 1965	Lecturer

b. Research:

1959 - 1967: IIT Research Institute, Chicago, Illinois

From Assistant Research Engineer to Manager, Structural Dynamics and Nuclear Weapons Effects Section, Mechanics Research Division, conducting research studies for both government and industry.

- Principal Engineer on programs involving site hardening of missile and missile guidance systems, theoretical and experimental studies of soil-structure interaction;
- Principal Investigator in the development of large computer programs to study stress wave propagation through soil and rock materials; developed first finite element program to treat this problem for the Air Force;
- Participant in studies of reactor containment shell structures subjected to static and dynamic loadings; large strain plasticity analyses for these facilities;

1967 to date: Department of Civil Engineering, CCNY

Conducting research studies on stress wave propagation through soil and rock materials, primarily associated with earthquake effects on structures.

- Problems are centered on the study of large strain and nonlinear effects on wave propagation, soil-structure interaction and the influence of pore-water on dynamic response.
- Large finite element computer programs have been and are continuing to be developed to study these problems. Doctoral and Masters students in these areas are being directed to continue the growth of these activities.

c. Consulting:

1956 - 1958 Geotechnical Engineer with
Tippetts, Abbott, McCarthy, Stratton
Resident Engineer on large earth moving project, involving soil
stabilization and compaction for an industrial site. Field
supervision of soils exploration programs for earth dam sites,
flood control structures and river erosion projects.

1972 to date Soils Consultant for
New York City Transit Authority
Provide consulting services to TA Engineers on soil and
foundation projects at both the design and construction stages.
Assist in the development of TA Standards for Structural
Design, Field Design and Soil Exploration.
- Perform studies of dewatering programs, related settlement
analyses and laboratory testing of both disturbed and
undisturbed soil samples obtained from exploration programs;
includes strength, consolidation and permeability testing of
samples;
- Analyze soil loadings on buried structures, develop
recommendations for instrumentation programs to monitor
loadings and movements, and inspect installation and monitoring
programs; includes load, vibration and displacement measuring
devices;
- Assist TA Engineers in the design of pile and footing
foundations, soil stabilization (sand/wick drain studies),
including the development of specifications, assist in the
monitoring of such projects;

1975 to date Seismic Consultant for
Nuclear Regulatory Commission
Perform seismic studies for NRC on nuclear reactor facilities
at both the design and review stages;
- Provide NRC with computer programs to review facility
designs; Perform seismic studies of soil behavior under dynamic
excitations;
- Provide critical review for NRC Licensing Division of seismic
studies required for licensing of new and existing facilities;
- Assist NRC with audits of existing plant facilities; site
visits to conduct review of facility designs;

1970 to date Private Consultant
Provide consulting services to various private engineering
firms on soil and foundation designs, slurry wall construction,
field instrumentation, etc. Conduct soil tests for various
agencies, providing laboratory data for use in engineering
designs.

EDUCATION

BCE	1956	City College of New York
MSCE	1958	Columbia University, major in Soil Mechanics with Prof. D. M. Burmister
PhD	1966	Illinois Institute of Technology, major in Soil Mechanics with Prof. E. Vey

REGISTRATION

Registered Professional Engineer, New York State

SOCIETY MEMBERSHIP

Technical Societies:

- American Society of Civil Engineers
- American Society of Mechanical Engineers
- American Institute of Aeronautics and Astronautics
- Transportation Research Board

Positions:

- Chairman, Applied Mechanics Division, Chicago Section,
ASME, 1964 to 1965
- Member, Education Committee, Soil Mechanics Group, Met
Section, ASCE 1980 to 1981
- Reviewer, Applied Mechanics Reviews, ASME
- Reviewer, Structures Division Journal, ASCE
- Reviewer, Pressure Vessel and Piping Division, ASME

Honor Societies:

- Sigma Xi
- Chi Epsilon
- Tau Beta Pi

PUBLICATIONS

"Representative Triaxial Testing", Dept. of Civil Engineering, Columbia University, 1958

"Stresses in the Vicinity of Deep Underground Shelters", Proceedings, 32nd Symp. on Shock, Vibration and Associated Environments, Part II, Office of DDRE, Bulletin 32, 1962

"Approximate Burst Strength of Thin Walled Cylinders with Hemispherical Caps" with N.A. Weil and M.A. Salmon, Journal AIAA, vol. 1, no. 9, Sept. 1963

"Comparison of Approximate Theories for the Burst Strength of Finite Cylinders" with N.A. Weil and M.A. Salmon, Transactions of the American Nuclear Society, vol. 6, no. 1, June 1963

"Effect of End Conditions on the Burst Strength of Finite Cylinders" with N.A. Weil and M.A. Salmon, Journal of Applied Mechanics, vol. 31, no. 1, March 1964

"Strength of Thin Walled Cylinders Subjected to Dynamic Internal Pressures", Journal of Applied Mechanics, vol. 32, no. 1, March 1965

"A Simplified Soil-Structure Interaction Model to Investigate the Response of Buried Silos and Cylinders" with R.R. Robinson and M.A. Salmon, Proceedings, Symposium on Soil-Structure Interaction, Univ. of Arizona, Sept. 1964

"Experiments on Circular Cylinders with Flexible Roof Plates Buried in Sand" with A. Longinow, Proceedings, Symposium on Soil-Structure Interaction, Univ. of Arizona, Sept. 1964

