CONNECTIONS

The EERI Oral History Series

Mete A. Sozen

Robert Reitherman
and
Robert D. Hanson,
Interviewers

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Earthquake Engineering Research Institute

Graphics: George Mattingly, Berkeley, California, www.mattinglydesign.com
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Oakland, California 94612–1934
Tel: (510) 451–0905 Fax: (510) 451–5411
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Table of Contents

The EERI Oral History Series vii

Foreword. xi

Personal Introduction xiii

Chapter 1: Growing Up in Turkey 1

Chapter 2: Robert College 7

Chapter 3: Master's Degree at the University of Illinois and First Job 11

Chapter 4: Ph.D. at the University of Illinois. 17

Chapter 5: Academic Career 23

Ph.D. Students of Mete Sozen, University of Illinois at Urbana-Champaign 29

Ph.D. Students of Mete Sozen at Purdue University. 30

Chapter 6: Research 31

Chapter 7: Consulting Engineering Projects. 47

Chapter 8: Studying Specific Earthquakes 55

Chapter 9: Family and Avocations 67

Photographs of Mete Sozen and Maps 77

Index 105

The EERI Oral History Series

This is the twenty-sixth volume in the Earthquake Engineering Research Institute's series, *Connections: The EERI Oral History Series*. EERI began this series to preserve the recollections of some of those who have had pioneering careers in the field of earthquake engineering. Significant, even revolutionary, changes have occurred in earthquake engineering since individuals first began thinking in modern, scientific ways about how to protect construction and society from earthquakes. The *Connections* series helps document this important history.

Connections is a vehicle for transmitting the fascinating accounts of individuals who were present at the beginning of important developments in the field, documenting sometimes little-known facts about this history, and recording their impressions, judgments, and experiences from a personal standpoint. These reminiscences are themselves a vital contribution to our understanding of where our current state of knowledge came from and how the overall goal of reducing earthquake losses has been advanced. The Earthquake Engineering Research Institute, incorporated in 1948 as a nonprofit organization to provide an institutional base for the then-young field of earthquake engineering, is proud to help tell the story of the development of earthquake engineering through the *Connections* series. EERI has grown from a few dozen individuals in a field that lacked any significant research funding to an organization with nearly 3,000 members. It is still devoted to its original goal of investigating the effects of destructive earthquakes and publishing the results through its reconnaissance report series. EERI brings researchers and practitioners together to exchange information at its annual meetings and, via a now-extensive calendar of conferences and workshops, provides a forum through which individuals and organizations of various disciplinary backgrounds can work together for increased seismic safety.

The EERI oral history program was initiated by Stanley Scott (1921–2002). The first nine volumes were published during his lifetime, and manuscripts and interview transcripts he left to EERI are resulting in the publication of other volumes for which he is being posthumously credited. In addition, the Oral History Committee is including further interviewees within the program's scope, following the Committee's charge to include subjects who: 1) have made an outstanding career-long contribution to earthquake

engineering, 2) have valuable first-person accounts to offer concerning the history of earthquake engineering, and 3) whose backgrounds, considering the series as a whole, appropriately span the various disciplines that are included in the field of earthquake engineering.

Scott's work, which he began in 1984, summed to hundreds of hours of taped interview sessions and thousands of pages of transcripts. Were it not for him, valuable facts and recollections would already have been lost.

Scott was a research political scientist at the Institute of Governmental Studies at the University of California, Berkeley. He was active in developing seismic safety policy for many years and was a member of the California Seismic Safety Commission from 1975 to 1993. Partly for that work, he received the Alfred E. Alquist Award from the Earthquake Safety Foundation in 1990.

Scott was assisted in formulating his oral history plans by Willa Baum, Director of the University of California at Berkeley Regional Oral History Office, a division of the Bancroft Library. An unfunded interview project on earthquake engineering and seismic safety was approved, and Scott was encouraged to proceed. Following his retirement from the university in 1989, Scott continued the oral history project. For a time, some expenses were paid by a small grant from the National Science Foundation, but Scott did most of the work pro bono. This work included not only the obvious effort of preparing for and conducting the interviews themselves, but also the more time-consuming tasks of reviewing transcripts and editing the manuscripts to flow smoothly.

The *Connections* oral history series presents a selection of senior individuals in earthquake engineering who were present at the beginning of the modern era of the field. The term "earthquake engineering" as used here has the same meaning as in the name of EERI—the broadly construed set of disciplines, including geosciences and social sciences as well as engineering itself, that together form a related body of knowledge and collection of individuals that revolve around the subject of earthquakes. The events described in these oral histories span many kinds of activities: research, design projects, public policy, broad social aspects, and education, as well as interesting personal aspects of the subjects' lives.

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Foreword

Bob Hanson and I conducted our first interview with Mete Sozen in 2007 in his office at Purdue University. Subsequent work was accomplished by correspondence, mostly in 2016 and 2017. I spent several days with Mete and his wife Joan in Turkey in September, 2017, finishing the interviewing process.

Professor Santiago Pujol of Purdue University provided some of the photographs of Mete for this book, as did Mete's wife, Joan.

EERI Oral History Committee member Loring A. Wyllie, Jr. provided helpful editorial comments. Sarah Nathe edited and indexed the manuscript; George Mattingly was the page layout consultant; and Rita Ortiz, EERI Manager of Membership and Communications, assisted in seeing this work through to completion.

Robert Reitherman
EERI Oral History Committee
January 2018

Postscript: Mete A. Sozen died on April 5, 2018, while visiting his daughter's family in London with his wife Joan. The manuscript for this book had already been completed and reviewed and was in the final production stages.

Personal Introduction

I first met Mete Sozen during the aftermath of the San Fernando earthquake of 1971. A Veterans Administration hospital building designed in the 1920s collapsed, killing 46 patients and staff. It had no earthquake-resistant features, but none was required during its design nor were there any seismic retrofitting requirements at the time of the earthquake. But the most important design failure I saw was the collapse of a two-story building at nearby Olive View Hospital designed to the latest standards and opened only about a month prior to the earthquake. Obviously, the then current earthquake design standards were inadequate and had to be revised.

As the Chief Structural Engineer of the Veterans Administration (VA), I organized an Earthquake and Wind Forces Committee to study the problem and appointed three members: Roy Johnston, structural engineer in Los Angeles, whose oral history has already been published by the Earthquake Engineering Research Institute; Bruce Bolt, Professor of Seismology at UC Berkeley; and Mete Sozen, professor of structural engineering at the University of Illinois at Urbana-Champaign. Mete was well known for his contributions to reinforced concrete and earthquake-resistant design. Under his guidance, the committee developed a comprehensive program that was far-reaching and innovative.

Seismic and geologic risks at all VA hospital sites were investigated. Wind forces (hurricanes and tornadoes) were part of the overall scope of review. The new seismic criteria, though still under development, began to be used to design all new VA hospitals. Architectural, mechanical, and electrical systems were included so the hospital would remain operational after an earthquake. In fact, the standard is among the first to set post-earthquake functionality as an essential criterion.

Existing VA facilities were evaluated and strengthened as necessary. Again, this was years ahead of its time. A number of well-functioning facilities were found to be grossly inadequate in the face of the risk, and they were evacuated and demolished. This required Veterans Administration and Congressional approval as well as funding for replacement facilities. It was also unusual in the early 1970s for the seismic program of a federal agency to be elevated to the attention of the top levels of the government. It took 40 years to complete the seismic program.

This was a pioneering, unprecedented program in many ways. The VA raised eyebrows when hospitals in locations such as New York City were designed or reinforced to resist earthquakes, at a time when the ordinary building code provisions for such regions and engineering practice did not address the risk. As a side benefit recognized later, this also would mitigate damage from terrorist attacks. Professor Sozen and I introduced this methodology to the State Department Foreign Buildings office. The National Science Foundation's earthquake engineering research program, led by Chuck Thiel, promulgated the development of such provisions and now they are included in most modern building codes.

I was fortunate enough to join Professor Sozen in the 1976 Bucharest, Romania earthquake investigation. My most vivid memory of that experience was when we were studying foundation damage in a collapsed building when one of us commented, "One small aftershock and we are history." We then slowly crawled out of the basement rubble and continued our study, from a bit of distance.

Although he has accomplished much in many areas, Mete Sozen is first and foremost an educator. Recognized as a taskmaster, he earned the respect and admiration of his students. His provocative questions challenged the students to think, and his comments were based on his prodigious reading. One measure of his success is that, at last count, five of his former students (Sharon Wood, James Wight, Luis Garcia, James Jirsa, and Anthony Fiorato) have been elected Presidents of the American Concrete Institute (ACI), and another, Jack Moehle, is currently the head of the ACI committee that produces the ACI-318 standard for structural concrete that is incorporated into the building codes. And, of course, many others are leaders of other organizations throughout the world. He has written textbooks and countless papers for ACI, the American Society of Civil Engineers, EERI, and other organizations, and lectured at many professional society meetings throughout the world. In addition to his earthquake engineering work, he has led or participated in on-site investigations of other failures and collapses throughout the world, including the 1995 bombing of the Murrah Building in Oklahoma City and the 2001 World Trade Center and Pentagon attacks.

His pioneering and imaginative research efforts are highly appreciated and recognized. For

example, dissatisfied with then-accepted test methods for earthquake studies, he proposed and guided development of a small-scale shaking platform for dynamic testing of various approaches to earthquake-resistant design. He was an early investigator of drift control as the centerpiece of design methods for multi-story buildings rather than simply another check on the completed design. This revolutionized all earthquake-resistant design.

I believe Mete's most important paper was "A Thread in Time," written for the 2011 conference on Earthquake Engineering and Seismology: Past Achievements and Future Prospects, held at Middle East Technical University in Ankara. In that paper, he reviewed and discussed his efforts to develop a better approach to earthquake-resistant design over the years, acknowledging each student's research and contribution, and even pointing out important areas that had been missed while the work was progressing. The patience, imagination, and obstacles overcome are an important lesson for all of us. That paper inspired me to write an article on the role of "Eureka" in structural engineering, scheduled for publication soon.

Our friendship continues to this day.

James Lefter
February 2018

CONNECTIONS

The EERI Oral History Series

Mete A. Sozen

Chapter 1

Growing up in Turkey

I started out in life in the hands of nurses and entered my first school as a boarder at the age of four.

Reitherman: Please begin with your youth in Turkey.

Sozen: I was born in 1932 in the Moda district of Istanbul, on the western side of the Bosphorus.[1] [See map in Photographs section at the back of this book.]

Reitherman: What day?

Sozen: The 22nd of May, so they tell me, but I can't verify that because I didn't take notes.

Hanson: What about your parents and ancestors?

Ancestors and Turkish History

Sozen: Unfortunately, my answer will be long and involved. Had you asked me the same question before I was 15 years old I would

1 The name of the strait dividing Istanbul has two accepted spellings, Bosphorus and Bosporus; Bosphorus (boss-four-us) is the Turkish pronunciation, and that spelling is used here.

have said my father's name is Huseyin Avni Sozen and mother's name is Ayşe Saliha Sozen, as recorded in my Turkish identity document. Today, to cover up my lack of reliable knowledge, I need to tell you a long and involved story.

When I was 14, I had a soccer injury to my left knee. My doctor said I had two choices: to have an operation or to spend the summer with my knee covered by hot sand for a few hours a day with the hope that the pain will go away. My family took the second alternative, and I found myself spending my days on the beach. During that time I met a girl a few years older than I was who told me that she was my cousin. I was surprised. To prove her point she took me to my father's sister who told me the whole story.

In the sixteenth century two families from Georgia, large enough to be called clans, joined the army of the Ottomans. In those days Ottoman soldiers had to have a trade to maintain themselves when they were not on a campaign. One of the families took on the job of making boots for the officers. The other one took care of some of the hunting birds of the padishah, or the sultan, of the Ottoman Empire. Until the nineteenth century, both families continued in the army and were very close to one another, although the men by then had started serving as officers and had given up their peacetime employments.

The last war in the nineteenth century between the Ottomans and the Russians took place during the years 1877–78. It had disastrous results for the Ottomans. Even though the loss of land was limited on the eastern frontier where the two families were fighting, on the western front the Russian armies came to within 12 kilometers of Istanbul, to the location of the current Istanbul airport. This was a serious threat not only for the Ottomans, but also for the British leadership, who feared that if the Russian Black Sea navy had free access to the Bosphorus and Canakkale Strait,[2] they might enter the Mediterranean and threaten Egypt and maybe even India. The British navy was dispatched to the Marmara Sea, and British diplomats started talks between the combatants to stop the war before Istanbul was invaded by the Russian forces. Russia agreed to pull back its forces on the western front if the Ottomans conceded more land on the eastern front.

I was told by relatives that Abdul Hamid II, who was then the Ottoman padishah, announced to his forces still fighting on the eastern front that, if they laid down their guns and returned to Anatolia, he would reward them by giving them a farm if they owned a small field and a cow if they owned a goat. The family who used to make boots accepted the deal, stopped fighting, and was given land in Ordu, a Black Sea coastal town inhabited mostly by Greek and Armenian Anatolians. I have a special love for the Black Sea because my two families lived near or on the shore of Georgia for centuries. But I know that its most enjoyable time is limited to two months in summer. And I have a particular weakness for

2 Çanakkale is the narrowest part of the Dardanelles (Çanakkale Bogazi), known in antiquity as the Hellespont. The Dardanelles link the Aegean Sea region of the Mediterranean to the Sea of Marmara, and at Istanbul the Bosphorus strait links the Sea of Marmara to the Black Sea.

Black Sea cooking, which is primarily vegan except for fish.

The family that took care of the birds continued fighting more or less as guerillas for a while longer. In the end both families lost. The land given in Ordu was worthless, and those that continued fighting were virtually wiped out except for a few. Most of the men were lost along with the friendship between the two families.

In the early part of the twentieth century, the family in Ordu, no longer in the army, who had managed to make a living as hazelnut farmers and real estate developers, moved to Istanbul so that their children could continue their education. They interacted with other Caucasians who had to come to Istanbul, only to discover that their old friends in the army, who then held high positions in the military hierarchy, were making life difficult for them. To solve the problem, they resorted to the classic remedy. They managed to have a marriage between their older daughter, then 18 years old, my mother, and the son of the other family. I have been told by relatives that the marriage did not last more than two years. My mother, with me as a baby, left her house to rejoin her family in Moda, Istanbul. I had already been registered in Bakirkoy, another district of Istanbul in the European or western area of Istanbul, and had been issued an identity card. My maternal grandparents decided to obtain another identity record for me showing me to be their child.

So I grew up to the age of 14 thinking my mother and aunt were my sisters and my uncle was my brother. That is why my last name is Sozen, the name that my maternal family acquired in 1934 when the surname law[3] was passed long after their arrival in Turkey. And my middle name is Avni after my grandfather. Legally, I have a brother and two sisters. In fact, the older sister was my mother and her sister was my aunt. The brother of my mother, of course, was my uncle. Because of the age difference, I had little contact with the family. The one who took some notice of me was the younger "sister," Meliha Avni Sozen, who was a well-known orator and writer.

So, I am biologically Georgian, grew up Turkish, and American by citizenship. (My uncle, in order to increase his share of the family inheritance, managed to have my name erased from the family record as well as denying me Turkish citizenship after I had immigrated to the U.S. and had American citizenship.)

That may have been too many words to claim that I have the wrong last name, but I think it also explains other strange things about the way I grew up. I started out in life in the hands of nannies and entered my first school as a boarder at the age of four. Then my grandparents managed to raise my age by two to have me accepted at a primary school by getting me another identity card, the one I continue to use.

3 During the time of Mustafa Kemal Ataturk, this law was enacted to standardize surnames. Previously, some families had locally known names that changed from time to time. In that year, Mustafa Kemal's formally adopted Ataturk as its surname (father of the Turkish people).

Childhood in Istanbul

Reitherman: What sort of house did you grow up in?

Sozen: In winters we lived in apartment units in town. In summers we lived in a hotel on an island not too far away from Istanbul before we changed our summer residence to another island on the Bosphorus.

Reitherman: Orhan Pamuk writes about his childhood memories of growing up in Istanbul and going off to an island in the Marmara Sea for the summers in similar localities.

Sozen: Yes, reading his first book I could tell that he had similar experiences. We had both rented books at Alaattin's store near the Tesvikiye Police station, on the western side of the Bosphorus. Incidentally, it may be interesting to mention that the Tesvikiye district was created during the last 20 to 30 years of the Ottomans to develop a Turkish middle class from those whose main occupation had been military.

Hanson: Do your relatives come to the U.S. to visit?

Sozen: They have come to the U.S. for visits, but they are all gone now. They were much older than me. I was the runt of the litter.

Hanson: What about your early schooling?

Sozen: After being a boarder at a kindergarten on the western shore of Bogaziçi, an area of the Bosphorus in Istanbul, my education went on through the sixth grade to then include six years at a very small English high school in Istanbul. It was a good school, but it had no standing in the Turkish educational system. When I completed the six years at the age of 15, I had no qualification to continue in Turkey unless I was willing to go back to ninth grade in a Turkish school.

So, I took the British matriculation examinations, and on that basis was qualified to attend a British university, but the family thought, much to my chagrin, that I was too young to go there. I spent most of that summer sailing, swimming, and rowing, as I had the previous summers, thinking I would be going to a British university a year later.

Reitherman: Did you have an early interest in engineering, even before college?

Sozen: Because my "sister" was a poet, my early interests were in twelfth and thirteenth century Anatolian poetry. That's what I loved, I loved literature, I loved history. But, you see, in Turkey of that time they told you that if you can become an engineer you should. That was the highest and most needed profession in the country. I wanted to become an engineer, but not because it came from within me. It didn't come from within me at all, but the propaganda was constantly telling us to be engineers. This was because Turkey had been devastated at the end of World War I, and at the end of the War of Independence[4] they needed

4 The Ottoman Empire, on the losing side of World War I, had treaty terms dictated by the victorious nations, chiefly the United Kingdom, France, the United States, Italy, and Greece. They parceled out most of the territory that included what are now Syria, Lebanon, Jordan, Israel, Palestine, Lebanon, Iraq, Saudi Arabia, and Kuwait, as well as Turkey. The Allies' treaty, the Treaty of Sévres, gave France and Britain large parts of the former Ottoman territory as

civil engineers. There was a constant flow of that kind of propaganda. The National Science Foundation is now trying to recruit engineers, and I keep saying that what they have to do is to start a television series called "L. A. Engineer." [laughter] That influences kids, huh? That's why I became an engineer. Not that I had much talent for engineering. I had talent for other things. But they told me, if you can cut the math, you should be an engineer. I went into engineering because it was the respected profession. Unlike in the United States, which is an engineering country but where engineering does not receive its due respect.

Hanson: You mean in our current generation?

Sozen: Nor was it respected in previous generations to my knowledge.

Hanson: I would say it was respected, to a limited extent, because coming out of the lower echelon, not the intellectual group, the way you went up that ladder was that engineering was the next step, and being a doctor was a step above that. So engineering was on the upward path.

Sozen: You can tell the hierarchy by the types of people who go into engineering. You're quite right. Engineers in the U.S. came primarily from the blue-collar class, while the sons and daughters of the upper-middle class didn't go into engineering as much. However, in Turkey they did. They used to but not anymore.

Hanson: It is not just the United States and Turkey where civil engineering has trouble attracting the brightest students. It's the same thing in Japan. They can't even get their students to go for Ph.D.s anymore.

Sozen: They're getting smart. [laughter]

1939 Erzincan Earthquake

Reitherman: You must have been a young child when the 1939 Erzincan earthquake occurred. Was that when you were living in Istanbul?

Sozen: I remember that night. I was seven years old. I remember my family working very hard to help the people whose lives had been devastated by the earthquake. I remember learning to knit blankets for them. It was said some 40,000 people were killed. I don't know if that is an exact number, but it was terrible. It left an impression on me. When the 1939 earthquake happened, I was visiting Ordu, the small town in Turkey on the coast of the Black Sea, in a three-story timber house. I was sleeping on the third floor and the house shook. Thinking I was opening the door to go out, I went into a closet. [laughter] I couldn't get out. I still remember that frightful experience.

colonies or protectorates and they took control of Istanbul. Italy and Greece obtained all the land along the Mediterranean Coast, France and Armenia took large areas of the east, leaving the Turkish nation with only central Anatolian territory around Ankara up to the Black Sea. In 1919, Greece invaded farther into what is now Turkey, 400 kilometers (250 miles) to the vicinity of Ankara. Led by Mustafa Kemal Ataturk, Turkish forces were victorious in pushing back in the War of Independence (1919–1923) and regained territory, including Istanbul, that now forms modern Turkey.

Chapter 2

Robert College

In a chance meeting with a friend, I learned there was a possibility I could be admitted that year to the Engineering School of Robert College. That's where I spent my four college years, at that beautiful campus overlooking the Bosphorus.

Reitherman: Tell us about your undergraduate education.

Sozen: In late July of 1947, a family friend told me that Turkish high schools had college entrance examinations in September for students who flunked in examinations given in June, and that I could apply to take the September exams claiming home schooling. Most of the examinations were oral, a baker's dozen of them plus three written exams, and I did not think I had a chance. I took them anyway, and by sheer luck I passed. It was then October, and there was no chance to get admitted to a British university or a university administered by the Turkish government. In a chance meeting with a friend, I learned there was a possibility I could be admitted that year to the Engineering School of Robert College. That's where I spent my four college years, at that beautiful campus overlooking the Bosphorus.

Robert College was established as a missionary college to create

an intellectual and religious revival of sorts within the Ottoman Empire and to make Turks Protestant rather than Catholic, Orthodox, or Muslim. That was the main idea. The founder, Cyrus Hamlin, was a fascinating guy from what they tell me. He went there all by himself to Istanbul as a missionary and used to run a bakery. He came to Istanbul about the time of the Crimean War, which was fought in 1853–1856. During the same years Florence Nightingale came to Istanbul as a nurse for the British casualties. I have read that her services were hyped up by the British press to take the attention away from the number of dead and wounded.

Reitherman: There is the story that Hamlin had a boat loaded with a cargo of his bread, and Christopher Robert, a wealthy American philanthropist, saw the boat, was curious about it, and got to know Hamlin. The college originated in that happenstance meeting of the two of them. Is that a true story?

Sozen: Yes, the bread was intended for the British soldiers who were being shipped to Crimea to fight in the war. For some reason, Robert happened to be there, I don't know why, and he ran into Hamlin when he got curious about the boatload of bread.

Reitherman: Describe the campus of Robert College, later to become Bogaziçi University.

Sozen: Have you been there?

Reitherman: I've visited the Kandili Observatory of Bogaziçi University and the earthquake researchers there—Mustafa Erdik, Attila Ansal, and, I'll apologize in advance for not pronouncing this name correctly, Ozal Yuzugullu.

Sozen: You may not be pronouncing Turkish correctly, but your facial muscles are getting a good workout. [laughter]

At the time, when I went there in the 1950s, there was hardly any housing around the campus. It was a beautiful place on top of a hill, on the European side of the Bosphorus, overlooking the Kandilli Observatory on the Asian side. It still is beautiful, but there are houses all the way around it now.

Reitherman: When you started at Robert College, did you enroll immediately in an engineering curriculum?

Sozen: Yes. I entered Robert College in 1947–48, and I finished with my undergraduate degree in engineering in 1950–51.

Reitherman: What kind of sports did you play in college?

Sozen: Everything. I played soccer, volleyball, basketball, cricket—I played a neat game of cricket as a wicket-keeper—and water polo. I never specialized in any one of them. Allow me a memory that describes our relationship with the rest of the world in my college years. I was a member of the Turkish water-polo team when the Hungarian team made a visit. Before the game we wondered where they had been able to learn to play water polo. They did not have a seacoast. How could they know how to play the game? During our match, they destroyed us. Then we realized that a country without a seashore may have many swimming pools. There were only two in Turkey, and they were both on the seashore.

Reitherman: Sorry to digress, but this year [2016] Alex Tarics passed away, the first

engineer to apply seismic isolation to a building project in the United States. He was the oldest living Olympic gold medalist: he was on the Hungarian water polo team in the 1936 Olympics in Munich.

Do you still have a connection with Bogaziçi University because of your undergraduate days there? From your curriculum vitae we see that they gave you an honorary degree in 1988.

Sozen: Oh yes, in fact I went and taught there for a semester. I haven't broken away from the old campus, and it hasn't changed very much, other than becoming a state university. It was transferred to the Turkish government in 1971. When I was a student there it was very small. The entire university, including a high school, had no more than 1,200 students and the engineering school might have had a total of 200. You knew everybody in school. Now it is a lot bigger. It is a good school. It is still one of the top schools in Turkey.

Reitherman: Did you ever take a course in earthquake engineering or have some content on that subject in your undergraduate work at Robert College?

Sozen: No. It wasn't taught then.

Chapter 3

Master's Degree at the University of Illinois and First Job

I always meant to get a master's degree because at that time in Turkey, if you were an engineer with a B.S., they wouldn't even let you carry stones.

