CONNECTIONS

The EERI Oral History Series

John F. Meehan

Stanley Scott,
Interviewer

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The EERI Oral History Series

This is the twenty-fifth 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 at 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 received assistance in formulating his oral history plans from 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 from 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* 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.

Published volumes in *Connections: The EERI Oral History Series*

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Foreword

The interviews with John (Jack) Meehan, who died in 2011, which formed the basis for this oral history were conducted in 1988 by the late Stanley Scott. Editing and preparing the manuscript for publication were accomplished by Thalia Anagnos and myself. Professor Anagnos did the majority of the work on the manuscript and also conducted background research, including interviews with colleagues of Meehan to flesh out or verify parts of the interviews. The review comments of Oral History Committee member Loring Wyllie are gratefully acknowledged. George Mattingly was responsible for the page layout work. Rita Wilds, EERI Membership and Communications Manager, edited the manuscript and managed the production process.

Robert Reitherman
EERI Oral History Committee
August 2017

Personal Introduction

My first oral history interviews were with Henry Degenkolb in 1984. Because those interviews went well, I decided to start recording similar interviews with others who had been active in earthquake engineering. I also submitted the idea to the Regional Oral History Project at Bancroft Library, University of California, Berkeley, where it was approved for inclusion in their program on an unfunded basis. The Institute of Governmental Studies agreed to my using a limited amount of office time for such interviews, and I went ahead with a number of others, such as with San Francisco Bay Area structural engineers John Blume, John Rinne, and Mike Pregnoff.

I very much wanted to include someone with experience in California's Field Act program for the seismic safety of public school buildings. I had known Jack Meehan from the early 1970s, when we had both participated in advisory groups to the Legislature's Joint Committee on Seismic Safety, chaired by Senator Alfred Alquist. As a member of the California Seismic Safety Commission, I was also aware that Jack attended Commission meetings regularly as the Office of the State Architect Structural Safety Section's principal liaison with the Commission.

Consequently, he seemed a logical candidate to be interviewed, especially after his retirement in 1987, and in 1988 I made several trips to interview him at his Sacramento home. Transcripts of those interviews provided the basis for the present version. As is typical of oral history interviewing a great deal of additional work was done on successive drafts, with many corrections, modifications, and additions. Reading drafts were sent to Eugene Cole, a Sacramento structural engineer, and Donald Jephcott, a long-time associate of Jack Meehan's in the Office of the State Architect. On the basis of their suggestions, the manuscript was revised further and additional topics were discussed.

Jack spent much of his working life in the Field Act program, playing a quietly effective role within the state bureaucracy, as well as outside it. For about ten years, he was the Schoolhouse Section's Research Director, and Jack gives readers a good account of the wide-ranging activities sponsored to facilitate the Field Act work. Jack made many earthquake site visits, starting with the 1952 Bakersfield Earthquake and continuing after his retirement. He made effective use of what he learned in helping promote improved seismic design of public

schools and hospital buildings. His observations and photographs of 1964 Anchorage earthquake damage reversed the attitude of Architect's Office top management regarding the value of earthquake site visits.

In addition to his work within the state system, Jack was also active in regional and statewide structural engineering associations, as well as in EERI. He participated in several World Conferences on Earthquake Engineering, for a time managed EERI's Learning From Earthquakes program, and made overseas trips on behalf of U.S. foreign aid and information agencies. All these activities are discussed in this oral history.

Stanley Scott
Institute of Governmental Studies
University of California, Berkeley
May 2000

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John F. Meehan

Chapter 1

Family and Early Background

While I was studying at Berkeley, I cannot recall one time when they presented anything about earthquakes.

Scott: Start with your family, your childhood, and your entry into your professional career.

Meehan: Probably one very strong reason that I got into engineering was the fact that my father, Andrew "Andy" J. Meehan, was a structural engineer. He was a structural engineer who learned structural engineering without attending a university full-time. He got most of his engineering education through International Correspondence School correspondence courses, extension classes given at the University of California, and from other such classes.

Scott: I remember when I was young seeing the ICS advertisements in various magazines.

Meehan: My father did a great deal of home study. Ever since I can remember, he was studying at home at night and on weekends. In classes given by University of California extension, local high schools, and other seminars, he studied all kinds of subjects

like languages, writing, administration, and, of course, engineering subjects. He earned his structural engineer title through the examination process. He was not grandfathered in. Of course, he was also a civil engineer, because that's the way the laws were then and still are—you become a civil engineer first, and then later a structural engineer with work experience and more testing.

I was born in a house in San Francisco—my mother didn't go to a hospital, although I don't know why she didn't. Anyway, I was born October 1, 1920, in a little house at 182 Banks Street in San Francisco, with just my grandmother there to attend to her. My father was not there at the time, as he was working for the U.S. Bureau of Public Roads, and he was a resident engineer on a bridge located, I believe, in San Bernardino County. He came home several weeks after I'd been born.

My parents had been married in Rochester, New York, and Dad worked as a draftsman, surveyor, inspector, and design engineer in different places, such as Rochester, Cleveland, and Paragould, Arkansas. They came to San Francisco in 1919. He was a field engineer and would go out to the jobs. Then, in 1921, he started with the state, and they moved to Sacramento before I was a year old.

When I was about four years old, we moved to Orange County for about a year while my father was working on a bridge construction project. I started kindergarten while we were there. Then we moved back to Sacramento, where I went through elementary school, high school, and junior college. In my early teens, I wanted to earn some money by selling subscriptions to the *Saturday Evening Post*, but I do not remember actually selling any. Later, I wanted to take a paper route, but my father did not want me to do that, saying that he was working steady, and my doing it would take the job from some other teenager. This would have been sometime between 1932 and 1934—the middle of the Great Depression.

At that time, what is now called Sacramento City College was called Sacramento Junior College. I went there for two years. I did surveying with the Sacramento County Surveyor, worked for the state Division of Highways on a survey crew, and worked for the Teichert Construction Company on a flood control levee near Marysville.

My first real paying job was with Walgreen Drugs, where I was a dishwasher, getting twenty-five cents an hour. I rode my bike to and from the job, and worked for two hours at lunch and about four or five hours in the evening. After Sacramento Junior College, I went to U.C. Berkeley and graduated in 1942.

Scott: Say something more about your choice of engineering. You mentioned that your father's example was very influential.

Meehan: Our family liked to travel, and I still like to travel. In the old days when we were on a trip, Dad would stop the car to get out and look at the bridges along the way. This was when I was a little kid growing up. We'd say, "That's one of dad's bridges—we've got to stop and look at Dad's bridges."

Scott: Those were bridges he had designed and worked on?