"Theory of Limiting Equilibrium for Axisymmetric Problems: A Comparison with Experiment on Silo Skin Friction" with A. Longinow, Proceedings, Symposium on Soil-Structure Interaction, Univ. of Arizona, Sept. 1964

"Crushable Materials for Structural Blast Shields", Journal Structures Division, ASCE, vol. 91, June 1965

"Response of Buried Silos and Internal Systems to Ground Shock" with A. Wachowski, Proceedings, International Symposium on the Use of Electronic Digital Computers in Structural Engineering, Univ. of Newcastle-Upon-Tyne, Sept. 1966

"Response of Crushable Foam Encased Buried Cylinders", PhD Thesis, Illinois Institute of Technology, June 1966

"Finite Element Approach to Stress Wave Problems", Journal Engineering Mechanics Division, ASCE, April 1967

"Finite Element Solution for Wave Propagation in Layered Media Caused by a Nuclear Detonation" with A. Wachowski and W. L. Barnwell, International Symposium on Wave Propagation and Dynamic Properties of Earth Materials, Albuquerque, New Mexico, Sept. 1967

"Response of Crushable Foam Encased Buried Cylinders" with E. Vey, Journal Soil Mechanics Division, ASCE, vol. 95, no. SMS, Sept. 1969

"Two Dimensional Wave Propagation Through Nonlinear Media", Journal of Computational Physics, vol. 4, no. 2, Aug. 1969

"Structure-Foundation Interaction of a Nuclear Power Plant with a Seismic Disturbance" with C.A. Miller, Nuclear Engineering and Design, Dec. 1970

"Analysis of Soil-Structure Interaction Effects Under Seismic Excitation", First International Conference on Structural Mechanics in Reactor Technology (SMIRT), Berlin, Sept. 1971

"Dynamic Response of Nonlinear Media at Large Strain" with J. Heifitz, Journal Engineering Mechanics Division, ASCE, vol. 98, no. EM6, Dec. 1972

"Seismic Analysis of Liquid Sodium Storage Tanks" with C.A. Miller, Fifth World Conference on Earthquake Engineering, Rome, Italy, June, 1973

"Rocking Effects in a Nuclear Power Plant Subjected to a Seismic Disturbance" with C.A. Miller, Fifth World Conference on Earthquake Engineering, Rome, Italy, June, 1973

"Influence of Soil-Structure Interaction Parameters on Floor Response Spectra" with C.A. Miller, 2nd International Conference on Structural Mechanics in Reactor Technology (SMIRT), Berlin, Sept. 1973

"Finite Element Analyses for Soil Amplification Studies" with L.A. Lufrano, Proceedings, ASCE Specialty Conference on Structural Design of Nuclear Plant Facilities, vol. 2, Chicago, Dec. 1973

"Mesh Size Criteria for Soil Amplification Studies" with C.A. Miller and L.A. Lufrano, 3rd International Conference on Structural Mechanics in Reactor Technology (SMIRT), London, Sept. 1975

"Facility Design Constraints for Combined Seismic and Thermal Loadings" with C.A. Miller, 3rd International Conference, on Structural Mechanics in Reactor Technology (SMIRT), London, Sept. 1975

"Soil-Structure Interaction Parameters from Finite Element Analyses" with C.A. Miller and L.A. Lufrano, Proceedings, Conference on Extreme Load Conditions, Berlin, Sept. 1975

"Seismic Analysis" with C.A. Miller, Shock and Vibration Computer Programs, Reviews and Summaries, edited by W. and B. Pilkey, Shock and Vibration Information Center, US DoD, 1975

"Soil-Structure Interaction Methods", Volumes I thru IV, with C.A. Miller, U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, NUREG/CR-1717, BNL-NUREG-51263, Sept. 1979

"Seismic and Dynamic Qualification of Safety Related Electrical and Mechanical Equipment in Operating Nuclear Power Plants" with J. Curreri and M. Reich, U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Regulation, NUREG/CR-3266, BNL/NUREG-51667, Jan. 1983

"High Soil/Structure Interaction Combined with Low Structural Damping", with C.A. Miller, A.J. Philippacopoulos, 7th International Conference on Structural Mechanics in Reactor Technology (SMIRT), Chicago, Ill., Aug. 1983

"Seismic Models for Buried Tanks", with A.J. Philippacopoulos, C.A. Miller, accepted for presentation at Annual Meeting, American Society of Mechanical Engineers, Pressure Vessel and Piping Division, July 1984

"Upper Bound Floor Response Spectra", with F.C. Wang, A.J. Philippacopoulos, C.A. Miller, 8th World Conference on Earthquake Engineering, Los Angeles, Calif., July 1984.

RESUME

PERSONAL DATA

Name : A.J. Philippacopoulos
Home Address : 11 Vernon St., Farmingdale, NY 11735
Date and Place of Birth : July 18, 1950. Greece. U.S. Permanent Resident.
Marital Status : Married. One child

EDUCATION

Doctor of Philosophy in Civil Engineering, Polytechnic Institute of New York, May 1980. Major for doctorate: Civil Engineering. Minor for doctorate: Applied Mechanics, Mathematics.
Master of Science in Civil Engineering, Polytechnic Institute of Brooklyn, June 1976.
Bachelor of Science in Civil Engineering, Aristotelion University of Thessaloniki, School of Engineering, June 1975.