Sozen: I always meant to get a master's degree because at that time in Turkey, if you were an engineer with a B.S., they wouldn't even let you carry stones. The Turkish engineering school had a five-year curriculum. With a four-year degree they didn't give you what they called the "high" engineer's degree and license, just like in Germany. So I had to go to an engineering school to get a graduate degree. Of course, in Turkey at that time we knew America through Hollywood, right? In Hollywood, there were only Harvard, Yale, and Princeton. There were only three schools in America. Of course, I also knew about the fact that Yale had a good theater school and I thought that maybe

I could slip from engineering to drama. As an undergraduate, I spent a lot of time with drama activities.

Hardy Cross[5] was a famous professor at Yale in those days, which was another reason I thought I wanted to go to Yale, though he might have been approaching retirement when I would have been a student there. Then I ran into somebody who had been trained in the U.S.—another of those chance encounters in my life—and he said, "Don't be silly—if you want to be a civil engineer, go to the University of Illinois." I took his advice, and I was very happy that I did. At that time, in 1951, Illinois was one of the very few graduate schools in civil engineering in the United States. You may have a different opinion, Bob [Hanson], having been on the faculty at Michigan a little later. Michigan had great people, but it wasn't the composite that Illinois was. Timoshenko[6] had been at Michigan, for example, though he had already gone to Stanford by that time.

Reitherman: Egor Popov noted in his EERI oral history[7] that Mihran Agbabian was the first structural engineering Ph.D. student at Berkeley, getting that degree in 1951. We tend to forget that while advanced degrees in natural sciences were fairly common at American universities prior to World War II, graduate degree programs in civil engineering disciplines were rather rare in the U.S.A. as of the start of the 1950s.

Though you didn't go to Yale where Cross was, he had earlier been on the faculty at Illinois, hadn't he?

Sozen: Hardy Cross had left Illinois in 1937, but actually Cross's influence remained at Illinois for many years and didn't disappear until very recently. At least, so they tell me, I haven't been there recently. His way of thinking, his teaching style, his approach to structural engineering, all remained there at Illinois. After all, Nate Newmark[8] was his student.

5 Hardy Cross (1888–1959), who developed the most widely used moment distribution method of the 1930s, had academic affiliations with Harvard, Brown, and Yale Universities in his career, but he is mostly known for his research and teaching influence while on the faculty of the University of Illinois at Urbana-Champaign (1921–1937). From 1937 to 1953 he chaired the civil engineering department at Yale. During his years at Illinois he published "Analysis of Continuous Frames by Distributing Fixed-End Moments," (*Proceedings of the American Society of Civil Engineers*, May, 1930). It was a practical method for analyzing how bending moments flowed through frames that had rigid joints, and it facilitated the use of reinforced concrete and steel frame construction.

6 Stephen Timoshenko (1878–1972) developed important concepts in mechanics used by mechanical and structural engineers while a professor in Ukraine and Russia. After the Russian Revolution and when the Bolsheviks had won the civil war, he emigrated to the United States, working for the Westinghouse Electric research and development lab before becoming a professor at the University of Michigan in 1927. In 1936 he became a professor at Stanford University. He is best known for his books on dynamics and strength of materials.

7 *Egor Popov*, *Connections: The EERI Oral History Series*, Stanley Scott, Interviewer, 2001, p. 48.

8 Nathan M. Newmark (1910–1981) had a long career as a researcher and professor at the Univer-

Hanson: So Newmark had the same teaching approach?

Sozen: Actually I have always claimed that Newmark had in a way combined Westergaard[9] and Cross, which was a wonderful blend. Illinois was still in the Hardy Cross tradition when I went there. I found a statement from the engineering college of the University of Illinois, I think written in 1877, when it said, "This University produces good practical engineers." That was also the Hardy Cross tradition. And it has continued until very recently.

Reitherman: We will need to talk more about Newmark when your story extends to your Ph.D. and your faculty years at Illinois. At Illinois, you became famous for your work in earthquake engineering, although when you started there at the beginning of the 1950s, Illinois had yet to enter the earthquake engineering field, is that correct?

Sozen: You could say that even in the 1960s, earthquakes were something that California structural engineers worried about while the rest of us didn't give a hoot—earthquake engineering simply didn't happen in the rest of the country. Some very far-sighted research had been done by Westergaard[10] much earlier, but the rise of Illinois in the earthquake engineering field as we know it today had yet to begin when I got there. Westergaard proposed that earthquake intensity should be related to energy, a truth that took the profession over half a century to discover. I'll mention that later when we come to the ATC-3 project.

Reitherman: It is fascinating how professors, such as Newmark, who were not exposed to earthquake engineering as university students, became prominent teachers of earthquake engineering. There was only one generation when that happened. Now, there are many professors teaching earthquake engineering who were exposed to that subject as early as in some of their undergraduate classes.

Hanson: When did Illinois start picking up earthquakes as an issue?

Sozen: When we ran out of the Cold War money. That was the late 1950s. That's my opinion, at any rate. Maybe Bill Hall has a different opinion. He and Newmark were more knowledgeable about that.

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sity of Illinois following his Ph.D. there in 1934. As a student, Newmark studied with Hardy Cross and Harald Westergaard. While well-known in the earthquake engineering field as one of the key individuals in its development in the 1950s, 1960s, and later, his engineering skills were applied to a wider variety of topics, including geotechnical engineering, military structures, blast effects on structures, nuclear power plant design, and computer science. Cited later is the EERI *William Hall* oral history, which contains information on Newmark.

9 Harald M. Westergaard (1888–1950) (not to be confused with the statistician Harald L. Westergaard) conducted research on concrete, including concrete airfields for heavy aircraft in World War II, and dams. He was later dean of the graduate engineering school at Harvard.

10 "Earthquake Shock Transmission in Tall Buildings," *Engineering News-Record*, 1933, vol. III, pp. 654–656. Westergaard wrote this paper, as well as his paper on earthquake effects and dams, and on earthquake intensity, papers cited later, prior to the availability of any strong motion records, which began to accumulate only in 1933.

Hanson: In my career, my recollection was more tied to the Vietnam years, when universities walked away from the defense type of research because it was politically incorrect.

Sozen: That had nothing to do with Illinois.

Hanson: It did in Michigan.

Sozen: Well, Michigan is a university, it's an eastern Ivy League university. Illinois is a place that trains practical engineers. [laughter]

Reitherman: You started in the master's program at the University of Illinois, Urbana-Champaign, in 1951. You finished your M.Sc. in two semesters. What was your specialization in your master's work?

Sozen: I specialized in structures. I took courses from Newmark, Siess,[11] Shedd,[12] also what we now call geotechnical engineering from Peck,[13] but all I wanted to do was finish and get out. Imagine: If your image of America is Hollywood, and you find yourself in Urbana, Illinois, the first thing you want to do is get the hell out of there as quickly as possible. [laughter]

Reitherman: You mentioned these names of professors who are pillars in the history of civil engineering in universities in the United States. Did you have a sense then that you were being taught by these historic figures?

Sozen: I certainly did. I did appreciate that, there is no question about it. But that still didn't prevent me from wanting to leave as quickly as I could and get out of school.

First Job

Reitherman: You then went to San Francisco. How come?

Sozen: Because San Francisco, Rio de Janeiro, and Istanbul are said to be the most beautiful metropolises of the world, those of us from Istanbul especially want to see San Francisco. When I was first there it was a lightly

11 Chester Paul Siess (1916–2004) worked as a researcher at the University of Illinois at Urbana-Champaign after professional experience working for Ralph Peck on the Chicago subway project. He received his University of Illinois Ph.D. in 1948 and became a full professor there in 1955, heading the civil engineering department from 1973 to 1978, when he retired. His research centered on reinforced and prestressed concrete. He was a member of the National Academy of Engineering and was influential in the development of the building code provisions of the American Concrete Institute (ACI), which established in his honor the annual Chester Paul Siess Award for Excellence in Structural Research.

12 Thomas Clark Shedd (1890–1959) was on the University of Illinois at Urbana-Champaign civil engineering faculty from 1925 through 1958. He authored *Structural Design in Steel* (John Wiley & Sons, 1934), and co-authored another influential textbook, *Theory of Simple Structures* (John Wiley & Sons, 1941).

13 Ralph Peck (1912–2008), a member of the National Academy of Engineering, worked under early soil mechanics pioneers Arthur Casagrande and Karl Terzhagi before joining the University of Illinois at Urbana-Champaign faculty in 1942, where he taught and conducted research until 1974. He was a key consultant on major construction projects in the U.S.A., beginning in 1939 as Terzaghi's chief on-site engineer during the construction of the Chicago subway system.

populated city without traffic lights at most intersections. I loved the place. I went there without any intent to spend more than a week there.

I had some acquaintances there, and when I was talking with one of them he said, "You like San Francisco. Why don't you hang your hat here for a while? You can get a job at Kaiser Engineers. They are looking for entry level engineers." So I went and got a job at Kaiser Engineers, at that time headquartered in Oakland. I don't know if they're still there.

Then, of course, one of the most wonderful things that happened to me was that I ran into Boris Bresler, who was working at Kaiser on the side so to speak, while he was on the faculty at Berkeley. He was a renaissance man and an engineer. To talk with him was a wonderful experience. It was really he who told me at that time to go back to graduate school. Later, when I knew Boris much better as a fellow member of the American Concrete Institute, he told me, "I was amused by your weird ideas of engineering." He didn't think that I would make a good practicing engineer, so he thought maybe I should go into academics. [laughter] I loved San Francisco. I loved the weather. Much later, when I was doing some consulting work with Tony Peret of Wiss Janney Elstner there, my wife Joan and I talked about moving there.

Reitherman: What were you designing at Kaiser?

Sozen: I believed in analysis. I wasn't designing, I was intent on doing "high-level" analysis. I was analyzing industrial structures like steel sheds, conveyor structure trusses and that sort of thing if I remember correctly. The analyses I made were a waste of time but I did not know that. However, I learned drafting, which was a very good skill to obtain.

Reitherman: Drafting in those days would have been accomplished on an inclined drawing board with a T-square or a parallel rule?

Sozen: It was a luxury if you had what was called a drafting machine to use on the drafting board, the articulated arm and the right angle at the end of it that could be rotated around. That was the high-class instrument to use. Anyway, I did benefit from the work because I learned how to draft, which I hadn't really learned in college.

Reitherman: Do you think there is any difference with engineers today, who have never learned pencil-in-hand drafting?

Sozen: I don't know, but of course there's something to "touching" the building that you are designing, and it doesn't happen with the computer drafting.

Hanson: Do you think that today's graduates can actually read a drawing? They haven't been forced to make drawings.

Sozen: I don't really don't know. What do you think?

Hanson: It's harder for them.

Sozen: That is a good question because I was trying to read these computer-drafted drawings recently, and there is a new language that draftsmen now use.

Hanson: A cross-referencing language.

Sozen: Yes, and if you don't know that language, you're really at sea. I had to re-learn drawing all over again.

Reitherman: Tell the story about how you left San Francisco expecting to go to Istanbul in December of …what year?

Sozen: It was 1952. I had a car that was my most valued possession, and I couldn't sell it quickly after I made my decision to move from San Francisco back to Turkey. So I thought, I shall drive through Illinois to New York and sell it there. I came to New York, I ran into some friends, and I suddenly found that there was tremendous cultural life in New York that I didn't know anything about, and I liked it. I could afford to go to the Metropolitan Opera three times a week, standing room, at a total cost barely exceeding one dollar. That convinced me to stay in NYC for a while. I already had a recommendation to work for Hardesty and Hanover. Shortridge Hardesty was a great engineer, a great bridge engineer. I went to their office and asked for a job supposedly designing bridges. I learned a lot; it was a very positive experience. For me it was eye-opening to observe Hardesty guessing at the result of an engineering analysis and seldom being off the result obtained by painstaking analysis. That's how I ended up living in New York. In fact, I started living in Greenwich Village, where I discovered Eugene Debs, the famous socialist, and Chumley's pub, but after about three months I realized I couldn't handle it. I couldn't handle the village life and the work life at the same time. So I moved.

Hanson: Just living in Greenwich Village was a full-time occupation?

Sozen: Almost. My friends would have fun all night and sleep all day. I couldn't do that. [laughter]

Chapter 4

Ph.D. at the University of Illinois

The important thing about teaching is for the teacher to go there and think in front of the students, and that's what Newmark did.

Sozen: I had the outlandish idea that I didn't know enough, not a bad conjecture in itself, but I thought that the only way that I could learn enough was by going back to school. If you want to learn engineering you should stay on the drafting table or on the construction site. But I thought if I went back to the university and made further studies, I would be a much better engineer. That's why I went back.

In August of 1953 I called the University of Illinois Civil Engineering Department. It was very fortunate, because evidently two good Ph.D. candidates who had applied to Illinois and had been given research assistantships had suddenly decided to go elsewhere. So they gave me an assistantship right away.

Reitherman: From your biographical information and publications, it looks like the research topic that you were set to work on was prestressed concrete?

Sozen: Right.

Reitherman: That was a relatively new innovation as of then. What experience did you have with it in your education, or while working in Oakland or New York?

Sozen: None. I'd heard about it, I'd read about it. At that time it was the miracle material. The strongest thing. It didn't fail in shear. It didn't deflect. It did all those wonderful things. It was the star material of structural engineering in those days.

Hanson: Who was the professor in charge of the project at Illinois?

Nathan Newmark

Sozen: Actually, two were in charge of the research, Newmark and Siess. Putatively, I worked for Newmark and he was my advisor, but actually I worked with Chester, or Chet, Siess. Newmark didn't have much time to fool around with graduate students, even at that time. I met him once a month along with a few other students.

Hanson: Is that right? You were advised by Newmark and Siess? Quite a pair of advisors. I didn't know Newmark was involved in prestressed concrete research.

Sozen: Nate Newmark did all sorts of things. Did you know he tested masonry walls? He was a good experimentalist. He always claimed he was a generalist. I would think when I was student, "Oh he's just being modest. How can this high-level specialist be a generalist?" But now I realize that if you're going to be a structural engineer, you need to be a generalist. You can't simply say, I only do earthquake engineering, or I only do prestressed concrete, or I only do shells.

Reitherman: As of then, Siess had been in reinforced concrete for a long time?

Sozen: Oh, yes. Indeed, in a way, my advisors and teachers were the Dream Team of civil engineering faculty at Illinois. And chief among them was Newmark, who taught you not because he came to class prepared and dedicated to what he was going to teach about. I don't think he ever thought much about what he was going to talk about in class before he came in. But you watched the man thinking in class. That was the greatest learning experience I had. That's what I always claim. The important thing about teaching is for the teacher to go there and think in front of the students, and that's what Newmark did. You learned how to think about structural engineering. He was great. For me it was very instructive. I cannot help but think that, under current requirements, he would not even be given tenure. He continued to work as an engineer, not caring about number of dollars he brought to the academy and number of papers he wrote. To boot, he didn't exactly coddle the students. But he did inspire them.

I remember Professor Henry Langhaar, who was also a great teacher, and was more of a pure mechanics type. It was a thrill to be at the lab in the wee hours of the morning and be working and then hear the typewriter sounds from his office as he methodically tapped out his books. It was very inspirational. You would also see Newmark's Cadillac (that was his only visible weakness) parked in Burrill Avenue until midnight seven days a week when he was in town.

We had a Professor J. O. Smith who was a well-known name in mechanics and who

wrote the book *Advanced Mechanics of Materials* with Professor Fred Seely. Smith also was a great teacher. There were four of us in Smith's graduate class, and it was like a private education. None of my classes had more than 14 or 16 people in them.

Then there was Chet Siess, who is a very fine thinker and very careful writer. I do not remember any other teacher at Urbana who was as sensitive as he was to grammar. You could almost hear him thinking. He was sharp, very critical, and very well organized. I did not know what critical thinking was until I took a few half-baked ideas to Professor Siess. He cut them like a razor blade.

And I was fortunate to be a student in Ralph Peck's classes. He was superb, a genius. To listen to one of Professor Peck's lectures gave one as much enjoyment as listening to a concert. When he lectured, you sort of wondered, how could this man form these sentences and communicate to you that this is the end of the paragraph? A wonderful lecturer. Despite the fact I was not a geotech student, I took several geotechnical engineering courses. I think Peck had a tremendous influence on my thinking about engineering. He was a very practical and brilliant engineer.

Reitherman: What was Newmark like in the classroom? You said as a student you were watching a professor think.

Sozen: He would come in and say, "Here's a problem. Help me solve it. Let's see how we can do this." And at the same time he scared the bejesus out of you. There was this man with the sharpest mind and there you were, sitting helpless in front of him expecting him to ask you a question any moment. I thought he was an excellent teacher to those who understood him. I cannot resist telling you the following anecdote. During one class, he was discussing his unbelievably simple way of estimating the possible slip of a dam during an earthquake. He started by assuming the earthquake demand to be one constant-acceleration pulse over a fraction of a second. As naïve as I was, I raised my hand and said, "Sir, would it not improve accuracy of the result if one assumed it to be one-half of a sine wave?" He stopped. Pretended to think, not to embarrass me, and said gently, "Mete, before you make such a judgment, think of all the other approximations involved in such an evaluation." I must admit it took me years to understand fully what he said. If one is going to be wrong anyway, one should be wrong the easy way.

Allow me to share with you a personal memory. At one time, it must have been after the 1967 Caracas earthquake, we were traveling together there. I happened to have heard that his father had been a rabbi, trained in Lithuania and famous for his preaching there to attract all his followers to farming, something they were not allowed to do in Europe. He was so preoccupied with that goal that he did not care about earning a living. The family was poor and lived in New Jersey on income made available by Mrs. Newmark's family, who hailed from North Carolina, I believe. Nate told me that he had not tasted ice cream until, at the age of 12, he had started work as a paper boy and made some money. Hearing his story I could understand why he favored a Cadillac.

Thomas Shedd was one of Hardy Cross's students. There was more than one person

who imitated Cross in Urbana, but Shedd probably was the most effective. He would come to class and say, "Mr. Smith, come to the blackboard." Then he would ask a very simple question, and if that student didn't know the answer, he would say, "Mr. Bean, please come to the blackboard." [laughter]. You had to go to class prepared. An instructor couldn't do it now—the students would sue the instructor [laughter].

Reitherman: Both Hardy Cross and Nathan Newmark are mostly known for the methods they developed that were used in practice, but I notice that you, as well as Bill Hall in his EERI oral history,[14] emphasize what great teachers they were.

Hanson: There are several modes of teaching. One is the lecture mode, which is what we're talking about, with a projected PowerPoint presentation or overhead transparencies. The other is more of what we call a recitation technique, which is interaction with the students. I always find the recitation interaction more fun to do. Harry Bolton Seed was a lecturer. If he didn't have 150 students sitting in front of him listening, he didn't figure that it was worth his time to prepare a lecture. How did you do your classes, Mete?

Sozen: It was mostly interactive. They were small classes at Illinois, and here too at Purdue it has been mostly interactive. I'm teaching a graduate class in reinforced concrete this semester. It is sort of a research class in which the students are asked to write brief reports on practical problems, but at the end I give them a whole bunch of little questions and ask them things like, if you are going to design a beam that has a span of L, how deep would you make it? You see, this is something that they may not otherwise think about. This is what I learned at Illinois, how to develop a sense of proportion, something which a structural engineer needs. I think that earthquake engineering should be taught to students as a design course, not as part of a structural dynamics course.

Reitherman: When you were in Illinois, working on your Ph.D., what courses were you taking?

Sozen: The university wanted you to take some of your courses outside the department, so I took courses in math, in physics, even one in English from Professor Paul Landis, although it did not count. Of course, I took civil engineering courses not necessarily focused on reinforced concrete, mostly on mechanics. Illinois had a very good philosophy of education at that time.

Nate was not only a brilliant engineer, but also a man who managed people very well. I'll tell you something very funny. Who was his best student? Whom did he most admire in the faculty? Well, it was I. I know because he told me it was I,…just as he told everybody else. I always thought of the analogy of a man in a singles bar talking to different women, talking to the first woman and telling her, "You are the most beautiful woman I've ever met," and then saying that to the next woman.

14 *William J. Hall*, *Connections: The EERI Oral History Series*, Robert Hanson and Robert Reitherman, Interviewers, Oakland, CA, 2015. The appendix in that volume provides biographical information about Newmark, photographs, and a complete list of his publications.

Reitherman: How did Newmark get into the earthquake field?

Sozen: I think Newmark was connected to earthquake work through association with Westergaard, who got involved in the design of the Hoover Dam, but Newmark was doing mostly blast work when I was a student. You see, earthquake engineering comes to Illinois insofar as I know through a Japanese student from Hakodate, later to become Professor Mikishi Abe[15]. He was at Urbana in the teens of the twentieth century doing a thesis. He worked with Westergaard, and you may know that Westergaard worked in the earthquake trade, especially with respect to dams.[16]

Research on Prestressed Concrete

Sozen: My Ph.D. work was an experimental study. I tested beams and developed abstruse theories about the shear strength of prestressed concrete girders. I must say, not on my behalf, but for the whole project, that it was very useful research for engineering in the United States. Prestressed concrete had come from gifted artistic engineers like Eugene Freyssinet, Gustave Magnel, P. W. Abeles, and later T. Y. Lin. Lin was as much an artist as a structural engineer. Prestressed concrete needed a rigorous research base. With the support of the Illinois Division of Highways, the project went through the fundamental aspects. It went through flexure, to shear, to bond, to anchorage zone stresses, to deformations, to continuous spans. It covered the entire domain, so to speak, and I think it provided a very good base for teaching and designing in the United States. Much of the engineering science of prestressed concrete was developed in Talbot Laboratory in the tradition of A.N. Talbot and F.E. Richart through patient testing and analysis and retesting under the direction of Professors Newmark and Siess. Initially V.P. Jensen's approach to the flexural strength of prestressed concrete was extended to beams with bonded reinforcement and then to beams with unbonded reinforcement.

Experimental analysis of the shear strength of prestressed concrete beams was full of shocking surprises. One found out, against conventional wisdom, that draping prestressing tendons could result in a reduction of the shear strength.

As important as the research results of that project were, it was also significant for the group of brilliant teacher-researchers it brought together, such as J.H. Appleton, A. Feldman, N.M. Hawkins, J.G. MacGregor,

15 Mikishi Abe was born in 1883 and died on February 20, 1965. He graduated from the Sapporo Agricultural College in 1905 and joined the Government Railways, where he expanded his civil engineering practice to include the architectural design of buildings. He went to the University of Illinois at Urbana-Champaign to study reinforced concrete, completing his doctoral degree in 1914 on statically indeterminate reinforced concrete frame structures. He wrote *Analysis and Tests of Rigidly Connected Reinforced Concrete Frames,* University of Illinois Bulletin No. 107, October 21, 1918.

16 An early paper by Westergaard was on hydraulic pressures on dams induced by earthquakes: "Water Pressures on Dams during Earthquakes," Bureau of Reclamation (U.S. Department of the Interior, 1930). While consulting on the Hoover Dam, Westergaard kept a model of the dam in his house.

G Hernandez, P. Gergely, M. Stocker, J. Warwaruk, W. Welsh, and E. Zwoyer. To see their talents and perspectives develop through the course of the project was exciting.

Reitherman: Today, prestressed concrete is such an ordinary term, and the material itself is a commonplace industrial product. You drive into a typical parking garage and you see dozens of prestressed concrete girders. It is hard for people to imagine back when it was the latest and greatest new material, and not yet fully understood. In the past few years, synthetic fiber materials became and are still news stories, for example with regard to large airliners with fuselages made out of these new materials instead of aluminum. Will these new fiber-reinforced materials become commonplace in civil engineering, as prestressed concrete did?

Sozen: It's still an open question as to how much civil engineering construction in the future will be based on new materials. About 15years ago a colleague said this is the age of the new materials; there is going to be a revolution in structural engineering; we are going to use new materials for everything. Well, we are still using steel. We're still using concrete. Synthetic wraps have some very good applications, but sometimes I think their use is hyped up.

Reitherman: Did fellow graduate students of yours go into earthquake engineering?

Influence of Defense Research on Blast Engineering

Sozen: I recall that many of my fellow graduate students were somehow absorbed into the defense effort and totally disappeared from view because they did mostly secret work. They worked for places like the Rand Corporation. They were very, very, fine engineers.

Reitherman: Bill Hall in his EERI oral history talks a little bit about the World War II work of Newmark and Westergaard, and defense-related work afterward. When you were getting your doctoral degree in 1957, was the defense funding still going strong?

Sozen: It was still going strong. There were still tests at Illinois. I grew up around the blast-resistant trade so to speak, because that was the brand new technology going on.

Reitherman: When you were working on your doctoral degree, was there a course called earthquake engineering?

Sozen: Not when I was a student, or I would have taken it.

Hanson: Structural dynamics?

Sozen: Well yes, but you took it indirectly, and blast-resistant design was also studied indirectly, as part of a standard course, rather than as a separate subject.

Chapter 5

Academic Career

With funding from the National Science Foundation and elsewhere, and sustained help from MTS, we were able to assemble the earthquake shaking simulator by 1967.

Sozen: When I finished with my Ph.D., I was once again ready to return to Istanbul. This time my family thought I should cool my heels in the U.S. for a little longer because the Turkish political scene was unstable. I accepted a position at the University of Illinois and dived right into one of the most interesting research projects I have ever worked on, reinforced concrete floor slabs.

