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WIND ENGINEERING RESEARCH CENTER
EXECUTIVE SUMMARY

The Wind Engineering Research Center (WERC) was established by action of the Board of Regents at Texas Tech University in September 1988. The Center's objectives are to promote multidisciplinary research in wind engineering, to attract external funding for wind engineering research, to provide a forum for faculty and students from various disciplines to work as a team and to provide information and materials to the public through its outreach program. The Center continues to pursue these objectives with measurable success.

During the year Texas Tech submitted an application for membership to the University Corporation for Atmospheric Research (UCAR), a prestigious organization in atmospheric research. UCAR's evaluation team visited the Texas Tech campus and has recommended admission. The membership of UCAR will vote on the application at a meeting in October.

Highlights of wind engineering activities during 1996-97 are as follows:

- 18 funded wind engineering-related research projects were pursued during the year. Some of these projects have commitments to continue over the next few years.

- Research was supported by $861,874 in external funds ($777,323 in governmental grants and $84,551 in contracts from the private sector) and $315,024 in internal funding totaling close to $1.2 million.

- 17 faculty members representing 9 academic departments are actively pursuing wind engineering-related research.

- 32 graduate students pursued wind engineering-related research; 5 completed M.S. degrees and 1 completed a Ph.D. degree during the year.

- 5 publications in refereed journals and 35 publications in proceedings of conferences and reports have resulted this year from research projects.

- 23 proposals were submitted for over $20 million.

- WERC submitted a prospectus and a five year program (included in this report) which were presented to a legislative subcommittee. The Wind Engineering program was praised by Senator Kay Bailey Hutchison and entered into the Congressional Record.

- A short course, Engineering for Extreme Winds, was offered to practicing professionals in February 1997.
• Texas Tech's damage documentation team traveled to Wilmington, NC to document damage from Hurricane Fran and from tornadoes in Arkadelphia, AR; Lubbock, TX and Jarrell, TX. The storm chase team captured a small tornado on video during the April 10 Lubbock tornado outbreak.

• Texas Tech's Wind Engineering program was featured on NBC Dateline; the program highlighted the missile launcher and development of the in-residence shelter. Over 1000 calls poured into the Wind Engineering office. A separate phone line had been set up to handle the overflow but the office staff was still kept busy answering inquiries. This also led to several other appearances on television and radio programs and interviews featured in newspapers including the New York Times and USA Today.

• An exhibit, Winds of Destruction, Currents of Change, continues at the Science Spectrum in Lubbock.
WIND ENGINEERING PROSPECTUS AND PROPOSED FIVE YEAR PROGRAM

Windstorms - hurricanes, tornadoses and thunderstorms - cause multiple fatalities and injuries, significant business interruptions, a large amount of building and property damage and major disruptions in the lives of people. Insured property loss data collected by Property Claim Services shows that dollar losses in natural hazards have increased eightfold in the last ten years (see the accompanying chart in Figure 1). Of these insured property losses, the windstorm-related losses account for almost 70 percent of the total losses. The property losses will continue to increase because of urban sprawl and movement of people toward coastal areas.

Personnel of the Wind Engineering Research Center (WERC), Texas Tech University, have conducted research in wind-induced damage to buildings starting with the tornado that struck the city of Lubbock in 1970. Wind damage documentation has been conducted in more than 65 events of hurricanes, tornadoses and other storms (see the map in Figure 2). These documentations (photographs, observations, comments; see Figure 3) are archived in WERC and represent a rich resource to conduct research in wind damage mitigation. Window glass damage due to wind pressure and flying debris in windstorms has been found to be one of the significant items causing property damage to the contents of buildings.

Since 1970 Texas Tech University has conducted a variety of research projects and produced significant results and output. Major accomplishments achieved by the Wind Engineering Research Center for the understanding of wind damage, reducing human suffering, and reducing economic loss from severe winds are:

- Initiated a basic research program in wind engineering funded by the National Science Foundation in cooperation with Colorado State University.
- Constructed a unique field site facility to test the effects of winds on low buildings (see Appendix).
- Determined wind speeds in tornadoses by analyzing damage and photogrammetric analyses.
- Correlated observed damage with wind tunnel test results.
- Impacted the National Weather Service advisory for occupant safety in windstorms.
- Provided professional advisory services to government and industry to upgrade building codes.
- Developed WIND-RITE®, an expert system software for the Insurance Institute for Property Loss Reduction to evaluate vulnerability of buildings in windstorms.
Figure 1

Insured Losses in Catastrophes assembled by Property Claim Services

*An occurrence is considered catastrophic when a significant number of individual claims are made and exceed $5 million in property loss claims

Dollar Losses (in Billions)

<table>
<thead>
<tr>
<th>Year</th>
<th>Losses (in billions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>0.9</td>
</tr>
<tr>
<td>1987</td>
<td>0.9</td>
</tr>
<tr>
<td>1988</td>
<td>1.5</td>
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</tr>
<tr>
<td>1994</td>
<td>17.0</td>
</tr>
<tr>
<td>1995</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Dollar Losses by Type (as Percent of Total)

- **Hurricane/Tropical Storm**: 32.7%
- **Wind/Hail/Tornado**: 36.5%
- **Earthquake**: 24.9%
- **Riot/Civil Disorder**: 1.0%
- **Explosion/Fire**: 4.5%
- **Other**: 0.4%
WINDSTORM DAMAGE INVESTIGATIONS
CONDUCTED BY THE WIND ENGINEERING PROGRAM 1970-1996
• Gained an understanding of the sources, behavior, and damage potential of windborne debris (missiles).

• Developed methods and equipment to test for windborne debris.

• Developed preliminary windborne debris design criteria for various levels of protection ranging from occupant protection in residences to criteria for critical facilities.

• Developed design for above ground In-Residence Storm Shelter for occupant protection in tornadoes.

• Improved test methods and design criteria for window glass.

• Presented annual seminars to practicing architects and engineers on *Engineering for Extreme Winds*.

• Contributed to development of deemed-to-comply standards for wind resistant design of one- and two-family dwellings.

• Developed a process-based wind erosion and dust generation model.

• Provided solutions to stabilize sand barriers against wind erosion during Operation Desert Storm.

• Provided United States Department of Agriculture with an assessment of the effects of policy change on air quality from wind erosion.

• Maintained an academic program with publications, courses and education of graduate and undergraduate students.

These accomplishments are a result of projects funded by several governmental agencies and private industry (e.g., Metal Building Manufacturer's Association, Insurance Institute for Property Loss Reduction, Florida Power and Light, National Roofing Contractor's Association and others).