AWARDS

Research Fellowship, Senior Grade. Received during graduate studies at Polytechnic Institute of New York. Research grants sponsored by the National Science Foundation.

MEMBERSHIPS

Sigma Xi, The Scientific Research Society of North America, Associate Member, May 1977.
American Society of Civil Engineers, Associate Member, November 1976.
Technical Chamber of Greece, Member, June 1975.

PRESENT EMPLOYMENT

Brookhaven National Laboratory, Department of Nuclear Energy, Structural Analysis Division, Upton, NY 11973. Position: Assoc. Scientist.

PUBLICATIONS

1. "An Assessment of Soil-Structure Interaction Effects Based on Simple Models", Philippacopoulos, A.J. and Miller, C.M., 7th International Conference on Structural Mechanics in Reactor Technology, Chicago, IL, Paper K 10/3.
2. "Site-Structure Dependent Excitations", Philippacopoulos, A.J., Journal of Nuclear Engineering and Design, Vol. 74, 1982, pp. 153-163.
3. "Critical Seismic Assessment of Life Line Structures", Wang, P.C. and Philippacopoulos, A.J., Proceedings of the 7th World Conference on Earthquake Engineering, Istanbul, Turkey 1980, pp. 257-264.
4. "Application of Reduction Methods to Nuclear Power Plant Structures", Miller, C.M. and Philippacopoulos, A.J., Report NUREG/CR-3074, prepared for the U.S. Nuclear Regulatory Commission, October 1982.
5. "Evaluation of Simultaneous Action of Earthquake, LOCA and SRV on Mark III Containment and Drywell Structures", Philippacopoulos, A.J. and Reich, M., 6th International Conference on Structural Mechanics in Reactor Technology, Paris, France, 1981, Paper J 2/2.
6. "Critical Seismic Response of Nuclear Reactors", Drenick, R.F., Wang, P.C., Yun, C.B. and Philippacopoulos, A.J., Journal of Nuclear Engineering and Design, Vol. 59, 1980, pp. 427-439.
7. "Seismic Inputs for Nonlinear Structures", Philippacopoulos, A.J. and Wang, P.C., Journal of the Engineering Mechanics Division, ASCE, Vol. 110, No. 5, May 1984, pp. 828-836.
8. "Evaluation of Concured Peak Responses", Wang, P.C., Curreri, J., Shooman, M., Wang, Y.K., Philippacopoulos, A.J., Reich, M. and Subudhi, M., Report NUREG/CR-2685, prepared for the U.S. Nuclear Regulatory Commission, May 1982.

PUBLICATIONS (Cont'd)

9. "Dynamic Combinations for Mark II Containment Structures", Philippacopoulos, A.J. and Reich, M., Report NUREG/CR-2039, prepared for the U.S. Nuclear Regulatory Commission, June 1982.
10. "Critical Response Spectra for Linear and Nonlinear Structures", Wang, P.C. and Philippacopoulos, A.J., International Conference for Protection from Natural Disasters, Asian Institute of Technology, Bangkok, 1980, pp. 427-435.
11. "ABS, SRSS and CDF Response Combination Evaluations for Mark III Containment and Drywell Structures", Philippacopoulos, A.J., Report NUREG/CR-1980, prepared for the Nuclear Regulatory Commission, June 1982.
12. "Errors Resulting from Reduction Methods", Miller, C.M. and Philippacopoulos, A.J., 7th International Conference on Structural Mechanics in Reactor Technology, Chicago, IL, Paper K 3/4.
13. "Large Scale Polymer Concrete Vessels for the Direct Utilization of Geothermal Processes", Philippacopoulos, A.J., Koplik, B. and Reich, M., Report BNL-29027, August 1980.
14. "Probability Based Load Criteria for the Design of Nuclear Structures: A Critical Review of the State-of-the-Art", Shinozuka, M., Ellingwood, B.R., Wang, P.C., Meyer, C., Wen, Y.K., Kao, S., Shoorman, M.L. and Philippacopoulos, A.J., Report NUREG/CR-1979, prepared for the U.S. Nuclear Regulatory Commission, April 1981.
15. "High Soil-Structure Damping Combined with Low Structural Damping", Miller, C.M., Costantino, C.J. and Philippacopoulos, A.J., 7th International Conference on Structural Mechanics in Reactor Technology, Chicago, IL., Paper K 10/10.
16. "Review of Load Combinations for NSSS and BOP Piping and Equipment of Mark III Plants", Philippacopoulos, A.J., Reich, M. and Wang, P.C. Report NUREG/CR-2686, prepared for the U.S. Nuclear Regulatory Commission, May 1982.