It is appropriate to claim that the research done at Illinois changed the way two-way slabs are designed, by developing explicit relations among slab behavior, theory of linear plates, and yield-line theory, as well as correcting the yield-line criterion that had become quite abstruse as a result of inappropriate testing. Again, even more important than the research results produced by the project was the training of some highly productive engineers and academics such as G. Corley, W. Gamble, D. Hatcher, J. Jirsa, R. Lenschow, G. Mayes, D. Vanderbilt, and M. Xanthakis.

A few years after I started on the faculty at Illinois, my aunt's premonition about the political situation in Turkey turned out to be correct. A few family members and friends ended up in jail for

what the government considered to be their political indiscretions. You'll recall that I had been intending to return to Turkey before I ever started my doctoral work at Illinois, but I found myself firmly embedded in a career at the university in Illinois.

The Shake Table at Illinois

Reitherman: We should talk about the shake table at Illinois. It think it was up and running by the late 1960s, the first of the large, modern simulators in the U.S.A. or maybe the world. That would have been about five years before the 20-foot-square table at Berkeley was operating.

Sozen: One day, in the early 1960s, I was having a cup of coffee with Herb Johnson, then C.E.O. of the MTS company, at the Illini Union. I wanted him to build a loading system for concrete cylinders that would permit me to measure the "true" stress-strain history of concrete after the peak stress is reached. As I listened to him, I realized that he had the equipment and software to control the actuators to reproduce an earthquake record. I sketched out an acceleration record and asked him whether he could reproduce that while pushing and pulling on a 12-kip mass. "No sweat," he said. A couple of years after our conversation and after the "earthquake simulator system" started being built, I realized that I had not known what I wanted and neither had he. But things worked out.

I took my case to Dr. Michael Gaus at the National Science Foundation, who had been a student of Bill Hall's. He was sympathetic but thought that the $70,000 that I needed was too much. I thought I could build the shaking platform at Urbana in-house, bringing the cost down to approximately $45,000. Dr. Gaus referred me to Dr. Newmark, saying that if Newmark agreed, he'd try and support the effort.

Because Dr. Newmark had known of more than one of my hare-brained schemes in the laboratory, it took a certain amount of nerve for me to try and sell him an idea that I was not sure would work. Quite to my surprise, he supported me. Another positive development was that I relinquished my idea of building the platform myself and managed to raise the money that was needed to buy it from a company in Los Angeles. Had I built it, I know now it would not have worked properly. With funding from the National Science Foundation and elsewhere, and sustained help from MTS, we were able to assemble the earthquake shaking simulator by 1967.[17]

Immediately we moved into a make-believe world, trusting that the toy would yield us the truth, and we sought the "realistic" hysteresis relationship for reinforced concrete by testing, essentially, single columns. Dr. Takeda

17 Mete Sozen, Shunsuke Otani, Polat Gulkan, and Norbert Nielsen, "The University of Illinois Earthquake Earthquake Simulator." *Proceedings of the Fourth World Conference on Earthquake Engineering, Vol. 3,* Chilean Association on Seismology and Earthquake Engineering, Santiago,1969, pp. 140–149. The one-axis shake table had accelerometers and linear variable differential transformers (LVDTs), was 12 feet by 12 feet in plan, and could handle a 10-kip test specimen. Its displacement amplitude was approximately two inches in each direction. The maximum velocity was 20 inches per second. The maximum acceleration of the table was 5 g.

of Obayashi-Gumi, who had been a student of Professor Umemura at the University of Tokyo, and Dr. Norby Nielsen, worked with me. In our fixation to explain everything by nonlinear dynamic analysis based on force, we missed by a wide margin what the early test specimens were telling us point blank. Consider the results from the tests. We shook a specimen so it yielded. Then we shook it with twice the intensity and the displacement response was approximately twice as much. When we shook the same specimen with an intensity three times as much and the maximum displacement was three times as much. Not one of us questioned why that occurred, proving once again that looking is not seeing.

The reason for my not seeing what the test results were telling me had to do with my preoccupation with force as the dominant factor in developing drift. I should have noted that doubling the intensity beyond yield essentially doubled the drift and tripling it tripled the drift. Therefore, there had to be another factor, other than force demand, in the ground motion that set up the drift demand. It was the energy demand that had been identified by Westergaard years ago. It took me years and many other tests to understand what was going on.

Following those tests, we started testing small-scale frames. Polat Gulkan's work opened the door to circumventing nonlinear dynamic analysis by assuming a softened but damped linear system. Shunsuke Otani, another student of Prof. Umemura's, worked with a series of multi-story frames on the earthquake simulator to develop the SUSHI and SAKE linear and nonlinear response software for reinforced concrete frames. The experimental work was later continued by D. Aristizabal, D. Abrams, J. Moehle, C. French, M. Kreger, J. Lybas, J. Bonacci, and S. Wood to develop a healthy base of knowledge on dynamic response, albeit in 2D, of various types of structures in reinforced concrete. M. Eberhard's work, building on those of the others, showed that the driving parameter for design was simply drift for a wide range of low- and medium-rise structures with and without walls. J. Dragovich carried the experimental work forward to include torsion. K. Shimazaki compiled the entire earthquake simulator experience in Urbana to confirm that nonlinear drift could be determined easily using a modified linear response spectrum within the nearly-constant velocity response range. A. Lepage carried his generalization into the nearly-constant acceleration response range by establishing that nonlinear drift could be estimated over the range defined as the linear acceleration response range by Shimazaki's approach projected to the origin of the acceleration response plot of the system, defining a linear relationship between the drift and the first-mode period of the structure.

So, the University of Illinois shake table started as a simple machine, but it produced a totally different understanding of drift and an entire generation of first-rate researchers, all of whom remained in the academy to make even more durable contributions to engineering while teaching succeeding generations of students.

Most importantly, the test results from the Illinois Earthquake Simulator led to the revolutionary understanding that the main function of dynamic analysis is determination of drift, and that can be done simply by considering the maximum ground velocity, the type of

structure, and the fundamental period of the structure. Today's thinking is still based on the imaginary lateral force model that the Italian engineers used after the 1908 Messina earthquake. We imagine a lateral force pushing the building to get the drift. That is, force is the initiator of the phenomenon. I think of drift being the initiator of force. The ground motion demands drift in the structure and the drift creates the force. It is the difference between loading a beam with a weight and "pushing" the beam.

Picture a cantilever column. I assume that its lateral strength is ideally elasto-plastic. Once it reaches yield, there is only deflection. No increase in resistance. Now if one loads this column with a lateral force, once the lateral force reaches the yield force and goes infinitesimally above yield, the deflection goes to "infinity." But that is not what happens in an earthquake. If the ground motion is sufficient to develop the yield force, the column deflection is the yield deflection. If the ground motion is "tripled," the column undergoes three times the yield deflection. It has nothing to do with the force causing the deflection concept. So it makes more sense to think of the earthquake as demanding drift. And drift leads to force (if there is strength).

Here's another way of saying it. Given a single-degree-of-freedom system, such as a column with a concentrated mass on top, its period and the displacement response spectrum for a given ground motion, the drift demand is established. If the column reaches its yield point, the force does not increase beyond that, but the drift reaches the demand. If the column does not yield at that drift, the force (picture the vertical axis) climbs up the straight-line elastic curve until it reaches the drift demand (the horizontal axis). That is what I mean by claiming drift, and the properties of the structure, determine the force.

Once drift distribution is estimated, one can judge the correctness of the dimensions of structural members chosen based on knowledge of how much damage will be sustained by the nonstructural elements attached to the structural elements. A study by Bekir Algan of the tests on the earthquake simulator led to the conclusion that tolerable drift is typically determined by damage to the nonstructural elements. In effect, it was found that for saving the investment, structural analysis is important. For saving lives structural detail is important because that is what keeps the structure together after the drift limit based on the nonstructural components is exceeded. What should govern design, especially for frames, in most cases is the inter-story drift ratio capability of the nonstructural elements that seldom exceeds 1%. A research effort that had started with the goal of accurate definitions of ductility demand and capacity of structural materials ended up demonstrating that, for protecting the investment, those issues were of secondary importance and, for saving lives, it was not analysis but structural detailing that was important.

Because Nate Newmark was also the director of the computer science laboratory at Illinois, we had very close relations with the faculty members who developed the ILLIAC, one of the early digital computer systems. That turned out to be great help in recording, reducing, and interpreting data. Whenever I

had a problem, I would go to the Computer Laboratory, which was right next to our laboratory, in the wee hours of the morning and talk to those whom I found working at that time. It was very seldom that they could not solve my problem.

Universities Council for Earthquake Engineering Research

Reitherman: Do you recall the Universities Council for Earthquake Engineering Research, UCEER, a forum for annual get-togethers of all the professors in the country doing earthquake engineering research?

Sozen: Yes, that was a wonderful series of meetings. I thought those meetings were very constructive. It brought people together. It made us exchange ideas. Why did it disappear? I think that it was because NSF did not have the money for the costs, like travel. They were very, very good events. I have not thought about it for a long time.

Reitherman: The annual UCEER conferences are useful historical benchmarks. The big players in the field then, like Illinois, Michigan, Caltech, Berkeley, and MIT, summarized the earthquake engineering research projects underway that particular year at their school.[18] Most of the universities at the meetings seemed to have only one or two people in the field. The discipline in the U.S.A., and I think Canadians were included in those annual get togethers, was small enough to survey it from standing on that one hill, the annual UCEER meetings. One of the organizers, Don Hudson at Caltech, commented that "it had a pleasingly vague structure" that facilitated information sharing.

Sozen: Yes, they were very helpful. The meetings resulted in critical exchanges of new knowledge resulting in new perspectives that would not have been developed without the UCEER meetings.

Hanson: The closest thing to the UCEER annual meeting now, though not the same thing, is the annual meeting of the Network for Earthquake Engineering Simulation, NEES.

Sozen: We can talk some more about NEES later if you wish.

Move to Purdue University

Hanson: Tell us about your 1993 transition from the faculty of Illinois to the faculty of Purdue.

Sozen: Somehow, being a homegrown product of Illinois, in effect I was considered something of a long-term graduate student, somewhat taken for granted. And that year Neil Hawkins, who had been my student, who was the department head at the time, came to me and said, "Mete, I've got a great deal for you. Take early retirement, and I'll give you more money, but that way I will be able to move your salary out of the departmental budget." I didn't like it. It was like being fired. Then —would you believe it? —that very weekend Dean Yang of Purdue came to Urbana and made me an offer I couldn't refuse. And that's how I came to be on the faculty at Purdue.

18 Universities Council for Earthquake Engineering Research, *Report on NSF-UCEER Conference on Earthquake Engineering Research, March 27–28, 1969,* University of California, Berkeley, May, 1969.

Hanson: So it was a matter of timing.

Reitherman: How do you find the two universities as a whole, in terms of similarities or differences?

Sozen: Well, Illinois has had the goal of becoming a complete university. It has a school of architecture, school of literature, strong in liberal arts and the sciences. Purdue is agriculture and engineering. Although they tell me there are more people here at Purdue in psychology than in any other department, it is sort of a narrow-band university. There are other differences. Illinois has a very liberal faculty, which is strange, and hard to believe it's in the Midwest. Here at Purdue in 2007, if Mr. Bush, George W., was running again for president he would be elected hands down by the faculty. There are differences in thinking. Purdue has a very contentious faculty. At Illinois, the faculty was like a family, and people seldom said anything that appeared to be selfish. Everybody worked for the common good, at least we pretended to be, and we were what we pretended to be. Here at Purdue, it's just the opposite.

Reitherman: Is Purdue the largest engineering school in the country?

Sozen: It may be the one that produces the most civil engineers. Of course, that may change from year to year, and Texas A&M is also very big in civil engineering. They sometimes call Purdue the Aggies of the Midwest. Purdue was a great undergraduate teaching school. No question about that; they produced good engineers. But now, it's going along a different path. I've got to read the book that I think has the title *Academic Capitalism*. Now, as Illinois has gone, we are going in the direction of academic capitalism. We are more interested in selling research and entrepreneurial work. Purdue is changing. I think it has some wonderful people in it, but the administration is different. It has always been that way. Why? I can't tell you that. It is very much like driving rules. In San Francisco, it used to be that people drove very gently, respecting each other's health so to speak, and New York was just the opposite. How does that happen? Well, it happens I guess through tradition. I think it is the same thing in the academy.

As has been said, "If you hire A-class employees, they bring in A-plus employees. If you hire B-class people, they attract C-class employees." Even though I know very little about administrative matters, I suspect that was the problem at Purdue. Come to think of it, I remember that when Nate asked me to join the faculty, he told me emphatically to stay away from committee and administrative work. I managed to follow his advice throughout my working years. At one time in Urbana, two members of the search committee for a new engineering dean came to me saying that Dean Everitt thought I should be considered for the job. I begged off saying that I was not qualified. A few days later they returned saying that the committee would like to hear my definition of a good engineering dean. I complied. During my interview I announced that a good dean should have lunch almost every weekday with different members of the faculty. They made fun of me. How could a supreme administrator waste time chatting with faculty members? I said otherwise he is not likely to know what needs to be done. That answer shocked them, and I did not think they understood what I was trying to say.

Hanson: Earlier you mentioned that esprit de corps within the civil engineering department of Illinois was very strong, you were very supportive of each other. Around the country now there are some engineering departments and colleges that are that way. Some are the other way, where the individual faculty feel that their own work is the most important, and they compete against each other rather than work cooperatively.

Sozen: Purdue has the tradition of internal friction, I think. That is my observation. I have been here 13 years [as of 2017]. People here do not hesitate to argue for their own selfish interest. At Illinois you never did that, even if you had your self-interest, you never did that.

Hanson: Same discipline, different cultures.

Reitherman: What about the status of civil engineering? At Purdue, is it rising, stable, or declining?

Sozen: I think the university managers now are preoccupied with nanotechnology and bioengineering and my take is that they think of civil engineering as third rate. Hey, it is very clear. Recently we have a new president, who has formed what she calls "Tiger Teams," very much like the federal government, to do strategic planning. Strategic planning is one of those words that always gets to me because strategy means a plan. Is a strategic plan a plan for a plan? [laughter] Anyway, in these groups there isn't a single civil engineer. That suggests how our university administration thinks of civil engineering. On the other hand, our civil engineering graduates now have three or four or five job offers. I'm not exaggerating. There is a tremendous demand for structural engineers these days.

There's a nice thing about dealing with grad students. You deal with them in the best times of their lives and they have their own personal desire, so you don't have to motivate them. If they don't work, they just drop out.

Reitherman: How many advisees do you have at one time?

Sozen: It is usually four Ph.D. candidates.

[See the next page for a complete listing of Professor Sozen's Ph.D. students.]

Ph.D. Students of Mete Sozen at the University of Illinois at Urbana-Champaign

Daniel P. Abrams
Ahmet Emin Aktan
Bekir B. Algan
Jose D. Aristazabal-Ochoa
Juan J. Bariola Bernales
John F. Bonacci
Robert N. Bruce, Jr.
Alex Cardenas-Enriquez
Halek Cecen
Marvin E. Criswell
Jaime De La Colina
Jeffrey J. Dragovich
Mark O. Eberhard
James P. Fedorkiw
Anthony E. Fiorato
Catherine E.W. French
William L. Gamble
Peter Gergely
Polat Gűlkan
Dradjat Hoedajanto
Lung Wen Hsu
Fernand A. Imbeault
James O. Jirsa
Bengt I. Karlsson
Michael E. Kreger
Rolf. J. Lenschow
Andres Lepage
Ricardo R. Lopez
John M. Lybas
Adolfo B. Matamoros
Jack P. Moehle
Walter P. Moore
Denby G. Morrison
Shunsuke Otani
Detlef H. Rothe
Hedley E. H. Roy
Mehdi Saiidi Movahhed
Arturo E. Schultz
Roberto Stark
Manfred F. Stocker
John H. Storm
M. D. Vanderbilt
Howard P. Walther
William A. Welsh, Jr.
James K. Wight
Sharon L. Wood

Ph.D. Students of Mete Sozen at Purdue University

Lili A. Akin
Oscar A. Ardila-Giraldo
Ingo Brachmann
JoAnn P. Browning
Cemalettin Dőnmez
Damon R. Fick
Tűrel Gűr
Burak Z. Koru
Konstantinos Miamis
Baki M. Oztűrk
Santiago Pujol
Jhon P. Smith

Chapter 6

Research

The primer on earthquake-resistant design for the Portland Cement Association is what really got me into the earthquake engineering field for good.

Design of Multistory Reinforced Concrete Buildings for Earthquake Motions

Reitherman: One of your most important research accomplishments must be your role in the production of *Design of Multistory Reinforced Concrete Buildings for Earthquake Motions*, even though you are not listed as one of the authors.

Sozen: The primer on earthquake-resistant design for the Portland Cement Association[19] is what really got me into the earthquake engineering field for good.

I always laugh at myself because at the time the blue-covered book was being done, we were thinking that energy absorption was important. How far would the load-deflection diagram extend? That was wrong. It wasn't the absorption, it was the dissipation that mattered in earthquakes. But I moved from blast-resistant design

19 John A. Blume, Nathan Newmark, and Leo Corning, *Design of Multistory Reinforced Concrete Buildings for Earthquake Motions* (Portland Cement Association, Chicago, 1961, republished 1992).

to earthquakes, thinking that they are about the same more or less. I'm sure Newmark knew much better, but it took me some time to figure out what the demand differences were.

By absorption, I am referring to the area under the load-deflection relationship of a monotonically loaded structure. Energy dissipation refers to the area enclosed within the load-deflection relationship of a structure loaded cyclically. Of course, work by Kazushi Shimazaki later suggested that energy not created does not have to be dissipated.

Hanson: That book by Blume, Newmark, and Corning was very influential. What role did you have in the production of that work?

Sozen: My work in the preparation of that book that book was an education for me. You have to understand the construction materials industry after World War II. The steel industry didn't sell steel—they assigned steel. They permitted you to buy steel. [laughter] This was true, in fact I had friends in the steel industry who told me, "We don't sell it; customers apply to us and then we sell it to whomever we like." It was at that time that reinforced concrete building construction sort of took a step into the game, into bridges with prestressed concrete for example, and for the design of medium- and high-rise buildings. But as the concrete industry developed, the steel industry woke up. I don't know the history first-hand, but I heard that they somehow convinced the engineering profession in Los Angeles to set a height limit on reinforced concrete buildings. And the committee opinion was that it should only be 150 feet. The story goes that when this was being typed the secretary typed 160. It turned out that 150 seemed like a round number, 160 sounded scientific. Maybe the P.C.A. would not have taken notice if it had been 150, but P.C.A. figured that these earthquake engineers out in California knew something.

The concrete industry decided to fight back, to establish itself in the earthquake-resistant construction business for tall buildings. To do that they came to Nate Newmark, because they knew he was a dynamics expert. Nate took the contract and wanted George Housner to work with him. George didn't do it. He either didn't want to get into a commercial struggle or had other commitments. Housner is one of the great academics in earthquake engineering, I think. Then Nate went to John Blume, and thank God John Blume accepted. It was essentially Nate and John Blume who developed the book.

With Leo Corning at P.C.A. were Al Parme and John Sbarounis. Blume had H. Sexton and Rol Sharpe on his company staff working with him. Working with Newmark were Chet Siess, Art Feldman, and I. Because Chet and Art were overloaded with other projects at the time, I ended up as the other worker at Illinois on the project, doing the legwork for Nate.

Reitherman: Let me pry a little bit: what do you mean by legwork?

Sozen: I did the preliminary writing of three chapters, which Nate would then correct and send on.

What was really very fortunate for me is that I was able to interact with John Blume, who was really a highly competent and wonderful engineer in every way. He had a very broad view of life. It was an education to listen to Dr. Blume

discuss technical matters during working hours with Dr. Newmark and switch to art and music during dinners. Both persons had not only brilliance but sensitive egos, and I can tell you a little story about that, involving Blume's reserve energy technique, where it ended up in the book, and the order in which authors are listed on the title page.

John Blume was very preoccupied with his reserve energy technique at this time.[20] It had influenced every one of us. What we do today is essentially a variation of the reserve energy technique. He certainly influenced me, but somehow the P.C.A. staff thought that this would just be too high falutin' to be in the book. Nate had the tough job of convincing Blume that it should be left out of the book. Nate did that elegantly. Bear this in mind: both of these men had great egos. Neither was going to play second fiddle to the other. [laughter] There were some subtle but heated arguments going on, and finally I think Nate convinced Blume to put the reserve energy material into the appendix at the price of Newmark being listed as the second author, which was very unusual for Nate when it came to major publications. And I must note that Nate determined the object and scope of the book and he was on top of every detail.

I still remember Blume teaching me how to talk to a client. He explained to me that it was self-defeating to tell the client simply that you'd design the building. What you should say was (1) you would study the seismological environment to determine the peak acceleration; (2) you would study the soil conditions to determine the correct shape of the response spectrum; (3) you would determine the ductility of the available materials, and so on. The client had to understand the magnitude of the work and pay accordingly.

Reitherman: In the 1961 book, is there the germ of the idea, or the explicit idea, of capacity design Is that the origin of the philosophy of trying to proportion capacities, especially in the frame, such that you're very purposefully designing the hierarchy of inelastic behavior, controlling the capacity of the beam so that it doesn't force more moment into the column than is good for the column? Is that idea in that book or does it come later?

Sozen: I think the germ of the idea is in that book, and it came from a very strange source. Let me use a very simple example. We are to design a frame. You ask the question, how much transverse reinforcement should I use in its members? The Achilles' heel of earthquake-resistant reinforced concrete construction in those days was inadequate transverse reinforcement. People tended to think of reinforcing only in terms of longitudinal bars and didn't pay much attention to transverse reinforcement. And the question was how much of it to put in there. Of course, one way is to go back to the peak ground acceleration, determine base shear, assume a lateral-force distribution over the height of the structure and distribute the base shear to the columns, etc. Now at the same time, work was going on with the similar problem of prestressed concrete bridge beams. If you have a vehicle on a

20 John A. Blume, "A Reserve Energy Technique for the Design and Rating of Structures in the Inelastic Range," *Proceedings, Second World Conference on Earthquake Engineering,* Tokyo and Kyoto, 1960.

prestressed concrete beam of the bridge, how do you design the web reinforcement? How do you determine the shear? A simple solution was found: say we shall determine the maximum weight of the vehicle that can drive over the bridge with respect to flexure. Then, we design the web reinforcement to carry that same vehicle, as it is placed in different places determining the shear from the flexural capacity. The solution made the design of prestressed concrete elements very simple. So when that P.C.A. book was being prepared, the same idea was used. We said, if you know the maximum moment capacity of the column you know the maximum shear that the column is going to develop using simple statics. So you calculate that and use it. Now of course the funny thing is that you can't always do it with reinforced concrete columns because the shear becomes huge, and then compromises are made.

I was wrong and I admit it. I assumed that the shear strength would be exactly what I would have in a statically loaded column or in a statically loaded beam, and it wasn't so. However, the damage was contained reasonably well because at that time Jim Wight was making tests, or maybe a few years later, of reinforced concrete beams under cyclic loading, and was to come across the obvious finding that if you cycle the member the shear strength tends to decay. We had to get out of the strange situation where you designed the girders assuming the concrete didn't contribute to shear, but you had to design the columns assuming it did, because you couldn't do it economically any other way and you could rationalize it by claiming the positive effect of the axial load on shear, at least in theory. So, I think there is no question about the fact that the idea of what is called capacity design came from that book.

Reitherman: What's a better term for it?

Sozen: It is really "balanced design," but you can call it whatever you want. It is balanced design in that you balance the shear with respect to the flexural strength. To ensure toughness of those elements, it was decided that the shear demand should be determined by the flexural strength of the element as illustrated in Figure 6.1 the 1961 book. Definitions of the shear strength and the magnitudes of the end moments changed as more experimental data became available but the overall requirement—that the shear should be determined from the flexural strength of the girder or column—survived as can be inferred from codes related to earthquake-resistant design in the USA. Those who took part in the preparation of the book considered this requirement to be an obvious part of analysis for design requirements. Consequently, they did not assign it a special name. Later, this method was called Capacity Design and adopted by engineers in New Zealand who were also successful in convincing European engineers to use it.

The rule that the sum of the column flexural strengths should exceed the sum of the girder flexural strength at a joint was part of the basic idea. It took some time, and tests by James Wight, to figure out that one should not rely on the concrete strength for shear strength under cyclic loading (the blank portion of the shear diagram in Figure 6.1 of the book) or that column strengths exceeding beam strengths in flexure would guarantee no yielding in columns (JoAnn Browning's thesis at Purdue).

Reitherman: Suppose you were a structural engineer who knew how to design a reinforced concrete building but knew nothing about seismic design. Then you're handed one book, the P.C.A. book. Would that book suffice to produce a decent earthquake-resistant reinforced concrete frame design, even if not as efficient or advanced as you could do with today's know-how? Or have things changed so much that you couldn't do a basically adequate job with that level of knowledge?

Sozen: I must admit I never considered that question. But I would say that it still suffices. It may not be up to the standards of our understanding of reinforced concrete today but, in terms of producing competent buildings that would not fall apart, I think that would suffice. There are incorrect impressions in it because it was done under the shadow of blast-resistant design. Still, an engineer should get the impression from that book that detailing is the most important issue for safety.