WERC at Texas Tech University is at the threshold of producing research results that can reverse the trend of escalating property damage, benefit the national economy and minimize disruption in the lives of people.

A five year program was submitted to the legislative subcommittee. Senator Kay Bailey Hutchison from Texas acknowledged the accomplishments of WERC and entered them into the Congressional Record. A summary of the program is on the next page. New initiatives in the research, education and service/outreach will be pursued to the extent of available resources.
Figure 3: Wind Damage from tornadoes and hurricanes
Five Year Program in Wind Engineering
1998-2002
Texas Tech University

Research

- Develop improved wind hazard maps considering all types of windstorms - thunderstorms, hurricanes, tornadoes.
- Understand turbulence characteristics in various windstorms in the atmospheric boundary layer and develop reasonable models. New tools such as Doppler radar, portable wind instruments and ASOS can provide data.
- Expand and utilize experimental capabilities (field laboratory, wind tunnel that is under construction, water tow tank, impact cannon) to understand wind effects on buildings and structures and develop a database for wind load design standards.
- Evolve new concepts of building construction to resist effects of windstorms.
- Develop strategies for retrofitting existing buildings that include classification of buildings, expert system based evaluation and cost-effective retrofit concepts.
* - Develop an information base on economic aspects of severe winds including design, construction, shelters, relief, planning, evacuation, recovery, etc. This effort will be supported by working with Howard Kruerether of the Wharton School of University of Pennsylvania along with economists Jamie Kruse and Robert McComb from Texas Tech University.

Education

- Continue to educate students in various disciplines in the technology of hazard mitigation.
- Continue to educate professionals on design for wind effects.
* - Expand education efforts through distance education programs utilizing high technology. Target this effort toward practicing professionals, government and industry decision makers and K-12 students.

Service and Outreach

* - Establish and maintain a National Information Center for Wind Design and Windstorms utilizing the internet to make available interactive computerized information and the resources of the wind library, damage archives and test data at Texas Tech University. This effort should receive high priority over the next five year period.

* These are new thrusts with the potential of high returns.
PROMOTIONAL AND PROFESSIONAL ACTIVITIES

PUBLIC OUTREACH

Tours/Presentations for Schools/Civic Groups
Multimedia presentation on “Tornadoes: Myths and Misconceptions” for Science Day, Fall '96 held at Texas Tech University presented by J.R. McDonald, November 23, 1996, attended by 23 high school students and teachers.

Tour of Missile Impact Facility, Woolworth schools given by J.R. McDonald, January 1997.

Tours of Wind Engineering facilities in the Civil Engineering (CE) building, given by James Wedding and Janie Wood, 1997 Science Fair, 95 student participants.

Tours of Wind Engineering facilities in the CE building, for University Day, given by Anna Gardner, James Wedding, and CE students, February 28, 1997, 12 students, 8 parents.

Presentation on WERC research to Lubbock Lions Club given by R.E. Peterson, March 1997.

Presentation to Carillon residents and identification of safe areas at this facility by J.R. McDonald, April 1997, 25 participants.

Presentation on Wind Engineering to Rotary Club of Lubbock given by K.C. Mehta, May 1997

Tour of Wind Engineering Research Field Laboratory (WERFL), Meadow ISD Sixth grade, given by Anthony Rodriguez and Shawn Balcar, May 15, 1997, 28 students.

Slide and video presentation for Lubbock High “Storm Chasing” class on Wind Engineering program and tornadoes by Anna Gardner and John Schroeder, May 16, 1997, 28 students.

Texas Floodplain Management Association annual meeting participants, introduction and missile launcher shot described by J.R. McDonald, in-residence shelter explanation by Russell Carter, June 11, 1997, 35 participants.

Abernathy Summer Enrichment program, tour of field site, given by Shawn Balcar, June 19, 1997, 16 students.


Allied Signal Aerospace, Kansas City, MO included information on tornado safety and the in-residence shelters in their Safety Day. Pictures of tornado missiles from the archive, 200 in-residence brochures and 100 tornado safety brochures were sent to them.

Grinnell Mutual handed out in-residence brochures to all 400 participants of a meeting they sponsored.


Shake Hands with Your Future Engineering classes, two two-week sessions for upper elementary and one two-week session for High School students, taught by Mona Fritsch and Anna Gardner with assistance from College of Engineering faculty, summer 1997.

Shake Hands with Your Future Atmospheric Science, two-week session for 5-7th grades, taught by Jesse Kenyon with assistance from Kyle Hill, John Schroeder, Bill Turner and Steve Weinbeck, summer 1997.
Exhibits

"Winds of Destruction, Currents of Change" exhibit continues at the Science Spectrum. It was designed to inform the public about the twenty-five years of progress in wind engineering research carried on by the Institute for Disaster Research and the Wind Engineering Research Center. It includes over 75 large photographs showing effects of wind and windborne debris and current research in progress at the field station. An interactive computer allows patrons to access instructional segments on thunderstorms, tornadoes and hurricanes.
Lakeview Museum of Arts and Sciences, Peoria, IL has an exhibit on tornadoes which uses photographs of Wind Engineering research facilities at Texas Tech and of damage documentation. The exhibits staff used a minivan tailgate to reconstruct a scene from one of the photographs showing a wooden board stuck through the back end of a van. A video of the IDR missile launcher (tornado cannon) is accompanied by a miniature version of the missile launcher which shoots pencils through 3/4” blocks of wood. According to Sheldon Schafer, Director of Science Programs and Facilities, this is one of their most popular exhibits. The exhibit opened March 10.

Popular Print Media

"Working From Ground Up Is Ineffective In Detecting Tornadoes, Scientists Say," *Dallas Morning News*, Science Update, December 23, 1996, discussed Dr. Peterson and Dr. Gurrola’s research on the seismic record of the Lubbock tornado.


"Tech Tornado Research Teams Begin Preparations for Chases,” *University Daily*, March 27, 1997 reported on storm chasing team and disaster documentation teams; interviewed Dr. McDonald, Anna Gardner and Todd Flanagan.


"Aggregate Blow-off,” a note in *NRCAction*, vol. 2, issue 1, pg. 12 referred to the TOC's approval of the development of a design guide for evaluating the potential for aggregate blow-off during high wind events. This guide is being developed by IDR.

"Four Major Initiatives Bring Montford’s Vision into Focus,” “Tech Officials Push Research Initiatives in Washington,” and “Big Capital Improvements Ahead for Tech,” all appeared in the May 4, 1997 issue of the *Lubbock Avalanche Journal* and discussed Texas Tech’s initiative to obtain funding for research, including an expanded Wind Engineering facility, from the federal government.