Meehan: Yes, or they were bridges that had been designed in the office where he worked.

As he got older he went into administration and did a lot of the hiring. Even today I occasionally run into people whom he once hired. Anyway, we would stop while Dad looked at the bridges, and my brother and I would explore along the bank and throw rocks in the creeks. So I was immersed in engineering kinds of things, although my father never really tried to push me into it. But I was fascinated with engineering.

Construction of the Bay Bridge

Meehan: One of the big engineering and construction projects in the 1930s was the building of the San Francisco-Oakland Bay Bridge. That was a state job, so the state asked if my father wanted to go down to work on it. He accepted it and went to San Francisco, where he would work during the week and come home to Sacramento on weekends.

Scott: Your family stayed here in Sacramento the whole time.

Meehan: Yes. I think he was down there for a total of about three years. At first he stayed in hotels. After he had been there a while, my brother Carl, having finished junior college in Sacramento, went to U.C. Berkeley, taking pre-med. (He is now a general surgeon in Sacramento.) When he started at Berkeley, the two of them lived together in an apartment in Berkeley. Dad commuted by ferry between Berkeley and San Francisco.

Mom and I stayed in Sacramento. On the weekends Dad would come home to Sacramento, and once in a while he would take the family down to San Francisco. We would ride across the Bay on the ferry and see the Bay Bridge under construction. Dad had access to the state boats in order to visit the construction of the piers. At the time, of course, I did not fully understand everything that he was showing me, but now I do appreciate what I saw back then. After I got older, I put my recollections together and was able to understand more about construction. I can recall seeing all phases of construction going on, so it makes a lot of sense to me now. We not only visited the Bay Bridge while it was in various stages of construction, but also looked at the construction of the Golden Gate Bridge.[1] The state did not have anything to do with the Golden Gate Bridge, which was under a special bridge district, but we'd go over there anyway. We would walk the piers and the foundation, look at the construction of the towers, and so forth.

Going Up a Catwalk

Meehan: The one thing I recall most vividly during the construction of the Bay Bridge was when Dad arranged for my brother and I to go with him up the cable catwalk to the top of one of the towers of the suspension bridge portion of the bridge that goes from San Francisco to Yerba Buena Island. That was when they were spinning the main cables. That's all they had, just the catwalks, as they were spinning the cables. I guess I was about thirteen or fourteen years old. We walked up the catwalks, which were just a woven wire fence like you see around school grounds, but it was laid down on its side. So you just walked on the mesh. They had a two-by-four laid down every five

1 The Golden Gate Bridge construction (1933–1937) and the Bay Bridge construction (1933–1936) occurred at the same time.

or six feet to keep the mesh fairly flat. It was soft walking in the flat area. The catwalk got steeper as it went up, and near the top of the tower it got quite steep. Near the top, the 2 x 4s were laid flat every twelve to fifteen inches. They were like stair steps. The cable spinning wheels rode on lighter cables and were dragging the main bridge cable strands back and forth. There must be thousands of strands in that main cable. The supply spools of cable wire were located on the bridge anchorages. The spinning wheels pulled a loop of wire from one anchorage to the opposite anchorage. (We had a sample cable strand around the house for a long time; it was about 3/16 of an inch in diameter.) The end of a strand was cut on a diagonal, and the end was threaded through a coupling that was screwed to the end of the strand.

There were guard cables like guard rails—outside cables along the edge of the catwalk so you wouldn't fall off and into the Bay. Because the guard cables had steel slivers, Dad told us not to put our bare hands on them. There was a top cable and an intermediate one or two. A good friend of Dad's was injured pulling himself up the cable. He ran some steel slivers off of the cable into his hand. It would have been good, however, to have had something to hold on to, especially up near the top of the tower.

Anyway, we made it to the top of the first tower from San Francisco, and Dad asked if we would like to walk out farther. We could go to the next tower, or all the way out to the central anchorage, come down, get in the boat, and go back. We could even go out all the way to Goat Island (Yerba Buena Island), or we could just go back from the first tower. My mother didn't go with us. She would not go up that catwalk. Since she was waiting for us below, we decided to go only to the top of the first tower, cross over, and come down the other cable.

When we finally got to the top of the tower, I remember looking down from up there. Boy, that was a long, long way down. I wished I had something to throw, so as to watch it fall. But I could spit. The spit went twirling around and around until it disappeared. I don't know whether it evaporated or got beyond the resolving power of my eyes. Every time I cross the bridge I always clearly recall walking up that catwalk. I can also recall all the equipment at the anchorage for pulling the strands of the cables into position, the large number of spools of strand, and all of the distribution devices used to transmit the load from the cable into the concrete anchorage. It just spreads out into the concrete. Very impressive.

I also remember that they had a couple of big signs saying "American Bridge Company" hanging out there so everybody and the world could see the bridge was being built by the American Bridge Company. Turned out I later went to work for them.

To the University of California at Berkeley

Meehan: In the fall of 1940, I went to Cal Berkeley and took engineering. Structural engineering looked as if it would be pretty interesting. I graduated in 1942 with a BS in civil engineering, with what at that time was called a "structural option." We had static design classes of simple structures, and some elementary dynamics classes. We also had a lot

of surveying and drafting, including drawing of rivets with ink—really a waste of time.

That's what we had to do in those days to get a degree. A lot of it was really a waste. You had first to be a draftsman—you could not be an engineer without being a draftsman. We had to draw the details in ink and on cloth. There were lots of rivets, so you had to draw rivets, and you had to make nice little round ones! I had a pile-driver compass that my dad gave me, so I made pretty good rivets.

I stayed in a men's dormitory called Alka Hall on the corner of Haste Street and College Avenue. It cost about $35 per month and included three meals a day and two meals on Sundays. About twenty or thirty students lived there, and many of them were high achievers. We all got along very well, worked hard, had fun, and were involved in intramural sports. We even won some trophies. They were a great bunch of fellows, and we had many enlightening bull sessions on every conceivable subject. I learned a lot from those sessions, which broadened my knowledge of people and the world.

While I was studying at Berkeley, I cannot recall one time when they presented anything about earthquakes. In those days they hardly mentioned codes.

Scott: They never mentioned earthquakes in connection with engineering while you were attending Berkeley?

Meehan: No. I just remember that it was a lot of work. I was not a great student. I was lucky to get through the academic part of it. I enjoyed parts of the work, but to me much of it was drudgery, and I didn't feel overly comfortable going to school. I wanted to get out and make some money so I could have some fun. I couldn't have any fun if I didn't have any money, and I had hardly any money. My parents funded my schooling, and I had just enough money to get by on. I was not very high scholastically, and I probably would never be accepted today. But I wanted to be an engineer—probably in high school I had recognized that I wanted to be an engineer.