Hanson: Was the intent to make concrete meet the concrete moment-resistant frame requirements equivalent to those of the steel moment-resistant frame?

Sozen: The central theme was ductility. The goal was ductility and the tool for it was the moment-curvature diagram, assuming failures in shear and bond were avoided. The book actually tells you that what you need is a force-displacement diagram rather than a force-curvature diagram because it is very difficult to go from curvature to deflection when you are in the nonlinear range. It's true with steel structures as it is with reinforced concrete structures. I think the song was sung with respect to this moment-curvature relationship. Maybe the emphasis should be placed on the relationship between lateral force and drift.

There is a very simple example that I still use. Tests were made in connection with the preparation of the book. Cheap in those days. This was a very simple reinforced concrete beam, [pointing to pages 523 and 524 in the Blume, Newmark, Corning book] and in a way it's an incorrect test because we were loading the beam with a concentrated load and monotonically, the same way that was done in relation to blast-resistant design. But anyway this is the measured load-deflection diagram that showed that reinforced concrete was ductile. This broken line is what you could calculate by "theory." We still don't know how to calculate this limit. It is not easy. Of course, there are better fits, especially if the result is known. If I had to criticize it I would criticize it from that viewpoint, but in terms of getting a good result, I think the book is still adequate.

I still remember Dr. Newmark's disappointment in me when, early one Saturday morning, he was trying to explain to me, with great enthusiasm, how simple it was to understand the maximum relative displacement of a SDOF with a very soft spring being equal to the maximum ground displacement. It was not simple for me, not on that day.

There were interesting developments in writing the book. The concept of determining the amount of web reinforcement required by the flexural strength of the column was inspired by experience with prestressed concrete bridge beams for which the maximum shear was determined in relation to the wheel load that resulted in flexural failure. Unfortunately, it did not occur to me that the shear strength of

a reinforced concrete element would change if the load was cycled. Fortunately, other factors covered up for it until strength reduction was discovered. The numerical method for developing interaction diagrams also came from experience with prestressed concrete. Eivind Hognestad had used the idea of the P-M interaction diagram, but his approach was that of a closed-form solution. I cannot help but smile now when I think that, once I decided to develop it numerically, I had to go to a friend in the Computer Science Department, Bill Gear, for him to help me with the development of the software. Today, a sophomore can do it in a snap. I still have guilty feelings about putting overdue emphasis on the moment-curvature relationship when I knew that to convert a moment-curvature plot to a moment-displacement plot in general took more than I knew then and even now.

Reitherman: Tell us about the role of Corning, the third author listed on the title page. Was he the official P.C.A. person?

Sozen: He was the P.C.A. person with the money.

Hanson: Quality control, from the sponsor's point of view?

Sozen: Yes, you could call it quality control. Actually Al Parme, who was the genius of the P.C.A. in those days, worked on it. He did a lot of work related to details in multi-story frames.

Hanson: One of the things when you work with industry is that they have quality control people that make sure that the message is clear.

Sozen: That's what he did. I thought Corning was very kind and diplomatic.

Hanson: The sponsor needs to be delicate when you have egos involved.

Reitherman: The P.C.A. book generated what might be called a rebuttal,[21] co-authored by Henry Degenkolb and Roy Johnston. Published by the steel industry, it criticized the claim that reinforced concrete frames could have equivalent treatment with steel frames under the seismic code provisions of the Uniform Building Code.

Sozen: I had a taste of Henry's personality. I ran into him when I was in Alaska in 1964. He more or less attacked Newmark via an effigy… and I was the effigy. [laughter] He verbally whacked me out in a technical meeting there. I kept wondering, "Why is he hitting me?"

Hanson: Let me go back to your statement about ductility, that it was the wrong thing to be preoccupied with. I guess part of the problem was that ductility is how people define it. Maybe we should focus on deformability, rather than what most define as ductility.

Sozen: The drift ratio is the key. I was giving a talk about ten years ago at Lehigh University and was asked, "Don't you think buildings should be ductile?" I said, "No, a good design seldom has anything to do with ductility," and that was a shock to them. They seemed to take it personally. Look, if I design a building, I don't want it to have a drift ratio in the design earthquake of more than 2%. That is not much in terms of ductility because a reinforced

21 Henry J. Degenkolb and Roy G. Johnston, *Engineering Evaluation of the Portland Cement Association's Book, Design of Multistory Reinforced Concrete Buildings for Earthquake Motions*, American Iron and Steel Institute, 1963.

concrete frame building may go up to a drift ratio of about 1% before it yields, so I really don't want it to go much more than that. I was talking about that to Jack Moehle the other day and he didn't realize that I was kidding him. This performance-based engineering—collapse prevention, life safety, immediate occupancy—is a joke because you don't have that room. You have this only if you load something monotonically. If you load something dynamically, you're lucky if you can go to a 2% drift ratio in a reinforced concrete frame structure. By the time that is developed, you have lost most of the investment. That really doesn't give you all that room for these various performance states, but the idea has taken hold because it's attractive.

Hanson: You get a lot of "ductility" out of a shear wall building. A shear wall concrete structure has to generate a huge amount of ductility to get to even much smaller drifts. That's why I agree with you that ductility is not the proper term to be looking at.

Sozen: Development of the chapter on design and detailing in Applied Technology Council 3,[22] was exemplary and, to my knowledge, it has never happened again. The drafting of the chapter was assigned to one engineer. The product was then evaluated by a few designers and accepted with a minimum amount of changes. Thus it remained pragmatic, though it contained some old bad design habits. The committees of the American Concrete Institute have included experienced engineers whose main concern has been to keep the code simple, such as Martin VanBuren, Eivind Hognestad, Loring Wyllie, and Chet Siess, as well as many others, but there also are those who make it complicated. An example of the product of the latter type is that we still use force related to the peak ground acceleration to proportion many types of structures. Nevertheless, codes provide a reasonably safe consensus determining the limits of design choices. In my opinion, a code should restrain itself to the definition of the design limits, such as the calculated period of a structure or the minimum acceptable member dimensions, and not be a textbook specifying how the analysis for proportioning should be executed.

Tentative Provisions for the Development of Seismic Regulations for Buildings

Sozen: When I worked on the ATC-3 project, I think the only contribution I made was to convince Henry Degenkolb—and I admire Henry for that —to shift from ductility to response reduction factors, the "R" factors. I said they had nothing to do with ductility. It's reducing the linear response, and I'm very proud to say that I stuck to "R" values of 4 or 2 or 3. I tried to convince others that we don't know enough to go to 3¼ or 3⅛. Unfortunately we did.

Hanson: What did you work on in the ATC-3 project?

22 Applied Technology Council, *Tentative Provisions for the Development of Seismic Regulations for Buildings*, ATC 3–06, June, 1978.

Sozen: I worked on structural design provisions and of course had to do the writing on the chapter on reinforced concrete.[23]

Reitherman: You mentioned in your biosketch notes that you were also simultaneously at work on Chapter 21 of the American Concrete Institute (ACI) building code.

Sozen: The initial draft of Chapter 21. You see I thought that ultimately the great diplomatic achievement of engineering at that time would occur eventually when the SEAOC Blue Book and the ACI 318 came together. I thought that result would be admirable because, after all, SEAOC had been developing seismic code provisions for many years and had the requisite experience. The American Concrete Institute was a newcomer to the seismic code game. To achieve that goal took a long time but ultimately the two tended to come to the same page, so to speak.

My work on ATC-3 taught me that one cannot write a smooth engineering document with many brilliant engineers participating in the exercise, and that one should strive for simplicity even if one knows that it cannot be achieved. The ATC-3 experience strengthened my resolve to limit Chapter 21 of ACI 318 to the essentials, a task at which I was not quite successful.

Strong Ground Motion Records

Sozen: You know it took us a long time to realize the velocity response was much more important than the acceleration response. And guess who identified it? Westergaard, in the year 1933.[24] It is really a landmark paper that very few people know about.

Reitherman: It's fascinating how estimates of peak ground acceleration climbed with time. The Japanese in the 1920s, people like Tachu Naito, were using numbers like 0.2g, or 0.3g based on what they acknowledged were only educated guesses from a 1923 Great Kanto earthquake seismographic record in Tokyo. Comes 1940 and the El Centro earthquake writes a record with a third of a g, and because it's a relatively large-magnitude earthquake relatively nearby, it becomes thought of as a good representation of very severe ground motion.

Hanson: That's a record that went off scale and they extrapolated to estimate what the peak should be, so how much confidence can you have in that? But it became the most widely used record in research, along with the 1949 Olympia, Washington and the 1952 Taft, California records.

Sozen: I always wondered where Nate would have gone in his earthquake engineering research if it had not been El Centro that was the key record. You know I believed it to be so

23 Roland Sharpe was the Project Director of the entire effort. Nathan Newmark was chair of the Project Steering Group for the overall project and also the chair of the Structural Behavior branch of the project, which included the Structural Design group of seven people, one of whom was Sozen.

24 Harald M. Westergaard, "Measuring Earthquake Intensity in Pounds per Square Foot: A Suggested Deduction Based on a Controlling Maximum Ground Velocity for All Periods in a Given Building," *Engineering News-Record*, April 20, 1933, p. 504.

when I was a graduate student, even when I started working on the faculty. The maximum I believed in was a little over 0.3g. At that time there were actually three El Centro records. One was the Caltech El Centro. Another was the University of Illinois El Centro. And then there was the MIT El Centro. They were all reduced by hand. I remember that well, and they were different from one another. You know you can see that the El Centro record here in the P.C.A. book is different from the one that is in the Cal Tech book.[25] But the beauty of the 1940 El Centro record was that it had a wide band response. And I believe Newmark based everything really on that one record.

Hanson: It was also convenient that almost all of the energy input in the El Centro record was in the first ten seconds. So you don't have to do long calculations.

Sozen: In the production of the 1961 Blume, Newmark, Corning book, we had just one spectrum calculated. It took a long time to get those things calculated in those days. But I'm sure Nate had this intuitive feeling before he got into earthquake engineering because there were similar things in ground motion in relation to blast. But they were not exactly the same, and Maurice Biot and George Housner were the first ones to come up with the design spectrum for earthquake motion, no question about that.

Hanson: Smooth spectrum.

Sozen: It made sense. But it was Nate who came with these three simple lines [on a tripartite plot of acceleration, velocity, and displacement] and in a way this was the Hardy Cross, Harald Westergaard tradition.

One of the lines represented what is often called constant acceleration, though he never said constant acceleration; he called it nearly constant acceleration response. The other one indicated nearly constant velocity response, and the third nearly constant displacement response.

I need to tell you a story. Once he had called me to work with him on a Saturday. I must admit all I remember is that our meeting was to be focused on a nuclear containment structure located in one of the Carolinas. I think he had hit on the "tri-partite plot" that week or maybe even that day and seemed very excited. Having looked, until then, only at linear plots of acceleration response full of peaks and valleys, I could not quite follow what I was being told. It took me months to figure out what he was so excited about. Since then I have heard many criticisms of that brilliant insight. I am afraid those who criticize it do not seem to sense the difference between a design and a prediction procedure. Newmark's concept simplified design even if it had its roots in a log-log plot. When one considers how wrong we have been in the business of predicting ground motion and still gotten away with it, the tri-partite representation is a rare vision for proportioning structures, even though we have yet to learn a lot more about the amount of ground-displacement.

25 California Institute of Technology Earthquake Engineering Research Laboratory, *Strong Motion Earthquake Accelerograms Digitized and Plotted Data*, July 1969.

Network for Earthquake Engineering Simulation (NEES)

Sozen: You know how NEES got formed? We had a committee really under the control of Chi Liu[26] at NSF, and we were trying to get experimental equipment for U.S. universities, because we could see that we were falling behind.

Reitherman: Are you referring to the EERI report on the need for experimental facilities?[27]

Sozen: That was probably a product of that committee; what I am talking about happened in the 1980s. We kept making applications to the National Science Foundation for big equipment for U.S. universities and failed. One year while we were having a couple of drinks after another failure, I thought of it as a joke said, "Look, the astronomers just got the big telescope in the sky because all the campuses are working with it. Why don't we pretend that we have a single laboratory that is spread through the country?" Chi Liu took that idea and worked on it very hard, and he really created the NEES idea. He managed to get $80 million from the National Science Foundation for the laboratory that was all over the country. At the same time, Dr. Eugene Wong, an electrical engineer from Berkeley, became head of the Engineering Directorate at NSF. I think President Clinton was going to get the Berkeley chancellor, Chang-Lin Tien, who was also of Chinese background, but that didn't happen and he got Wong instead.

When Dr. Wong came to NSF, the money that Chi had obtained arrived at the same time. Dr. Wong had been in the business of software. This idea later called NEES is about connecting all the campuses through computer connections so that you can sit at Berkeley and have a test done at MIT, you know, that sort of thing. So he brought us all in and told us, "From now on there will be no more testing. We will do everything by numbers, by simulation." I disagreed respectfully. I suggested that theoretical ideas required physical confirmation. And it was cheaper to do it in a laboratory than observe it in damage to the built environment. He told me, "You will learn that you are wrong." There started the downhill path of NEES. It was good for the University of Illinois because NSF gave an IT contract to Illinois for about $12 million. That budget went up and I think the Illinois computer scientists milked the NEES earthquake engineering budget for $15 million. Then they started building sophisticated machines all over the country. My idea was really a joke. It wasn't serious. You couldn't sit here and test there except in rare instances. The idea, carried to its limit, was that you could test a wide flange beam by testing the flanges here, the web in Michigan.

26 Dr. Shih-Chi Liu was a doctoral student of Joseph Penzien and held positions primarily in earthquake engineering at the National Science Foundation for three decades, including a leadership role in U.S.-Japan joint research programs until he was convicted in federal court in Silver Spring, Maryland in 2012 of illegally diverting to himself travel reimbursement money on NSF grants.

27 Earthquake Engineering Research Institute, *Experimental Research Needs for Improving the Earthquake-Resistant Design of Buildings*, Oakland, CA, 1984.

Reitherman: So the shortcomings in the NEES program are Mete's fault. [laughter]

Sozen: OK, it's my fault—not Chi's fault. I may have suggested it, but he made it happen. [laughter] But I never meant it to be that way. I meant it to be a gimmick whereby we would get the support and then do high-quality earthquake engineering research relevant to construction. Then of course, due to some Byzantine intrigue that was going on at NSF, they kicked Chi out of the NEES program and earthquake branch at NSF into a job related to sensors. Later, I was called to a meeting in California. I go there and I look at it and I tell them, hey you guys are like Ali Baba and the 40 thieves. I understood what they were doing. These were not research people; in a way they were running a bunch of hotel chains across the country. Really, that was their attitude. It's Hollywood, not research. Well, now the NEES program has gotten poor reviews. That system does not work. Research is done by individuals through personal interactions. You can't do it by bureaucracy. I was on the first National Academy of Engineering committee that recommended establishing the earthquake engineering research centers. I was intrigued to find that some of the committee members were flown to Washington D.C. by corporate aircraft. In our first meeting I objected strenuously. I said this is nothing but the system that was used in Soviet Russia and it didn't get anywhere. The next year they kicked me out. [laughter] It was that simple. I don't think that the centers were worth it.

Hanson: We're talking now about the first one, NCEER at Buffalo?

Sozen: Look at the scandal. The earthquake center was based in Buffalo, not in Berkeley. That was ridiculous. I agree that Berkeley took it for granted that they were going to get it, so they didn't try very hard. But it was sheer smart management that made it go to Buffalo, I think.

Reitherman: Concerning NEES, I have to say that I was involved as head of the CUREE project for NSF to set up the original management part of the NEES system, the NEES Consortium. But note that we original developers of that organization wrote a proposal that said it would be headed by an "executive director" in the org chart; that later became "chief executive officer," a C.E.O. with a golden parachute. We had a position called the "manager of business and finance;" that position was aggrandized to "chief financial officer."

Hanson: The status now, December 2007, is that there is going to be a re-competition for the NEES consortium, and there will be a big black eye for the whole enterprise unless it eventually does something good.

Sozen: But the underlying system cannot go on. This business of running a hotel for other people to come and use your rooms—proposals funded that make shotgun marriages of investigators at one university and labs at others—doesn't produce good earthquake engineering research. If you are an experimentalist, you need to be intimately involved in your experiment. I have done tests at Berkeley because I did not have the requisite tools at Purdue, but it was very difficult, even though I knew the people there well so there was no miscommunication. It is difficult to be remotely involved.

Hanson: There are some fundamental problems, and there are some logistical and management snafus that could be fixed. Both have been going on.

Sozen: If they will give me $2 million a year so I can pay my lab technicians, I will love it. And they wouldn't ask for anything in return. For the NEES labs, this a great deal.

Hanson: You don't have to go and beat the bushes for that money right? The other half of the whole thing is what Mete pointed to earlier: the vision that NEES is simulation. The notion that, by the end of ten years, we should have the software simulation things up and running that benefited from all of the experiments and obviate the need for expensive experiments. That's not going forward.

Sozen: Research is conducted to fit the requirements of the bureaucracy.

"Transformative" Research

Sozen: Now we all have to do what NSF calls "transformative" research. Do you know where it is coming from? It is coming from the schools of education. We at Purdue have the first school of engineering education—we give Ph.D.s in that. Here's a slick brochure describing it. [He takes a Purdue brochure off the shelf in his office.]

Reitherman: "Transformative" is now getting to be old-fashioned; next I predict we'll be told to be "transcendental."

Hanson: I don't have the qualifications to teach in high school because I haven't taken any education classes.

Sozen: But pretty soon, Bob [Hanson], you can't teach in college unless you go through an engineering education program. [laughter]

Reitherman: I see the word pedagogy here in your university's brochure; I'm scared already! If educators can't talk about teaching and learning, it's a bad sign.

Hanson: This program looks like a bunch of key words, but there is no content.

Sozen: Maybe I am over-generalizing, but I think the American university is captive to the schools of business and education. That is where we are going. These words, like transformative, come from those schools. There is an education journal of transformative education, for example.

Somebody was asking me why this happened at the NSF. In the old days, Caltech would send one of their professors to NSF for a couple of years, and he would manage the distribution of support fairly and elegantly. Now when I think back to Chuck Thiel, I say, "Oh, I wish he would come back." What is happening now is that some people who do not do well in the academy go to the NSF as permanent staffers, quality goes further and further down, and they are the ones distributing the support.

In Bill Hall's festschrift, I presented a paper when the "smart building" was coming onto the horizon. I was talking about this building that would be so smart that, when people came in, it would sense them, know how old they are, even their professions and know which floor they go to. And in the event of the earthquake it could of course sense all the accelerations, and if it looked like one of the floor responses was too much for the building, it would eject its

contents. But being smart, it was also humanitarian in that it would calculate the ages of the people and only if they were old it would shoot them out! [laughter] We talked about this very seriously because I hated that "smart" term. Then, someone comes to me and very seriously starts talking to me and says, "Instead of doing that, why can't you fill them with water and eject the water." [laughter]

Reitherman: I thought you were going to have the smart building eject the lawyers. [laughter]

Sozen: Buildings that have both intelligence and a conscience! [laughter] I don't know. Again, I'm the conservative. I'd much rather put my faith in the structure.

Would you believe that we have one of those smart TV sets at home and I can hardly use it? My wife can't use it at all, she can't even turn it on. It is too smart for us. Thinking back about a month ago [2007], I switched to the Microsoft operating system Vista and the new Word at home on my computers. Sometimes I am completely lost as to what I am doing. When you searched a file in the previous system, it led you to a whole bunch of files, but at least you knew where they were. This one finds it "zip" like that and it gives you that file, but I don't know where it is. [laughter] I just discovered that last night.

High-Strength Transverse Reinforcement

Sozen: Recently, colleagues in the ACI committee, and probably they work with International Building Code (IBC) committees too, decided to switch to high-strength transverse reinforcement. In California, you make only some of the frames the earthquake-resisting part of the structure; the rest are just ordinary frames. How is the poor inspector in the field going to decide which one has the high-strength transverse reinforcement? How can you tell them apart unless they are clearly identified? It becomes a quality control problem.

Core-Only Seismic Force-Resisting Systems for Tall Buildings

Sozen: In California now, some people are pushing for just using core walls in a high-rise building. That scares me, perhaps because of my structural engineering narrow-mindedness if you like. I don't like to go against tradition. These guys are saying we can do it. In fact I was at a competition as a judge in Chicago and a prominent engineering C.E.O. entered a design they had done in Seattle, similar to the tall one now being built in San Francisco at the west end of the Bay Bridge. He said that they had done seven nonlinear response analyses on it, so it has to be good. I was scared, because I work with nonlinear analysis and I can make a nonlinear analysis meow like a cat or moo like a cow.

Hanson: But they better not be very nonlinear. They better be pretty close to being linear. People do nonlinear analyses, but they have to do some thinking beyond that.

Sozen: At Illinois, we were taught a sense of proportion. Above all, an engineer has to have a sense a proportion. Where do you get a sense of proportion? By looking around you, looking at what has been successful. I bet if you grow up in Japan, the sense of proportion is different

from if you grew up in San Francisco or Chicago. Still an engineer has to have a sense of proportion in designing structures.

Experimental Research

Sozen: With regard to experimental research the final arbiter of truth is the experiment, not the analysis. I also have an interest in analysis, and I really operate in between the two. Usually when people get into research they either go towards experimentation, or, which is easier, they go toward analysis. I tend to stay in that no-man's land in between the two.

Hanson: I noticed this reinforced concrete model you have in your lab here at Purdue looks like a real building a few stories tall. Is it full-scale or close to full-scale?

Sozen: It is full-scale.

Hanson: You made a comment earlier that testing a 60-story linear model on a shaking table really doesn't give you much.

Sozen: In that case I would rather do an analysis. It is cheaper. As long as I can model the building, and we can now model almost anything. When we tested these small-scale reinforced concrete frames, we never claimed that these were reinforced concrete frames. We claimed that these were small structures and that whatever we could do in analysis openly we could take to the real world. For example, as long as the dominant action and response was bending, flexure, which we understand, and as long as I could determine the response analytically, then I would have the courage to take that analysis to a full-scale building that would fail in flexure. But if the small-scale model failed in shear or bond, then I am out of luck.

Hanson: Shear and bond are two phenomena that don't scale very well.

Sozen: Correct, and not only that, but I don't have a good theory for you. I cannot project it to different conditions because there are too many unknowns. But I didn't think of these as models or frames but rather models of structural action. I'm embarrassed to tell you that when we tested a ten-story frame I observed, despite my prejudgment, that the first mode was enough to know what was going on with building. I should have known it from analysis. But somewhere in the analytical plane I was confused by the combination of the modes and of course I was thinking of force. So in that respect I think that experiments help show the obvious, something I should have known from theory if I had asked the right question.

Hanson: In the U.S.-Japan Cooperative Research Program Utilizing Large-Scale Test Facilities program studying concrete buildings they had a full-scale building model in Japan, a one-third scale building in Berkeley, and a one-tenth or one twelfth scale building at Stanford. What did you do?

Sozen: I did one-tenth scale experiments and its dynamic analysis. In some ways they were comparable. I would never go to that one-tenth scale experimentation to ask questions about material behavior, but for flexural behavior it was easy. Any structure that you test in the lab does not necessarily represent what happens on the field.

Reitherman: In China I've been in labs in Beijing, Shanghai, and Harbin, where they

have shake table facilities with 30-foot-high models of structures that at full-size will be built to several hundreds of feet in height, high-rises over 70 stories in height. Is it true that shake table test results with such highly scaled models provide results that can be extended only up through the elastic range?

Sozen: That is true. Especially if there are material properties you don't know about. Some people might think otherwise. Look, even within linear response, you reduce the size, and even if you compensate with some added mass you increase the frequency to compensate. So you are operating at a much higher frequency, and the damping properties may not be the same, even within the linear range. In that case I would much rather do an analysis than go to an experiment.

Blast Engineering

Reitherman: You did early work at Illinois with regard to blast effects. Then more recently you have gotten involved again with blast effects. What are some of the fundamental differences between earthquake engineering and blast engineering?

Sozen: In earthquake engineering less mass is its own reward. In impact or blast, more mass is its own reward. Then of course, when you load the structure with blast in one millisecond, the strength may go up, or it may become more brittle. Things like that don't happen in earthquakes unless you are dealing with a low-rise shear wall where the frequency is high and there may be some related material effects. I wouldn't worry about material properties changing in an earthquake because of speed of loading. I would worry about them changing because of size and repetition but not because of speed. But in blast-resistant design they do change.

Reitherman: In blast engineering do you have significant response of the whole structure or is it a more localized effect?

Sozen: I always think of it locally, because when something happens it usually happens locally in the blast. Things happen before the rest of the building knows what is going on, and it depends on the velocity of the impact. That's another reason why most analysts dealing with blast on a column will model it as a simply supported element because they feel that things happen before the column knows what its end conditions are like. I don't think there is any precise relationship, but I think the biggest difference in seismic and blast design is mass. Mass is good in blast resistance design and bad in earthquake design. Also, stiffness is what is important in earthquake-resistant design.

Reitherman: Are there cases where a characteristic of a building is good for both earthquake and blast resistance?

