

SEISMIC HAZARDS IN THE SOUTH CAROLINA  
LOW COUNTRY: AN EMERGING  
MITIGATION PROGRAM

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"There is a great a potential of earthquakes to kill and damage in the Southeastern United States as there is in Southern California and parts of other Western States. South Carolina, as well as the Southeastern United States, is not prepared to cope with the social and economic impact of any damaging earthquake much less with a recurrence of the 1886 Charleston earthquake. Constructive and prudent steps must be taken to ensure that a seismic safety policy is established that will alert the public and various public industrial agencies to this danger and improve the state of earthquake-preparedness in our region."

Col. Charles Lindbergh  
The Citadel, Charleston<sup>2</sup>

Historically, the east coast has received substantially less attention concerning seismic risks than the west coast region, where the previous two case study communities are located. However, as is widely known, the east coast is seismically active and the potential for disaster is substantial. This was dramatically illustrated by the 1886 earthquake which rocked the Charleston, South Carolina area. Killing 60 people and causing more than \$5 million in property damage (the equivalent of \$460-\$560 million in 1985 dollars), this earthquake was one of the strongest and most devastating to occur in the U.S. in known history. The potential risk in the Charleston area has not gone unnoticed, however, as efforts are being made to better plan for and mitigate such risk.

Charleston is an old and historic city, founded in 1670. It lies on a peninsula at the intersection of the Ashley and Cooper Rivers. Frequently referred to as the "Low Country," the Charleston area developed as a thriving seaport. The city has relied heavily in recent years on tourism, which was stimulated by successful efforts to preserve and protect its historic district. The City of Charleston contains a population (in 1980) of approximately 70,000,

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\* See endnote 1 for explanation of method of data collection used for this report.

while the Charleston-North Charleston SMSA contains a population of more than 430,000 (U.S. Census Bureau 1980a). As Table 1 indicates, the State of South Carolina generally lags behind the nation as a whole in income and education. By South Carolina standards, the City of Charleston is a relatively prosperous community, with higher per capita and median family income levels, and considerably higher median home values.

### **The Nature of Seismic Hazards in the Low Country**

About three hundred years of documented earthquake history is available for South Carolina, with the earliest recorded earthquake occurring in Charleston in 1698 (Town of Visvanathan 1980). By far the most powerful and damaging earthquake to strike South Carolina was the August 31, 1886 Charleston earthquake. This earthquake was the third largest to strike North America, with an estimated magnitude of between 6.6 and 6.9 and an estimated intensity at MMIX (Modified Mercalli Intensity) at its epicenter, and IX in the City of Charleston. It was felt as far away as Wisconsin, and caused damage in New York City. Within the City of Charleston, nearly 1300 buildings were damaged, or 66 percent of the city's existing building stock, the majority constructed of brick. Figure 1 depicts the damage patterns for the 1886 earthquake, and shows a strong correspondence of damage levels to brick construction materials. Other factors found to have contributed to the Charleston damage include: areas of high water table and resulting liquification; building type (commercial and public buildings received the greatest damages); and the quality of construction (e.g. the type of mortar used).<sup>3</sup>

Table 1: Socioeconomic Characteristics of Charleston, South Carolina,  
and U. S.: (1979)

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	<u>Charleston City</u>	<u>South Carolina</u>	<u>U.S.</u>
Median per capita income	\$ 6,906	\$ 5,886	\$ 7,198
Median family income	\$ 17,041	\$ 16,978	\$ 19,917
Median years of education	12.6	12.3	12.5
Median value of owner- occupied homes (dollars)	\$ 47,900	\$ 35,100	\$ 47,200

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Source: U. S. Census Bureau (1980a, 1980b).

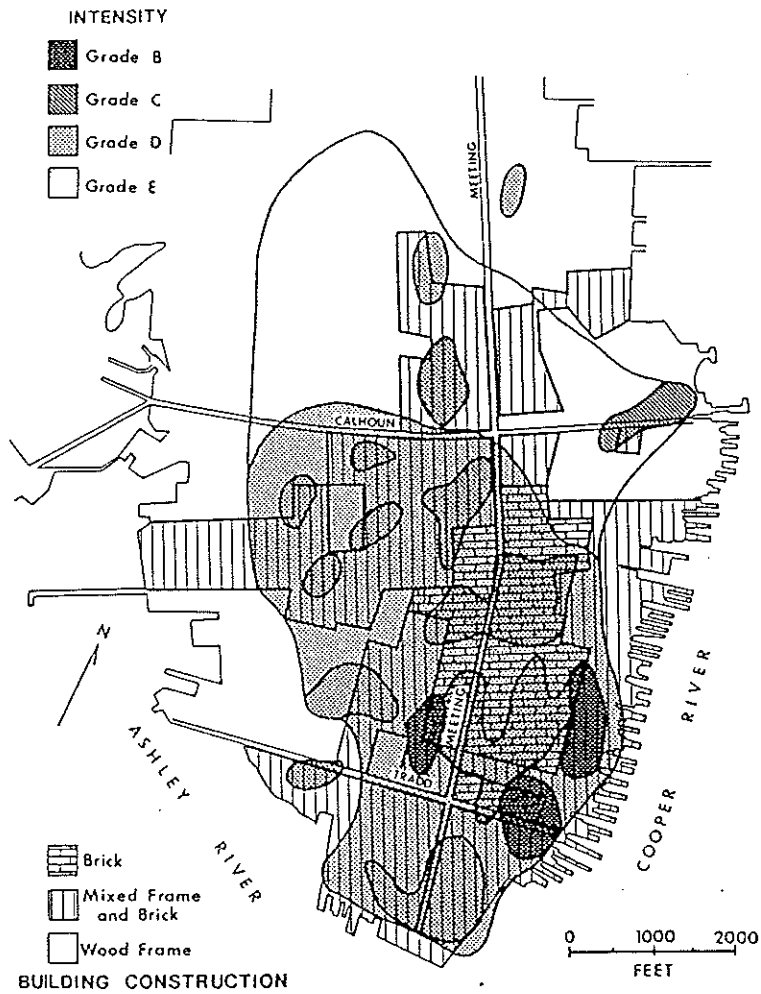


Figure 1: The Damage Intensity Compared with the Construction Type to Illustrate the Effect of Building Type on the Observed Damage  
Source: Robinson and Talwani 1983.