PUBLICATIONS (Cont'd)

17. "Design of Prestressed Polymer Concrete Vessels for Use in Geothermal Power Plants", Koplik, B., Philippacopoulos, A.J. and Reich, M., Report BNL-31127, February 1982.
18. "Upper Bound Floor Response Spectra", Philippacopoulos, A.J., Wang, P.C., Miller, C.M. and Reich, M., Proceedings of the 8th World Conference on Earthquake Engineering, San Francisco, California.
19. "Independent Seismic Evaluation of the Diablo Canyon Unit 1 Containment Annulus Structure and Selected Piping Systems", Philippacopoulos, A.J., Reich, M., Bezler, P., Miller, C.M., Wang, Y.K., Subudhi, M., Shteyngart, S. and Brown, P., Report NUREG/CR-2834, prepared for the U.S. Nuclear Regulatory Commission, August 1982.
20. "Prediction of Earthquake Resistance of Structures", Wang, P.C. with contributions from Philippacopoulos, A.J., Polytechnic Institute of New York, Final Report to NSF, Grant No. PFR 76-14893, January 1980.
21. "Seismic Models for Buried Tanks", Philippacopoulos, A.J. and Costantino, C.J., Pressure Vessel and Piping Division Conference, ASME, 1984.
22. "Correlation of Fukushima Data with Lumped Parameter Code", Miller, C.A., Costantino, C.J. and Philippacopoulos, A.J., March 1984.
23. "Use of Composite Damping in Seismic Response Problems", Miller, C.A., Costantino, C.J. and Philippacopoulos, A.J., 3rd International Modal Analysis Conference.
24. "Mode Shape Errors Resulting from Guyan Reduction", 3rd International Modal Analysis Conference.

SUSHIL K. SHARMA

9 Bancroft Street
E. Setauket, NY 11733

516-751-6955 (Home)
516-282-2095 (Office)

Born: 7-24-48
Married; two children
Excellent health: 5'10", 150 lbs.

Naturalized U.S. Citizen

EDUCATION

1977	University of Illinois, Urbana, IL Ph.D., Theoretical & Applied Mechanics.	GPA: 5.0 of 5.0
1971	University of Missouri, Rolla, MO M.S., Engineering Mechanics.	GPA: 4.0 of 4.0
1969	University of Roorkee, India B.S., Mechanical Engineering.	Graduated in First Division.

PROFESSIONAL EXPERIENCE

Brookhaven National Laboratory, Upton, NY 11973
Mechanical Engineer
Assoc. Mechanical Engineer

(1982-Present)
(1980-1982)

- Responsible for the development of analytical methods and computer codes for nonlinear finite element analysis of structures with specialization in the following areas: (1) elastic-plastic analysis of composite structures, (2) failure response of reinforced concrete structures, (3) heat transfer and thermal stresses in structural systems at elevated temperatures, and (4) fracture mechanics applications to ductile crack growth.
- Determined load-deformation responses and failure loads for several reinforced and prestressed concrete containment structures under severe accident loads. Obtained results that predicted cracking of the concrete, large scale yielding of the rebars and tendons, and various concrete-rebar interaction effects including tension stiffening and shear transfer.
- Performed finite element analyses for heat transfer, thermal stress and fatigue life to establish best designs for various water-cooled copper mask assemblies subjected to intense synchrotron radiation beams.
- Evaluated elastic-plastic crack growth in steam generator tubes based on J-integral concept, and intergranular stress corrosion crack growth in stainless steel pipes based on stress intensity factors. Studied the effect of various parameters (crack configuration, applied and residual stresses, base metal sensitization, and environmental chemistry) on the crack growth rates.

- Assessed the seismic qualification and safety of various mechanical and structural components of nuclear power plants under postulated earthquake loads.

The General Tire & Rubber Company, Akron, OH

Group Leader

(1979-1980)

Senior Research Engineer

(1977-1979)

- Initiated a comprehensive research program to study the mechanics of tires and other automotive products made of rubbers and rubber-cord composites. Developed a nonlinear finite element computer code with several special features (incompressible element, contact algorithm, composite material model, out-of-plane shear element, deformation-dependent pressure loads) that allowed modeling of the large-deformation analysis problems encountered in the tire industry. The code has been used extensively by many engineers in this company as a design and analysis tool to expedite the product design process.
- Conducted finite element studies on rubber-cord composites to determine interply shear strains and stresses, out-of-plane rotation under uniaxial loading, and edge effects. Verified the theoretical results by experiments with specially design fixtures.
- Investigated heat transfer in a cast tire subjected to thermal loadings for curing, cooling, and frictional heat build-up.
- Analyzed the nonlinear mechanics problem of contact between a rubber disk and a flat surface. Numerical results for the contact area and contact forces were substantiated by experimental measurements.
- Studied the effects of deformation-dependent pressure loads on inflated profiles and cord forces in bias-ply and radial tires.

Construction Engineering Research Lab., Champaign, ILL

Principal Investigator

(1974-1977)

- Evaluated dynamic responses of several structures and structural sub-systems under earthquake loads using various general purpose computer programs, namely, SAP IV, NASTRAN, MARC and NONSAP.
- Incorporated an improved plasticity hardening rule in NONSAP program for determining energy dissipation due to cyclic plastic deformation.
- Used finite element models to study the effect of hysteretic dampers for isolating structures from earthquake forces.
- Developed uniaxial cyclic stress-strain relations for reinforced concrete.

BLM Applied Mechanics Consultants, Champaign, IL

- Completed occasional assignments for this consulting company during 1972-1977. These assignments included: (1) developing a set of finite element programs for reinforced axisymmetric shells subjected to asymmetric wind, thermal, and gravity loads, (2) predicting propagation of edge stress concentrations in hyperboloidal cooling towers, and (3) determining an equivalent set of boundary conditions for column supported shells.