Sozen: Details that work for earthquakes will also work for blasts, in general. For example, if the Murrah Building in Oklahoma City that was bombed in 1995 had been designed for earthquake, it could have survived. The El Nogal Club in Bogota was designed for earthquakes and when somebody burst a car bomb in its parking garage in 2003, the building survived because it had been detailed to resist earthquake. So proper details are good for both.

Reitherman: The blast loading typically impinges on the building from one direction and then it is over within an instant. The earthquake gives you cyclic motion in various directions over ten seconds, or tens of seconds. Does that make a big difference in terms of the detailing?

Sozen: An earthquake tends to change the stiffness and strength of a building. It tires it out so to speak and the blast doesn't do that. In blast, the important thing is that the building doesn't unravel. Look, take the Pentagon building hit by the airplane. It was old-fashioned conservative design for gravity loading. Typically the spans were 10, 15, maybe 20 feet, so when a few columns were removed because of the incoming airplane, the structure survived, and to boot the reinforcement had been carried through the columns. Something they don't usually do. The building did not unravel as a whole. That's how to explain it in one word. The World Trade Center was a fine design—nothing wrong with it. If the insulation had remained onboard I believe we would not have had that tragic collapse. In fact, I remember sitting in my office that day and my secretary coming in and telling me it is on television why don't you come in and watch it? I said why should I watch it? They will put out the fire and that's it. It didn't occur to me that the incoming aircraft would scrape away all the insulation and if you leave steel exposed for a while to the fire it loses strength as well as stiffness and may lead to collapse. So these are the differences. Now that didn't happen in the Pentagon building, because after all concrete is its own insulation, and if you look at the columns the insulation was gone, the cover was scraped off, but there was still some concrete inside that didn't fall apart. I think that is the most important difference between the two. In an earthquake, properly detailed buildings very seldom unravel. In a blast, you can pull out a critical column and much of the building can come down.

Chapter 7

Consulting Engineering Projects

I consider the best work in my consulting career to be the Veterans Administration hospital seismic code, which in my opinion was the first really modern code for seismic design.

V.A. Hospital Building Seismic Code

Hanson: One of the biggest things that happened in the 1971 San Fernando earthquake in some respects was the VA hospital collapse That triggered the Veterans Administration efforts.

Sozen: You know the VA took it seriously. I don't know that it would happen today. But the VA put money into it then. I consider the best work in my consulting career to be in the VA hospital seismic code, which in my opinion was the first really modern code for seismic design.[28] It was done by Bruce Bolt, Roy Johnston, Jim Lefter, and me. If I remember correctly, the business part of that code was fewer than eight pages, and over the years it got reduced

28 Veterans Administration, Office of Construction, *Earthquake Resistant Design Requirements for VA Hospital Facilities*, Handbook H-08–8, March, 1974.

rather than expanding as our codes do now. Bruce handled the ground motion part deftly. Jim knew very well what level of detail to provide to the design engineer. Roy, a soft-spoken and highly creative engineer, set the limits of how much risk we could take.

I remember Roy asking me at the completion of the document production, "Mete, after we retain the best in the west coast to strengthen the hospital buildings, how much do you think the risk of earthquake damage will be reduced?" I made an estimate of at least 40%, which I thought was low. He said, "You will see that some of the strengthening projects will make the building worse." And he was right.

Reitherman: What would be an example of making a building worse with a retrofit? Putting stiffness where it shouldn't be?

Sozen: Let me give you a benign case: a VA Hospital in Anna, Illinois. If I remember correctly, the structural engineer put a 36-inch-thick reinforced concrete wall into one of the bays. This was in a three-story building. Maybe it actually made the building more vulnerable than before because that wall would end up shaking strongly the other parts of the building and end up causing more damage, especially to the equipment. In a hospital building the cost of the equipment may be a multiple of the building cost. I don't want to get into details where I thought engineers misinterpreted the VA Code. But Roy was right to be a little skeptical. He was a great engineer.

And Jim Lefter is not only a highly competent engineer, he also knew how to handle the bureaucracy. There are very few people like that anymore. He pushed it until he managed to fix, as best could be done, all the VA hospitals in the country.

Reitherman: The first new VA hospital built after the San Fernando earthquake was the Loma Linda one, also in a highly seismic southern California area. That design process was so heavily motivated by the VA's insistence to put earthquake safety first that the structural engineers, Rutherford and Chekene, sat down with the architects—Stone, Marracini & Patterson and Building Systems Development—and were able to set guidelines on how to lay the building out. An unusual case of seismic design precepts having such a large influence on the configuration of the building.

Sozen: That reminds me of the case of another VA hospital, not the collapsed San Fernando one but the Los Angeles VA hospital, the Sepulveda Hospital Complex, which was farther from the earthquake epicenter and was moderately damaged. After 1971 we went to visit it. It had unreinforced masonry all over the place. Our recommendation was to close it down immediately. Of course, this was a very expensive closure, and officials in the Nixon Administration didn't like that recommendation. But we stuck to it, and after the building was evacuated, they asked us what should be done with the building. I said, "Demolish it immediately!" because I thought if there was an earthquake and it survived they would hang us." [laughter]

Reitherman: What did you think of the ground motion studies done around the country at the VA hospital sites by Dames and Moore and Woodward-Clyde?

Sozen: A lot of people worked on those reports. Let's say that they were not consistent, but they did improve our perspective of the risk in the U.S.A. Until that time we didn't believe that the peak ground acceleration could exceed 0.5 *g*. In fact, I still remember the day after the San Fernando earthquake in 1971 when George called us into Caltech and showed us the Pacoima Dam record that they had obtained, with its peak acceleration of over 1 *g*. It was a chilling moment.

Reitherman: The late David Leeds told me that in 1952 he was working for the Coast and Geodetic Survey and was the one who went out and retrieved the Taft record—from the instrument he had earlier installed —and he processed the record. He was proprietary in a subtle way about that squiggle—he put the accelerogram on his business card. He pointed out that the town of Taft is on the western side of the Central Valley, 40 miles from the earthquake source of the 1952 Kern County earthquakes in the mountains over on the eastern side of that very broad valley. He concluded that there were stronger motions in the earthquake than the less than 20% *g* recorded at Taft, but Taft just happened to be the place where a strong motion instrument was located and could document the shaking. Those two records, El Centro and Taft, were very often used in earthquake engineering research, though in retrospect, there might have been reason to speculate that they could be surpassed. In the NOAA volumes on the San Fernando earthquake, even as late as 1971, you can find in the section written by the EERI team an estimate of 0.4 *g* for the peak ground acceleration in the heaviest-hit corner of San Fernando Valley, near Olive View and Pacoima Dam. This was where one-fourth of the roof area of tilt-ups in an industrial park had fallen on the ground. They were not the code-complying tilt-ups or masonry wall-wood roof buildings with the wall-diaphragm connections we would use today. Nonetheless, if an earthquake engineer went out and looked at the same area and its damage today, they might well say, "This looks like more than 0.4 *g* peak ground acceleration." The engineers had to get re-calibrated.

Reducing Earthquake Risk in Turkey

Sozen: I appreciate the earthquake risk in Turkey. I know what is going to happen to Istanbul. I know the buildings in Istanbul. I have analyzed them, I have studied them. And I know that the threatening earthquake may occur today, and if it happens, it will make the Hurricane Katrina disaster in 2005 in New Orleans look minor.

The city grew from about one million in the 1960s to about 15 million now, with mostly, I would say, substandard construction—very bad, very weak, very badly detailed construction. Much of the city will go down on its knees. There will be little water, little food, damage to hospitals, transportation systems disrupted, and I've been working on that problem for some time now with no result. Bruce Bolt was kind enough to come and help us out, just before he passed away. The information we need is available, but there's no action.

What I saw in the 1992 Erzincan earthquake, the 1999 Izmir and Düzce earthquakes, and the 2003 Bingöl earthquake increased my concern about Istanbul.

With Polat Gulkan of the Middle East Technical University in Ankara, Dr. Otani and Dr. Okada of Japan, and Bruce Bolt of UC Berkeley, we organized a workshop in Eski Doğanbey, an old village near Izmir, in 2005. [See later discussion of Eski Doğanbey in Chapter 9.] The conclusion from the workshop was very simple. There had been enough risk assessment. There had to be action. With the help of an old friend, Ersin Arioglu, who, besides being an outstanding structural engineer in Turkey, was a member of parliament, we took the report to the Turkish Prime Minister and his cabinet. We proposed a specific plan for starting to strengthen the buildings in the city. But nothing happened.

Hanson: Lack of money, lack of resolve?

Sozen: Other crises took precedence. There is always a crisis. We have been in touch with the government, with the Prime Minister. The government is always dealing with today's problems, rather than concerned with ten years in the future.

Hanson: Our country is not much of a role model in that respect.

Sozen: That's true. Our first plan was for how to fix the city within 15 years. That wasn't going anywhere. We met with a committee of the Turkish Security Council that understood the risk quite well. We suggested that if the strengthening plan was politically infeasible, an alternative would to build a new satellite city so that you could move the banks, the corporations, the hospitals, and government offices there so that at least they would stand up after the earthquake. There would also be a place for refuge, for the people to go to. Well, I'm finding out that that is not going anywhere. I've even made an animation out of the idea, just to sell the idea. [Sozen shows a 3D animation of buildings in the new city.]

Hanson: The roofs are green. Did you have plants growing on the roofs?

Sozen: I used a concept from an old Turkish symbol, the eight-pointed star, and yes, I have plants growing there. It is a green city, and it is a cyber city.

Hanson: They weren't interested in building a new city outside Istanbul?

Sozen: They want to make sure that they get the maximum dollars out of the city before they release it, and they keep holding it back.

Reitherman: Where would it be built?

Sozen: That's a secret, but in the northern part of Istanbul. It would be far enough away from the faults, and it would be earthquake-resistant construction. It would be a well-developed city. Of course, the minute this thing becomes a fact, they will probably have teams of architects and city and urban planners working on it. I mean the concept is just a preliminary toy.

Everything will no doubt be computer-controlled to the point that if you take a fall, the emergency medical people will know about it and send an ambulance—we are joking about unbelievable things, of course. There will be smell sensors in every apartment building so that when people cook, the smells will be registered and the information sent to the supermarket. Then they know what to stock. And of course there will be cameras all over the place. It will be an impossible place to live in. It's all

against my principles. We had two meetings with the Prime Minister and his people on the new city idea, and they seemed to be very enthusiastic until they found out that our proposal was to put the whole thing under a single authority. None of the ministers liked it. So the project management had to be left loose to be divided among different ministries.

Hanson: Because they are losing power?

Sozen: Losing support. That's why that was pushed to the back burner. When we went to talk to the Security Council they understood. They were the people who were very open to the idea of having another city nearby to save some people and take the others in. I thought that was going to go and I worked very hard on this. I had six students from computer science working with me. But it slowed down because of the expenses associated with it, I believe.

Now it is my third try, after the incremental retrofitting of the city and the satellite city concepts were dead ends. I'm trying to develop a plan to evacuate the city through boats. I call it the Marine Evacuation. I think that might work, because you have to take the people out of there. When it occurs, they can't live in the dysfunctional city. Now I have to get in touch with the Turkish Navy and see. They have to do a rehearsal. Without a rehearsal it is nothing. Istanbul is really a very exciting place to live. But every night we stay there, I worry. I don't want to be in Istanbul when the earthquake occurs. You have the whole list of the vulnerabilities—soft stories, stories added to old buildings, unreinforced masonry, poorly detailed concrete frames, inadequate consideration of the geological conditions.

Reitherman: Where would you take the refugees?

Sozen: Around the region. You may have to take as many as six million people out of there and that is not easy. It's difficult to get people to confront these issues.

Reitherman: In Orhan Pamuk's *Other Colors*, he describes the reaction of one woman to the 1999 Izmir earthquake and how she confronts earthquake risk. She says, "I'm extremely afraid of being on a balcony when the earthquake occurs. I just know I'm going to be thrown off or it will collapse. I remember walking down the street and there was a balcony all crunched up. I'm just very afraid of balconies." So she says, "I am going to walk out on your balcony right now. I'm here, intentionally feeling my earthquake fear, because I know it can happen any time, maybe right now, but I have to live my life, so I'm actually going to stand here. I'm going to say I know it can happen anytime but that I'm going to go on with my life." Maybe that's fatalism, maybe that's practical, but of course, retrofitting balconies and buildings would solve both the psychological and safety problems.

Hanson: What about your first plan, retrofitting the existing construction? Is that idea moving ahead?

Sozen: Very, very slowly. You know in Istanbul the land is worth more than any building that you have, unless you have a 30-story building or higher. The typical building is five to eight stories high. Our plan basically was that we have a kitty of about $10 billion to start with which we could get from anyplace really. Turkey is rich; there is cash flow in Turkey.

The plan is to go to the building owner or owners and say, "We would like to take you out of your vulnerable apartment building and put you in another building for six months. We will destroy your building and build a new one and we will add two stories. Those two stories will pay for rebuilding the building. Those two stories will belong to the state and the state will receive rent from them.

It was a very simple plan and of course I don't think we shall finish fixing the entire city by the time the earthquake arrives, but it would help reduce the expected disaster. I was at a party talking to a friend of my childhood and I explained this plan and he said, "I have three large stores on a very busy street in Turkey. You're going to tell me those stores will be out of business for three or six months?" I said, "Yes" and he said, "The rent on those stores is $50,000 per month. I can have you killed for $800." [laughter] He was right in his cost estimates.

Hanson: A lot of storeowners wouldn't want to do that because they feel that all the customers in that length of time will find a replacement store.

Sozen: My friend continued to say, "The earthquake doesn't scare me. My kids live in Switzerland anyway, and if there is such a thing as this big disaster I will come back and buy land cheap, and then my family is fixed for the next six generations." [laughter] This is the corporate thinking that defeats efforts to reduce earthquake risk.

Hanson: I have a colleague who bought a place down near San Bernardino, right next to the San Andreas Fault. He got a mortgage to 90% of the value, and uninsured for earthquake damage, keeping the money he might have spent on a big down payment for the house in investments. He says when the earthquake comes, the house will be trashed, and he will turn it over to the bank. The bank can own it and he will take his money out of the bank and buy four more places right in that area. Because the real estate prices will go way down.

Sozen: And that means that the bank will lose the money?

Hanson: The California law is that if you have a loan on a house, the bank has rights to the house and no rights to any other of your money.

Reitherman: Any recollections about A. Rifat Yarar?[29] From visiting some engineers in

29 A. Rifat Yarar (1913–2004) received his undergraduate degree from Istanbul Technical University and shortly thereafter helped organize one of the first conferences, perhaps the first conference, on earthquake engineering in Turkey after the 1939 Erzincan earthquake. In the 1940s, he helped the Ministry of Construction develop Turkey's first seismic code. After receiving his master's and doctoral degrees in structural engineering from Harvard, he returned to Istanbul Technical University as a faculty member. In the 1950s, Yarar's expertise in earthquake engineering was boosted by visits to his university from Japanese engineers, including Hajime Umemura and Kiyoshi Muto. At Muto's invitation, he stayed in Japan for a long visit after the 1960 Second World Conference on Earthquake Engineering, helping to organize the International Association of Earthquake Engineering. With this background, he was the obviously qualified person, perhaps the only person with

Turkey a few years ago, I got the impression he is respected, perhaps revered, as the originator of modern earthquake engineering in Turkey.

Sozen: Dr. Rifat Yarar was a brilliant professor at the Istanbul Technical University. Unlike many of us Turks, he was neither self-centered nor selfish. He did not think that he had built any one of the seven hills of Istanbul, and he was sincerely interested in the future of Istanbul. He was of great help in organizing a series of meetings to inform the public of the risk for the city. It was wonderful to have someone like him as an advisor in getting us in contact with the right people and telling us the limits of what could be done to help save the city.

Reitherman: I believe he was someone who might be referred to with the respectful "effendi"?

Sozen: Yes, but now anyone can assume that prefix to their title; it's inflation. Turks are too preoccupied with honorific titles. If I introduced myself to someone as Professor Doctor Sozen, you might think that was a little much, wouldn't you? But it's done.

the necessary standing, to organize the Turkish National Committee for Earthquake Engineering in 1965, unifying the disparate university, government agency, and practicing engineer interests in the country.

Chapter 8

Studying Specific Earthquakes

Looking at earthquake damage is very, very important because you can't do everything by numbers, and laboratory experiments test what you think needs testing, while the earthquake tests everything.

Hanson: Talk a little about going out to look at earthquake damage.

Sozen: Where do I start? Looking at earthquake damage is very, very important because you can't do everything by numbers, and laboratory experiments test what you think needs testing, while the earthquake tests everything.

1960 Agadir, Morocco

Sozen: The first damaging earthquake of the 1960s I recall was in Agadir, Morocco. During a period of 5 seconds, 15,000 people were killed because the buildings had been built without any concern for earthquake resistance. I don't think there had been any earthquakes there for a long time, and the French, who colonized Morocco, really didn't know about earthquake engineering.

Reitherman: Agadir may still hold the record for the smallest magnitude, 5.7, to cause such a large number of fatalities. The earthquake was very shallow and was a direct hit to the city above, and as you say, there was a very vulnerable building stock.

1963 Skopje, Yugoslavia

Sozen: The Skopje earthquake in what was then Yugoslavia once again showed the problems with reinforced concrete construction—that's why the steel people loved it. It demonstrated that you could have torsional oscillations in a building and a building could fail because of that. That is the thing that I really remember. It hasn't happened very often since then. Maybe once in Alaska then once in Mexico City, but otherwise many buildings that should have destructive torsional oscillations don't. Of course, identification of the "captive column" problem was a product of the Skopje earthquake.

1964 Alaska, U.S.A.

Sozen: Alaska, of course, was politically very important because it was then that the California Senators got into the game to start what became the National Earthquake Hazards Reduction Act, NEHRP. Senator Alan Cranston became very influential in that cause. The Alaska earthquake was also the event that enriched Professor Seed, because of the liquefaction. I still remember him out in the field there, overjoyed. And Alaska showed a few mistakes that we could make with prestressed concrete construction. In my opinion, the Four Seasons Building collapsed because the shear wall wasn't connected to the foundation properly. It had very short anchorage, and when the shear wall experienced overturning, the whole structure overturned. It wasn't the fault of prestressed concrete, although you could see the cables all over the place that shot out. In my observation, it was a continuity problem. There was also the complete collapse of the Anchorage airport control tower. Again, it was an anchorage problem, a detail problem. You know, engineering is detailing when you come right down to it.

Reitherman: What about the coupled shear walls in the two identical buildings, the Mount McKinley Building and the 1400 L Street building?

Sozen: May he rest in peace, Karl Steinbrugge used to talk about vertical shear versus horizontal shear, which has to do with those coupled walls. We didn't know enough about how these things behaved and it came to us right straight in the face where you could have one wall going down in one edge and the other one going up at the neighboring edge and tearing out the connections in between.

1967 Caracas, Venezuela

Sozen: Didn't I see you in Caracas, Bob [Hanson]?

Hanson: Yes.

Sozen: There was a formula in the SEAOC blue book that said if you had a structure of so many stories, then you could reduce the overturning moment because of the interaction of the modes.

Reitherman: The *J* factor?

Sozen: The capital *J* factor, you are quite right. Then we go to Caracas and we find axial tension cracks in columns. I don't think that if we didn't have that field experience, we would have been convinced that there was something wrong with the method of considering overturning. I think it is very important to make detailed, serious analyses of earthquake damages. I benefited from it tremendously myself in terms of my understanding of structural behavior.

But observations can be misinterpreted. Let me cite a trivial case. I talked to one lady who was on the top story of one of those ten-story buildings that collapsed in Caracas. She described the earthquake as a bunch of vertical jolts or decelerations. Of course! She was riding her story down and felt each story crush in sequence under her pancaking building, one by one.

Reitherman: What about the Caracas earthquake in terms of depth of soil deposit and how certain sites responded versus other sites?

Sozen: The most dramatic thing was the limitation of the damage to a very small portion of the town. And the fact that the earthquake epicenter was way offshore. Sort of a mini 1985 Mexico City earthquake. The other one was the overturning moment that some of these buildings experienced.

Reitherman: Did the 1967 earthquake have a big code influence in the U.S.?

Sozen: It did with respect to the *J* factor. By that time I think we knew that we needed transverse reinforcement, that we needed anchorage.

Hanson: At that time we were beginning to understand we needed continuous bars on the top of the slabs. Some of the slabs were failing. They used bent bars and straight bars that weren't long enough. The slabs would fail there. So I think the continuity of steel top and bottom reinforcement through the beams was introduced into the U.S. code shortly after that.

Sozen: I think that it also woke us up to the fact that you don't build a building and then add one or more stories on top of it later with rather poor connections. I think it was the Mansion Charaima that failed that way. Four stories were added to a building that originally had seven stories, and since then we have seen many other examples of that. If I remember correctly, that was the first time the problem made itself strongly visible. And the knowledge disturbs me, being aware of the number of buildings in Istanbul having added-on stories.

1971 San Fernando, U.S.A.

Sozen: The next earthquake I visited was San Fernando, which again repeated the same things. I don't think there was a surprise at San Fernando other than the Pacoima Dam record with its peak over 1 *g*. It was almost like we should keep this a secret. [laughter]

Hanson: A big study was done to see if the large acceleration was due to a site effect, if the cracking of the rock under the instrument would jack the acceleration up that much higher. What surprised me in the San Fernando earthquake was the psychiatric building of Olive View hospital, with lightweight concrete. That essentially exploded. There were fragments of concrete 50 yards away from the building.

Sozen: Add of course the non-collapse of the Olive View main building. It didn't collapse because of the spirally-reinforced columns. But it was really asking for trouble because of the soft story. There was a very heavy, relatively rigid, mass sitting on top the first-story columns.

Reitherman: Olive View was a very expensive new hospital to throw away but a good investment in earthquake engineering research and education. Thousands of engineers memorized the photographs that show destroyed columns that had little transverse reinforcement next to damaged but still intact columns that had much more transverse reinforcement.

Sozen: Before we get away from San Fernando, there is the damage to the Lower San Fernando Dam. I saw it from the air; I couldn't believe my eyes because it was the perfect Swedish Circle of Failure, and I think it was on the verge of going away and flooding over 80,000 people downstream.

Reitherman: What is the Swedish Circle of Failure? Sounds like a group you're banished to if you really screw up.

Sozen: The "Swedish Circle" is an idealized model used in determining slope stability. The collapses of freeway overpasses in San Fernando motivated Caltrans to start doing something, which was another big outcome of the earthquake.

I must tell you this out of personal viciousness, though I won't mention the name. There was a design of a surge tank in the California water system. I had gone to Sacramento to talk about that project with some of the engineers in the state agency. This was a few years prior to 1971. One of the leading bridge engineers of Caltrans was there and I asked him, "How do you design your bridges to resist earthquakes?" He said, "We use the Uniform Building Code." And I said, "But the Uniform *Building* Code is calibrated to buildings, not bridges." He said, "When was the last earthquake in Illinois?" [laughter] I didn't say anything, and then comes San Fernando and Caltrans loses its bridges. They lost bridges in Loma Prieta, and they lost bridges in Northridge.

Reitherman: If you didn't know any better you might have thought that seismic bridge engineering would have preceded seismic building engineering simply because the former type of construction is such a pure engineering problem. The typical bridge more closely matches the structural diagram of it, while a building is complex—even a relatively simple building is a relatively complicated 3D structure, and of course that structure is stuffed full of various nonstructural components that bridges don't have. In Penzien's EERI oral history, however, he describes how that wasn't the case, and in fact that bridge seismic codes lagged behind building seismic codes.[30]

Hanson: I will give you my prejudice. The reason that it occurs in California is that Caltrans employed all the engineers that designed the bridges. It was all dictated in-house by one organization.

30 *Joseph Penzien, Connections: The EERI Oral History Series*, Stanley Scott and Robert Reitherman, Interviewers, Oakland, CA, 2004, p. 85.

Sozen: There is one more factor. Where do your better students go when they become structural engineers?

Hanson: Private practice.

Sozen: It is the level of experience of students who go to the bridge departments and public agencies that affects the design quality.

Reitherman: LeRoy Crandall, in his EERI oral history,[31] tells the story of coming out of UC Berkeley, getting a job with the State Highway Department, and lasting only nine months, even though he was getting decent pay out of it. Whether it was a culvert or bridge or whatever was needed, they would turn to a page in the manual. He thought that he had studied to be able to do engineering, but he wasn't really engineering anything. That's when he got a job with Dames and Moore.

Sozen: That was fortunate for him and fortunate for us

1972 Managua, Nicaragua

Reitherman: What was your experience in studying the Managua, Nicaragua earthquake in 1972?

Sozen: They had two tall bank buildings in Managua, Banco de America and Banco Central. The behavior of the wall building, Banco de America, was much better than that of the frame building, the Banco Central, and I think that was the strongest impression. Was there anything else?

Hanson: In the wall building, the coupling beams were penetrated with openings for ducts, and that caused damage.

Sozen: Yes, the Banco de America had critical structural failures, but the real estate it contained survived, because it didn't drift very much. The other building had some structural failures, but it was so flexible that there was great nonstructural damage and it became virtually a total loss.