Scott: There must have been a fair amount of drudgery in the engineering programs, especially with the kind of drafting you described, and the labs, work projects, and the like.

Meehan: I did have some fun at school, but nothing like what I see going on today. Nothing at all like that. Back in those days, the boys went one way and the girls went the other way. Not at all like the modern campus life. But I finally graduated.

After graduating, during my working career, I have taken many classes and attended many seminars on subjects including metallurgy of welding, dynamics, mathematics, letter writing, speed reading, handling stress, management, dealing with people, contracts, and computer science, along with updating courses in structural steel, concrete, wood, masonry, pulmonary resuscitation, and foreign languages.

Scott: Sounds like you took after your father in more than one way.

Chapter 2

The War Years

I was fortunate that accident didn't cut the whole damned leg off.

Meehan: After the war started in December 1941, they were offering commissions to the students right and left. I had never taken any R.O.T.C., so I'd never had any kind of military orientation at all—not even until today. I was never in the service.

When I graduated, I recognized that I didn't really know much of anything. I had some knowledge of civil engineering kinds of things, but there were a lot of things that I did not know. I think my father recognized this, too. He suggested that, since I would probably get drafted, and the war was going to last for a while, he thought I should try to get some engineering experience. That way, when I did get out of the service I would at least have a jump on some of the graduates who just went straight into the service out of college. I felt that the kinds of things learned in the service would not be applicable to engineering after the war.

The American Bridge Company

Meehan: My father got me an interview with a fellow by the name of Jack Fox, who was a San Francisco representative of American Bridge, or maybe it was U.S. Steel. He said he would be happy to make arrangements for me to work in Gary, Indiana, in the steel mills for the American Bridge Company. He said, "If you

want to work for American Bridge, that's where you should go. If you want to be an engineer, that's where you've got to go. You can't be an engineer without knowing how to detail structural steel. That's good experience for you."

So that is what I did—I went back there to American Bridge in the summer of 1942, after graduating from Cal. I was in Gary, Indiana for three years, from 1942 to 1945. My first job was drawing details of structural steel columns to show where to punch holes in the steel members. We did the drawings with pencil, which was easy to erase and change. We could use pencil there. Basically, we had to show the length of the members, where to put the holes, their size, the cuts on the members, and things like that.

We worked on all different kinds of buildings and saw the drawings of many private engineering offices. I had never seen many project drawings before, and when I got out of school, I did not even know what they did with a set of building drawings. Then when I went back there to Gary to start this job, they said, "Here are the building drawings." While I was there, I worked mostly on buildings.

Scott: Even though it was the American Bridge Company?

Meehan: Yes. They did a lot of things. They made bridges, sections of ships, caterpillar tractor parts, bridge cranes, barges, flight decks for ships, and had many kinds of projects utilizing structural steel.

Scott: What kinds of buildings did you work on?

Meehan: I did not work on any multistory buildings, but mostly on factory-type buildings. One I remember working on was a building for an automobile plant, a mill type of building. That job was kind of interesting at first, but it got awfully boring, too.

Visualize this: Here's a piece of steel and now you've got to tell somebody, "You've got to measure 2¼ inches from the end and 1¾ inches from the edge to that first hole, and then you make a hole $^{13}/_{16}$ inch in diameter for a ¾-inch rivet, and then you go up so far to the next hole, and the next hole." I had to learn fractions, and how to add and subtract in fractions of an inch, because that was what the plant used. They all had to come out right, otherwise the building wouldn't be put together properly. If you made a mistake, one side of the column or the beam might be longer than the other side, which does not work. Somebody was always there who checked the dimensions. Anyway that was the work I started out on, and I was detailing for about a year.

Then they needed a person in their plant maintenance department. The company's procedure was to pick the kids after graduation from college and put them to work in detailing. After that, they would put them in the shop for a while to get experience assisting in the actual fabrication of the structural steel.

Scott: So in effect, they put the new employees fresh out of college through kind of an internship or apprenticeship program to learn the business?

Meehan: Yes. There were fellows from Oklahoma, Iowa, et cetera. We roomed and boarded in homes and walked to the plant. Anyway, the company asked me if I'd like to go

into the maintenance department, which gave me a chance to get away from all those fractions, from adding and subtracting fractions such as ⅛ inch and 1/16 inch. That fraction work was a big nuisance. Back in those days, we did the fractions mentally, as they did not have calculating machines.

The maintenance department had all kinds of interesting projects. I actually designed some buildings and built some buildings in the plant. I wouldn't dare put up a building today like one of those we did back then in Indiana. Back there they did not know the word "earthquake."

Scott: Are you saying that those buildings were not tied together too well?

Meehan: Yes, not tied together. They had concrete block walls with no reinforcement or grout—just the blocks and mortar. When they got up to the top, they just stopped. The walls were not anchored. Nothing was.

Scott: They simply put a roof on it and let the roof just rest on top of the walls?

Meehan: Yes. I also did surveying for them. I had already gotten a lot of experience with surveying while I was in junior college. I had worked for the former Sacramento county surveyor, and we used to do a lot of surveying around Sacramento. Engineering students had to take a lot of surveying classes in school, including several in junior college, plus a couple of summer survey camps. At American Bridge I did a lot of surveying on skids, assemblies, and fabrication jigs, as well as railroads.

A jig is a device to assist in fabricating and assembling the pieces. When they made a bridge crane, I had to establish a line and camber for the drive shaft bearings. I set the points where they drilled the holes for assembling the drive shafts. Also I established elevations and put proper camber in some of the big members and some of the big bridges.

Scott: Did you make the whole bridge pier there?

Meehan: Yes. Then it would be disassembled and shipped to the site. In fact, that is how the Bay Bridge was built. A lot of the Bay Bridge was fabricated in the Gary plant, disassembled, and put together again on the site.

We did a lot of dam gates, which had to have very large assemblies of steel plate 1½ inch or two inches thick. The parts had to be accurately fabricated to fit into the slots of the dam these big gates would ride in. It took a lot of time to get those milled pieces together properly. I would set up and give them alignment information for the elevation and so on.

Scott: So even though those dam gates were huge things, the tolerances had to be pretty close.