"In-house Shelters Provide Protection,” by Art Chapman appeared in *the Fort Worth Star-Telegram* on May 28, 1997. It quoted Dr. Smith and described the in-residence shelter as well as providing an address for the Institute for Disaster Research.

“Conventional Caution Endorsed in Disaster’s Wake,” *Austin American-Statesman*, May 29, 1997 quoted Dr. Smith regarding the in-residence shelter.
Popular Print Media (cont)


"Experts Say Texas Twister Was an F-5," was released by UPI on May 29, 1997. It mentions work at Texas Tech to retrofit an interior room to form an in-residence shelter.

"Twister’s Fierceness Makes it a Rarity," by Chris Miller, The Dallas Morning News, May 29, 1997 quoted Dr. Peterson regarding wind speeds in tornadoes and mentioned the damage documentation team.


"Tornado Alley’s Residents are ‘living on the edge,’” USA Today, May 30-Jun 1, 1997 quoted Dr. Peterson regarding tornado formation.

The San Angelo Standard Times interviewed Dr. Kiesling for “Sitting Out the Storm,” on in-residence shelters, June 16, 1997.

The Waco Tribune-Herald interviewed Dr. Kiesling for an article on Jarrell tornado victims, June 16, 1997.

The Lubbock Avalanche-Journal interviewed Drs. Peterson and Smith regarding data collected by the new Doppler on Wheels, June 23, 1997.

The Houston Chronicle interviewed Dr. Kiesling for article on tornadoes in downtown areas, June 24, 1997.


Charlotte, NC paper and the Houston Chronicle and others interviewed Dr. Peterson about tornadoes and hurricanes.

Visual/auditory Media

In-residence shelters were discussed by Bruce Thomas, weatherman on KCEN-TV, Temple/Waco/Killeen, November 1996. He also gave an address for viewers to write to obtain these plans. Eight requests were received as a result of this broadcast.

RAI Corporation of New York requested information on the missile launcher and IDR to use in producing a program for Italian television, December 1996.

Office Kei, Inc., New York requested information on the missile launcher and wind flow visualization at the field site for use in producing a program for Japanese television, December 1996.

“Earth and Sky,” a radio program on National Public Radio interviewed Dr. Peterson on why the wind howls, December 1996.

KPRC-TV news, Houston, TX interviewed Dr. McDonald and filmed the missile launcher in action, aired February 13, 1997. A transcript of this program also appeared on the KPRC-TV’s internet home page.

Visual/auditory Media (cont)
KCBD-TV news, Lubbock, TX interviewed Dr. Mehta for Severe Storms week, March 6, 1997.
KCBD-TV news, Lubbock, TX interviewed Drs. Smith and Peterson regarding the Doppler Radar project.
KXAS-TV, Dallas, TX re-aired a program filmed previously, "Texas Weather: From Drought to Floods," on March 18 and March 25, 1997. Forty-seven requests for in-residence plans were received as a result of this program.
KYTV news, Springfield, MO interviewed Dr. McDonald and John Schroeder and filmed a missile launch shot, April 1, 1997 to be aired in May.
KAUZ-TV, Wichita Falls, TX, presented a segment on their evening news featuring the missile launcher and field site facility as part of a week long series, "Eye of the Storm," aired April 1997.
KAMC-TV, Lubbock, TX interviewed Dr. McDonald regarding occupant safety in manufactured homes for a two-part series, aired May 11 & 12, 1997. These segments included a special missile shot through metal siding such as used on manufactured homes and a tour to examine manufactured homes in the area.
Channel 10, Waco, Texas, segment commemorating the Tornado of 1951 mentioned the in-residence shelter.

NBC Dateline interviewed Dr. Kiesling and featured the Wind Engineering Program, the missile launcher and in-residence shelter, aired June 2, 1997. Approximately 1200 requests for brochures and 750 requests for plans were received from 47 states. A special phone line was set up to handle the increased volume of calls.

KCBD, Channel 11, Lubbock, TX interviewed Dr. Kiesling and featured a missile launcher shot live on the 5pm and 6pm news on June 3, 1997.
KCBD, Channel 11, Lubbock, TX interviewed Dr. Peterson on tornadoes, June 1997.
KVUE, Austin Channel 24 interviewed Dr. Kiesling live on a morning talk show regarding the in-residence shelter, June 4, 1997.
TopSpin Creative Corporation, New York interviewed Dr. Kiesling and filmed two tornado cannon shots for a one hour special on tornadoes as part of the Travel to the Mysterious World series for TBS TV in Tokyo, Japan, to air July 6, 1997.
KETK-TV, NBC Affiliate, Tyler, TX interviewed Dr. Kiesling on camera on the in-residence shelter, July 7, 1997.

On-line
Wayne Curtis, reporter for the Discovery Channel on-line (http://www.discovery.com), interviewed Dr. Kiesling regarding in-residence shelters and Dr. Smith regarding the Wind Engineering Research Field Laboratory, May 29, 1997.
Wind Engineering has a web page at http://www.ce.ttu.edu/wind/main.html
PROFESSIONAL ACTIVITIES

Classes/Presentations for Professionals
Presentation of Wind Program to engineers from the Commonwealth of Independent States, part
of tour organized by U.S. State Dept., September 1996, presented by E.W. Kiesling, D.A.
Smith and T. Robbins.
ASCE Wind Load short course; Tampa, FL; Charleston, SC; Chicago, IL; October - November
1996; Kansas City, MO; Orlando, FL; Raleigh, NC; May-September 1997 by K.C. Mehta and
Dale C. Perry.
Invited lecture on ASCE 7-95, Fifth Building Professional Institute, University of Texas,
Arlington, TX, January 1997, J.R. McDonald
Texas Tech Engineering for Extreme Winds short course, Lubbock, TX, February 1997 presented
by K.C. Mehta, J.R. McDonald, D.A. Smith and J.E. Minor, 37 participants from ten states
and Mexico.
“Wind Engineering Research at Texas Tech,” presented to Mechanical Engineering Department
of University of Auckland, New Zealand on March 20-21, 1997 by K.C. Mehta; Dr. Mehta
also visited the wind tunnel facility for yachts.
“Wind Load Standards in the United States,” presented to staff of the Cyclone Testing Center,
James Cook University, Townsville, Australia on March 26-17, 1997 by K.C. Mehta;
Dr. Mehta also visited their house testing and wind tunnel facilities.
“Wind Load Provisions of U.S. Standard ASCE 7-95,” seminar presented at Monash University,
Melbourne, Australia; Dr. Mehta also visited with faculty to discuss wind engineering research
and reviewed the wind tunnel facilities.
Workshop on Tornado Risk Methodology, DOE/LLNL, Gaithersburg, MD, presentation by J.R.
McDonald.
Invited luncheon speaker, U.S. National Conference on Wind Engineering, Baltimore, MD, June,
Wind Design Seminar as part of Multihazard Building Design Summer Institute, sponsored by