The nature of the earthquake threat in Charleston, and the east generally, is different from the threat in California and the west. On the one hand, the frequency of large and damaging earthquakes in the east is obviously much lower than in the west. On the other hand, earthquakes which occur in the east will affect a much larger geographical area. As Figure 2 illustrates, for earthquakes of roughly equivalent magnitudes, the distances affected will be much greater in the east. The 1886 Charleston earthquake was felt hundreds of miles away from its epicenter. In comparison, the energy from a similar earthquake in California would have dissipated quickly, affecting a much more localized area.

Certain types of hazards typically associated with earthquakes in the west are not present in South Carolina. Surface faulting does not generally occur in the east, while this is a serious problem, as we have seen, in the west. Tsunamis also do not generally occur in the east, and did not occur following the 1886 Charleston Earthquake.<sup>4</sup>

It is clear that the risk of people and property to future earthquakes in Charleston is substantial. Little effort was made following the 1886 earthquake to ensure that rebuilt structures, many of which are in use today, would be better able to withstand earthquake forces. Many structures built in more recent periods are also constructed of similarly vulnerable unreinforced masonry, and until very recently have not been constructed to account for seismic forces (see Figures 3a and 3b). In particular, many key public buildings, and most existing schools, are constructed of unreinforced masonry as are many new public buildings (Lindbergh undated).

A group of engineers at The Citadel in Charleston have conducted a vulnerability analysis of the Charleston area (Charleston, Berkeley and Dorchester counties) which quantitatively documents the existing risk. A key

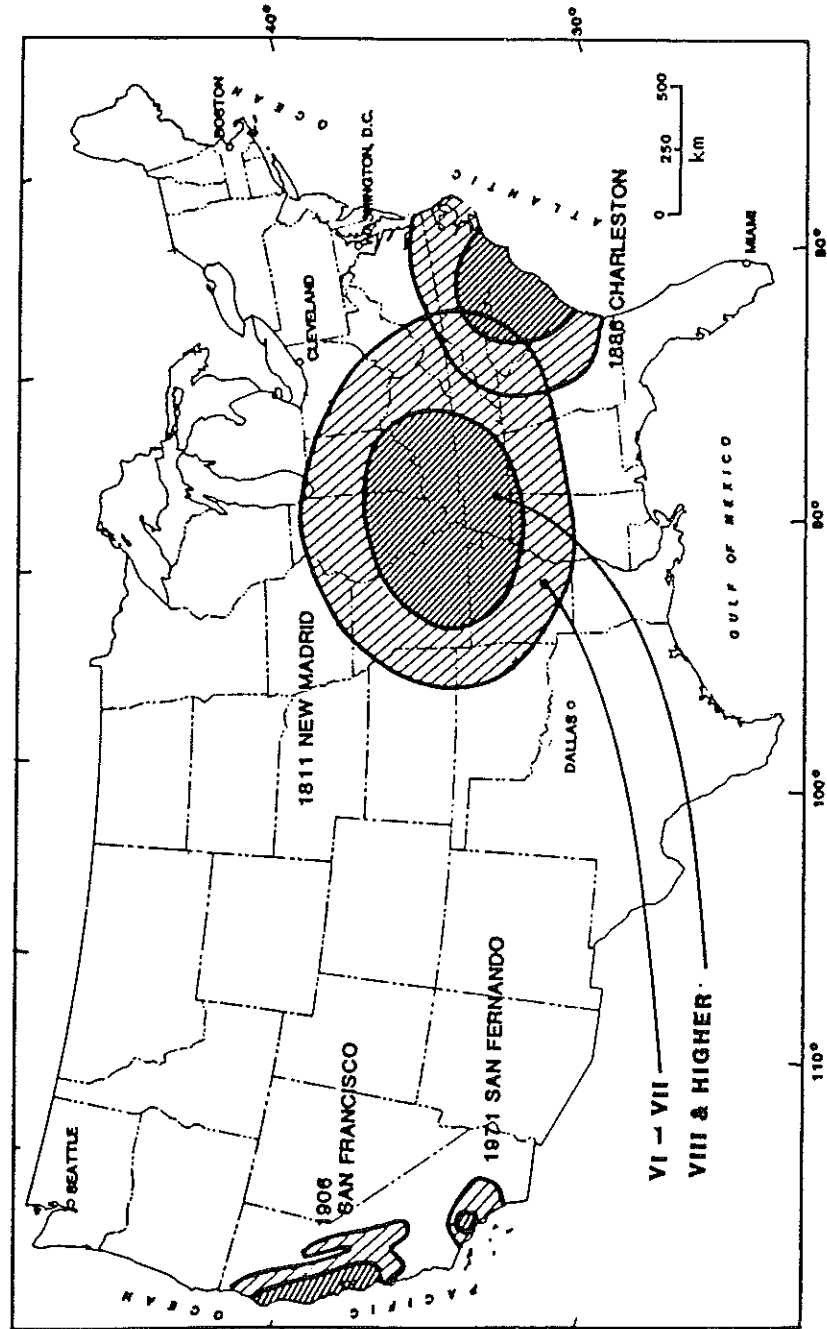


Figure 2: Comparison of Isoseismal Contours for Earthquakes: San Francisco (1960), New Madrid (1811-12), San Fernando (1971) and Charleston (1886).

Source: Lindburgh 1986.



Figure 3a: View of Typical Historic-URM Structures in Downtown Charleston



Figure 3b: Typical URM Brick Structure in Downtown Charleston

study finding was that a severe event (MMI IX) would cause more than 2,100 fatalities, with about half occurring in schools (Harlan and Lindbergh 1988). Maximum property damage could approach \$5 billion. Moreover, 136,000 individuals could be homeless for between 5 and 30 days, and nearly 20,000 homeless for more than a month.

## **Mitigation Policy in South Carolina**

### *An Emerging Mitigation Program*

Many current seismic activities in Charleston, and South Carolina generally, are intended to lay the foundation for future policymaking. Planning and mitigation efforts are in the early stages of development, with emphasis on educating citizens, building and design professionals, and public officials about the risks and risk reduction actions. Emphasis has also been placed on developing professional networks within and outside the state to facilitate such efforts.