Reitherman: I don't know the truth of it, but I heard T.Y. Lin say in one of his structures classes that the yielding of the connecting beams was by intent, to lengthen the period of the structure and move it out of the part of the spectrum that was most intense.

Hanson: A huge vault was in the basement of the Banco Central, and my recollection is that one of the secondary faults went around the vault. So you could actually track the trace of the fault around the building.

Sozen: Managua was a hard place to live. I stayed there for about three weeks in a tent and it wasn't fun. The tent was actually in a garden of the residence of President Somoza.

Hanson: We stayed in a steel fabricating plant about 20 kilometers away, sleeping on cots.

Reitherman: Chris Rojahn tells one of his early experiences in the earthquake engineering field. He was on a DC-3 that Somoza had loaned to fly earthquake investigators around, and Henry Degenkolb was on the flight. Henry went back to use the little potty in the back and then couldn't figure out how to open the door.

Sozen: Because it slid.

31 *LeRoy Crandall, Connections: The EERI Oral History Series*, Stanley Scott, Interviewer, Oakland, CA, 2008, pp. 13–14.

Reitherman: He was banging and yelling and nobody could hear him with these loud motors. Finally someone went back there and opened the door and saw that Henry had largely disassembled the door with a pocket knife trying to get out.

Sozen: That was on the return trip, I think. It wasn't during the earthquake, it was after the earthquake when Somoza invited some engineers back. Somoza soon lost the country, partly because of that earthquake and the way his government responded to it.

Hanson: Yes, the Sandinistas took over the country because of that. Of course that was also in the context of the corruption before the earthquake as well as the corruption and poor response following the earthquake.

Sozen: I had been to Nicaragua the year before to give a talk, and they said that there will be a cocktail party afterwards and the great Somoza would come. I didn't see him. But I was having drinks with a guy that I was sure was a colonel in the U.S. Army because he was from West Point and he spoke with a perfect American accent. Afterwards I asked, "So where was Somoza?" And they said, "You were talking to him." [laughter] I thought he was an American military officer, which in a way he was, coming out of West Point.

1978 Sendai, Japan

Sozen: Were you there in Sendai, Robert?

Hanson: Yes.

Sozen: We went to Sendai as a matter of protocol. I think it was Dr. Watanabe who felt that America hadn't sent its best to Sendai, that America was taking Japan lightly. So the Japanese pooled together a group of us and brought us over there. But in general the buildings there had done very well, hadn't they?

Hanson: Except for some of the school buildings. The short-column shear failures at the windows in these school buildings.

Reitherman: In that 1978 earthquake, along with the 1976 Tokachi-Oki earthquake, we saw the kind of school buildings with short "captive" columns between the strip windows, columns accidentally shortened and stiffened by the concrete spandrels.

Hanson: It did two things for Japan, but it didn't do much for us in the U.S. One is that they established a good research program on concrete in Japan, and they started a seismic retrofit program for those types of buildings. They were cutting vertical slits through the spandrel walls or beams to separate them from the columns and putting soft material in there to eliminate the short columns.

Reitherman: That must be one of the most bewildering retrofits to the ordinary person. The earthquake engineering experts say, "We are going to make your building more earthquake-resistant." Next thing you know—bzzzz bzzzz bzzzz—concrete saws slice through your walls, and then they say, "There, now that we've weakened the structure, it's much better." [laughter]

Hanson: Not everything in earthquake engineering is intuitively obvious.

1985 Mexico City

Sozen: Of course, Mexico City is another remarkable earthquake. It was a special event. Yes, it was an earthquake, but the ground motion is not what we normally deal with.

Hanson: Not typical California ground motion.

Sozen: Not typical anywhere else ground motion. It is a lake motion, it is a sea motion.

Reitherman: What about the Torre Latinoamericana that Newmark had consulted on — the big tall steel building. Do you know anything about how that was designed?

Sozen: I think Bill Hall should be able to give you that information. What I know is that the building had already been designed before Nate got into it. In fact, it was already being built and Nate essentially gave them a clean bill of health after analyzing it. Nate was not only brilliant and creative, but he was also lucky. [laughter] The survival of the Latinoamericana Tower was really no big deal in 1985 because it was way out there on the spectrum of periods, so tall it was much longer in its period than even the 2-second predominant motion period in some parts of the city. It wasn't affected very much. If I had designed that building, I might have put it right there [indicating the peak on the response spectrum].

Hanson: But it was really a tough building. It was not under-designed.

Sozen: When I was in Mexico City looking at the damage, they told me about a tall steel building collapse, which of course wasn't the Torre Latinoamericana. My Mexican guides kept saying there was a tall building that had collapsed at the Pino Suarez complex, and I kept looking for a tall building. I turn around and I see this collapsed building in front of me. It was a religious experience to see a 21-story building lying on its side.

Hanson: And knocking down a neighboring 14-story building on its way down. Of course, if you like conspiracy theories, the reason the building collapsed was because the government stored military ammunition on the upper floors and that increased the lateral forces.

Reitherman: Another theory is that the name of the building doomed it: Pino Suarez was a vice-president of Mexico, who, after one of their revolutions, was taken out and shot. Not a good omen. The Pino Suarez building was the first I had ever seen that fell over, not down. The generalization we learn is that a building comes pretty much straight down when it collapses. The earthquake uses up its vertical-load-carrying capacity by yanking it back and forth enough times, and then gravity, which every second has been patiently waiting, pulls the weakened structure down. A good generalization, in terms of statistics, but not a good generalization if it keeps you from thinking of the exceptional case.

Sozen: They told me that there was a janitor that happened to be on one of the upper floors and he survived. But you know, we looked at that damage and we said, "Ah yes, Mexican welding." The Japanese came and looked at buildings after the Northridge earthquake and said, "Ah yes, American welding." Unfortunately, within a year of that event, the same observation was made in Japan in the Kobe earthquake.

Hanson: It is easy to criticize. The buildings in the Pino Suarez complex were designed to keep the subway from floating. The whole block of five big Pino Suarez buildings was built over a subway line and station. That hollow volume of the subway, in the soft soil, had buoyancy, and needed the heavy lid on top to stay put. So when they were talking about the demolition they had to be careful to maintain enough weight on the platform so that the subway station underneath wouldn't rise. All five buildings were on the same foundation platform.

Sozen: Did you hear the story of the guy in the medical campus? He had just bought a refrigerator and filled it full of beer, and when the building collapsed, the refrigerator held up the ceiling over him, but he was pinned in there for several days. He was very happily drunk when they got him out. You know dehydration is the worst thing. He didn't dehydrate.

Reitherman: A "religious experience," making a true believer of me in the difference in dynamic response of buildings because of their periods of vibration, was the completely collapsed ten-story Juarez Hospital across the street from an undamaged one-story pharmacy where the contents stayed put on the shelves.

1985 Algarrobo, Chile

Sozen: The Algarrobo, Chile earthquake in 1985 was very important for me because when I first went there and started looking at buildings, I said, "Hey these guys must be in cahoots with the Japanese." Like the Japanese, their reinforced concrete buildings had large members, lots of walls. Only to find out that no, it was their own style of building. In fact I wrote a paper called the "Chilean Formula." What they had done, very simplistically, was to limit the shear on their columns and walls to 5 kg per square centimer, about 50 or 60 psi. That gave them huge column sizes and numerous thick walls. In fact I also wrote a related paper about designing walls based on the drift ratio. But suddenly the Japanese idea clicked for me and I said, "If you have a building that is not very high so that you don't have the problem of multi-mode response, all you have to do is have big low-stress columns." In a way that was demeaning because I have grown up on the approach of *Design of Multistory Reinforced Concrete Buildings for Earthquake Motions*. People misunderstood the book. They thought that a reinforced concrete frame had to be ductile and flexible, which were interchangeable in people's minds. In fact there was a building in Managua that had been designed by this book and the designer had made it intentionally flexible. Anyway, it sort of set me back but I started thinking about it after Chile. The Chilean engineers didn't pay much attention to detail but they paid attention to size and they got off easy when the earthquake came. I think there was only one major failure, the El Faro building, which went over because I think it had very light reinforcement and the reinforcement fractured. But other than that, what I learned from Chile was that if one simplified the design sort of along Japanese lines of having so many square inches of area of columns or walls for so many square feet of floor, it would work. The Japanese and Chileans think differently, but they came up with the same answer.

Reitherman: Sharon Wood was a student of yours?

Sozen: Yes.

Reitherman: She wrote a paper[32] on the statistics of a few hundred large reinforced concrete buildings in Viña Del Mar in the 1985 Chile earthquake and how good their performance was. About 80% were undamaged—the top of the performance scale. Then she studied the ratio of the quantity of shear walls in plan, that is, the measure of resistance, compared with the quantity of floor area, the measure of load. Comparing these ratios to U.S. practice, she found that the Chileans allocate a lot more wall and they are getting more performance out of it, but it is something that American designers feel that they can't do, given the architectural restrictions.

This also relates to some research you did with regard to Turkey for new design or for the evaluation of existing buildings. For buildings of a certain type and kind of material, you would add up the square centimeters of wall, a measure of resistance, and compare it to the square centimeters or meters of floor area, a measure of seismic load, to produce a ratio. A high ratio would predict good performance, a low ratio poor performance.

Sozen: In fact, later I wrote a three-page code for Turkish buildings in reinforced concrete. Maybe I'm exaggerating, but it was very brief, which of course they threw away. Because Turkish engineers belong to the upper class, they are very sophisticated, they don't like to be understood, and something that simple would be beneath them. The Turkish code is based on the Uniform Building Code, but is much more sophisticated and scientific than the Uniform Building Code.

A problem with the approach is that if you design a building by the design part of the code and check it against the evaluation part, the building is likely to be designated as a vulnerable structure.

Hanson: That's like designing by the new building code and checking it by ASCE 41, *Seismic Evaluation and Retrofit of Existing Buildings*, and finding the brand new building is already deficient, right? Same philosophy? [laughter]

Sozen: The basic procedure I used for the proposed Turkish code really came out of the Chilean experience, although it was inspired by Toshio Shiga and Akenori Shibata. We call it the Hassan Index. I worked on it at Purdue with an Egyptian engineer, Dr. Ahmed Hassan.[33] You need to have a certain amount of wall or column area for a given amount floor space. You can design a seven-story building with that, and it works as verified by the 1992 Erzincan earthquake, and I think it worked in the Düzce earthquake in 1999, the Izmir earthquake in 1999, and the Bingöl earthquake in

32 Sharon Wood, "Performance of Reinforced Concrete Buildings During the 1985 Chile Earthquake: Implications for the Design of Structural Walls." *Earthquake Spectra*, 7 (4), pp. 607–638, 1991.

33 Ahmed F. Hassan and Mete Sozen, "Seismic vulnerability assessment of low-rise buildings in regions with infrequent earthquakes," *ACI Structural Journal*, vol. 94 no. 1, January-February 1997.

2003.[34] The method doesn't require spectra and so on, and in a way that is demeaning to sophisticated engineers, but it works.

Reitherman: There really isn't anything like that in the U.S. code is there? Putting one of the approved lateral braces every 25 feet in a small woodframe building isn't really the proportional idea of relating floor area, as a surrogate for mass and thus seismic force, to the amount of wall, which represents the resisting force.

Sozen: In the Japanese code there is. The problem of the Hassan Index is that it doesn't tell you how strong the earthquake is going to be and it doesn't change with the intensity of the earthquake, but the buildings are not that sensitive.

Reitherman: From the architectural side, one of the beauties of simplified structural methods would be very quick guides for architects for laying out a building, a simple way to realize that you don't have enough wall, either in the right place, or not enough of it overall, and you would get a sense for that early in schematic design. Unless the ideal (and rare) case applies, where you have an engineer and architect sitting side-by-side right from the first blank piece of paper on the drawing board, the architect begins to make preliminary configuration design decisions alone.

Hanson: Architects are out front dealing with the client and selling their designs before the engineer enters the picture, and then you can't change the designs, right?

Sozen: Architects don't like the results of this simplified approach, because it requires a lot of columns and a lot of walls. You can't move concrete walls around once you build them.

1989 Loma Prieta, U.S.A.

Sozen: Loma Prieta wasn't a major earthquake. I was amused to hear my colleagues in San Francisco say, "You see we came out of it with flying colors." It wasn't a San Francisco earthquake, it happened way over there to the south. But I do remember going to the Veterans Administration psychiatric hospital in Palo Alto, which had been re-evaluated for something like 0.6 *g*, a very strong earthquake, which of course, it didn't see in the Loma Prieta earthquake. That VA hospital is very near to the San Andreas fault, but not to the segment that ruptured in the 1989 earthquake. People were doing cosmetic fixes to it. I looked at all the columns, which had shear cracks that nobody had seen. And the columns of course didn't have proper transverse reinforcement, so that ended up being a $350-million hospital retrofit project for Degenkolb. [laughter]

Reitherman: You mention that it wasn't a San Francisco earthquake. It's called the Loma Prieta earthquake because of the epicenter being near that hilltop, Loma Prieta, and the USGS quadrangle map of that area shows no urbanized areas; it's light green, indicating forest cover, with little black dots that indicate individual cabins and houses here and there. It was about as rural an epicentral location in the greater Bay Area as you could find.

34 Mete Sozen, "Surrealism in Facing the Earthquake Risk," in A. Ilki and M. Fardis, editors, Seismic Evaluation and Rehabilitation of Structures edition, *Geotechical, Geological and Earthquake Engineering*, vol. 26, June 2014.

Sozen: What else came out of Loma Prieta? Of course the collapse of the Cypress Street Viaduct in Oakland, that was a disaster. I would have bet money that there were no such bridges left that had been built like that, but there was that one.

Reitherman: The Caltrans defense was not that they thought it was a good structure, it was just that their program was in an early phase: do all the simple bridges that were all over the state, using standard retrofit approaches. They were working their way through those, while they needed some additional research to tackle a different beast such as the double-decker Cypress Viaduct.

Sozen: I don't find them guilty, but they were caught with their pants down, huh?

Hanson: In the Loma Prieta earthquake, there were some steel connections in moment frame buildings that had fractures they didn't find right away. A number of buildings have been upgraded now, but they didn't do it until after Northridge. Then they went back to look those buildings.

Sozen: A good friend of mine claims that all those cracks that they found in Northridge were there before the earthquake, so no problem. What do you think?

Hanson: Not all the cracks were there, some were.

Sozen: Some of them are just too big to have been missed. But anyway that's what he claimed, that they were all there before the earthquake.

Hanson: People still make the argument: so you crack the bottom flange; nobody was killed and it just makes them more flexible.

1992 Erzincan, Turkey

Sozen: In 1939, when the Erzincan earthquake disaster occurred, they had the city here, and the fault was very close, so they moved the development over here. Then in 1992 the fault was quite near the new location and there was devastation again. What did I learn from those earthquakes? I learned that the proportion of wall length to floor area works for low-rise buildings, and it is just the easiest way to design them.

After the Erzincan earthquake in 1992, I moved to Purdue. There the information I had compiled was developed into the simple method we've discussed, working with Ahmed Hassan.

In 1999 in Izmir and in Düzce, two disasters that happened within three months of one another, I would have never had guessed that a major earthquake would occur in the same region on different parts of the fault system. In fact, in the town of Düzce they had just allowed the people to return to their homes and then boom! What I observed in the 1999 earthquakes, and what I had observed earlier in earthquakes in Chile, Nicaragua, and Guatemala, confirmed my conclusion that a simple method of proportioning the amount of wall to the amount of floor area was the quickest way to reduce earthquake risks of low-rise buildings in Turkey. It would be an adequate solution for most of the construction, which is simple in layout, not very large, and relies on walls for vertical and horizontal force resistance. It is a simple concept that a builder or

building official can understand and implement, and if you can't get a more sophisticated code approach applied well in that part of the construction industry, what good is it?

Unfortunately, its simplicity is one thing going against it. It is hard to get the support of the engineering community for a method that, however efficacious, really doesn't need engineers.

Reitherman: I recall Ted Zsutty saying that, after the 1980 El Asnam, Algeria earthquake, when Stanford engineers were doing code consulting work there, their conclusion was that a California-type code should not be adopted for Algeria's concrete frame construction. The reason was not because the California code did not have the most up-to-date provisions, but because those provisions couldn't be reliably implemented in that country's design and construction industry context.

Chapter 9

Family and Avocations

I go back to Turkey every year, sometimes twice. I have a fixation on old classical cities and ruins.

Sozen: I've started feeling guilty. I think I should quit this business. My wife wants to go to San Diego and spend time there because one of our children is out there.

Hanson: How many children do you have?

Sozen: Three, and they are all over the place. One is in London, one is in New York, and one is in San Diego.

Hanson: Your son must be around 40-some years old now.

Sozen: I am afraid you are on target. Ayshe lives in London, Adria lives in San Diego, Timothy (Tim) lives in New York.

Ayshe is my daughter with my wife Joan. Joan, had one child, Adria, when I married her, and I had a son, Timothy, from my first marriage. Joan was on the faculty at Illinois when I was there. Her specialty was clothing design and textiles, and she curated a university collection of textiles.

Reitherman: Do you go back to Turkey much?

Sozen: I go back to Turkey every year, sometimes twice. I have a fixation on old classical cities and ruins. Places like Priene or Miletus, and we have a house in an old stone village very much like Pompeii. It is a very interesting place, because there are so many archeological sites within 30 miles of us. I spend a lot of time at the sites. Why I don't know, but I like them. [See maps on the first page of Photographs section, following.]

Reitherman: Can you picture from ruins what a whole ancient building was like?

Sozen: Yes. I've been looking at these ruins for a very long time. It's the Ionian architecture. The Phrygian architecture didn't survive, because they built with wood. Very few of their examples survived, whereas the Ionians built with stone, and some of their construction has survived.

Reitherman: The Phrygians were inland from the Ionians, and the Ionians were along the current Turkish western coast and nearby islands?

Sozen: Yes, the Phrygians were near Ankara, toward the middle of the Anatolian Peninsula. You've been to Turkey right?

Reitherman: Briefly, a couple of times.

Sozen: You should see this region. For an architect, I think you would be fascinated.

Reitherman: On the coast, I saw Ephesus when I was college-age, and just this year [2007] I saw a grand model of it in Vienna in the complex of Imperial Palace museums, a beautiful model all made out of wood. It was about 20 feet square, showing the whole vicinity—the harbor, the hills all detailed with contour modeling, the little buildings here and there, like the temple of Artemis that was one of the seven wonders of the ancient world.

Sozen: Austrians worked on the archaeology of Ephesus, digging it out. So that is why you saw that in Vienna. But I'm not impressed with Ephesus for two reasons. One is that it has become too much of a tourist trap, and second it is mostly a Roman city, not a Greek city. Priene is a beauty, nearby on the coast, and the Greek theatre there is still the same old Greek theatre. Of course the wood parts are gone, just the stone remains. You must come sometime. I would be very happy to take you around.

Reitherman: I love ancient architecture. Almost always, the average was excellent. In our own time, average architecture is mediocre. I wonder what it must have been like to walk around Istanbul a few hundred years back in the Ottoman days, or earlier when it was the Byzantine capital, or even way back as Byzantium, a Greek outpost.

Sozen: Istanbul is a beautiful city. It is more interesting than San Francisco. It's not as civilized. But it has great culture, it has great history, it has great food, great music—anything from jazz to classical, to classical Turkish—a fascinating place.

Reitherman: The Istanbul area has so much interesting coastlines. You stand on one shore and you have a grand view across to more than one other scenic coastline. Except for the Golden Gate, and the area of San Francisco Bay encompassing Angel Island and Alcatraz, and the Richardson Bay inlets, most of San Francisco Bay is a bit too wide to be scenic, and with flat land at its edges rather than hills.

That large picture of old Istanbul you have on your wall here [office at Purdue] is an example of how many exotic, scenic views of Istanbul there are.

Sozen: It is on the open sea, and it also has a combination of the feeling of a river and the sea. My wife Joan wants to go there and stay there. She doesn't want to live in Lafayette, Indiana, and I don't blame her.

Reitherman: That must be fascinating to be able to know two countries so well. You can be at home here in the U.S.A. and also in Turkey. For me, like most Americans, I am either at home here, or I'm a foreign visitor elsewhere.

Sozen: Orhan Pamuk's first book, *Mr. Cevdet and His Sons,* sort of captured Turkish society, the Turkish bourgeois society. It's a city that captures the imagination. But his later books I have not liked as much.

Reitherman: What about *My Name Is Red*?

Sozen: That drove me to sleep.

Reitherman: Me too, at least half the chapters did, except that the other half are macabre and that doesn't put me in the mood for slumber. It has a clever device, the first-person narrator changing from one short chapter to the next, from a murderer, to the person murdered, then a dog, or maybe an image in an illustrated manuscript that comes to life and talks. I tried to read it because it was famous, but I confess I never finished it.

Sozen: Don't miss Vonnegut's last book if you haven't read it, *A Man without a Country.* A small book, delightful. It's funny, and tragic at the same time but it is worth reading. I am always amused to see Vonnegut's Grocery in Indianopolis, run by a relative of his I believe.

Reitherman: What else do you like to read?

Sozen: I read anything. I read any sort of junk.

Reitherman: Do you have Turkish authors that you like to read in Turkish?

Sozen: Yes, there are a couple. I read anything that I can lay my hands on. I like to read the *New York Review of Books*, which I think is the best journal in the country. I think that it is a brilliant collection of essays. Or course if you are a conservative it is hard to take.

Other Pastimes

Sozen: I used to enjoy sailing, skiing, dancing, and hiking in addition to swimming. But since I returned to Urbana to get my Ph.D., I have spent most of my time in the laboratory except for playing tennis every now and then. My travels were mostly related to work. I served as a consultant to the State Department for a decade. That responsibility took me virtually all over the world. The most interesting part of it was after the dissolution of the Soviet state when I visited all parts of the U.S.S.R from Ukraine to Kyrgyzstan. I had a whole range of experiences that were not all positive. In Astana, I happened to visit a McDonald's run by a Korean company. Their hamburger was a slice of ham in a hamburger bun. The continual surprise was that, despite my having been told that Turkish might be of use only in Germany, if I needed my garbage picked up, knowing that language turned out to be of great advantage in the string of Turkic republics that were in the U.S.S.R.

When I was in Azerbaijan, I was asked to evaluate the earthquake resistance of a building that was given to the U.S. for an embassy. Its architecture did not make sense to me. To put it simply, it included a high ceiling single room in its first level with a collection of small rooms in its upper level. What sort of a business did it support? I was in the dark until a local explained that it had been used in the sex trade. I needed floor plans of that building. The embassy staff had already retained a Turkish firm for that job. The firm asked for a very stiff price in excess of $10,000. Strangely enough, when I went to Tbilisi the following week and said I needed the same plans for a building, I was directed to the President of the Georgian Architectural Society who said he would charge $200 for the service. I reached into my wallet and paid him on the spot.

Another memorable experience was coming across a building that weighed 400 lb/sq ft. that was beyond my knowledge on earthquake resistance based on experience. In Chisinau, Moldova, I was overwhelmed to hear Turkish being spoken. I did not know that Moldavians were Turkic.

Favorite music

Sozen: I grew up on western classical music and American jazz. I did not listen to Turkish music. A copy of Benny Goodman's "Sing, Sing, Sing" was my most precious possession. As I got older, I started appreciating Turkish music, especially the Anatolian folk music.

Ancient Greek Architecture

[The following discussions between Bob Reitherman and Mete Sozen occurred in September 2017 in Gundoğan, Miletus, Priene, Eski Doğanbey, Ephesus, Herakleia, and Euromos in Turkey.]

Reitherman: You and your wife seem to collect houses, for example, having more than one here in the half-ruined village of Eski Doğanbey (Dough-won-bay), houses that you have reconstructed and remodeled.

Sozen: No, I must correct you. It is Joan's hobby to collect houses, like four of these here in Eski Doğanbey that, except for one, were basically ruins. The small two-story one across the ravine we call the Goat House, for that is what it was. The goats lived downstairs and the people upstairs. The bigger house we usually live in when we come was the town's police office, but Joan has extensively remodeled it. One of the houses is Ayse's House; it is for our daughter when she visits. We still own two apartments that were in the family in Istanbul, and we have the house—a remodeled barn—back in Lafayette near Purdue, where I taught until I retired. There is a small classroom in the house where I used to teach graduate seminars.

The ruins you see around you here in Eski Doğanbey in this canyon, which by the way is located in a national park and is very protected from development, might look like ancient Greek ruins but they are ruins from our time. After World War I, what is now Turkey was occupied by the victors in the war—basically Britain, France, Italy, and Greece. There was fighting between Turks and Armenians, Turks and Kurds, Turks and Greeks. There was terrible friction, violent friction in the aftermath of the war and the collapse of the Ottoman Empire. After Mustafa Kemal Ataturk led the

Turks to victory in Turkey's War of Independence, there were Turks living in Greek-held territory and Greeks in Turk-held territory. Why not let everyone live together in peace? But no. The novel *Birds without Wings* has a lot of these historical facts woven into it as well as being good literature about this sad time. Turks, Armenians, Greeks, and the European foreigners were all in conflict, stirred up by the war and its aftermath, even though in most cases people had lived together peaceably, Muslims and Christians, for centuries.