Meehan: Yes. The tolerances had to be very, very close in some of the pieces they made. We had to position the large subassemblies of the gates to within 1/64 inch. That is the kind of work I did, using my surveying experience. I also did a lot of maintenance work on equipment and buildings in the Gary plant. I had a little crew of people working for me. The fabricating plant was arranged in such a manner that the raw steel from the rolling mill was stored in the receiving yard. They would pick up the steel and manually push it through the shop on carts running on rails. The paint shop

was situated at the end of the fabricating shop, and after being painted, the steel was stored in the yard and then shipped, either on railcars or trucks. Most of it went out on railroad cars. That was the process. In transferring the materials through the shop, they used little steel pushcarts to move the steel longitudinally, and cranes to move it transversely. First, the steel was cut to length, then moved to the next place, where it was punched and cut. Then it was moved to the next location, where they put some connections together by riveting, bolting, or welding. Then it was moved on down to be cleaned and painted.

Scott: It was organized like an assembly line?

Meehan: That's right, exactly. The pushcarts were on railroad rails, which were laid on a downslope toward the rear end of the shop. That way we did not have to push hard to move the material through the shop, because everything went in that one direction, downslope. I cannot recall what that slope was, but it was approximately 3/64 of an inch of slope per foot. When they first built the mill, they had steel angles cast in a concrete slab. The small rails were set on top of the angles. Because of subsequent settlement, however, the theoretical uniform slope no longer prevailed, so the track bed went sort of up and down. One of my overtime jobs was to reset the grades on those tracks. We'd stay there all day long on Sundays, working on that. They would break loose a section of rails and shim them up to the elevation I gave them. Then the welders would weld the stack of steel shims, ties, and rails together. Sometimes there was as much as three or four inches of steel shims. Sometimes there were just a few thin shims.

Looking down toward the welders was necessary to set the grades. I got a lot of welding flashes. It was really bad on the eyes. I'd wake up at night feeling like sand was in my eyes. It was hard to avoid because of the proximity of the welders and the work involved. So I'd end up with a weld flash almost every Sunday night.

Scott: You mean it kind of blinded you temporarily?

Meehan: No. They call it a weld flash and it comes from looking at or near the electrical weld arc. At night it feels like there is sand in your eyes. I'm not sure what it was, but everybody would get them. The hospital would put a few drops of Argyrol in our eyes, and that kind of relieved it.

Scott: This was electric welding?

Meehan: Yes. Also a lot of riveting went on in those days. I doubt if hardly anyone knows how to drive a rivet today. But we drove a lot of them.

Another thing that we did involved constructing welding skids where they assembled and welded parts together. It was a series of steel beams that were set so that the top of the beams would be level, so anything you laid down on it would be flat. The workers could then use squares in the fabrication. These welding skids would become part of the electrical welding ground system. The steel beams that we laid in the floor were interconnected to the building steel frame, which was interconnected back to the power house to complete

the welding circuit. They had portable electric welders that plugged into wall outlets.

I got a lot of really great experience in welding, because it was the early stage of development and a number of inspectors were there. We did a lot of work for the Navy, building ship parts, decks, bulkheads, et cetera. I gained good experience in watching and listening to the Navy welding inspectors. I got interested enough to take a course in welding metallurgy.

Scott: You picked it up indirectly. But you yourself didn't work on inspecting welding and that sort of thing.

Meehan: No, but as a result of working there, I had very broad experience in a practical structural steel fabricating plant, doing everything, with the men who were physically doing it—even though I wasn't physically doing it myself. Our standard workday was ten hours on weekdays and only eight hours on Saturdays and Sundays.

It was during the war, you know. There was much work to be done, and we got it done. There was a lot of overtime. I didn't save any money. I don't know where it went, but it went.

A Severe Injury

Meehan: I remember one day very clearly. It was on a Sunday. They had a big milling machine, which is a device that shaves off the steel to make it flat like on the bottom of a column or the bottom of a member, to make a smooth bearing when it is set down. It was like a great big grinder, with cutters. A big tower or column could be set down on the bed and then this machine would grind the end to make a smooth plane.

At this particular milling machine, we knew the location of the cutting surface, but they needed an accurately located perpendicular line. I was assigned to establish this perpendicular line. The milling machine has a bed which supports one end of the member and the cutters milled off the end. The opposite end of the member was supported on a very heavily built cart that rode on tracks. A turntable used to turn the members had about an inch of clearance under the cart.

I had a fellow helping me. The heavy cart was in the way, and we had to move the cart. I was pulling and he was pushing. The turntable was behind me, and it took a lot of force to start the cart to roll. As it rolled, I got my leg between the turntable and the cart. There was only about an inch or so clearance, and the bone in my leg stopped the cart from rolling and I got a big, bad cut on the front and back side of the lower part of my right leg. Well, that stopped everything right there. A terrible mess. I was fortunate that accident didn't cut the whole damned leg off.

I spent a week or so in the hospital to heal up. It didn't heal properly. The front or shin part of my leg developed a bump, so that every time I tightened up that muscle, the fibers would bulge out through a split of the fascia. The fascia is a container or sheath around the muscle. As time went on, the bulge got bigger and bigger.

The war was going along, and I decided that now it was about time for me to get into the war. The plant kept getting deferments for me because of my work. It was late 1943 or early 1944. I wanted to get into the service, so I got an appointment to go to Chicago for a

Navy physical examination. I wanted to get the commission they offered me while I was at Cal. So they said, "Sure, come on in, happy to have you." They gave me the physical, but they saw that bulge on my leg and they didn't like it. They told me "If you can get that thing repaired, come on back and we'll be happy to have you on board. So I went back to the mill and told them I'd like to have the bulge repaired.

It took several months. The doctor opened the leg and sewed some fascia in there, with the hopeful idea that it would act like a net, hold the muscle in there, and in the meantime then the fascia would grow together.

Well, nothing like that happened. All they did was plant a great big infection in my leg. There was much drainage, and it drained for a long, long time. It was a big mess. They even sent me into Chicago to another doctor, to see what he could do. They finally decided to open it up and let it heal from the inside out. This took about six months. I lost the tendons and muscle controlling the uplift of my right foot. This, of course, has restricted many of my activities to this day. My toe catches on the slightest uneven surface; I trip frequently and cannot move like I used to. The Navy didn't want me, and I was put in a 4F draft classification.

Convalescence and Marriage

Meehan: The first day that I went into that hospital for the repair, a student nursing hospital, Mercy Hospital in Gary, I met Liz, Anna Elizabeth Anderson, who was one of the nurse supervisors. She was a graduate of Mercy Hospital. I was in that hospital for almost six months. I did get off for a few weeks, but I had to go back in; however, I got a great big bonus out of it. Liz and I got married shortly after I got out of the hospital. In fact, we went back to the chapel in the hospital to get married. One of the nurses sang songs at our wedding and the hospital chaplain married us. That was on April 14, 1945.