The South Carolina seismic program, which has largely been initiated by activities in Charleston, can be viewed as a collection of ongoing activities broadly grouped into three somewhat overlapping, areas. One set of activities, beginning in a concerted way in the early 1980's and spearheaded by faculty at The Citadel and the Baptist College at Charleston, has focused on technology transfer, institution-building, and public education. These activities have included the creation of the South Carolina Seismic Safety Consortium, the Technology Transfer and Development Council, and the Earthquake Education Center at Baptist College.

A second set of activities centered around efforts to better understand the nature of the earthquake threat. Considerable emphasis has focused on research and theory-building in an effort to explain the causes and dynamics

of the 1886 Charleston Earthquake. A third activity area involves development and adoption of seismic building standards. Charleston has been a leader in the state (South Carolina does not require localities to adopt building standards) in establishing seismic building design requirements.

*Technology Transfer and Awareness-Building: An Emphasis on Creating New Institutions*

Many of the activities involved with creating new institutions stemmed from a 1981 national earthquake conference held in Knoxville, Tennessee.<sup>5</sup> This conference focused on the earthquake problem in the eastern U.S. Conference participants concluded that awareness of, and planning for, earthquakes in the east was relatively low. During this conference, the idea of forming the South Carolina Seismic Safety Consortium (SCSSC) was formulated. The initiative for forming this group came largely from an engineering faculty member of The Citadel, and a geology professor of Baptist College in Charleston, at the strong encouragement of a USGS geologist. The group held its first organizational meeting at The Citadel in February of 1982 (see Lindbergh 1986).

*South Carolina Seismic Safety Consortium.* The formation of the South Carolina Seismic Safety Consortium (SCSSC) has been one of the most significant actions taken to promote earthquake planning in South Carolina. Two key objectives of the consortium are: 1) to promote interdisciplinary cooperation among geologists, engineers, government officials and the public; and 2) to ensure that federal and state seismic research and development programs adequately address the needs of South Carolina (Lindbergh 1986).

The consortium membership is largely comprised of academicians and professionals involved in geology and engineering. Some representatives of businesses and public service agencies are also included, as well as local

government officials. The consortium is co-chaired by two faculty members of The Citadel and Baptist College. A key activity of the consortium has been conducting conferences focusing on issues related to earthquake prediction, planning and mitigation strategies and public awareness. Considerable attention has been given to bringing in outside experts during the conferences to provide information on strategies and technologies that might be applicable to South Carolina. The conferences were largely organized by faculty at The Citadel and Baptist College.

Another key activity of the consortium was the completion of the Charleston Vulnerability Study (Harlen and Lindbergh 1988). As mentioned, the study was prepared by faculty of the Department of Civil Engineering at The Citadel. It was conducted with FEMA funds, provided under the National Earthquake Hazard Reduction Program. The study will serve as an important educational tool in the future, as it is the first to quantitatively document a problem that has largely been given limited attention by public officials and the general citizenry.

The consortium has also focused on raising support outside of the state. A co-chairperson of the consortium has testified before Congress on several occasions, stressing the importance of planning for earthquakes in the southeast and the potential for disaster. This testimony has emphasized as well the need to reorient some resources and funding under the National Earthquake Hazard Reduction Program to the southeast, in addition to California and the west.<sup>6</sup>

*Technology Transfer and Development Councils.* A Technology Transfer and Development Council (TTDC) has also been established to facilitate development of regionally-applicable engineering technology. Consisting of engineers and scientists from around the southeast, its objectives are "(1) to

establish and maintain a technology baseline; (2) to disseminate technical information pertaining to earthquake effects; (3) to develop technical information pertaining to earthquake effects; and (4) to review, analyze, and provide technical support for applicable building code requirements and standards (Lindbergh 1986, p. 92)." In addition to engineers and scientists from within the region, the TTDC also includes representatives from the Applied Technology Council, Inc. and the Earthquake Engineering Research Center of California. The TTDC is a relatively recent creation, meeting for the first time in January 1986.

Among the recent activities of the TTDC is a collaboration with ABK Joint Venture of California to develop a methodology for retrofitting URM buildings in South Carolina, and to prepare appropriate retrofit code provisions. The TTDC has also been active in promoting the installation of strong motion instrumentation in certain Charleston buildings, and in advocating stronger building code standards for seismic hazards, including seismic design standards for all schools. The TTDC also intends to develop appropriate continuing education courses in seismic and wind design.

The TTDC has so far advanced its key objective of technology transfer in several ways. A primary strategy has been the conducting of a variety of workshops on important technological issues related to seismic safety, and the inviting of outside experts to South Carolina to share experiences and research from other parts of the country. Financial assistance for conducting the workshop came from NSF, FEMA and The Citadel. The TTDC is also involved in conducting engineering research and in producing educational materials of direct utility to engineers and building professionals. Two members of the Citadel's Civil Engineering department are currently preparing, for example, a

seismic and wind masonry building design handbook, funded jointly through NSF and the National Center for Earthquake Engineering Research.

*Earthquake Education Center.* The bulk of the educational activities directed at the general public have been undertaken by the Earthquake Education Center (EEC) at Baptist College in Charleston, under the part-time directorship of a college geology faculty member. Established in the fall of 1986, 70 percent of center costs are paid for by FEMA, with the remaining 30 percent provided by Baptist College, in the form of the professor's salary. The center, primarily through the efforts of the geologist has had a considerable impact in enhancing awareness of the seismic threat in the Charleston area. The center has attempted to target certain sub-groups within the general public, including: "...special need groups (elderly, disabled, non-English speaking), youth groups, school populations, neighborhoods, public officials, hospital, fire and other emergency response personnel, business and industry, volunteer agencies, community service groups, and the media (Bagwell 1988, p. 107)." Numerous members of these groups have attended EEC-Workshops and Conferences. Between 1983 and 1987 the EEC sponsored some 495 workshops and programs, involving some 40,000 individuals (Bagwell 1986, 1988).<sup>7</sup>

Much of the center's energy has focused upon conducting educational programs for Charleston area schools. Training programs have been given an appropriate preparedness actions for schools, and extensive earthquake drills have been undertaken.<sup>8</sup> The EEC has also encouraged and assisted commercial establishments in undertaking earthquake preparedness<sup>9</sup>, and has emerged as a regional clearinghouse.<sup>10</sup> The Center has also been actively involved in recording earthquake events. It now operates a system of seismographs, covering approximately an eight mile radius.