The old town of Eski Doğanbey is a small example of the wholesale relocation of populations between Greece and Turkey that occurred, beginning in 1923. Eski Doğanbey was a Greek town. You see all the gable roofs, a sign of their Greek construction. You can see such small Greek houses many places in Turkey, side by side with flat-roofed Turkish construction. All of a sudden, as decided by governments far away, the entire Greek population here had to take what belongings they could, go down to the sea, board boats, and sail off to Greece. Turks who were living in what became Greek territory were rounded up and shipped here to inhabit Eski Doğanbey. But this forced migration did not suit everyone's needs and desires. The Turks living here wanted to live down next to the sea, and that is where the larger, modern town of Doğanbey is. Eski Doğanbey up here on the slope was abandoned; it became a complete ghost town. Timber roofs without any maintenance eventually collapsed, portions of stone walls were quarried to use the material elsewhere.

So my wife Joan's architectural projects here have deep historical meaning in this little town. And one by one, these old ruined stone-wall houses are being purchased and fixed up. As you have seen in the house you stayed in, with water, electricity, and cell phone services, you can have very comfortable dwellings here. Some of them you can drive a car to, slowly, over the stone streets; some you have to walk to on the narrow stone paths.

Reitherman: How do you reconstruct the walls, when the local historical preservation rules make you re-use the stones to make the buildings good as new, or perhaps "good as old"?

Sozen: You basically have to remove the stones down to the foundation and start by building a new reinforced concrete frame throughout the house, or at least I have. Because the walls are half a meter thick, when you build them back up, the frame embedded in there is not visible, and so the architectural appearance is preserved. That's about the best you can do with what you have, given the regulations.

The construction industry can also be a constraint. For example, we discovered that the architect running one of our house reconstruction projects had sold a lot of our reinforcing steel that we had bought to go into our house. Workers hadn't been paid from the money we had advanced. She hadn't all the proper permits. So I paid all the workers, bought more steel, dealt with the permit issue. To complete construction I paid another contractor who ended up building a wall where he shouldn't have, and there was more trouble. The building authority came after me. I was even subject to arrest! Eventually I appeared before a judge and it got straightened out; after

six years' probation my record was clean in Turkey. Still, after the various troubles, we are happy to come here every year, and now that I am retired we spend months here. I held a seismic seminar here a few years ago, and Joan arranged for the participants to have the use of various houses in town.

The ruins of the houses are gradually being made back into habitable residences. On the Illinois faculty, my wife Joan had teaching responsibilities related to interior design and she curated the university's collection of textiles. You can see the rugs and other things around our homes that Joan has found over the years. One of our friends here in Eski Doğanbey established a museum of Anatolian costumes, things like wedding dresses that the Turkish women used to wear, and Joan helped her with that.

Reitherman: You have been my guide to ancient Greek city state sites in on the Aegean coast of Turkey: Miletus, Priene, Didyma, Herakleia, and Euromos. Why do you say that Priene is your favorite ancient Greek city?

Sozen: You can understand Priene, because it is all there, the entire city-state, everything within its walls: agora, stoa, theater, temples, all the houses, the stone pedestrian streets. Around it is nothing new to spoil its setting. Its Temple of Apollo is not as grand as the one at Didyma, but it has a view of the sea, or at least it overlooked the Aegean in that time before the siltation of the Meander River moved the coastline 20 miles away. Now at our hillside house in Gündoğan (Gun-dough-wan), I enjoy seeing the sun set over the islands of the Aegean in the distance, Samos, Lipsi, Leros. By the way, when you gaze out over the Aegean from our house in Gündoğan, you see islands that are part of Greece, only a little ways away, so close, and yet there are still unsettled cultural and political differences between the two countries. It is irrational, just like the forced resettlement of Eski Doğanbey. We enjoy going down to the sea for a swim on warm days. It is a very simple human experience to watch the sun set over the Aegean, as it was in ancient times.

Reitherman: Miletus is famous for, among other things, the invention of the grid layout of a town. Priene has that rectilinear configuration of its streets also, but it's anything but monotonous.

Sozen: In Priene, you look down the street, any street, and it's an interesting streetscape, and you look to the side one way or another to see the sea or the massive cliffs of the acropolis or to see one of the big public buildings. Of course today, we see pine trees growing in the middle of the four walls of what used to be rooms of houses, but even back then two and a half thousand years ago when it was in its busy prime, you were close to nature. At the Temple of Apollo or the theater, the backdrop is pine trees and the rocky cliffs of the acropolis. The grid system of laying out streets that we are familiar with in towns and cities all over the world is quite visible here at Priene, and from Priene you can see Miletus where it was invented by Hippodamus. But even though the pedestrian streets were straight, every short block or two there was an open area around a temple, or where the theater that has survived intact is, or the agora, so it was not the experience of urban grid we have today. You can feel something of what it was like to live in that

small town of Priene, such a small place with a few thousand inhabitants, but a place where so much civilization was developing.

Reitherman: Priene is better preserved, but we should not overlook Miletus, a more important center for the development of Greek science, philosophy, and history. I'm thinking of Thales, Bias, and Hecataeus, respectively, for some of the first work in those three fields, as well as others in Miletus. Anaximenes didn't get the cause of earthquakes right, but he did try to come up with an explanation based on nature, not the gods. When you took my wife Noralee and me to your favorite winery, we enjoyed the wine they bottle as Bias, along with one they label Pythagoras. Is Bias a favorite philosopher of yours?

Sozen: The ancient thinkers were all interesting, because they put so much thought into their lives. But Bias is definitely one of my favorite wines. The Anatolian vineyards yield very good wine grapes, though the wines are not well known in the U.S.

Miletus was the jewel of the cluster of little city-states here in Ionia that developed what we know as Greek culture a century or more before anything similar was happening in Athens. It is so simplistic to think that Ionia only invented the Ionic capital, the Ionic order. We have been seeing half a dozen of these ancient Ionian city-states that we drive to less than 20 minutes or a half hour apart. Such a small part of the world but such a big part of the story of civilization.

Even though Priene is in ruins, you can picture the intact city-state there and understand the layout of it and how its neighborhoods with different functions worked together. And you've noticed that we have been walking around them, and not just around temples but all through them, rather than seeing cordoned-off antiquities like in Athens. And in several of them, we were the only people there.

Ephesus is Roman grandeur built on the pre-existing Greek city. The theater at Priene in Greek fashion was small enough to function so perfectly, visually and acoustically. When the Romans overhauled the Greek theater at Ephesus, and also you can see this in the theater at Miletus, they had to make everything so big. My wife Joan and I see several performances in the theater of Ephesus every summer, and it is wonderful, but there are so many people. It takes a while to get to and from your seats. The music is amplified. Quantity often is purchased at the expense of quality. You can think of examples today where a smaller work of architecture that has authenticity and originality is more beautiful than one that is derived from the original and aggrandized into something lavishly impressive. It is true that the scale and complex architectural layout of the Temple of Apollo at Didyma is very wonderful to see—such massive columns! But Priene is still my favorite. Didyma is strength. It had the money because it was an oracle, so people paid large offerings to have their fortunes told. Priene is elegance.

Reitherman: Priene's temple is Corinthian, the one at Didyma is Ionic. The Corinthian capital is more ornate and elaborate, but that is just the easily recognized difference most people memorize. Priene's Corinthian order meant that the proportion of its columns was the most slender. Roughly, the slenderness ratios of the

columns were: Corinthian 10 to 1; Ionic 8 or 9 to 1; Doric 6 to 1 or even as stocky as 4 to 1.

Sozen: I spent many hours with an architect friend of mine in Istanbul to prepare drawings, calculations, and cost estimates and make proposals to the Turkish government for the reconstruction of Priene. That was approximately 1970. It was a crazy idea, but a wonderful one. We wanted to put the stones back up that you see lying all around. The archaeologists have in many cases identified where those puzzle pieces should be put. Of course there would be new material to fill in for what is missing, but those new pieces would be identified so visitors would know what the original material was compared to what was added to complete the buildings. We never got anywhere with the necessary government approvals, though I think the idea would have excited people and raised the necessary funds.

When I showed you Euromos, with the columns of the Temple of Zeus still largely intact that let you clearly imagine what that temple was like, although its roof is gone, it inspired me to think that a smaller reconstruction project there would be feasible. Rather than reconstructing an entire town like Priene, it would just be one building. It is easy to picture the wonderful result. There are sources of money in Turkey. The government wouldn't even have to pay for it.

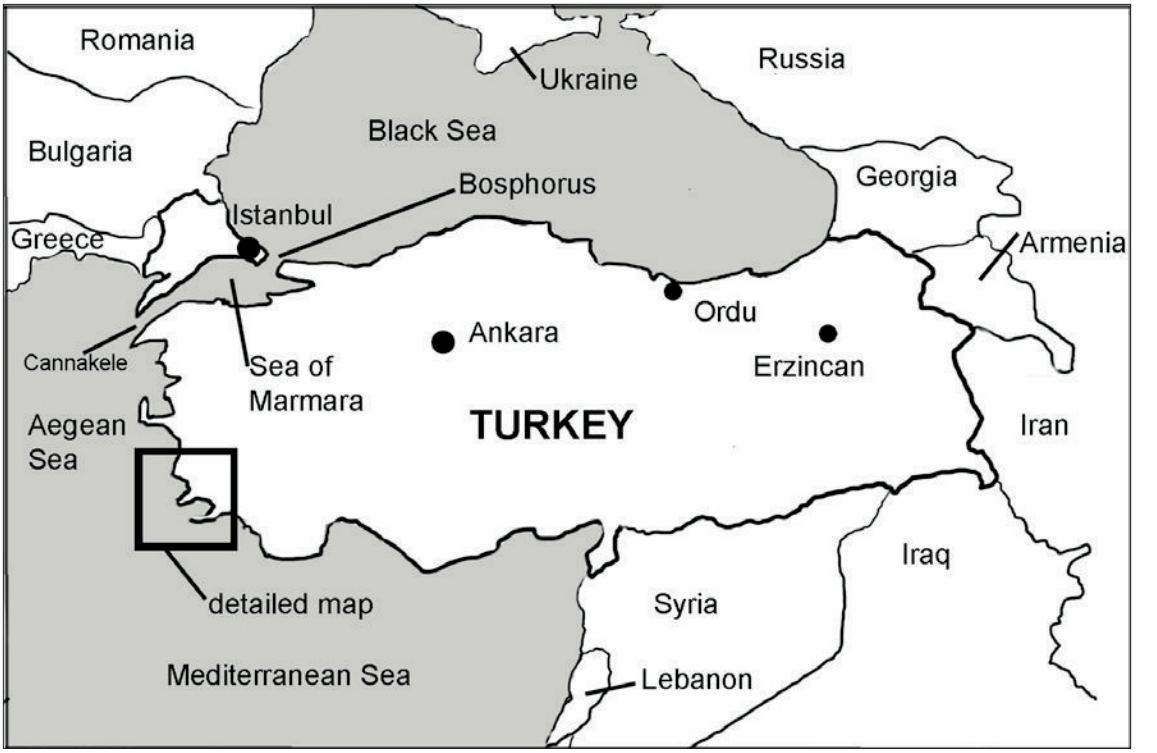
Reitherman: How would you reconstruct a Greek temple like that one we saw at Euromos? Though wars and invaders, remodeling and pillaging of materials for new construction, and other human effects have been the primary agents of destruction, most all of these ancient constructions went through damaging earthquakes. In a seismic region, how would you implement a seismic retrofit in the process of accomplishing an archaeological reconstruction? Today, designers must go to great lengths to conform to historic preservation regulations for a building that is one century or less old. These Greek buildings are approximately 2,500 years old, and thus more historic and precious.

Sozen: We've talked before about the importance of drift control as a tool of seismic design for modern construction. I'm not petty, but several other people have taken credit for the development of that design insight that I worked on in the 1960s at Illinois. An ancient Greek temple is an ideal building to retrofit with drift in mind, because the cella, the rectangular walled "core" that was inside the colonnades on the four sides, is much more than a small core in the center of a large floor plan as in a modern tall building. Most of the plan area of the temple was within those massive meter-thick walls. So we put the big blocks of stone back up to reconstruct the walls—you saw how most of those stones lying on the ground have been identified and numbered by the archaeologists—and we hide our modern shear wall technology in the middle of them, providing very strong but also very stiff lateral support. The wall stones are more than half a meter thick so this is no problem. When we reconstruct the roof, the ceiling is structured to be a strong and stiff diaphragm. When the diaphragm, the lid on the box, is connected to the columns around the perimeter, we have a stable structure that won't let the tops of the columns excessively deflect so as to hurt themselves.

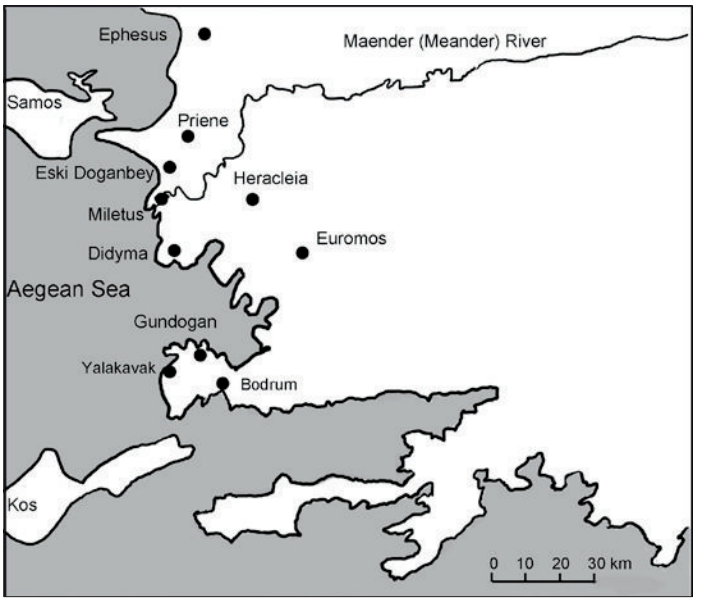
Reitherman: The fact that each column is a stack of drums, cylinders, allows you to connect the drums up as you wish, hiding those connections as the Greeks hid their iron dowels sealed in molten lead. You could run steel tendons up through holes drilled in the centers of the drums without affecting the appearance, and you could make those drums wobble a small amount without damage as the top of the column goes along with the small deflections of the diaphragm.

Sozen: The Priene reconstruction scheme was feasible. We could have put it back together again, except for the government permits to do it. But to reconstruct the smaller-scale Temple of Apollo at Euromos is even more feasible, and it might get the backing of the archaeologists and politicians for the necessary permissions. At Priene, if you squint and use your imagination, you can see the ancient Greek city, but at Euromos, the temple still stands so intact that you can easily picture it in complete form with your eyes wide open. I hope very much that someday it will be reconstructed and conserved as it should be.

Photographs of Mete Sozen and Maps



Turkey and its environs, above. Detailed map below shows Turkish sites discussed by Mete Sozen in the final chapter.





A biographical book published in 1982 about Meliha Avni Sozen, Mete Sozen's aunt, who was involved in Mete's upbringing. The book's title is Meliha Avni Sozen's Oratory is a Volcano. Sozen was a famous political writer and orator who once addressed a crowd of tens of thousands of people, in her speech calling Mustafa Kemal Ataturk the "beating heart" of Turkey.



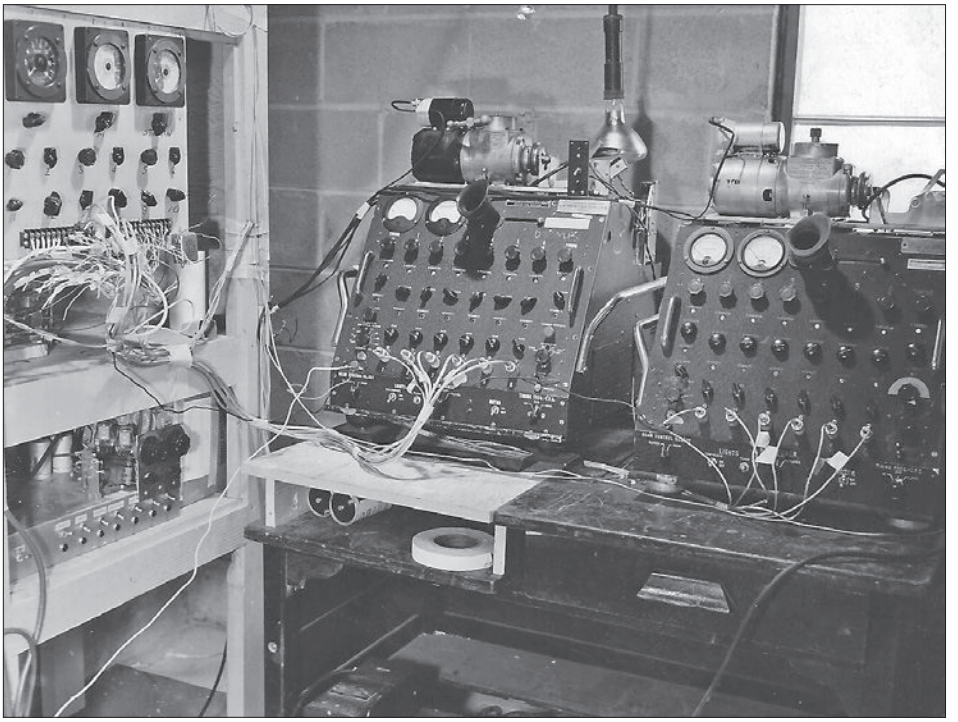
Mete Sozen's 1949 driver's license.



Mete in 1952 in Oakland, California, where he worked for Kaiser Engineers.



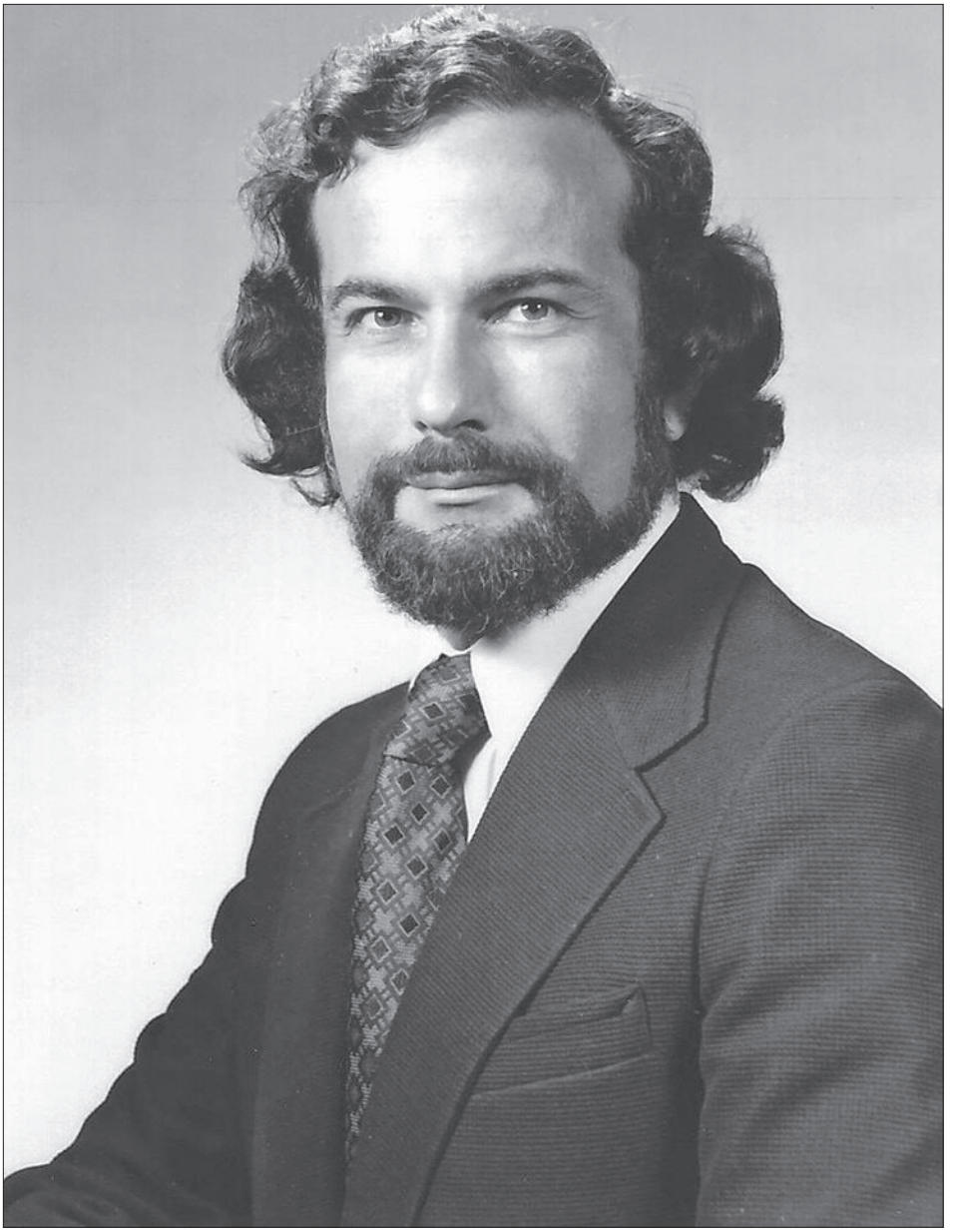
Left to right: Mete Sozen, Helen Siess, the Siess's daughter Judy, Chester (Chet) Siess, Helen Siess's mother, T.Y Chen, Andy Veletsos, and Fazlur Khan, 1955.



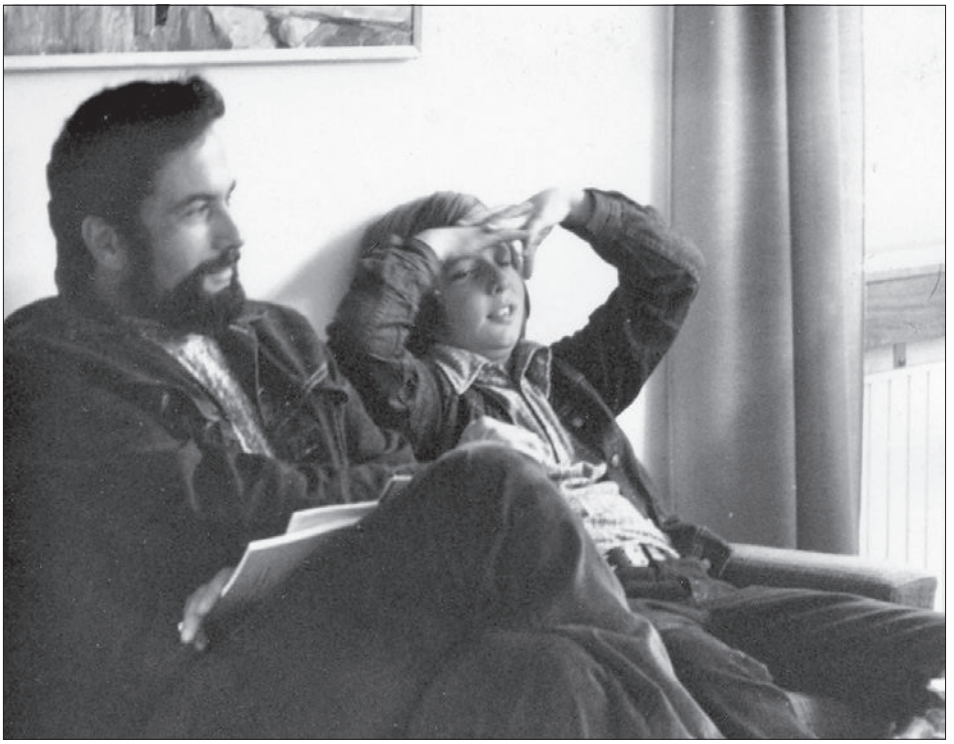
Instrumentation at the Talbot Laboratory, University of Illinois at Urbana-Champaign, used in a series of nine-panel slab tests, 1957.



Mete with a model of a brick-infilled concrete frame, 1967.



Mete Sozen at the University of Illinois at Urbana-Champaign, 1971.