I went back to the American Bridge drawing room then, because I could hardly walk. I really had a tough time. I had a skin graft to try to heal it up and they gave me all kinds of new penicillin-type medicines, like Tyrothricin. In fact, we named our first dog Tyrothricin. We called him Ty for short. Boy, it's funny what recollections come back when you start thinking like this.

Leaving Gary for California

Meehan: I decided that I didn't need any more of that Chicago/Gary atmosphere. The mills were so dirty, with all that stuff coming down out of the air.

Scott: Coal, smoke, grime?

Meehan: Yes, all that grime and smoke and cold. I never did enjoy being back there.

Chapter 3

Back to California

The difference in California practice was because of the Field Act and the way it was carried out by the state with regard to public schools. The practice of engineers then was carried over into their other work.

Meehan: We were coming back across country by train on VJ day, the victory day ending the war with Japan. We were going through Boone, Iowa, and the people and the high school band came out to meet the train when we got the official word that the war was over.

Back in Sacramento, we stayed with my folks for a while. I went to San Francisco to try to get a job and talked to a friend of my father. They used to work together for the state, and he had opened a consulting engineering office. It turned into a very large office in San Francisco. It was the Donald R. Warren Company. So I started working for them.

Scott: Your resume says you worked there in 1945–47.

Meehan: When we first got to San Francisco in 1945, we wandered all over the town, trying to find a place to live. Liz was pregnant. We would walk up and down the streets among all of those apartment buildings, rap on the door, see if there was an apartment or something open, some place to stay. There was just nothing

available. We did finally find an apartment in Oakland, near Berkeley. I could ride the train back and forth to San Francisco and could walk to the train from our apartment. We didn't have a car.

William John, or Bill, our first son, was born February 22, 1946. Today he's an internal medicine physician in Helena, Montana. On our first anniversary, our oldest son was two months old. He was born while we were living in that little rented apartment. We could look out the back window and see the Claremont Hotel up the hill. It was on Dover Street, between Shattuck and Grove, near 57th Street.

I wandered into John A. Blume's office. I didn't know John from Adam. He didn't know me either, but he needed some help. This was when John had a very small office. There were only about half a dozen people in the office. Joe Nicoletti, Don Teixeira, and a couple others were there. In fact, I got a letter from John when I retired, saying that I was the fifteenth full-time employee that he'd hired in his firm. That was a great job. I enjoyed working with John. He was a real fun guy and very smart. His was the only office I worked in where we had no rigid working hours. We could come and go freely and kept our own time on the honor system, but we had to meet deadlines. We frequently worked nights and there was no problem about singing as we worked. One of John's favorites was "Peg of My Heart." We sang many songs together. As I said before, I enjoyed working in his office.

Learning About Seismic Design

Meehan: While I was with Don Warren in San Francisco, they had shown me a little bit about earthquakes. Rigidities in buildings and things like that. I was doing structural type design and drawings. It was there that I saw what California practice was, compared to the way drawings were done back in the Midwest. Some of the drawings back there, I'm sorry to say, showed only one-line drawings of a truss and gave a member size and the end connection. No location of members or rivets was given; there was no concern for eccentricity in the members or joints.

When I started working with Don Warren, we showed complete details. This is going to be easy for the detailer; he will just copy it. We gave precise locations of everything, showed how the end was to be cut, the size, the members, the gauge, the distance from the back of the angle, location of the rivet or bolt or the amount of welding clearly shown on either side, et cetera. A good set of detail drawings tells the inspector exactly what is required—what to accept or reject.

Influence of the Field Act

Scott: Why was California practice so different? Is it principally the consideration of earthquakes, or were there other substantial factors? Is seismic concern only one of the elements that accounted for the difference between eastern practice and California practice?

Meehan: I have a very firm thought on that. The difference in California practice was because of the Field Act and the way it was carried out by the state with regard to public schools. The practice of engineers then was carried over into their other work. The names of the state agency enforcing the Field Act have changed over the years: the Division of

Architecture, the Office of Architecture and Construction, the Office of the State Architect, the Division of the State Architect.

Scott: And you think California engineering practice in general has been influenced by the Field Act?

Meehan: Yes. I really think that our plan check office improved the practicing engineer's work. The engineers recognize and see the advantage of a good set of drawings, because all contractors bid on the same job, and not a job where the contractor and inspector have to interpret the drawings as they wish, which then leads to loss of job control.

In going back to my experience in Don Warren's office, I was amazed at the amount of detail that the California engineers were showing, compared to what I had seen on the drawings in Indiana. I was doing steel detailing in Don Warren's office. I also did some bridges, buildings, wharf-work, and material-handling equipment.

I even worked on a hospital with Don. In that process, I began to hear about earthquake resistance and differences in stiffness and how to analyze it. It was kind of like a riveted joint and how the rivets share the load. When I was in Gary, I was not aware that hardly anybody recognized or did anything with the eccentricity or polar moment of inertia of a rivet group.

When I was working in San Francisco, I had a much better concept of how to build things. I think today a lot of people don't know how to build things. They can't visualize assembling the building components or the construction process.

Scott: You picked up all of this in Gary, but at the same time when you got to California you added to, or elevated your awareness to still a higher level, and partly because of the differences in the practice. Is that what you're saying?

Meehan: Yes. And I could recognize that some of the people here in California didn't know how to construct things very well, or know the actual construction process. I tried to visualize how to get the crew to work, and what they were to do. Who's going to do what, and how? And other people, I found, would just say, "Well, we're going to do it this way," not visualizing the type of worker and equipment needed and the sequence of construction. They were mixing trades. That's the thing that you hardly ever hear of, mixing trades.

Mixing Trades

Scott: Say more about what you mean by "mixing trades"?

Meehan: One trade depends on another trade to do something, before it can come on the job. For instance, if you have a masonry building and you have some steel beams supported on the masonry walls and interior steel columns, what do you do? Would you build the walls first with the masons, and then bring in the crane and steel crew and set the steel beams on the masonry? Or would it be better to have the steel framing erected, and build the walls around it? So you bring in the steel, the cranes, and steel crew, who would get in and out, and you've got a steel frame sitting there, waiting for the masonry to be built around the steel framing.

Scott: How much of that is also something the contractor is or ought to be responsible for? Do they both need to be responsible?

Meehan: Yes.

Scott: But the designer should have these considerations in mind.

Meehan: That's my point. He must be aware of them.

Scott: Otherwise the designer can make it very difficult for the contractor.