### *Advancing the Science and Understanding of Regional Seismology*

Much of the research and debate about Charleston seismicity, and South Carolina in general, has been a direct result of the requirements of the Nuclear Regulatory Commission (NRC). South Carolina has had the mixed blessing of having five nuclear power facilities within its border. Under NRC licensing requirements, proposals for such facilities must undergo stringent site and design considerations, including consideration of the seismic threats. Because of concern about the potential impact of seismic events, the NRC has been active in promoting and sponsoring seismological research. The NRC sponsored the first significant studies of earthquake seismicity for the Charleston area in 1974 (commonly referred to as the "Charleston Question" see Talwani 1986). Conducted by USGS scientists and university faculty, these and subsequent studies sought to explain the occurrence of the 1886 Charleston earthquake, and the causes and dynamics of seismicity in the Charleston area. Since this time there has been an active and ongoing debate in the scientific community on the nature of the earthquake threat.

Much of the debate has centered around alternative models for explaining the 1886 earthquake. Some models suggest that earthquakes in the east are the result of movements of large geologic and subsurface blocks (backslipping of certain areas due to gravity). The implication is that earthquakes similar to the 1886 Charleston earthquake could occur anywhere along the east coast. Others are local in character. That is, they apply to certain conditions thought to occur only in the Charleston region. However, as geologist Talwani notes "...all proposed models have one feature in common: none of them has been universally accepted by the scientific community (1986, p. 25)."

Despite such disagreement in the scientific community, in 1982 the USGS issued an influential position paper which, while acknowledging that the cause of the 1886 earthquake was still as yet unconfirmed, concluded that the 1886 event could occur at any location in the eastern U.S.<sup>11</sup> In response to the 1982 position paper, and at the encouragement of the NRC, an industry-funded research group called the Electric Power Research Institute (EPRI) initiated a research project to analyze in greater depth east coast seismicity. A number of technical studies were generated under the EPRI research which have substantially enhanced scientific understanding and consensus about the nature of east coast seismicity.

The 1982 USGS position has in recent years been strongly challenged by some seismologists, notably a faculty member at University of South Carolina. This scientist and others have argued that the occurrence of the 1886 Charleston earthquake was not completely random, but could be explained by local geologic structures. Specifically, this individual has argued that the existence of two intersecting faults--the Woodstock fault and the Ashley River fault--explains much of the seismicity of the Charleston area. Figure 4 depicts how the intersecting fault system operates (Talwani 1988, 1989). Simultaneous movement along the faults is thought to explain the 1886 earthquake. According to this individual the bulk of scientific opinion has shifted towards the localized intersecting fault theory. The USGS, while not retracting its early position, is apparently not pushing it either.

Another important activity has been the installation and upgrading of a seismic monitoring system. A joint USGS and NRC seismic monitoring program began in 1974 and has continued since. Additional seismic monitoring instruments have been added over the years, as in the case of the Baptist College network. Another seismic monitoring initiative, though only in its

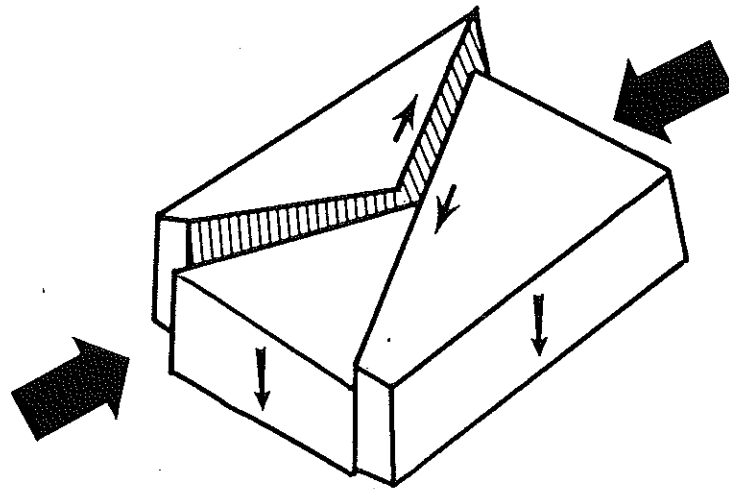


Figure 4: Schematic diagram to show the relative motion of blocks formed by two intersecting faults. If the main fault undergoes strike-slip motion, the adjoining block moves down due to kinematic adjustment. The large arrows represent the direction of the maximum horizontal compression. Source: Talwani 1989.

early stages, is the installation of strong motion instrumentation. In July 1986, a strong motion instrumentation system was installed in Charleston Place, a convention and commercial center in the historic downtown area. This is the first such system installed outside of California and is important for better understanding how buildings perform during strong motion events.<sup>1 2</sup>

In sum, research and scientific debate among seismologists concerning "the Charleston Question" has done much to advance understanding of earthquake dynamics in South Carolina, as well as the rest of the eastern U.S. Prompted by NRC requirements, and fueled through NRC and industry research monies, these scientific activities are laying the foundation for future seismic planning and policymaking.

### *Seismic Building Standards*

One area where South Carolina, and the City of Charleston in particular, have made significant advances is in seismic building standards. Under current South Carolina law, local jurisdictions are not required to adopt any form of building code or construction standards. However, if a locality does choose to adopt a building code, it is required to adopt the latest version of the Standard Building Code, issued by the Southern Building Code Congress International. While only about 50 percent of the localities in South Carolina have adopted the code, these jurisdictions together contain about 70 percent of the state's population (Lindbergh 1988). Most urban and populated areas have adopted the code.

The standard code incorporates design for seismic forces. Until recently the seismic provisions were contained as an appendix to the code, and had to be specifically adopted by each individual locality. That is, localities adopting the code were not required to adopt the seismic provisions. In 1988, the Southern

Building Code Congress International chose to move the seismic provisions from the appendix to the regular text of the code, thus making them mandatory for localities adopting the code.