Faculty members serve on the following professional committees:
Advisory Board for Hazard Response and Recovery Center of Texas A&M University
Mehta
American Association of Wind Engineering Board of Directors McDonald
American Meteorological Society Committee on Local Chapters Peterson
ASCE Aerospace Division Committee on Aerodynamics Mehta
ASCE- Caprock Branch, President 1996-1997 Smith
ASCE Committee on Wind Effects Sarkar and Smith
ASCE Standards Committee on Wind Tunnel Testing of Bridges and Other Structures
Sarkar
ASCE 7 Task Committee on Wind Loads McDonald
Institute for Business and Home Safety (formerly Insurance Institute for Property Loss
Reduction) Wind Damage Mitigation Committee Mehta
Institute for Business and Home Safety Retrofit Committee McDonald
Faculty Participation on Professional Committees (cont)
Manufactured Housing Standards Advisory Committee of the Texas Dept. of Housing and Community Affairs, Austin, TX McDonald
National Institute of Building Sciences, National Multihazard Mitigation Council Steering Committee Mehta
National Institute of Building Sciences, Wind Loss Estimation Committee Mehta
National Roofing Contractors Association Wind Committee McDonald
Roofing Industry Committee on Wind Issues McDonald
Texas Department of Insurance Building Code Advisory Committee McDonald
Texas Department of Insurance Loss Mitigation Committee - Wind/Hail McDonald
U.S.-Japan Natural Resources Task Committee on Design for Wind and Wind Hazard Mitigation Mehta

Meeting Participations
Kruse, J.B.

McDonald, J.R.
MBMA Research Symposium, October 1996.
Focus Group meeting for Multiprotection Building Design Summer Institute, Emmitsburg, MD, sponsored by FEMA, October 1996.
IIPLR Retrofit Committee, Corpus Christi, TX, December 1996; Irvine, CA, June 1997.
TDI Residential Loss Mitigation Committee, Austin, TX, December 1996; February 1997.
ASCE Structures Congress, Portland, OR, April 1997.
Manufactured Housing Standards Advisory Committee meeting, Austin, TX, May 1997.
Texas Insurance Commission hearing on Coastal Hurricane Building Code, Austin, TX, May 1997.
Hurricane Shelter Focus Group, Macon, GA, June 1997.
ASCE 7 Wind Task Committee, Baltimore, MD, June 1997; Denver, CO, August 1997.
Seismic Design Seminar as part of the Multi-Hazard Building Design Summer Institute, Emmitsburg, MD, July 1997.
Masonry Professors Roundtable, SW Research Institute, Arlington, TX, August 1997.
Mehta, K.C.
Focus Group meeting for Multiprotection Building Design Summer Institute, Emmitsburg, MD, sponsored by FEMA, October 1996.
ASCE Natural Disaster Reduction Conference, Washington, D.C., December 1996
National Multihazard Mitigation Council Steering Committee, Washington, D.C., March 1997; Dallas, TX, January 1997; Chicago, IL, May 1997.
ASCE Structures Congress, Portland, OR, April, 1997; co-chaired two sessions.
National Hurricane Conference, Houston, TX, April 1997.
ASCE Wind Loss Module Committee, Dallas, TX, June 1997.
Seismic Design Seminar as part of the Multi-Hazard Building Design Summer Institute, Emmitsburg, MD, July 1997.

Peterson, R.E.

Sarkar, P.P.
ASCE Structures Congress, Portland, OR, April 1997.

Smith, D.A.
ASCE Caprock Branch, monthly.
ASCE Structures Congress, Portland, OR, April 1997.
ASCE Wind Effects Committee, Portland, OR, April 1997.
GEMA Shelter Advisory Committee, June 1997.
Hurricane Shelter Focus Group, Macon, GA, June 1997, August 1997

Yin, J.
Awards/recognition

Dr. J.R. McDonald is listed in the 1997 edition of “Who’s Who in Technology.”

Dr. J.R. McDonald received an award from the American Association for Wind Engineering for his service on the Board of Directors.

Dr. J.R. McDonald received an award as Outstanding Researcher in the College of Engineering for 1996-1997.

The ASCE-7 Wind Loads Task Committee, chaired by Dr. K.C. Mehta, received the 1997 Engineering Award from the National Hurricane Conference, presented April 23.

Dr. K.C. Mehta and Dr. J.R. McDonald received awards from the American Association for Wind Engineering for their service on the ASCE 7 Wind Loads Task Committee, presented June 6.

Dr. K.C. Mehta was granted development leave by the university for the Spring Semester 1997. He interacted with researchers in New Zealand and Australia.
VISITING SCHOLARS

Dr. Jerry C. Wong, Civil/Structural Section, Power System Engineering, Florida Power and Light; visited October 1996 to discuss Transmission Line Wind Load Research project.

Bill Bailey, Acme Brick, presented three lectures on Masonry Design which were videotaped for use in design classes, October 1996.

John Hoyt, Jack Sinclair and Mr. Crocker, TXI, spoke to concrete class and later to ASCE meeting, October 1996.

Dr. Greg Reardon, Technical Director, Cyclone Testing Station, James Cook University, Townsville, Queensland, Australia, gave a seminar on current research at the Cyclone Testing Station and discussed his work with wind faculty members, visited November 4-5, 1996.

Ron Mizia and Jeff Lacy of the Idaho National Engineering and Environmental Laboratory (INEEL) visited November 5, 1996.

Larry Griffis, Walter P. Moore and Associates, Houston, and current Chairman of the ASCE Task Committee on Wind Loads, visited WERC including field site and gave a presentation to the graduate seminar class, December 2, 1996.

Thomas P. Grazulis, Director, The Tornado Project, spoke with Dr. Mehta regarding inclusion of information on the Wind Engineering Program on the Tornado Project’s web page and met with Dr. Peterson to discuss work on foreign tornadoes, May 15-16, 1997.

Cheryl O’Brien and Clark Williams, Idaho National Engineering and Environmental Laboratory, visited WERC to discuss possible collaboration on an INEEL URC project, June 26, 1997.

Japanese electrical engineers working in plasma physics visited Atmospheric Science to discuss the relationship between electrical properties of storms and tornadogenesis, June, 1997.
RESEARCH PROJECTS

Following is a summary of projects which were active during all or part of academic year 1996-1997. Project summaries are given for completed projects, progress summaries for those projects which are in-progress and plans for future research are given for those projects that have just begun.