Miscellaneous

- Membership in ASME and AAM (American Academy of Mechanics).
- Experienced in using CDC, IBM, VAX, PRIME and PDP-11 computer systems.
- Attended advanced short courses in nonlinear finite element analysis (MIT), geotechnical engineering (VPI & SU) and rubber-cord composites (University of Akron).

LIST OF PUBLICATIONS

1. "Analytical Models for Determining Energy Dissipation in Dynamically Loaded Structures", paper presented at the Joint Meeting of the U.S.-Japan Panel on Wind and Seismic Effects, Gaithersburg, Maryland, May 1974.
2. "Isotropic-Kinematic Hardening Model for Elastic-Plastic Structural Analysis", Technical Report M-148, U.S. Army Construction Engineering Research Laboratory, Champaign, IL, August 1975.
3. "An Analytical Model for Uniaxial Cyclic Inelastic Behavior of Reinforced Concrete", Technical Report M-180, U.S. Army Construction Engineering Research Laboratory, Champaign, IL, May 1976.
4. "Inelastic Behavior of Structural Metals Under Complex Cyclic Loading", paper presented at the 18th Annual Structures, Structural Dynamics and Materials (SDM) Conference, San Diego, CA, March 1977.
5. "Finite Element Weighted Residual Methods for Static Analysis of Reinforced Axisymmetric Shells", TAM Report No. 414, Department of Theoretical and Applied Mechanics, University of Illinois, Urbana-Champaign, IL, May 1977.
6. "Finite Element Weighted Residual Methods: Axisymmetric Shells", Journal of the Engineering Mechanics Division, ASCE, Vol. 104, No. EM4, August 1978.
7. "Nonlinear Two-Dimensional Analysis of Composite Structures", Research Report, The General Tire & Rubber Company, Akron, OH, August 1978.

LIST OF PUBLICATIONS (Cont'd)

8. "Thermal Stresses in Reinforced Hyperboloidal Cooling Towers", paper presented at the Annual ASCE Convention, Chicago, IL, October 1978.
9. "Large Deformation Contact Analysis of Rubber Disks", Research Report, The General Tire & Rubber Company, Akron, OH, November 1979.
10. "Effect of Deformation-Dependent Pressure Loads on the Inflation of Bias-Ply Tires", Research Report, The General Tire & Rubber Company, Akron, OH, January 1980.
11. "A General Nonlinear Finite Element Program for Two-Dimensional Analysis of Composite Structures, GENFEP-2D", Research Report, The General Tire & Rubber Company, Akron, OH, July 1980.
12. "Thermal and Gravity Stresses in Hyperboloidal Cooling Towers", Nuclear Engineering and Design, Vol. 61, 1980.
13. "Failure Evaluation of a Reinforced Concrete Mark III Containment Structure Under Uniform Pressure", NUREG/CR-1967, BNL-NUREG-51543, Research Report Prepared for The United States Nuclear Regulatory Commission, Washington, D.C., September 1982.
14. "Ground Support System for Deep-Based Tunnel Egress With The Use of Fast Setting Polymers and Cements", Phase I Report, Department of Energy and Environment, Brookhaven National Laboratory, January 1983.
15. "Review of Current Analysis Methodology for Reinforced Concrete Structural Evaluations", NUREG/CR-3284, BNL-NUREG-51673, Research Report prepared for the United States Nuclear Regulatory Commission, Washington, D.C., April 1983.
16. "Nonlinear Finite Element Analysis of a Reinforced Concrete Mark III Containment Under Pressure and Gravity Loads", Paper No. J 2/8, Transactions of the 7th International Conference on Structural Mechanics in Reactor Technology, Chicago, IL, August 1983.
17. "Thermal Absorbers for Beam Port X-17", Interim Report, Department of National Synchrotron Light Source, Brookhaven National Laboratory, Upton, NY, October 1983.
18. "Failure Response of a Reinforced Concrete Containment Under Severe Accidental Pressures", paper accepted for presentation at ASEC Fifth Engineering Mechanics Division Specialty Conference - Engineering Mechanics in Civil Engineering: 1984, University of Wyoming, Laramie, WY, August 1984.
19. "An Evaluation of Stress Corrosion Crack Growth in BWR Piping Systems", NUREG Report prepared for United States Nuclear Regulatory Commission, Washington, D.C., in print.

Biographical Information

WANG, PING-CHUN, Professor, Civil Engineering Department. Born March 10, 1920
Kiansu, China, Citizenship, USA.

College Degrees: B.S., National Central University of China, 1943; M.S., University
of Illinois, 1948; Ph. D., University of Illinois, 1951.

Major Fields of Interest: Structural Mechanics, Earthquake Engineering, Computer
Applications in Structural Engineering.

Courses Taught 1982-83 Academic Year: CE 252 Reinforced Concrete Structures, CE 331
Steel Structures, CE 609 Matrix Analysis of Structures I; CE 610 Matrix Analysis of
Structures II; CE 616 Finite Elements Method.

Professional Activities, Societies and Honors

Professional Society Memberships: American Society of Civil Engineers -
Fellow; American Concrete Institute - Member; Chinese Institute of Engineers -
Member; Earthquake Engineering Research Institute - Member.