There are currently efforts to make the Standard Building Code mandatory for all South Carolina jurisdictions. This proposal, currently under consideration by the South Carolina legislature, was largely the initiative of the South Carolina Seismic Safety Consortium and the Technology Transfer and Development Council. Companion legislation has also been proposed which will mandate certification for code-enforcement personnel, as well as certain minimum continuing education requirements. According to a high level building official in state government, this companion proposal addressed a basic problem regarding implementation of any seismic building provisions in many jurisdictions, particularly rural ones, in South Carolina. Specifically, building officials are generally poorly trained and do not have the skills to adequately monitor builders and engineers.

These building code proposals are currently heating-up politically, with a coalition group called "COMBS" (Citizens and Organizations for Minimum Building Standards) strongly supporting the bills. The principal organized opponents are the Municipal Association of South Carolina and the South Carolina Association of Counties, who appear strongly concerned that the bill will take away too much autonomy from local governments.

The City of Charleston was one of the first localities in South Carolina to adopt and enforce the optional seismic component. Adopted by Special Bulletin in June of 1981, the city council imposed the seismic standards on all new construction, with the exception of renovation and restoration of historic buildings. Existing structures are not required to meet the seismic standards; however, any renovations of a structure must not reduce the structure's

seismic capacity. The adoption of this Bulletin was largely the initiative of the Chief City Building Official, who had just been hired. This individual was uncertain as to whether the seismic provisions were in force, and aggressively lobbied for a clarification in favor of their enforcement.

## **Internal Factors Affecting Policy Response**

### *Interorganization Coordination and Communication Activities*

Most activities related to development of the Charleston and South Carolina mitigation program in general have attempted to facilitate interorganizational coordination and communication. These activities have lead to the creation of three new organizations concerned with promoting seismic issues. Specifically, the South Carolina Seismic Safety Consortium was established to promote interdisciplinary cooperation among scientists, engineers, building code personnel, and public officials in general. Membership of the consortium consisted of representatives from a wide range of technical disciplines, as well as those from private interest groups. It's activities, including conducting workshops and risk assessment studies, have done much to enhance awareness, involvement and cooperation among technical specialists and government leaders.

The Technology Transfer and Development Council is the second primary new institution. More technical and specialized in focus relative to the consortium, the council has undertaken several activities, such as producing educational materials for building inspectors, and bringing in outside expertise from other parts of the country, that have been successful in disseminating applicable earthquake engineering technology to South Carolina, and Charleston in particular. In addition, there has been a substantial degree of networking among these two institutions. That is, many

individuals participating in consortium activities have been active in the technology transfer council activities.

The third new institution established to promote seismic safety is the Earthquake Education Center at Baptist College. Activities of this organization are educational and directed at the general public. The center has conducted numerous workshops and conferences, and serves as a regional clearinghouse for seismic information in the Charleston area. During interviews several individuals, including scientists, building code officials and government leaders in Charleston, reported that the center has done much to enhance awareness about earthquakes in the region.

#### *The Presence of Advocates*

Similar to the other case studies presented in this book, the emergence of the Charleston and state level program can be attributed to the unwavering interest and enthusiasm of seismic advocates. Of particular importance are the activities of the engineering faculty member of The Citadel who, along with the geology faculty member of Baptist College, and a high-level USGS staffer, are responsible for the formation of the South Carolina Seismic Safety Consortium. The engineering faculty member has been the driving force behind the consortium and the Technology Transfer and Development Council, and has exercised tremendous personal initiative in organizing technical and engineering conferences, and in seeking and receiving grant funds for such activities as the preparation of the wind and seismic design handbook. This individual has testified before Congress twice arguing for the need for greater earthquake planning in the east and is largely responsible for the proposal made to the state to make the Standard Building Code mandatory for all South Carolina localities. The individual was also instrumental in putting forth a

proposal to the Southern Building Code Congress International which strengthened the seismic components of the Standard Building Code.

This faculty member has also been aggressive in rebuking the arguments from some in the scientific community that the risks of another great earthquake are low, and that consequently seismic planning and mitigation activities should be given low priority (Cox 1989). After traveling to Armenia following the devastating earthquake event in December of 1988, this individual brought back an extensive slide collection which has been effectively used to make the point that South Carolina is equally at-risk to such a catastrophe (Lindbergh 1989). The individual has also been involved more than any other in South Carolina with efforts to coordinate and communicate with engineers and building officials in other parts of the country. The individual is also actively involved with groups like Applied Technology Corporation, and with various national professional and code groups, always searching for ways to transfer knowledge and technology to South Carolina.

The director of the Earthquake Education Center in Charleston, has also been an important advocate, spearheading the effort to educate the public, and to encourage preparedness in the schools and elsewhere. This geologist has appeared numerous times on local television and radio shows and assumes a high public relations profile.

Within the city of Charleston, the Chief Building Official was also an important advocate. It was this individual's initiative which led the city to adopt the optional seismic provisions. Without the individual's presence it is unlikely that the city would have adopted the standards. Moreover, this official is aggressively enforcing the code, as well as promoting seismic design during the renovation of existing structures. The individual attributes such

success, in part due to being an engineer, and thus is able to challenge designs with more technical expertise than most building officials.

The relatively early phase of development of the programs in Charleston and South Carolina generally has lead to some public disagreements between the scientific community, which tends to be relatively conservative concerning involvement in public policy, and seismic advocates. The advocates are sometimes criticized for overstating the seismic risks and for unduly alarming the public (Cox 1989). Several people interviewed noted an important distinction between the basic perspectives of the advocates, who tended to be drawn from engineering and other professional backgrounds, and those in the scientific community. The advocates were more likely to focus on the need for some minimum level of public safety, and to plan for a 1886 magnitude earthquake, at least for critical facilities and high-occupancy structures. Geologists and seismologists, on the other hand, tend to take a more antiseptic view, focusing on the improbability of such large events and with relatively little emphasis on such concepts as risk and public safety.

#### *Availability of Resources*

Compared with the large amounts of resources directed towards the earthquake problem in western states like California and Utah, the amount of resources available in South Carolina has been relatively small. However, many of the start-up activities would not have been possible without this outside funding. As noted earlier, outside funds have been provided from NSF, USGS, FEMA and NRC to fund a variety of activities including public education programs, professional and technical workshops and conferences, and basic scientific research. Much of this has been funding provided under the National Earthquake Hazard Reduction Act. The SCSSC and TTDC have further

been funded through the Citadel Development Foundation, while the Earthquake Education Center has received additional funding from the Baptist College Development Board. This is an excellent example of the potential long term benefits of providing small strategically-placed seed monies.