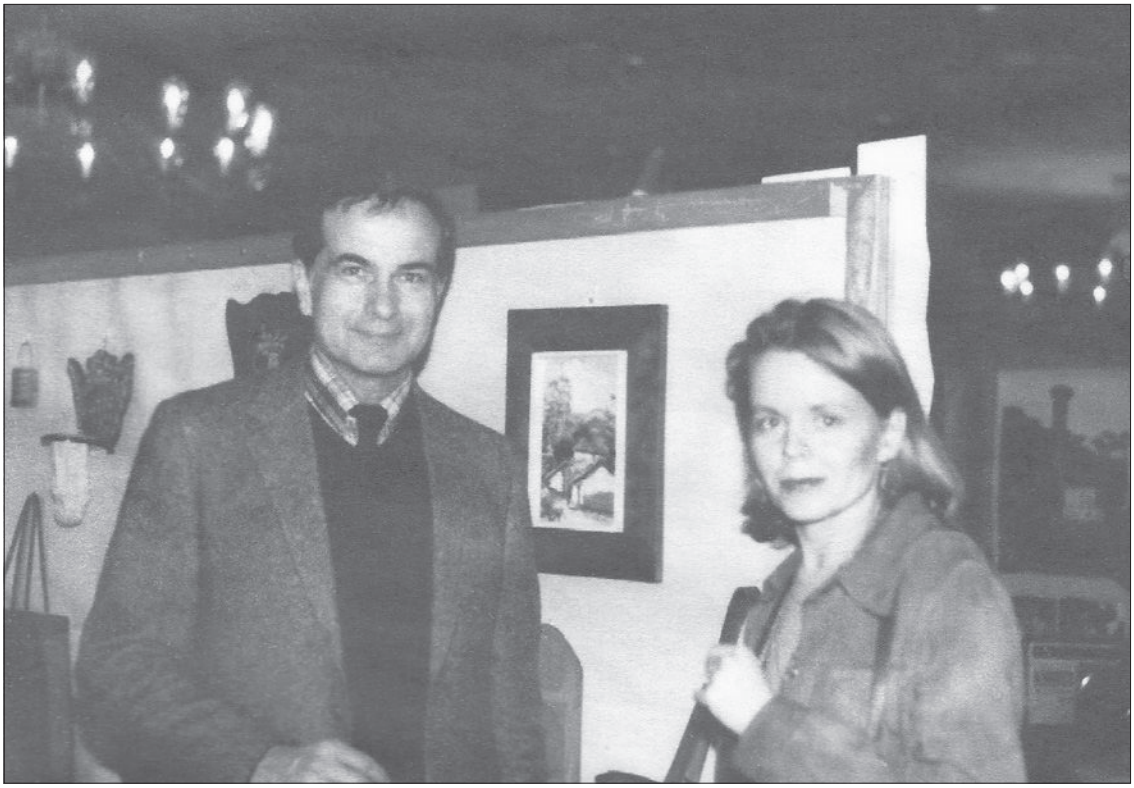
Mete with his son Timothy, 1971.



Donald Johnson, Director of the VA, left, and Mete Sozen, 1972.



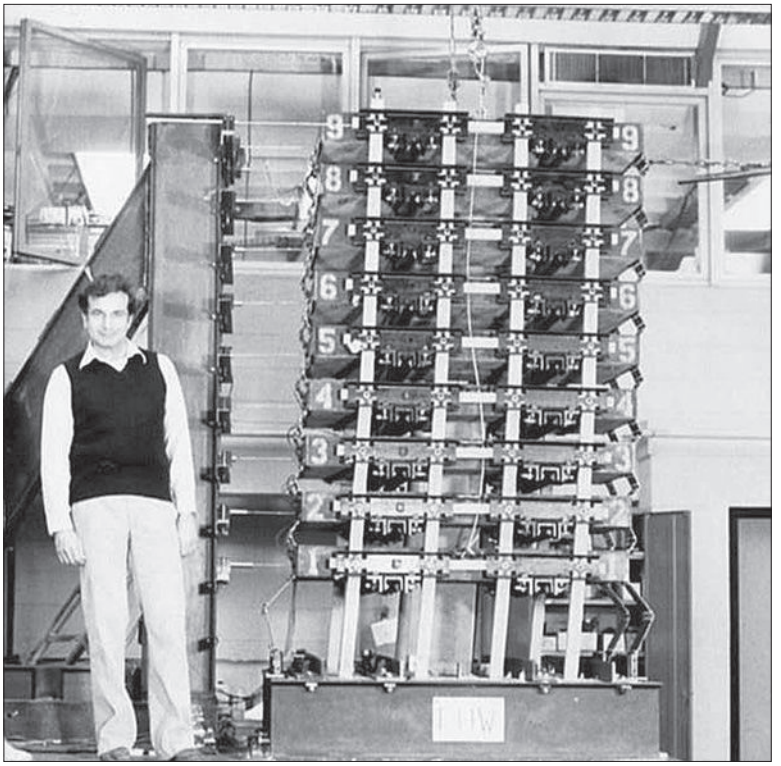
The VA Earthquake and Wind Forces Committee. Left to right: Armand Burgun, Ted Stevens, Max Clellan (Director of the VA), Roy Johnston, and Mete Sozen, 1977.



Mete with wife Joan while both were on the faculty at the University of Illinois at Urbana-Champaign, 1980.



Joan, Ayshe, Adria, and Mete in Urbana-Champaign, IL, 1981



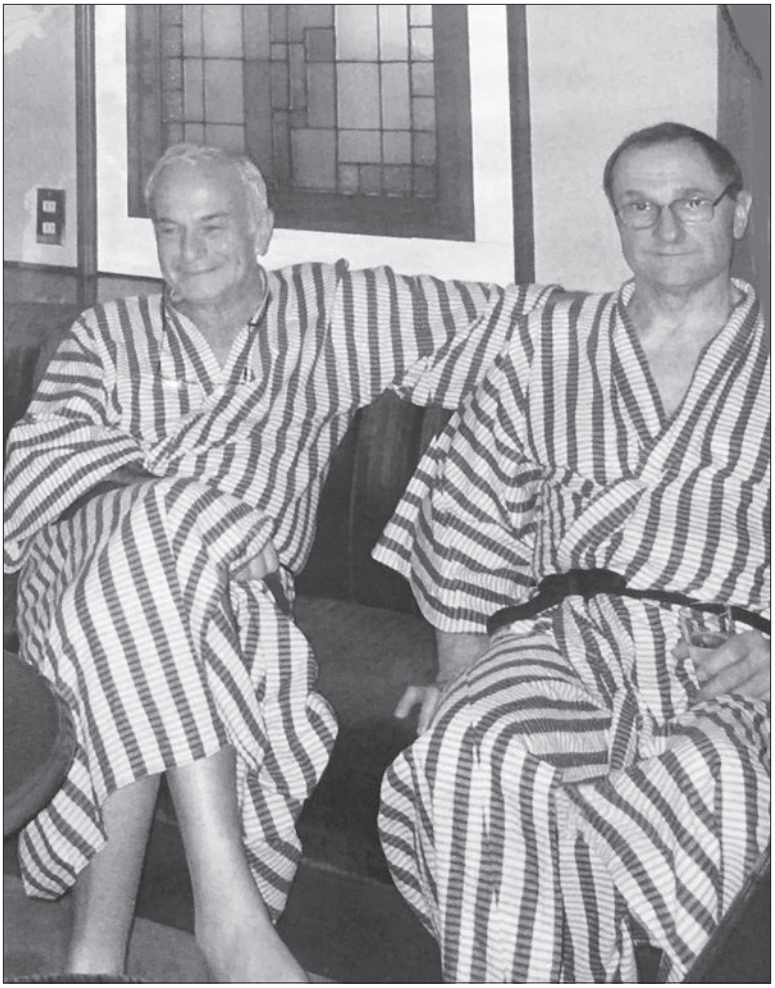
Mete Sozen as a professor at the University of Illinois at Urbana-Champaign in 1982 with a nine-story shake-table model of a reinforced concrete frame building.



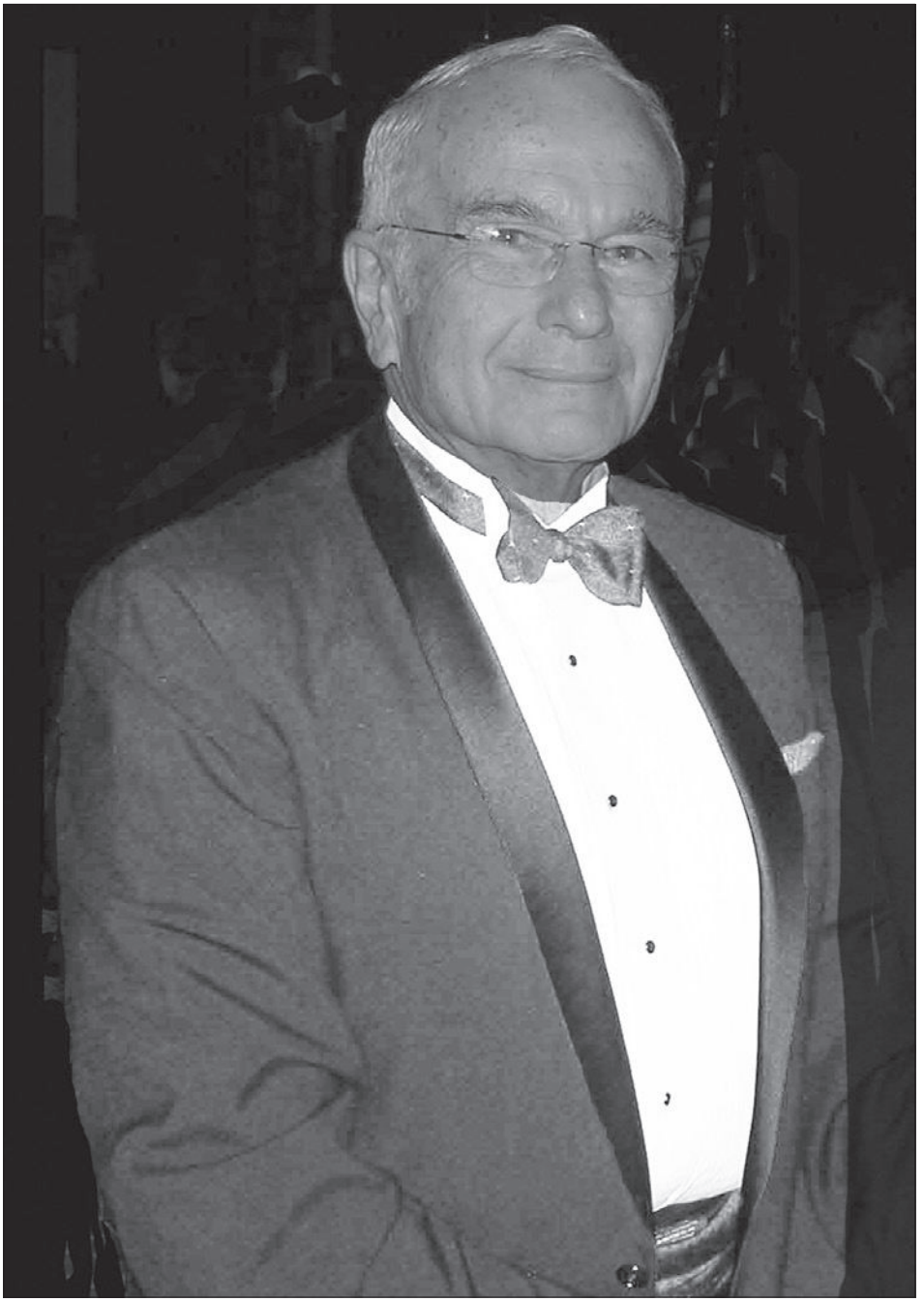
Mete A. Sozen, 1990.



Mete Sozen investigating damage in the 1999 Düzce earthquake.



Mete with Jim Jirsa at Lake Hakone for the retirement celebration of Shunsuke Otani, 2003.



Mete Sozen, 2014.



Mete Sozen delivering a lecture at Purdue University, 2015.



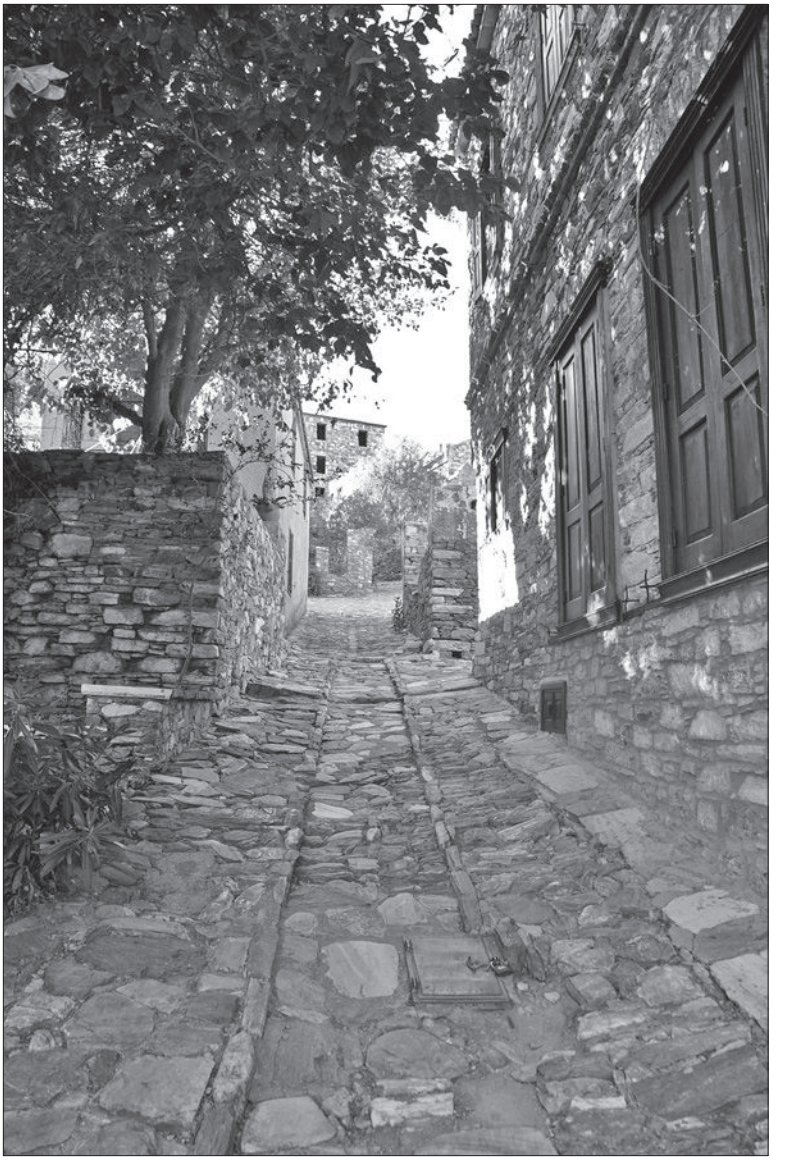
Mete at the theater, Priene, 2017.



Mete at the Temple of Apollo, Didyma, 2017.



Eski Doğanbey, where the Sozens have remodeled several dwellings, 2017.



A street in Eski Doğanbey, 2017.



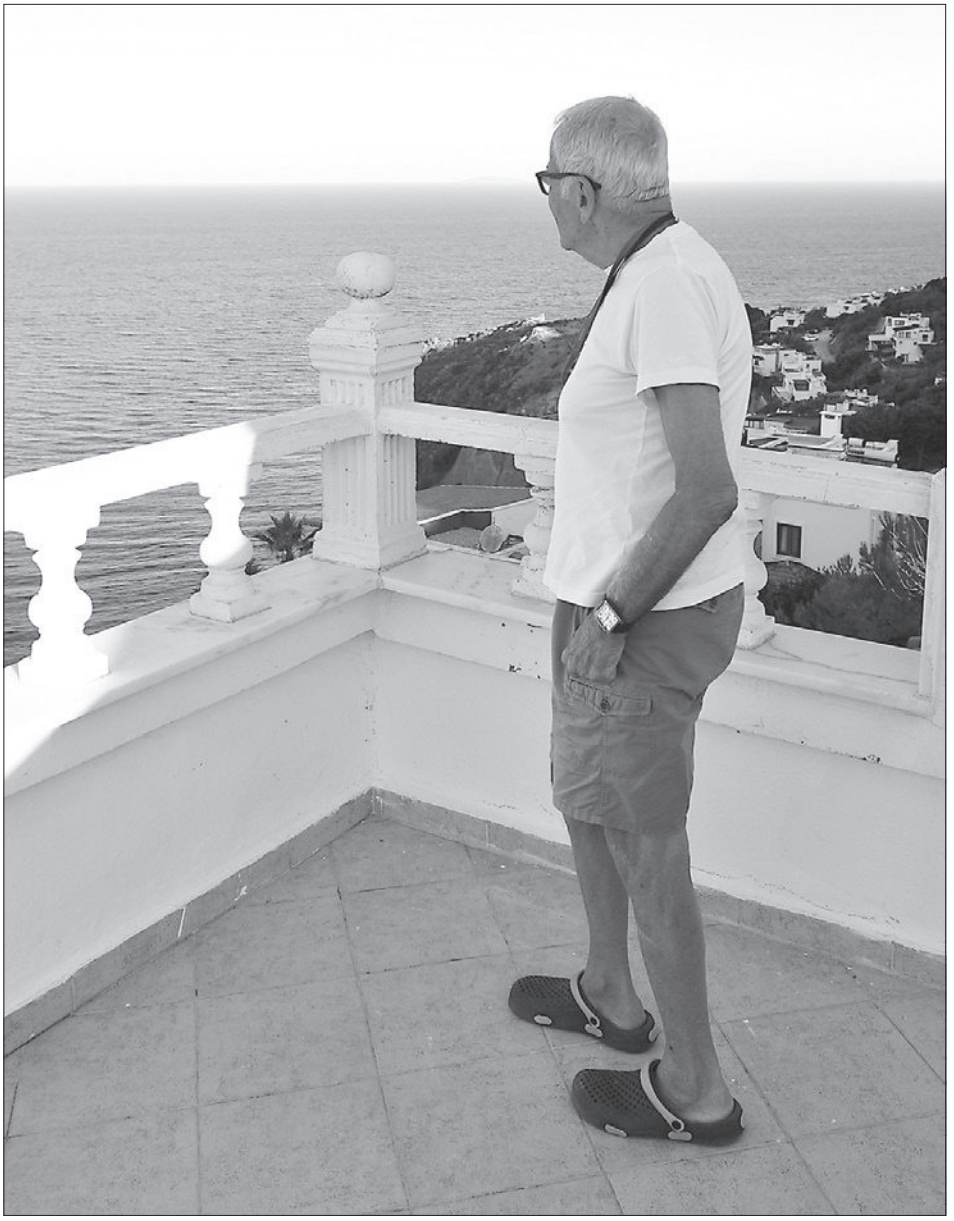
Joan and Mete Sozen at their home in Gündoğan, 2017.



Mete and Joan Sozen at a seaside restaurant in Yalikavak, Turkey, near their home in Gündoğan, 2017.



Mete Sozen at Euromos, 2017.



Mete on the roof deck of their home in Gündoğan, Turkey, overlooking the Aegean Sea, 2017.

Index

A

Abe, Mikishi 21
Agadir, Morocco earthquake (1960) 55
Alaska earthquake (1964) 56
Algan, Bekir 26
Algarrobo, Chile earthquake (1985) 62
American Concrete Institute
  building code Chapter 21 38
Applied Technology Council 37
Arioglu, Ersin 50
ATC-3 project. *See* Tentative Provisions for the Development of Seismic Regulations for Buildings

B

Bingöl, Turkey earthquake (2003) 49
blast effects
  Murrah Building 45
  Pentagon 46
  World Trade Center 46
blast engineering versus earthquake engineering 45, 46
Blume, John A. 31, 33
Bolt, Bruce 47, 49
Bucharest, Romania earthquake (1976) xiv

C

Caltrans 65
Caltrans bridge design 58
capacity design/balanced design 33, 34
Caracas, Venezuela earthquake (1967) 19, 57
core walls
  in tall buildings 43
Corning, Leo 31, 36
Crandall, LeRoy 59
Cross, Hardy 12
Cypress Viaduct collapse
  in Loma Prieta earthquake 65

D

Degenkolb, Henry 36, 37, 59
Design of Multistory Reinforced Concrete Buildings for Earthquake Motions 31
drift control xv, 36, 74
Düzce, Turkey earthquake (1999) 49, 65

E

Earthquake Engineering Research Institute
Experimental Research Needs for Improving the Earthquake Resistance of Buildings 40
El Centro earthquake (1940) 38
acceleration record 49
differing records 39
Engineering Evaluation of the Portland Cement Association's Book, Design of Multistory Reinforced Concrete Buildings 36
Ephesus, Turkey 68, 73
Erzincan, Turkey earthquake (1939) 5
Erzincan, Turkey earthquake (1992) 49, 65
Eski Doğanbey, Turkey 70
experimental research 44

G

Gaus, Michael 24
Great Kanto earthquake (1923) 38
Gulkan, Polat 25, 50
Gündoğan, Turkey 72

H

Hall, William J. 20
Hassan, Ahmad F.
Seismic vulnerability assessment of low-rise buildings in regions with infrequent earthquakes 63
Hassan Index 63
high-strength transverse reinforcement 43
Hognestad, Eivind
interaction diagrams 36

I

Istanbul 68
proposal to strengthen buildings 50
seismic risk 49
Izmir, Turkey earthquake (1999) 49, 65

J

J factor 56
Johnston, Roy G. 36, 47

K

Kern County earthquake (1952)
Taft acceleration record 49

L

Langhaar, Henry 18
Lefter, James xv, 47
Liu, Shih-Chi 40, 41
Loma Prieta earthquake (1989) 64

M

Managua, Nicaragua earthquake (1972) 59
Messina, Italy earthquake (1908) 26
Mexico City earthquake (1985)
ground motion 61
Latinoamericana Tower 61
Pino Suarez building 61
Mustafa Kemal Ataturk 3, 5, 70, 79

N

National Center for Earthquake Engineering Research at Buffalo 41
National Earthquake Hazards Reduction Act, NEHRP 56
National Science Foundation 24, 27
  research guidelines 42
NEES Consortium 41
Network for Earthquake Engineering Simulation (NEES) 27, 40
  shortcomings 40
Newmark, Nathan M. 12, 18, 31, 35, 39
  as teacher 19
  earthquake research 21
  shake table 24
Nielsen, Norbert 25

O

Olive View Hospital
  collapse in San Fernando earthquake 57
Ordu, Turkey 3
Otani, Shunsuke 25
Ottoman Empire 4

P

Pamuk, Orhan 4, 51, 69
Peck, Ralph 19
performance-based engineering 37
Priene, Turkey 68, 72, 73
Purdue University
  engineering department 28

R

Rifat Yarar, A. 52
Robert College
  campus 8
  history 7
Rojahn, Chris 59

S

San Fernando earthquake (1971) xiii, 47, 57
  Lower San Fernando Dam 58
  Pacoima Dam record 49
  VA hospital collapse 47
Sendai, Japan earthquake (1978) 60
Sepulveda VA hospital 48
Sharpe, Roland 38
Shedd, Thomas Clark 14
Siess, Chester Paul 14, 18
Skopje, Yugoslavia earthquake (1963) 56
Sozen, Adria
  daughter 67
Sozen, Ayşe Saliha
  grandmother 2
Sozen, Ayshe
  daughter 67
Sozen, Huseyin Avni
  grandfather 2
Sozen, Joan
  architectural projects in Turkey 71
  University of Illinois faculty 72
  wife 15, 67, 70
Sozen, Meliha Avni
  aunt 3
  poet and orator 4

Sozen, Mete
academic career at the University of Illinois 23
avocations 69
Bogazici University connections 9
childhood 4
complicated family history 3
consulting career 47
distinguished graduate students xiv
early schooling in Turkey 4
earthquake reconnaissance 55
first job with Kaiser Engineers 15
Master's Degree 12
New York job at Hardesty and Hanover 16
Ph.D. at University of Illinois 17
Ph.D. candidates at Purdue 30
Ph.D. candidates at UIUC 30
plan to strengthen Istanbul buildings 50
prestressed concrete research 21
Purdue University move 27
Robert College 7
Veterans Administration work xiii, 47
work on American Concrete Institute code book 38
work on ATC-3 38
work on Design of Multistory Reinforced Concrete Buildings... 32
Sozen, Timothy
son 67
Steinbrugge, Karl 56
strong ground motion records 38
Swedish Circle of Failure 58

T

Tarics, Alex 8
Tentative Provisions for the Development of Seismic Regulations for Buildings 37
transformative research 42
Turkey
after World War I 4
earthquake risk 49
Turkish architecture
ancient 68

U

Universities Council for Earthquake Engineering Research 27
University of Illinois at Urbana-Champaign
blast research 22
computer science laboratory 26
earthquake research 13, 23
engineering department 28, 29
shake table xv, 24

V

Veterans Administration
Earthquake and Wind Forces Committee xiii
Earthquake Resistant Design Requirements for VA Hospital Facilities 47
Loma Linda hospital 48
Palo Alto psychiatric hospital 64
San Fernando hospital collapse 47
seismic strenthening after San Fernando quake xiii

W

Westergaard, Harald M. 13, 38
earthquake research 21
Wong, Eugene
role in establishment of NEES 40
World Trade Center
collapse 46



Few professors have nurtured so many doctoral students to become leaders in the earthquake engineering field, and few have seen their research and consulting work play such a decisive role in bringing about new seismic design methods. This oral history documents the life of the late Mete Sozen, born in Turkey and raised in a somewhat unusual way as detailed herein, who went on to become prominent in earthquake engineering as a Ph.D. student and later professor at the University of Illinois at Urbana-Champaign. Among his accomplishments, Sozen had a hand in the creation of two significant documents: the book, *Design of Multistory Reinforced Concrete Buildings for Earthquake Motions,* published in 1961; and the Veterans Administration's seismic code, which he co-authored with three others a decade after the San Fernando earthquake. The wide range of Mete's interests (architecture, history, literature) and previously unpublished tenets of his engineering philosophy are represented in this oral history, as well as details of his career in earthquake engineering.

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