Honorary Society Memberships: Sigma Xi, Chi Epsilon, Tau Beta Pi

Positions Held: 1943-1947, Junior Engineer, China Bridge Company; 1950-51,
Designer, Ammann and Whitney, New York; 1951-1960, Supervising Engineer, Seelye,
Stevenson, Value & Knecht, New York; 1960-1963, Associate Professor, Stevens
Institute, Hoboken, New Jersey; 1963-Present, Professor, Polytechnic Institute of
New York.

Consulting:

Brookhaven National Laboratory, Nuclear Department - Safety of Nuclear
Structures
Safety of Nuclear Structures, URS, Inc. on Dynamic Response for DAC Super
80, LaGuardia Airport

Publications:

"Composite Action of Concrete Slab and Open Web Joists," by D. J. Kaley and P.
C. Wang. Engineering Journal, A.I.S.C., January 1967.

"Elastic-Plastic Analysis and Design of Flexible Arches," by G. Granik, P.C.
Wang and S.F. Borg, Trans., New York Academy of Science, March 1967.

"Design and Analysis of Frames for Stability," by H. Switzky and P.C. Wang,
Journal of Structural Division, A.S.C.E., Vol. 94, No. ST4, April 1969.

"Volume Minimization of Thin Plates Subject to Constraint," by Z. Sherman and
P.C. Wang. Journal of Structural Division, A.S.C.E., Vol. 97, EM3, June 1971.

"Minimum Weight Design of Finite Element Structures," by H. Switzky and P.C.
Wang Journal of AIAA, Vol. 12, No. 2, February 1974.

"The Behavior of Reinforced Concrete Columns in Flat Plate Structures," by P.C.
Wang and Y.W. Liu. Reinforced Concrete Columns, A.C.I. Publication SP-50, pp.
119-135, 1975.

Publications (continued):

"Critical Excitation and Response of Free Standing Chimneys," by P.C. Wang, W. Wang, R. Drenick and J. Vellozzi. Proceedings of the International Symposium on Earthquake Structural Engineering. August 19-21, 1976.

"Critical Seismic Excitation and Response of Structures," by P.C. Wang and R. Drenick. Proceedings of the Sixth World Conference of Earthquake Engineering, New Delhi. January 10-14, 1977.

"Asymptotic Solution for Thermal Stress and Deformation in Orthotropic Non-homogeneous Shells of Revolution," O.A. Fettalioglu and P.C. Wang. Third International Congress on Pressure Vessel, Tokyo. April 18-22, 1977.

"Transient Response of Orthotropic Plates," by P.C. Wang and A.V. duBouchet, Revue Romaine Des Sciences Techniques, Mechanique Applique, Tome 22, No. 1, pp. 149-155, Bucarest, 1977.

"Seismic Assessment of High-Rise Buildings," by P.C. Wang, Rudolf F. Drenick and W. Wang. Journal of Engineering Mechanics Division, A.S.C.E. EM2, April 1978.

"System Reliability Assessments Using Critical Excitations," by R.F. Drenick and P.C. Wang. The Shock and Vibration Digest. Vol. 10, No. 6, January 1978.

"Subcritical Excitation and Dynamic Response of Structures in Frequency Domain," by A.M. Abdelrahman, C.B. Yun and P.C. Wang. Computers and Structures, Vol. 10, pp. 761-771, October 1978.

"Site-Dependent Critical Design Spectra," by P.C. Wang and C.B. Yun. Earthquake Engineering and Structural Dynamics, Vol. 7, pp. 569-578, 1979.

"Effective Duration of Seismic Acceleration and Occurrence of Maximum Responses," by W.Y. Wang and P.C. Wang, Nuclear Engineering & Design, Vol. 52, March 1979.

"Along-Wind Gust Effect on Elevated Structures," by C.B. Yun, A.M. Abdelraham and P.C. Wang, Engineering Structures, Vol. 1, April 1979.

"Critical Seismic Response of Nuclear Reactors," R.F. Drenick, P.C. Wang, C.B. Yun and A.J. Philippacopoulos. Transaction of the 5th International Conference on Structural Mechanics in Reactor Technology, Vol. KB/4, August 1979.

"Critical Response Spectra for Linear and Non-linear Structures," by P.C. Wang and A.J. Philippacopoulos. Proceedings of the International Conference of Engineering for Protection from Natural Disasters, Bangkok, Thailand, January 1980.

"Critical Seismic Assessment of Lifeline Structures," by P.C. Wang and A.J. Philippacopoulos. Proceedings of the 7th World Conference in Earthquake Engineering, Istanbul, September 1980.

"Critical Seismic Response of Nuclear Reactors," by R.F. Drenick, P.C. Wang, C.B. Yun and A.J. Philippacopoulos. Nuclear Engineering and Design, 59 (1980) pp. 425-435.

Publications (continued):

"Axisymmetric Vibrations of Pressurized Orthotropic Shells of Revolution", by U.A. Fattahlioglu and P.C. Wang, AIAA/ASME/ASCE/AHS Structural Dynamic and Materials Conference, Lake Tahoe, Nevada, May 2-4, 1983.

"Evaluation of Concurrent Peak Responses", by P.C. Wang, J. Curreri and M. Reich, Transaction of the 7th International Conference on Structural Mechanics in Reactor Technology, Vol. M 2/4, Aug. 1983.