Meehan: Yes, and can make it a very expensive building. It is much more costly to mix trades. I have seen drawings come into our office with no or very little consideration given to construction sequence. It's an important phase. Design isn't just putting a bunch of members together, then walking away from it. The design and construction sequence is an important consideration. Our structural safety section office has no authority to get into that phase of construction practice; therefore it is an area that may not be well addressed

John Blume educated me about mixing the trades. That was always one of his considerations. How to build it, how to keep the trades separated as much as possible. For example, don't bring the trades back and forth, or don't bring that great big, expensive crane on the job without using it. Cranes are expensive.

Working for Blume

Meehan: I remember one day talking to John Blume about something or other, and I mentioned something about earthquake design. He asked, "Do you know about earthquakes?"

Scott: John Blume asked you?

Meehan: Yes. I said, "Not much, but I know a little about earthquake design." Of course, John was "Old Earthquake Engineer #1" as far as I was concerned.

Scott: It rang a bell for him when you mentioned earthquakes?

Meehan: Yes. It was something about the design. I can't remember now exactly how it came up. I had a little earthquake design experience with Don Warren's jobs, although nothing on it back in Gary or in school. I guess I got it through Don Warren and then through John Blume. John was very helpful to me, getting me set in the direction that I thought I really wanted.

Scott: Can you say a little bit more about ways he was helpful?

Meehan: He had both engineering experience and construction experience. His father did a lot of things.

Scott: His father had been a major contractor.[2]

Meehan: John got a lot of good experience from that work.

Redundancy: A Little Extra

Meehan: John Blume helped me a lot in design and basic concepts. He had me design buildings in a seismic manner, way before

2 Blume discusses his father, Charles A. Blume, in *John A. Blume: Connections, The EERI Oral History Series*, Earthquake Engineering Research Institute, Oakland, CA, 1994, p. 2 ff.

codes had certain limitations and requirements. For instance, he said to always put some moment-resisting frames in your buildings. Don't use simple connections without continuity and just depend on shear walls to resist lateral loads. In case the walls go, you will still have the moment resistance in the frames. Your moment-resisting frames will be able to resist a little lateral load and could prevent the building from collapsing. The broken walls that remain in position, from properly installed reinforcing, will absorb a lot of energy during the earthquake.

John was saying that way back before it got discussed in the literature. I remember very clearly that he always said to put in a percentage of the lateral load in the frames. And then if you have a chance, put in still a little bit more. Also, tie all parts of the building together. Look for the weak and strong parts of the building and take care to account for how the building will move during an earthquake.

Scott: So that way you would have a little reserve or redundancy.

Meehan: We designed standard wharfs, also unloading wharfs that were two-legged power poles laterally supported with a cable at the top, along with buildings in Arabia for the oil industry. We also did a lot of Pacific Telephone and Telegraph buildings. They were always designed so that there would be an expansion in one direction or the other, usually to add another floor or two. They wanted to be able to add floors, and they usually had extra space adjacent to the building, so they could go out horizontally. Perhaps have a permanent equipment building on half the site, and the other half would be office, which later could become an equipment facility.

We worked nights, and we did some crazy things there. I probably shouldn't even talk about them. John wasn't always there in the office. He'd be out meeting people, getting work, and attending meetings.

Scott: Meeting possible clients?

Meehan: Yes. He'd go out frequently. So we kids in his office started making and sailing paper airplanes for a break in the work routine. John's office was on the third floor, and we started making paper airplanes and sailing them out the window. That went on for quite a while. Then we decided that we had to control it. We couldn't just continue to make airplanes and sail them out the window, cluttering up the place. So we each put a nickel in a box for each plane sailed out the window. The first guy who got a plane into the light well of the next building across the alley got the pot, and then we would quit.

About that time John caught on to what we were doing. Also about the same time one of us made the first airplane that made the light well. John gave us all hell. He didn't give us verbal hell, but he put a big note on the wall about wasting time and materials. But we had a lot of fun. A lot of neat guys.

Scott: You were there for about two years?

Meehan: A couple years, yes. John was very influential in my career. I learned a lot from him. Good, solid engineering approaches to many subjects.

To the California Division of Architecture

Meehan: When I was a kid, I liked to hunt and fish around Sacramento, but I hadn't had much of a chance to do it in the Bay Area, although I went fishing a few times. I thought that I'd like to move back to Sacramento for the sport. Then I learned of the school plan check work in the Division of Architecture. I wrote to the Sacramento office, and Merle A. Ewing came to San Francisco for my interview. He said, "Sure, I'll put you to work. When do you want to start?"

I made arrangements with John to leave. I then went to work in the Schoolhouse Section of the Division of Architecture in San Francisco. That was in May of 1949. At that time Merle was supervising structural engineer. He had the San Francisco office, which was a fairly new office, and also the Sacramento office. He worked a few days a week in San Francisco and a few days at the Sacramento office.

Scott: He was in charge of both those offices?

Meehan: Yes. Then they had another fellow by the name of Ernie Kahlert who was in the San Francisco office continuously. Ernie ran the office. So I checked plans for a while. When I was first interviewed, Merle asked me if I'd had any field experience. I told him that I did. When I was checking plans, I could see this wasn't a whole lot of fun. I wondered what the fieldwork involved.

One day when he came to the San Francisco office I asked him about it. He agreed to give me a try and sent me out with Karl V. Steinbrugge, who was a field man in the office. At that time, Karl Steinbrugge was a field engineer. Of course, later on I was to have many experiences with Karl, when we were both devoting our time to earthquake engineering work.

The first field trip I ever went on for the state was with Karl. Karl showed me how to go about doing field man duties. There wasn't much training. We went out on a job or two. At that time, the jobs were listed on little three-inch by five-inch cards; each card was a job or an application. They assigned me to the Fresno area. By that time I had bought a new blue Chevrolet, so I drove my car to the Fresno area.

Anyway they gave me this stack of cards and a notebook and said, "You're the field man for that area." I was a civil engineer. I didn't have my structural title yet. I would not have been able to do that today. I was hired as a structural engineering associate. I got my civil license when I was working with Don Warren. Today our requirements are that you must be a structural engineer to go out in the field. Anyway, they didn't have enough people then. This was still not long after the end of the war, and people and housing were extremely hard to get.

Scott: This was in 1949–50 when you were doing field inspection?

Meehan: Yes, but we don't say "inspect," we say "observe." Inspectors inspect, and we observe the inspectors. A primary basis of the Field Act[3] is that the construction must

3 Glendale Assemblyman Don Field worked with State Architect George McDougall and several engineers to draft AB 2342, which was delivered to the California Assembly on March 23, 1933, less than two weeks after the Long Beach

conform to the approved documents. That's a major key to Field Act construction.