Title: Cable Stay Bridge Vibration
Sponsor: Texas Department of Transportation
Amount: $145,277
Duration: 9/1/97-8/31/98
Director: Kishor C. Mehta
Others: Partha P. Sarkar

The objectives of the project are to identify the cause of cable vibrations on the Fred Hartman and the Veterans Memorial Bridges in Houston, TX and to develop strategies to control cable vibrations. This project is in collaboration with Johns Hopkins University. To achieve these objectives it is necessary to instrument both bridges in the field to obtain vibration data and associated meteorological data during vibration periods, analyze and interpret data, and develop strategies to mitigate the vibrations. Development of mitigation strategies may require wind tunnel testing along with analytical studies. In addition, one or two mitigation strategies will be field tested prior to finalizing the strategies.

Title: CSU/TTU Cooperative Wind Engineering Program
Sponsor: National Science Foundation
Amount: $320,000 for 1997-1998
Duration: 1/15/95 - 1/14/2000
Director: Kishor C. Mehta
Others: Richard E. Peterson, Partha P. Sarkar, Douglas A. Smith, Jamie B. Kruse

The Cooperative Program in Wind Engineering with Colorado State University is in the third year of the second five year program (1995-2000). The program contains four interactive tasks related to wind effects on buildings: wind loads, wind flow around buildings, wind engineering meteorology and wind damage economics. During the year progress has been made on each of the tasks. Simultaneous measurements of velocity near building surfaces and surface pressures along with flow visualization using tuft and airfoil are being pursued to understand high instantaneous pressures in separation and corner vortex zones. Characterization of pressures and overall loads on the building are being pursued as part of the wind loads task. In the Meteorology task group, a comprehensive examination of the near-surface wind measurements of Hurricane Bob revealed characteristics of the internal boundary layer, gust factor, turbulence intensity and integral scale. WERFL tower measurements taken during thunderstorm outflow passages were analyzed to resolve the nature of the turbulent windfields. A detailed examination of the NWS wind measurements taken at Lihue, Hawaii, during Hurricane Iniki has begun. Work in the Economics task area has focused on developing new laboratory experiments on low probability losses to identify systematic differences in behavior as probabilities become small. Progress on the project
was presented and discussed with the Technology Assessment and Advisory Council in October 1996.

**Title:** Design of Residential Shelters from Severe Winds  
**Sponsor:** Greenhome & O’Mara  
**Amount:** $87,122  
**Duration:** 6/1/97-2/28/98  
**Director:** Ernst W. Kiesling  
**Other:** Kishor C. Mehta

This study developed criteria for designing above-ground residential shelters for hurricanes and tornadoes. Design criteria vary by zone across the country and include design wind speeds for the United States and its territories as well as the missile criterion for each wind speed. The study was based on the philosophy that occupant protection be provided in a small interior room and that the remainder of the building be designed and constructed to sustain minimum economic loss. In-residence shelters reduce the costs and risks inherent in hurricane evacuation. Research needed to design adequate shelters for each wind speed along with estimated costs of performing the research and the design effort needed were included in the final report.

**Title:** Development & Design Guidelines  
**Sponsor:** National Greenhouse Manufacturer’s Association  
**Amount:** $10,000  
**Duration:** 1/15/96 - 12/31/96  
**Director:** Douglas A. Smith

Greenhouses have traditionally been considered as agricultural structures which represent low risk to human life in the event of their failure. As a result, design and code enforcement attention to these structures has often been minimum. Greenhouses constructed adjacent to each other may exhibit large variability in resistance to environmental loads such as wind and snow loads. This may be due to mismatching the design criteria and location of the construction, e.g., greenhouses designed for 70 mph design wind speed are built where the design wind speed exceeds 100 mph, and to the varying amount of engineering attention given to the structure. The design guidelines identify the important criteria to be considered in the design of greenhouse structures so that they will adequately fulfill their intended purpose.

**Title:** Effect of Missile Impact on Internal Pressure  
**Sponsor:** Metal Building Manufacturers Assn.  
**Amount:** $32,000  
**Duration:** 5/1/96 - 12/31/97  
**Director:** James R. McDonald  
**Other:** Partha P. Sarkar

The South Florida Building Code requires wall cladding to be subjected to the same missile impact requirements as glazing. Other model building codes may follow suit. When a window lite is broken, the opening created by the impact allows wind and water inside the building and may
result in a substantial increase in internal pressure. The combined effects of internal and external pressure in a building create a much more severe loading condition on walls and roof than the external pressures alone. An argument has been presented for excluding wall cladding from missile impact requirements, because the opening created by missile perforation would be much smaller than from a broken window. This premise is probably correct, but very little is known about missile perforation into metal panel walls and roofs. Thus, the project seeks to answer two significant questions: 1) What size openings are created by debris impact on metal panel wall and roof cladding? and 2) What is the relationship between the size of opening and internal pressure build-up in a metal building? Should the internal pressure build-up be negligible, a case can be made for excluding impact requirements from wall and roof cladding saving unnecessary and costly testing and product evaluations.

During the past year, three kinds of steel panels were tested with the missile launcher which shot the planks at speeds of 30 - 55 mph. Timber planks with seven different end configurations were shot on end or at a 45° oblique angle to the panels. Interestingly, those missiles with a 45° end cut (pointed) perforated all three types of panels every time. The perforated panels have been installed at the WERFL test building in order to assess internal pressure build-up.

Title: Investigation of Load Factors for Combined Wind and Flood
Sponsor: American Society of Civil Engineers/FEMA (Federal Emergency Management Agency) Part II
Amount: $50,000
Duration: 6/1/97-5/30/98
Director: Kishor C. Mehta
Others: Douglas A. Smith, Richard E. Peterson

This project is designed to develop load factors for combined wind and flood. The combined loading is likely to occur in coastal zones where hurricane winds occur at the same time as storm surge. Using the Monte Carlo simulation of hurricane storms, correlation of the two loadings is being developed. Level of correlation will lead to the values of load factors that can be specified by standards and codes. The U.S. Naval Academy at Annapolis, MD, and WERC are cooperating on this project. Texas Tech’s portion of the project is scheduled for completion at the end of 1997.

Title: Investigation of Wind Projectile Resistance of ICF Homes
Amount: $9,196
Duration: 8/15/97 - 12/15/97
Director: E.W. Kiesling

Insulating Concrete Forms (ICFs) are hollow units of plastic foam that are assembled into the shape of a building’s walls. Afterward concrete is poured into the units and reinforced to form the wall. This type of wall has advantages over wood frame in terms of energy efficiency, sound dampening, design flexibility, strength, pest resistance and ease of construction. Texas Tech will test a variety of ICF walls of different thicknesses and structures for resistance to perforation by
wind-borne debris. Concrete, wood stud framing and steel stud walls will also be tested for comparison. Each wall assembly will be subject to the impact of a single 15 lb. 2 x 4" wood stud shot from the missile launcher at 100mph. Photographs, video tape and written notes will document the comparative impact resistance of the various tested exterior wall assemblies.