"Active Control of Structural Vibration", by P.C. Wang, F. Kozin, F. Auini, Engineering Structures, IPC Science and Technology Press, Vol. 5, Oct. 1983.

Textbooks:

"Numerical and Matrix Methods in Structural Mechanics", with Application to Digital Computer", John Wiley and Sons, 1966.

Reports:

"Discrete Systems Concepts in Civil Engineering Applications," Part I and Part II, by P.C. Wang and J.F. Werner, Report to National Science Foundation, Under Grant GE-2546, 1964.

"Review of the Building Requirements of Reinforced Concrete," by P.C. Wang. Sponsored by the Institute of Applied Technology National Bureau of Standards, October 1965.

"A Study of Concrete Spalling Conditions of Sidewalks, Center Malls and Bus Stop Areas," sponsored by Asphalt Products Association of Metropolitan New York, by P.C. Wang, 1969.

"Case Study of Critical Excitation and Response of Structures," Interim Report to NSF, by P.C. Wang, W. Wang and R.F. Drenick, under grant AE72-00219 A01, November 1975.

"Review of Methods and Criteria for Dynamic Combination in Piping Systems," by M. Reich, P.C. Wang, J. Curreri, S. Hou and H. Goradia. Report prepared for U.S. Nuclear Regulatory Commission, Report No. NUREG/CR-1330, March 1980.

"Prediction of Earthquake Resistance of Structures," by P.C. Wang. Final Report to NSF under Grant No. PER 76-14893, January 1980.

"Evaluation of Concurrent Peak Responses", by P.C. Wang, J. Curreri, M. Shooman, Y.K. Wang, A.J. Philippacopoulos, M. Reich and M. Subudhi, Report prepared for U.S. Nuclear Regulatory Commission, Report No. NUREG/CR-2685, May 1982.

"Probability Based Load Criteria for the Design of Nuclear Structures, by M. Shinozuka, B.R. Ellingwood, P.C. Wang, C. Meyer, Y.K. Wen, S. Kao, M. Shooman, A.J. Philippacopoulos, Report No. BNL-NUREG-51356, NUREG/CR 1979, April 1981.

Reports (continued):

"Review of Load Combination for NSSS and BOP Piping and Equipment of Mark III Plants", by A.J. Philippacopoulos, M. Reich and P.C. Wang, Report No. NUREG/CR-2686, June 1982.

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ADDENDUM TO
REVIEW OF WATERFORD III BASEMAT ANALYSIS

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Introduction

Recently, ultrasonic methods were used to perform nondestructive tests on the Waterford III basemat with the objective of defining the extent of cracking in the basemat. These tests were performed by Muenow & Associates, Inc. On July 31, 1984, BNL personnel visited the Waterford site with the intent of visually observing the cracks, discussing the methodology used for the nondestructive tests, and to review the results obtained by Muenow & Associates to date.

Visual Inspection of Cracks

The major basemat cracks shown in Fig. 2 of the BNL report dated July 18, 1984 entitled, "Review of the Waterford III Basemat Analysis", were inspected. The basemat crack patterns appear to agree with the crack map of Fig. 2 of the BNL report and no significant extensions or additions of these cracks were observed. The observed cracks are closed at this time and no observable water seepage through the cracks was noted.

The cracks along the sidewall and shield wall were also inspected. These cracks were all small and mostly of a type normally associated

with thermal and shrinkage effects. Leachate was noted from many of these cracks. The leachate from the shield wall is most probably associated with rain water accumulated in the annulus between the steel containment and shield wall during the construction phase, before placement of the dome section. Leachate from the sidewalls is most probably associated with water accumulated during construction.

All sidewall and shield wall cracks were restricted to about the lower twenty feet of the walls above the basemat and are usually within the first pour of concrete. They are associated with relative shrinkage and thermal effects occurring between the basemat and the sidewalls. The visual inspection of these cracks supports the conclusion previously given in the BNL report that they do not present a structural safety issue.

Results of Ultrasonic Testing Program

At the time of the inspection, the ultrasonic program conducted by Muenow & Associates had essentially been completed for those basemat cracks outside of the shield wall. Investigation of basemat cracks under the RCB was still being conducted, while the investigation of the side wall cracks had not as yet been undertaken. Mr. R. Muenow presented his interpretation of the results obtained to date as well as a detailed description of his procedures.

For the visible basemat cracks, the procedures employed by Muenow & Associates essentially measure time of arrival of a wave reflected off a discontinuity in the concrete. This wave is generated by a small spring loaded hammer applying an impact to the surface of the basemat. For a single impact, a transducer located near the hammer is focused in a restricted (but known) direction, and measures the arrival time. Knowledge of the arrival time and focusing direction leads to the determination of the location of the discontinuity. In addition, by restricting the viewing time of the sensor, only the reflection from the discontinuity being mapped is recorded. From a series of impacts at different locations, the extent (both length, depth and orientation) of the crack can be obtained. It is our opinion that this approach applied to the visible basemat cracks will give reasonable information as to the length, depth and orientation of the cracks.