There is also a kind of psychological boost that accompanies such resources. Several of the individuals interviewed stressed the importance they felt of the redirection of federal emphasis to the east. The Citadel engineer noted, the South Carolina contingent does not wish to impede the continued progress of seismic mitigation efforts in the west, but strongly argues for a need to view earthquakes as a national phenomenon and threat. Individuals we interviewed attributed much of the progress to date to an increasing orientation toward more of a national earthquake program.

With respect to efforts at advancing scientific understanding of South Carolina seismicity, the role of nuclear power and nuclear facilities cannot be overstated. Federal seismic safety standards imposed by the Nuclear Regulatory Commission (NRC) have spurred much of the scientific research. The NRC has funded much of this work, as has the Electric Power Research Institute. Beavers (1988) argues that the nuclear power industry is responsible for earthquake planning in the east as a whole and that, "A better understanding of the earthquake threat in the eastern U. S. may be the number one indirect benefit of nuclear power (p. 427)." While this effect may indeed be true for eastern U.S., it is especially the case in South Carolina, primarily because of the large number of nuclear facilities and the seismicity of the region.

### *Linkage with Other Policy Issues*

Several linkage issues that have influenced mitigation responses were identified. The most significant of these issues related to the presence of other hazards, particularly hurricanes and severe coastal storms. For most people, particularly architects, engineers and builders, the threat of hurricanes is more frequent and of greater concern than earthquakes. Seismic strengthening of buildings has occurred as a direct side-effect of designing for hurricane windloads in coastal areas. Most individuals interviewed with engineering backgrounds agreed that for smaller structures, designing for coastal windloads will also provide adequate protection from earthquakes. However, for larger structures, design for windloads will not necessarily provide such protection. A point made by several engineers was that it makes sense to link design for seismic building stresses to wind stresses, rather than undertaking separate designs for each hazard. Such linkage could enhance the political acceptability of hazards construction standards, and lessen resistance to the idea of designing for earthquakes. This linkage strategy was taken by The Citadel engineering faculty member when proposing to the Southern Building Code Congress International that the seismic and wind design provisions of the Standard Building Code be strengthened. A seismic and wind design handbook currently being prepared at The Citadel is also a reflection of this unified approach.

A second linkage issue uncovered was the relationship between seismic hazard mitigation and protection of historic structures. In a city such as Charleston, the economy is heavily dependent upon the tourism trade generated by its historic downtown. Indeed the historic structures are the very identity and lifeblood of the city. Coupled with the fact that few buildings were strengthened following the 1886 earthquake, it appears that the most

important economic and cultural resources of the city is in jeopardy of being destroyed or severely diminished from future earthquakes. The chief building official has argued that seismic design measures are good for historic preservation, i.e. ensuring that historic structures will survive the next earthquake. This argument has met with only marginal success, partly because some property owners believe that installation of seismic strengthening designs would diminish the historic nature of the buildings.

## **External Factors Affecting Policy Responses**

### *Stakeholder Response to the Earthquake Problem*

Because seismic mitigation programs in Charleston and South Carolina generally are only in the emerging stages there have been few explicit policy proposals for stakeholder groups to react to. As we have seen, the bulk of the activities have involved organization-building, technology transfer and information dissemination. These activities are, however, laying the groundwork for subsequent policy debates where the response of stakeholders groups will likely be much more positive than it otherwise would be. Moreover, while citizens and elected officials may already have a general awareness of the seismic risk (or at least of the 1886 earthquake), the current and future activities of the SCSSC and the Earthquake Education Center will likely have an impact in enhancing the perceived importance of seismic mitigation. As The Citadel faculty member notes, while the public is generally aware of the earthquake threat, and particularly the occurrence of the 1886 earthquake, such awareness has not translated into a groundswell of demand for planning and mitigation.

Several specific mitigation actions offer some insight into the reaction of stakeholders. First, the current proposal in the South Carolina legislature to

make the adoption of building codes mandatory statewide has generated some political conflict. It's potential for adoption is uncertain, but if it is adopted it is likely to be largely a result of an effective political coalition called "COMBS" or Citizens and Organizations for Minimum Building Standards. This coalition is heavily comprised of professional and trade organizations, including such groups as the Homebuilders Association of South Carolina, the State Board of Architectural Examiners, and the Building Officials Association of South Carolina, among others. The list of groups is an impressive, and conveys the impression that the force of technical and professional opinion is on the side of adopting the code requirements. On the other hand, the two principal organizations opposing the proposal are the Municipal Association of South Carolina and the South Carolina Association of Counties. They have argued strongly that such a mandate serves to unduly take away the autonomy of localities. According to one Municipal Association staffer, "If a locality deems a building code necessary it will adopt one, but it should be left the freedom to decide." This position has been actively supported by several state legislators representing rural counties who have expressed concerns about placing too heavy a regulatory burden on the average "mom and pop" establishment.

A second example of a mitigation action was the City of Charleston's adoption in 1981 of the seismic element of the Standard Building Code. While there was little involvement or conflict by organized stakeholder groups, support from local elected officials was the crucial factor. Specifically, the current chief building official indicated during an interview that adoption of the seismic provisions was made possible by council members who saw the need to prepare for the earthquake threat, and a supportive mayor in particular. Furthermore, the official indicated that the continual efforts of building inspection staff to strongly enforce the provisions of the seismic code

would probably not be possible without on-going support the staff has received from the council (and the same mayor who is still in office).

This case analysis also suggests the potential importance played by the insurance industry and lending institutions as stakeholders pushing for more stringent mitigation measures. Several individuals interviewed suggested that insurance and lending institutions were increasingly demanding that new buildings in the Charleston area be constructed to seismic standards. The feeling was that such demands were still fairly rare, but that a few prominent examples had arisen. The chief building official discussed the case of the Marriott Hotel, on the north side of Charleston. While under construction, ownership of the hotel changed hands, and as a condition of financing the lender required that the building be redesigned to withstand seismic forces (see Figure 5).