Title: Mitigation of Hurricane Damage to Constructed Facilities
Sponsor: National Science Foundation
Amount: $120,000
Duration: 9/1/92 - 12/31/96
Director: Kishor C. Mehta
Other: Tom English

This was a cooperative project with the University of Washington. The objective of the project was to develop a computer science based building damage prediction model. A procedure to develop an integrated model that combines knowledge-based expert systems with traditional algorithmic programs is advanced. The masters thesis by Mark Teal in Computer Science contains details on the model. The generic model is in the Microsoft Windows operating system which offers flexibility in intertask communication, user interaction and data management.

Title: Multimedia Development of Wind Engineering Course
Sponsor: Texas Tech University
Amount: $19,500
Duration: 11/1/95 - 12/31/96
Director: Partha P. Sarkar
Other: William Marcy

This course is designed for students who intend to gain a preliminary understanding of the wind environment and its effects on structures. It aims at training engineers who will ensure that the performance of structures subjected to the action of wind will be adequate in terms of structural safety and serviceability during the anticipated life of the structures. The course will cover the following subject areas: understanding of wind storms; boundary-layer wind and wind-structure interaction; wind-tunnel testing; wind loads on structures; and design for extreme winds including usage of wind-load standards.

Title: Performance Evaluation of Essential Facilities in Severe Windstorms
Sponsor: Georgia Emergency Management Agency
Amount: $298,750
Duration: 6/1/96 - 12/31/97
Directors: Douglas A. Smith, James R. McDonald

This project will develop a PC-based expert system that will establish the relative vulnerability of an essential facility to hurricanes or tornadoes. The computer software will provide emergency management officials with a tool to establish mitigation and retrofit options and priorities for essential facilities. The product will produce a damage scenario and a vulnerability rating as a function of wind speed. The damage scenario will establish threshold wind speeds at which the
building components and structural system will sustain damage. The expert system will be designed for use by emergency management officials, architects, engineers and other construction technologists. The first 15 months of this project has focused on identification of elements of the various subsystems, identification of the parameters affecting the resistance of each element, identifying loading parameters, and establishing possible failure modes and consequences of element failure.

Title: Regional Economic Loss Due to Windstorm
Sponsor: State of Texas
Amount: $6500
Duration: 9/1/96-8/31/97
Director: Robert P. McComb, Jamie B. Kruse

A search of the literature on the economics of insurance focused on effects on the homeowner/builder/lender, looking in particular at loss mitigation incentives. Additional literature review of the area of catastrophic loss estimation, modeling and mitigation extended outside the area of mainstream economics to the areas of urban and regional sciences. This information will provide the background for an analysis of wind loss mitigation behaviors and policy strategies. A regional economic Computable General Equilibrium modeling software was purchased to facilitate development of a model of the economic costs of evacuation. Initially this study will consider the case of a hurricane over-warming in the Houston-Galveston region.

Title: Software for Design of Aggregate Surfaced Built-Up Roofs
Sponsor: National Roofing Contractors Association
Amount: $29,708
Duration: 4/1/97-12/31/97
Director: James R. McDonald

The objective of the research is to develop computer software and a draft guide for the design of Build-Up Roofs (BUR's) with aggregate surfacing based on the Kind and Wardlaw (1976) procedures. An additional objective is to provide a design guideline written in language to facilitate introduction of code changes in the three U.S. model building codes. The computer software will be written in appropriate programming language. Two computer programs will be written: the first will generate the tables needed for the design guide and the second will be a user-friendly tool used by a roofing consultant in designing BURs with aggregate surfaces.

Title: Transfer of Wind Engineering Research to Curriculum
Sponsor: National Science Foundation
Amount: $90,000
Start: 7/1/94 - 12/31/96
Directors: Partha P. Sarkar, Kishor C. Mehta
Others: James R. McDonald, Jerry Dunn, R.E. Peterson

This courseware development project aims to transfer research results to curriculum through multimedia technology in the multi-disciplinary area of wind engineering. Educational modules,
using the latest multimedia computer technology and wind engineering research results, present complex wind-structure problems in a simplified form. These instructional aids will be integrated into different courses offered in the departments of Civil Engineering, Mechanical Engineering, Architecture and Atmospheric Science, both at the undergraduate and graduate levels. The primary thrust is to upgrade the undergraduate curriculum, first at Texas Tech University and then at other universities. This integration will help to reinforce the present curriculum and will create a stronger educational program in engineering, architecture, and atmospheric science at various universities. This courseware contains four educational modules on a CD-ROM. The contents of these modules are based upon research accomplishments in wind engineering at Texas Tech University. These modules include detailed descriptions of the subject areas in the form of text; supplemented by video clippings, computer animations, and color slides, which highlight specific principles. The modules are: (a) Thunderstorms, Tornadoes and Hurricanes: A General Overview, (b) Damages caused by Tornadoes and Hurricanes, (c) Impact of Windborne Debris, and (d) Wind Loading on Low-Rise Buildings. These modules can be used by instructors in the classroom as well as by students and other professionals outside the classroom.

Title: Transmission Line Wind Loading Research  
Sponsor: Florida Power & Light  
Amount: $104,400  
Duration: 6/1/95 - 12/31/96  
Director: Kishor C. Mehta  
Others: W. Pennington Vann, J. Walt Oler,

The latest wind design standard for the United States, ASCE 7-95, changes the basic wind speed from the long-standing "fastest mile wind" to a "3-second gust," or largest expected wind speed averaged over 3 seconds. For a flexible structural system such as a power line system, which has multiple components (poles, conductors, and groundwires) that can respond dynamically to the wind, the gust effect factors to be used to account for dynamic behavior must be significantly different when used with the 3-second basic wind speed. This study examines the determination of these gust effect factors by three of the methods allowed by the new standard: the new general method proposed in the standard's commentary, the method especially established for power lines by Davenport, and the general method of Simiu. It is recommended that a modified version of Davenport's method be used. In addition, the scope of the project involves testing of 12 electrical transmission conductors of different configuration for force coefficient. The testing is accomplished in an aerodynamic wind tunnel up to 120 mph at Texas A&M University and in a water tow tank up to 5 fps in Mechanical Engineering at Texas Tech.