We approve drawings, which must meet the regulations adopted pursuant to the Field Act. We approve drawings, but we don't approve construction. When the construction is completed, we say that we have received all of the verified reports in accordance with the Field Act, though we don't use the term Act, we say Education Code, section so-and-so.[4] Verified reports are very important because they tell us that the construction conforms to the approved construction documents. False reports carry a felony charge. This is another important aspect of the Field Act.

When I was working in San Francisco for the state, we bought a house in San Leandro, and the commute was the real thing that pushed me out of the Bay Area. It took me an hour and a half standing up on the bus and streetcar to go each way to and from work. So each day I contributed about three hours of my life going between 139th Avenue in San Leandro and McAllister and Van Ness in San Francisco. The Nimitz freeway did not exist, and all driving was on the streets.

I'd leave in the morning about 6:00 and got home around 7:00 or 8:00 at night. A lot of the time spent was on the bus from San Leandro to the terminal in San Francisco. About 95% of the time I had to stand up because the bus was filled by the time it got to me. I stood up all the way going into work, and the whole way home. There was always a long queue of people waiting to get on the bus and to get seats at the terminal. Or you could get on as a standee. Standees usually could get on without having to wait. So I thought, "The hell with it. I'll get on," so I stood up going home. That was not much fun at all. It was a lot of standing up, and rocking back and forth. When I asked Merle if I could move back up to Sacramento, he said, "Yes, you can work in Sacramento, but we will not pay any moving expenses." But nobody had paid for any move I had made yet. So we came up here, stayed at my folks' house for a while, and then rented a little house here in Sacramento on Bell Street. By the way, while we were living in San Leandro, our second son, Michael "Mike" Carl, was born on August 22, 1948. He is now an orthopedic surgeon in Vallejo.

Here in Sacramento, we lived out on Bell Street for a while. That was when they had the big floods. That house almost went under water in the 1951 flood, which was before Folsom Dam was built. The water came within two inches of the surface of the floor in our house.

When I passed the structural exam in 1951, I became a certified or licensed structural engineer. In those days it was automatic to go to a senior structural engineer assignment with the state architect's office. No additional examinations were necessary. I had that senior structural engineer title until 1957.

Earthquake. It was signed into law by Governor James Rolph, Jr. on April 10, 1933. More detail is provided in the appendix to this volume.

4 The Field Act constitutes California Education Code §§17280–17317 and 81130–81149. Design professionals (architects and engineers) must comply with the California Building Code (Title 24 of the California Code of Regulations, Part 2, Vol. 2) when they design and construct public school buildings.

Meehan: While I was in the field, I kept driving up and down the valley, and I was gone from home about three days a week. The kids were all young. We had our daughter Patty, Patricia Ann, born March 5, 1953, who is now a draftsperson in an engineering office in Bend, Oregon. She is also an artist. Because of being gone so much and the three young kids, I asked to be returned to the office to do plan checking, and they agreed.

Scott: You returned to the Sacramento office to do plan checking?

Meehan: Things changed. Plan checking is pretty much an eight to five kind of a job. You go in and you check plans, then you come home and try to forget about the job, and then go back in the next morning back to work. I did a lot of overtime, too. We had a lot of extra work. They were always short of structural engineers, so there was a lot of overtime.

Scott: To try to keep the backlog of work down.

Meehan: Right. Just like we're doing today [1988]. Trying to keep the backlog down to about four weeks, or something like that.

Becoming Research Director

Meehan: Things changed again in 1957. I got a new position. I became the Research Director to work directly under L. M. "Tex" Herd, Chief Structural Engineer. At the time, the agency had research funds, funds that were included in the budget to perform research. It was the kind of research that others would not do. It was to be a seed-type research, hoping that the industries or the universities would follow on and extend the research. This work was very interesting.

Scott: When you got the new title and moved into the research activity, were you in charge of it?

Meehan: Yes. In my position as Research Director, I did all the legwork and the follow-up. Of course, I had bosses over me, like everyone does. We discussed new projects and the progress of contracts in our staff meetings.

Chapter 4

Earthquake Research

I said I wanted them to design a shake table platform about one hundred feet by one hundred feet on which we could build a gymnasium and reproduce earthquake motions that would knock it down.

Scott: The research activities you referred to were supported by funds that the Division of Architecture administered? You would figure out some things that you really wished to know more about, but that the universities or the industries weren't doing research on. So you would either do the research, or use seed money to try to get it done?

Meehan: Yes. We wrote contracts for other people to actually perform the research. We had the program, we knew what we wanted done, so we would contract to do specific types of research. The money was available from the plan-checking fund. In order to spend any money, approval of the Department of Finance must be obtained. We had to go through the whole budgeting process.

In those days we had many research ideas, because back in the 1950s there were many rule-of-thumb designs that needed more substantiation.

Scott: Rules of thumb for seismic design?

Diagonal Board Sheathing of Walls and Diaphragms

Meehan: Right, for instance, I remember back in the old days we just laid the boards on the roof and on the studs, square with the framing, not diagonally. This was before plywood was common.

Then as time went on, they realized that if those boards were laid diagonally, the walls would be stiffer, because the boards now are carrying the load as a direct load, rather than by bending the boards through nail couples in the boards. I questioned Merle Ewing, Supervising Structural Engineer in the Sacramento office when I first came up to Sacramento, "Does diagonal sheathing really work?" Unbeknownst to me, at that particular moment they were running some of the initial tests on diagonal sheathing.

Scott: Under the research fund?

Meehan: Yes. I wasn't involved in it yet, but they had a contract with the Forest Service, in Madison, Wisconsin.

Scott: Forest Products Lab?[5]

Meehan: Right. They, together with us—we were called the Division of Architecture then—ran the very first tests on diagonally sheathed diaphragms. They tested a sizeable diaphragm, twenty feet by sixty feet. These were the first diaphragm tests that were run by anyone anywhere. We found that the diagonal sheathing would work, but that the allowable design loads we assigned were too high. At that time we allowed an in-plane shear force of 444 pounds a lineal foot. That was based on the component nail value, and the number of nails per lineal foot that we would get in the perimeter. That was a pretty high load.

We found that to put 444 pounds a lineal foot on a diaphragm, it would deflect a great deal, in the range of several inches. If the wall had to move that far, it would crack all the plaster and break all the windows. So we reduced the allowable shear load down to two hundred pounds per lineal foot.[6]

That was one of the big items. They were using only diagonal sheathing in those days, on shear walls and diaphragms. We were building a lot of wood frame school buildings at that time.

Scott: So that was a very important issue.