### *Political Culture*

The City of Charleston, and the State of South Carolina, are unmistakably a part of the south, and the political culture is conservative, pro-property rights oriented. Moreover, the proper role of government is typically seen as a limited one. These attitudes have surfaced, for instance, in the reactions of some state legislators to the proposal to make the standard building code mandatory for all localities. Concerns are being raised about the fairness of telling localities what they should do (in a home-rule state) and the effects such requirements would have on small businesses. More generally, South Carolina is conservative concerning most issues of land use and development regulation. Many localities, particularly rural jurisdictions still have not adopted even the most rudimentary of zoning or subdivision ordinances. As in the current case of the statewide building code proposal, this relatively



Figure 5: Hotel Designed to Withstand Seismic Forces

conservative political culture will tend to place certain parameters on the extent of future mitigation and planning.

There have been some indications in recent years that attitudes toward development regulations have liberalized somewhat. The state legislature recently passed, for instance, a fairly stringent (at least by South Carolina standards) Beachfront Management Act which has the potential of significantly restricting the rights of coastal property owners.<sup>13</sup> However, even in this case, it has been suggested during interviews that efforts are in the works to substantially weaken this law. Nevertheless, because most activities of the Charleston and South Carolina programs have focused on education, technology transfer and institution-building, and not on government mandates or regulations, the full importance of the conservative political culture has not yet been felt. As the state continues to feel increased growth and development pressures, particularly in its coastal region, it may be increasingly inclined to control development, which may in turn help the political prospects of earthquake mitigation policy.

#### *Earthquake History and Windows of Opportunity*

The great 1886 Charleston earthquake has had an important influence on seismic policymaking in the City of Charleston and in the state generally. While no seismic mitigation occurred during reconstruction, this event represents an important point in the city's chronology. As a consequence, many individuals expressed during interviews that citizens and public officials are more likely to be aware of the seismic threat. One local official maintained that the occurrence of such a large and damaging event "...changed the complexion of public debate about the earthquake threat."

Another suggested that, "The 1886 catastrophe has made it more difficult to argue that an earthquake in South Carolina is impossible or inconceivable."

During the 1980's the Charleston area has experienced numerous small earthquakes and tremors. Although these tremors did not lead to adoption of seismic policies, they raised public awareness, as indicated by many phone calls to the Earthquake Education Center during the weeks following each event (Bagwell 1988).

Similarly, the occurrence of the Armenian earthquake elevated seismic issues in South Carolina. The Citadel engineering faculty member, as mentioned, was part of an eight member technical team sent from the U.S. to Armenia to inspect building damage. Upon returning to the U.S. this individual issued a report which drew strong comparisons between Armenian buildings and construction practices, and those in South Carolina. As quoted in the *Charleston News and Courier*, the individual's plea is a compelling one, particularly when considering the vulnerability of schools:

I will never forget the profound feeling of remorse I felt as I examined the litter of unfinished class notes and wasted textbooks that reflected the many lives left unfulfilled, and realized that the majority of the suffering and loss could have been mitigated through reasonable measures. My feeling of remorse was mixed with that of commitment that our public not allow it to happen to our community (Findlay 1989, p. 7A).

While this disaster has not led to adoption of seismic policy, the resulting engineering report and numerous Armenia slide show presentations have contributed to the perceived need to plan for and mitigate seismic hazards in South Carolina.

### **Impact and Adequacy of the South Carolina Program**

Because the Charleston and South Carolina program is in the early stages of development it is somewhat premature to evaluate its success.

Nevertheless, the general direction of the program, and its accomplishments to date, can be evaluated. A general conclusion is that there has been significant progress in advancing seismic mitigation concerns in a relatively short period of time. Most impressive are the institution building and network activities, and specifically the creation of the South Carolina Seismic Safety Consortium, Technology Transfer Development Council, and the Earthquake Education Center. The most significant accomplishments of these organizations have been in the area of education; both education within and among engineers and design professionals, and the general public. The variety of workshops and training programs for these groups has been impressive. While it is difficult to document the results of such efforts, these organizations have had a positive impact, including raising awareness and effectively laying the groundwork for subsequent earthquake planning and mitigation activities.

It is also evident that significant advancements have been made, again in a relatively short period of time, in understanding the nature of the seismic hazard. USGS and the University of South Carolina research teams have made substantial progress, for instance, in estimating earthquake recurrence intervals. The Charleston vulnerability analysis has provided additional insight into the magnitude of damages and loss of life that may be generated by earthquakes, and the installation of strong motion instrumentation (e.g. the Charleston Place project) will provide new data on seismic characteristics in the region.

There are, however, significant scientific disagreements. Some effort needs to be made to reconcile the different technical perspectives which exist towards the earthquake issue. While the engineering and building design community has stressed the potential collapse of structures during

earthquakes, the geologic and seismological community appears to stress the infrequency of such large events, in turn leading to somewhat different policy conclusions.

One of the areas in which considerable progress is being made is in the expansion of seismic building standards. Under South Carolina law, if a locality chooses to adopt a building code, it must adopt the Standard Building Code, which now includes a mandatory seismic design component. While most individuals interviewed felt that the seismic provisions of the Standard Building Code were good, several problems exist which tend to undermine the extent to which new buildings are seismically strengthened. The first is that the building code is optional, and about half of the state's localities have not adopted it. Furthermore, under South Carolina law localities that have adopted the code are only required to implement the code standards that were current at the time of adoption. Thus, there are some localities that are enforcing older versions of the Standard Code which contain only optional seismic design standards. Finally, many localities lack the expertise, personnel, and political fortitude to adequately enforce the seismic provision even where they have been formerly adopted. The state, however, is attempting to correct this problem with the current proposal to mandate certification of, and continuing education for, local building officials.

An equally serious problem is that many critical facilities and high-occupancy structures are not designed to withstand seismic forces. The Charleston vulnerability study (Harlan and Lindbergh 1988) estimates that half of the daytime deaths from a large earthquake would occur in schools. Yet, the state Department of Education leaves the decision about seismic design up to local school districts (although it encourages seismic design). Some school districts impose seismic standards on new school construction, but

many do not. Unlike California, there are few state laws which mandate seismic design for such facilities as schools, hospitals, dams, and highway interchanges, among others.