Title: Wavelet Analysis of Turbulent Flow in the Surface Layer  
Sponsor: Texas Higher Education Coordinating Board (ARP)  
Amount: $85,000  
Duration: 1/1/96 - 12/31/97  
Director: Richard E. Peterson  
Others: James Dunyak, Douglas A. Smith
The surface layer comprises the lowest several hundred feet of the atmosphere. Quite often the winds are characterized by seemingly disorganized flow termed turbulence. Wavelet analysis is a technique rather recently introduced in meteorology to seek order in the surface layer turbulent wind flow observations. The Wind Engineering Research Field Laboratory has been collecting meteorological data in the surface layer with instruments on a 160 ft. tower. Quite often the wind records reveal bursts of momentum (which may be quite important when considering the effects on structures). Wavelet analysis has been applied to this data and is being interpreted in light of information derived from a survey of wavelet analysis literature. In the future, numerous analyses will be carried out for different meteorological scenarios so that common and distinct features can be identified.

Title: Wind Damage Prediction Using Doppler Radar  
Sponsor: Texas Higher Education Coordinating Board (ARP)  
Amount: $148,850  
Duration: 1/1/96 - 12/31/97  
Director: Douglas A. Smith  
Others: James R. McDonald, Richard E. Peterson

Predicting wind-induced damage to buildings using Doppler radar requires that the building damage observed on the ground be related to the Doppler radar signals and a relationship between the two be established. To establish these relationships, we have performed damage investigations for 2 hurricane events (Opal and Fran), 2 downburst events (Lee’s Summit, MO and Lubbock, TX), and 3 tornado events (Bullit County, KY, Arkadelphia, AR, and Jarrell, TX). Doppler radar data for these events is either currently in hand at Texas Tech or has been ordered.

A surface wind field for Hurricane Opal has been generated from the Doppler radar data using the synthetic dual Doppler (SDD) technique. This surface wind has been compared with sources in the literature. For Hurricane Opal, the surface wind field data predicted using the SDD technique provides reasonable estimates of the near surface wind field. Damage documentation from Hurricane Opal has been used to develop damage functions for several types of roofing and wall cladding materials. A technique which relates the percent damage to a component (such as the roof covering) with the wind forces acting on the component is used to establish these damage functions. These component damage functions are being refined and the algorithm to predict damage to the entire structure is under development.

Title: Wind Engineering/Fluid Mechanics Enhancement  
Sponsor: Texas Tech University  
Amount: $25,000 for 1996-97  
Duration: 9/1/92 - 8/31/97  
Director: Kishor C. Mehta  
Others: Faculty Investigators in Wind Engineering

This funding was effectively used to support student and research personnel, seed money for travel and small projects, visiting scholars and promotional and professional service activities. WE/FME funding partially supported two faculty members, one research associate, one graduate
student and two undergraduate students. These personnel represented the disciplines of civil engineering, economics and atmospheric science. A “storm chase” team studied various aspects of severe windstorms. This provided an opportunity for students involved in the wind program to gain first-hand knowledge of severe windstorms. They also took video film and still photographs of severe storm phenomena which will be used for presentations in courses, and outreach presentations to schools and civic groups. Dr. Robert McComb, Assistant Professor of Economics, continues research to estimate cost savings which would result with the adoption of various preventive measures. A new software package was purchased to allow economic modeling of windstorm effects. Dr. Chia-Bo Chang, Assistant Professor of Atmospheric Science, is developing a numerical model which will predict wind fields in hurricanes.

Title: Wind Engineering Research Center  
Sponsor: State of Texas (Line Item Funding)  
Amount: $261,000 annually  
Duration: 9/1/93 - 8/31/97  
Director: Kishor C. Mehta  
Others: Faculty Investigators in Wind Engineering

Several small projects were partially or completely supported in Civil and Mechanical Engineering, Computer Science, Architecture, Atmospheric Science, Economics and Mathematics. Some of the projects are Wind Resistance Evaluation of Existing Buildings, Wind Generated Missile Impact on Composite Wall Systems, Development of a Website for Wind Engineering, Wind Loads on Low-Rise Buildings, Stage III Validation, Development of Texas Tech Wind Tunnel, Numerical Modeling of a Hurricane Wind Field, Finite Element Modeling of a Roof Deck, Wall Corner Pressures, Characterization of Delta Wing Vortices, Hurricane and Storm Surge Modeling, A Model for Probable Maximum Loss in Hurricanes, Surface Layer Characteristics of Thunderstorm Winds, and Missile Impact Tests. The project provides support to Research Associates, Graduate students, Undergraduate students, WERC staff and a few faculty. In addition, publications and outreach activities are supported by this project.

Title: Wind Load Standards Compliance  
Sponsor: Florida Housing Finance Agency  
Amount: $275,000  
Duration: 1/3/95 - 12/31/96  
Director: James R. McDonald  
Others: Douglas A. Smith, Kishor C. Mehta

Residential construction receives extensive damage in hurricanes because it is not engineered. Florida Housing Finance Agency contracted with the Wind Engineering Research Center to design an expert system which would make it easier for non-engineers to comply with the standards and codes. Drs. McDonald, Smith and Mehta have developed a software program for use by building officials to ease adherence to, and enforcement of the building codes. The PC-based system has a graphics interface that provides customized prescriptive requirements for one- and two-family homes that satisfies a specified building code and type of construction. The program is user-friendly and will be used by Florida officials.
PUBLICATIONS AND REPORTS FROM WERC PROJECTS


*Proceedings and Presentations*


Reports


WIND ENGINEERING PERSONNEL
1996-1997

Wind Faculty
Chia-Bo Chang (Assoc Prof, Atmo)
Arthur L. Doggett (Asst Prof, Atmo)
Jerry R. Dunn (Assoc Prof, Mech Eng)
James P. Dunyak (Asst Prof, Math)
Tom English (Asst Prof, Comp Sci)
Michael A. Jones (Assoc Dean, Architecture)
Ernst Kiesling (Prof, Civil Eng)
Jamie B. Kruse (Assoc Prof, Econ)
Robert P. McComb (Assoc Prof, Econ)
James R. McDonald (Chairman and Prof, Civil Eng)
Kishor C. Mehta (P.W. Horn Prof, Civil Eng)
H. Scott Norville (Prof, Civil Eng)
J. Walter Oler (Assoc Prof, Mech Eng)
Richard E. Peterson (Chairman and Prof, Geosciences)
Partha P. Sarkar (Asst Prof, Civil Eng)
Douglas A. Smith (Res Asst Prof, Civil Eng)
Milton Smith (Prof, Ind Eng)
Richard W. Tock (Prof, Chem Eng)