It should be noted that the procedures used are based upon recording and viewing only the relatively low frequency content of the reflected waves. Therefore, any discontinuity smaller than 10 to 20 inches cannot be observed in this study; cracks of this small size are not structurally significant for a 12' thick base mat and need not be evaluated as a part of the NDT program. (This cutoff frequency can be controlled by the operator to pick up smaller discontinuities, if desired). Therefore, reflections from single reinforcing bars do not interfere with the crack measurements. However, the layers of closely spaced rebars in the bottom of the slab result in a measurable reflection.

Data at these depths are judged to be less reliable, since it would be difficult to differentiate between the reflections from the steel layers and reflections from the crack.

Based upon Mr. Muenow's presentation, the following characteristics of the basemat cracks were noted:

- (a) All of the cracks were vertical.
- (b) The E-W cracks exterior to the shield wall ran from the shield wall to the side walls. The depths of these cracks varied in an undulating manner from several feet (2' to 4') to as much as 9 to 10 feet in certain locations.
- (c) Based upon preliminary data, Mr. Muenow located three primary E-W cracks under the RCB. Two of these appear to connect to the E-W cracks exterior to the shield wall. The specific depth contours of these cracks were not available at the time of our site visit, but indications are that they may be similar to those in (b) above.
- (d) Cracks emanating in a radial direction from the shield wall are not as deep nor as continuous as the E-W cracks.
- (e) All of the basemat cracks are tightly closed. This observation is based upon the measured characteristics of the reflected signal.

Interpretation of NDT Results

As stated in the July 18, 1984 BNL report, the basemat cracks were most likely caused by bending moments due to dead loads developed during the construction phase, which resulted in tensile stresses at the top of the slab. These moments would enhance previously existing small and unobservable cracks due to normal thermal and shrinkage effects, causing them to grow in width, length and depth. This conclusion was based upon the observation that some of the computed bending moments (shown in Table 1) are large enough to cause flexural cracking at the top of the slab.

While the depths of some of the cracks measured by Muenow & Associates seem to be rather large (in fact they are deeper than BNL originally anticipated, before we completed our analyses), they can nevertheless be explained with the aid of Table 2 given in the BNL report. This table gives the strength characteristics of the slab in terms of the top reinforcement. The ratio of steel to concrete area for the top of the mat is very small (approximately 0.2%). Because of this reinforcement ratio the cracking moment for the slab is about 1640 Kips-ft/ft while the steel yield moment is about 1360 Kips-ft/ft.

The consequences of the above moments in terms of crack behavior when the top of the mat is in tension can be explained in terms of the load sharing occurring between the concrete and the top reinforcement steel.

It should be realized that the steel carries little load until the concrete cracks. Thus, for example, when the concrete at the upper surface of the mat reaches the modulus of rupture (i.e., 475 psi) and is at the verge of cracking, the top reinforcing steel is stressed to only 3600 psi. Once the concrete cracks, however, all of the tensile load carried by the concrete is transferred to the steel, which because of the light reinforcement ratio immediately reaches its yield stress of 60,000 psi. Because of equilibrium requirements, some of the applied moment will be transferred to adjacent sections adding to the lateral (as well as the depthwise) extension of the cracks. Since such a failure is rather abrupt, one would expect the cracks to propagate to deeper depths than would normally be the case if the crack developed more gradually.

Flexural cracks in concrete members normally extend through the tension zone to a level close to the location of the neutral axis (the neutral axis defines the region where the bending stress changes from tension to compression). It should be noted that the neutral axis for the basemat is located approximately 18 inches above the bottom of the mat for bending moments which produce tension in the top of the slab. (The depth of the compression zone is given by $d(-pn + \sqrt{(pn)^2 + 2pn})$ where p is the reinforcement ratio, n is the ratio of Young's Modulus of the steel to the concrete and d is the distance from the steel reinforcing bars to the bottom of the slab). Therefore, one would expect bending cracks to run rather deeply into the slab.

The cracking that has been observed does not affect the safety of the Waterford facility, for the following reasons. Reinforced concrete flexural members loaded in bending, such as the Waterford base mat, typically have cracks in the bending tensile stress region; generally, such cracked sections can safely carry bending moments and the presence of the cracks does not degrade the strength of the section. This is true because a flexural member resists a bending moment by developing internal tensile and compressive forces which develop a resisting couple (moment) equal to the applied moment. The reinforcement provides the tensile force and is clearly not affected by the cracked concrete. The compressive force in the concrete is not affected by the crack since a compressive stress can be transmitted across a crack. Furthermore, the presence of bending cracks does not affect the shear carrying capacity of the section (this is in fact the basis of the ACI Code provisions for shear), since interlocking between sections still occurs, and the cracks are not associated with diagonal tension failure.

As pointed out in Appendix C of the BNL report, the sidewall soil/water pressures produce compressive stresses in the slab. In fact, it is the action of these pressures which has caused the E-W cracks to close. It is shown in Appendix C that as a result of the side wall pressures, the stress across the basemat is primarily compressive under static soil pressure, as well as under north to south and south to north SSE plus soil pressure loading with rather small tensile stresses occurring at the bottom of the mat. Even if the E-W cracks propagated through the

mat, the crack would have no effect on the ability of the concrete to carry the applied compressive stresses. In effect, the side wall soil loads act as prestressing which closes the cracks that developed during construction.

The BNL report concluded that the basemat was adequate and suggested that certain confirmatory analyses be performed. For the reasons stated above, this conclusion is still considered to be valid.