It is also clear that little effort is currently being made to ensure that older existing buildings, often historic, are equally safe from earthquake damages. While many of the individuals interviewed mentioned the need for some form of retrofitting program, no such program has been undertaken anywhere in South Carolina. Under the City of Charleston's building standards, renovations are only required not to make the building less capable of withstanding an earthquake. Moreover, historic structures are specifically exempted from the seismic provisions. This is troubling in that many of these buildings are unreinforced masonry, and are the most vulnerable to seismic destruction. In Charleston, the Chief Building Official indicated that he often tried to push for additional seismic strengthening during renovation, on a case-by-case basis, but with mixed results. Part of the difficulty in promoting retrofitting is a lack of clear technological standards. Some of the current and planned activities of the TTDC and SCSSC, mentioned earlier, may help to fill this void in the future.

When asked about the possibility of a seismic retrofitting program in the City of Charleston, the chief building official was pessimistic. From this official's perspective a mandatory retrofit requirement like that of Los Angeles would simply be unworkable. Part of the problem is the high proportion of city buildings that are historic and would fall under such requirements. Such a program would, in the official's view, simply create large numbers of vacant structures, and would seriously undermine the city's tax base and economic viability. Mandatory retrofit would accordingly not be politically feasible in Charleston. It is possible, however, that a voluntary,

incentive-based program might work, such as that used by Palo Alto. Although of concern to many individuals was that development of a seismic retrofit program does not appear to be high on any local politicians' agendas.

Most of the technical experts interviewed also did not feel that liquefaction hazards were generally being considered at the local level. Many of these individuals pointed to the need for accurate and available mapping of liquefaction hazard zones. To our knowledge such maps have been prepared only for the City of Charleston. And, even here liquefaction is not a major design consideration. In Charleston, for instance, the city's building code does not require design for liquefaction.

## Notes

1. The method used for this case study entailed on-site interviews of key participants involved with earthquake mitigation programs. A snowball sampling technique was used to develop a comprehensive list of relevant participants in mitigation planning for each case locality. The objective was to reach knowledgeable influential people in the earthquake mitigation field. Initial participants were identified based on a review of key printed materials, e.g., records of public hearings, scholarly publications and agency reports. These individuals were asked during interviews to identify others that should be interviewed and the sample was thus expanded. A total of 10 interviews were conducted with local agency staff, interest group representatives, and knowledgeable experts on seismic safety. Interviews were conducted between the fall of 1988 and summer of 1989.

Interviews were rich in information on the substantive policy concerns and perspectives on earthquake hazards. They were designed to identify principal concerns about seismic safety issues, specific mitigation activities, modes of interaction among various participants in the earthquake mitigation planning process, and to explore explanations for the placement of the earthquake problem on governmental agendas. To supplement interview data, extensive documentary information, including technical reports, newspaper articles, and copies of plans and ordinances, was collected.

2. Charles Lindbergh, 1986, p. xi.
3. Knowledge of past earthquake history can be used to calculate likely recurrence intervals for different magnitudes of events. Ballinger (1972), summarizing historical earthquake data, concludes that the recurrence interval for a moderate earthquake of MMI VI or larger is about 100 years for South Carolina, and 20 years for the southeastern region as a whole. The chances are considerably lower for a MMI X, like the Charleston 1886 event, with a recurrence interval between 1500 and 1800 years (Talwani and Cox 1985, Talwani and Collinsworth 1988).
4. Tsunamis in the east are very rare. Along the Atlantic coast there has been only one tsunami recorded--a very small tsunami experienced from an earthquake off the coast of Newfoundland.
5. The 1981 Knoxville Conference was entitled "A Workshop on 'Preparing for and Responding to a Damaging Earthquake in the Eastern United States.'"
6. In addition to the South Carolina Seismic Safety Consortium, a Southeast Seismic Safety Consortium was also established, drawing membership from the broader southeastern region. This group has to date accomplished little, and is primarily intended to serve as a coordinating body, if hopefully other states adopt similar state consortiums.

7. One of the most interesting and innovative strategies was the Saturday Shopping Mall Earthquake Preparedness Display and Puppet Show (Bagwell 1988). While organizers did not initially believe this program was successful due to poor acoustics in the mall, extensive television coverage of the event greatly expanded the audience.
8. A particularly good example of a school which has taken significant actions as a result of the center's work is the Newington Elementary School in Charleston. As a result of the center's training program the school principal there initiated a series of earthquake-preparedness measures. Included among these were moving the school's air conditioners and certain light fixtures to safer locations, and anchoring bookshelves, among other things. The school also requires its students to periodically undergo earthquake preparedness drills (like the "drop and cover" routine).
9. A training program was conducted for Westvaco Industries, for example, which lead to the preparation of an earthquake preparedness plan. The EEC's efforts have also facilitated the upgrading of preparedness plans for the Charleston Naval Base.
10. It has received numerous phone calls from citizens, many immediately following felt-seismic events that often occur in the Charleston area. Even local police and fire departments have on occasion contacted the center for information concerning earthquake events. The center also operates a lending library which includes audio-visual and other materials on earthquakes and earthquake safety.
11. For a thorough discussion of the USGS position paper refer to Talwani (1986).
12. The request to Taubman Companies, the owners of Charleston Place, was made by engineering faculty at The Citadel, and was a joint proposal of the Technology Transfer and Development Council and the USGS, with USGS providing the funds. The hope is to eventually expand the network to include other important buildings in strategic locations in Charleston. USGS and the council have formed an advisory committee to guide this program, and the committee has already prepared a priority list of future sites for strong-motion instrumentation sites.
13. Signed into law in 1988, the South Carolina Beachfront Management Act imposes significant new restrictions on coastal development. Specifically, a new setback line is established based on average annual erosion rates. Habitable structures located seaward of the line can be no larger than 5,000 square feet in size. As well, a "no construction zone" is also created in which only beach access structures are permitted (twenty feet landward of the baseline). The act also bans all future permanent shore-hardening structures (e.g. seawalls), and imposes in advance certain restrictions on the rebuilding of structures should they be

damaged beyond repair (such damaged buildings cannot be rebuilt in the no construction zone).

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