Research Associates
Praveen Sandri
Eric Schuele
Jianming Yin
Manoj Paul (CompSci)
Robert Pruitt (CE)
Staci Pruitt (CE)
Vachana Rao (Arch)
Timothy Robbins (Ty)

Staff
Kim Aycock (Tech Ed)
Joyce Domansky (CS IV)
April MacDowell (Coordinator)
John Schroeder (Atmo)
Anindya Sengupta (CE)
Gary Skwira (Atmo)
Jeffrey Stroman (ME)
Christian Unanwa (CE)
Steve Weinbeck (Atmo)
Fuqiang Wu (CE)
Zhongshan Zhao (CE)

Research Assistants
Yuzheng Cai (CE)
Russell Carter (CE)
Mark Conder (Atmo)
Todd Flanagan (Atmo)
Mona Fritsch (CE)
Anna Gardner (CE)
Tom Gardner (ME)
Rob Howard (Math)
Aravamudhan Kumar (ME)
Yongqing Lu (CE)
John McAnulty (CE)

Graduate Assistants
Joe Charlton (CE)
Anirudha Gaidhane (CompSci)
Ali Jabri (CE)
Vidyamishv S. Rajpathak (CompSci)
Winston Rhee (ME)
Jagat Shah (CompSci)
Kevin Simmons (Econ)
Jinqiang Zhong (CompSci)

*Undergraduates*

Eric Allen (CE)
Michael Anderson (CE)
Nadine Balcar (Educ)
Shawn Balcar (CE)
James Beggs (CS)
Nathan Betzen (CE)
Becky Black (Engl)
James Caputo (GeoS)
John Conner (CS)
Peter Devito (CS)
Ryan Donahue (CE)
Amy Dowell (CE)
Lisa Dowell (CE)
Vanna Groves (CE)
Chris Machuca (ME)
Mark Martinez (CE)
Mary Ruth Moore (Bio)
Clint Moyer (CE)
Leonard Nail (CE)
Laura Opdahl (CE)
Shannon Reed (CE)
Bryan Robertson (CE)
Saul Rodolfo (ME)
Anthony Rodriguez (CE)
John Shockley (CE)
James Snelson (CE)
Audra Thomas (CE)
Ty Thompson (CE)
Janie Wood (CE)
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*If student is working on a degree in non-wind-related studies, the supervisor and project area within wind engineering are listed.


PROPOSAL ACTIVITY

ASCE Proposal to FEMA for a Cooperative Agreement to Develop a Standard for the Design of Flood-Resistant Coastal High-Rise Buildings, K.C. Mehta and D.A. Smith, submitted to FEMA through ASCE, $263,603 to ASCE, approximately $72,000 for Texas Tech. (pending)

Bridge Cable Vibrations on the Fred Hartman and Veterans Memorial Bridges, K.C. Mehta and P. Sarkar, submitted to Texas Department of Transportation, May, 1997, $49,023. (funded)

Cable Stay Bridge Vibration, K.C. Mehta and P. Sarkar, submitted to Texas Department of Transportation, $145,277. (funded)

CFD Application to Estimate Loads on Typical Low-Rise Buildings Due to Tornado Winds, P. Sarkar and J.R. McDonald, submitted to Texas Higher Education Coordinating Board, ARP program, $117,829. (pending)

Cost Effective Strategies for Hurricane Loss Mitigation, J.B. Kruse and R.P. McComb, submitted to the Texas Higher Education Coordinating Board, ARP program, $71,759.00. (pending)

Data Acquisition for Wind Power Study, D.A. Smith, submitted to Western Windpower, Inc., $17,980. (not funded)

Design of Built Environment for Atmospheric Hazards, preproposal, K.C. Mehta in cooperation with other universities, submitted to NSF, Mar. 1997, $19,981,000. Also, workshop held to prepare a preproposal held in Dallas, TX, Feb. 25, 22 participants; workshop funded by Texas Tech University, $7,000. (not invited to submit proposal)


Detection of Localized Structures in Hurricane Windfields, R.E. Peterson, submitted to the Texas Higher Education Coordinating Board, ARP program, $73,442. (pending)

Detection of Tornadoes Using Neural Networks, D. Wunsch (Elec. Eng.), submitted to the Texas Higher Education Coordinating Board, ARP program, $141,018. (funded)


Evaluation and Monitoring of Texas' Major and Unique Bridges, P. Sarkar, P. Nash and B. Green, submitted to Texas Department of Transportation, March, 1997, $ 264,326. (not funded)
Instrumentation to Characterize the Hurricane Environment, J.R. McDonald and R.E. Peterson, submitted to Office of Naval Research, $317,741. (not funded)

Investigation of Wind Projectile Resistance on ICF Homes, E.W. Kiesling, preproposal submitted to Portland Cement Association, $9,196. (funded)

Load Test Factor for Formed Metal Roof Panels Under Uplift Loading, K.C. Mehta, D.A. Smith, J.R. McDonald and J. Yin in cooperation with University of Western Ontario and Clemson University, submitted to Metal Roofing Systems Association, Oct., 1996, $5,000 to Texas Tech. (not funded)


A Mathematical Analysis of Tornado Dynamics, V.I. Shubov and D.S. Gilliam (Math.), submitted to the Texas Higher Education Coordinating Board, ARP program, $66,702. (pending)

Modeling of Wind-Structure Interaction Problems-Theories and Experiment, P. Sarkar, submitted to National Science Foundation, October 1996, $239,748. (not funded)


A Probabilistic Approach to Evaluation of Existing Bridges in Texas, R. Pigott, P. Sarkar and A. Gilman, submitted to Texas Department of Transportation, March 1997, $284,530. (not funded)

Proposal For Educational Outreach Program And Improved Housing Of Windstorm Damage Documentation Archive Of The Wind Engineering Research Center And Institute For Disaster Research, A. MacDowell, submitted to Helen Jones Foundation, April 1997, $14,240. (not funded)

Software for Design of Aggregate Surfaced Built-Up Roofs, J.R. McDonald, submitted to National Roofing Contractor’s Association, February 1997, $32,729.01. (funded)

A Stochastic Model to Predict Wall-Pressure Fluctuations, S. Parameswaran and D. James, submitted to Texas Higher Education Coordinating Board, ARP program, $121,500. (pending)

Wind and Building Pressure Field Data and its Simulation in the Laboratory, (5.5.5), preproposal, K.C. Mehta, D.A. Smith, R.E. Peterson, T.A. Reinhold (Clemson Univ.) and A. Kareem (Notre Dame), submitted to Idaho National Engineering and Environmental Laboratory (INEEL), April 1997, $856,000. (pending)