Meehan: It was a big change. Then we also found that if stiff members were placed around the perimeter of the shear wall—to take care of what they call the "lost component,"—the allowable shear value could be increased and the displacement reduced. The "lost component" is a fictitious load considered to act perpendicular to and spanning between the diaphragm chords. With two-by edge members, the allowable load was about two hundred

5 The Forest Products Laboratory, located in Madison, Wisconsin, has been in operation since 1909 under the administration of the Forest Service, an agency of the United States Department of Agriculture.

6 D. V. Doyle, *Diaphragm Action of Diagonally Sheathed Wood Panels,* Forest Products Laboratory Report 2082, Madison, WI, 1957. This was later reissued in 1969 with a few revisions under the same author and title as U.S.D.A. Forest Service Research Note, FPL-0205.

pounds per lineal foot. But if a larger member could span between the chords and resist that "lost component" load in bending, then we could apply a heavier load and keep the deflection or drift low. That is still in our code. The Uniform Building Code (UBC) picked that up some time ago.

Steel decking and other materials used as a diaphragm began to be used at about the same time. Around the 1960s, designers started using plywood and have been using plywood ever since as the main wood diaphragm resisting element in wood frame construction.

A lot of good things were done with that research money.

Testing Windows

Meehan: One of the first projects that I was involved in goes way back to 1958 or 1959 at U.C. Berkeley. I wrote a paper and presented it at the Second World Conference on Earthquake Engineering in Tokyo in 1960.[7] Professor Jack Bouwkamp at U.C. Berkeley did the tests and did a very good job. Actually we were joint authors on that article. He did the testing, we wrote a paper together, and I presented it. As a result of that, our office reduced the allowable drift by half of what we formerly permitted. We permit a drift of 1/16 of an inch per foot of height as allowable story drift, if the glass could tolerate it or if the glass did not resist load. That is, there must be clearance around the glass, so that when the frames moves, it wouldn't put any load on the pane of glass.

In our tests, we learned that if glass is set tight in hardened putty (we substituted plaster of Paris for hardened putty, which has about the same hardness) we found that glass would fail at 1/16 of an inch drift per foot of height of opening, so we reduced the allowable drift in half, to 1/32 of an inch per foot of height of opening for glass installed without edge clearance. That is our present limitation if special details are not provided to keep the glass free from bearing on the edges under a drift condition. So for a twelve-foot-high wall anchored to the floor below and floor above that contains a four-foot-high glass window, the allowable drift is 4/32 of an inch, and not 12/16 of an inch or 12/32 of an inch. It's calculated in terms of the drift per foot of height of opening.

Scott: It is drift in the window opening, not drift of the entire story?

Meehan: If the bottom of the wall is anchored to the floor and the top of the wall is anchored to the next story above, then it would be the story drift. Many architects and designers provide clearance around the edge of the glass. Another and more common way to handle this problem is to anchor the partition to the floor below and separate the top of the partition from the floor above, but provide out-of-plane support. If the drift displacement puts the glass in a diagonal compression mode and the drift displacement continues to go farther, the glass explodes. We saw that in our tests and in a school in Coalinga from the 1983 earthquake. The Coalinga experience was in a public school built before we had the drift

7 Jack G. Bouwkamp and John F. Meehan. "Drift Limitations Imposed by Glass," *Proceedings of the Second World Conference on Earthquake Engineering,* Tokyo and Kyoto, Japan, 1960.

regulations. That experience really drove the point home.

Scott: What about the Uniform Building Code on that score?

Meehan: They have a limitation of 1/16 of an inch for story drift, and also have minimum clearance around the edge of the glass, but it bothers me that it does not tie back to the structure and the size of the glass. I think there's a looseness in our codes in that area.

Forced Vibration Shakers

Meehan: The next big project was the development and construction of four portable shaking machines. I think that was the first contract that I wrote, to design and construct those four shaking machines. The shaking machines were designed at Caltech by fellows like George Housner and Don Hudson and others. I think Ray Clough at Berkeley was also part of that same committee. We wrote a contract with the Earthquake Engineering Research Institute. They in turn contracted with Caltech. The shaking machines were designed by the EERI Committee and then built under the supervision of Caltech.

These shaking machines were very sophisticated. There were four units. Each had a double vertical shaft and two eccentric counter-weights, an eccentric weight on each shaft. Variable weights could be placed in a basket and they would rotate in opposite directions. When the two weights are going in the same direction, it induced a resultant sinusoidal force in that direction into whatever the machine was fastened. Then when the weight came around at 90 degrees, the resultant force canceled; and then when it came back around 180 degrees, the force went the opposite direction. The weights produced the greatest forces when they were on opposite sides of the shafts, going in the same direction.[8]

It was pretty clever. In fact, they use that design a lot now in shaking facilities. The four machines were portable.

Scott: You affixed the machine to a building?

Meehan: Yes. Anchored them down to whatever you wanted to test.

Scott: You'd rev them up, and had gauges and sensors to see what the building did.

Meehan: Yes, accelerometers were placed around the building, and we could re-run the tests as many times as desired to reproduce the test. That was an advantage of these shaking machines. I believe the original design criterion was to produce shaking capability to collapse an ordinary school building.

Scott: Collapse a full-scale public school building?

Meehan: Yes.

Scott: That was a potent little machine.

Meehan: Right. But we never collapsed anything. Each of the four machines had a maximum output of 5,000 pounds force. Thus, with four machines, the maximum total output was 20,000 pounds in-phase or out-of-phase. An important feature was the controls for the

8 D. E. Hudson, *Synchronized Vibration Generators for Dynamic Tests of Full-Scale Structures*, Earthquake Engineering Research Laboratory, California Institute of Technology, Pasadena, CA, 1962.

speed of the machine. The real key, though, was to control the motion of the weights and synchronize them so that all four machines were working exactly as desired. Each machine had a set of controls, and there was also a master control to control all four units simultaneously. Four machines could produce forces in a parallel direction. Also, two pairs of machines could be controlled to produce forces in the opposite directions, thus inducing a torsional load into the building. That is, they could be controlled to operate in-phase or out-of-phase.

Scott: It sounds pretty complicated.

Meehan: It was complicated, but worked out very well. The electrical controls were really important, and they did the job.

Scott: Say a little more about how the machines were used, where they were used, and what you found out.

Meehan: Even if you shake a structure just a little bit, by varying the rate or frequency of the vibrations, you can find the rhythms that coincide with the structure's natural periods of vibrations. You can also figure out the damping. The first thing they tested was a concrete intake tower, I think at the Encino Dam in the Los Angeles area.[9] They put a machine on the top of it and shook it. As I remember, there was only one machine up there. Maybe that was the first one in operation. The amazing thing was that many people thought concrete structures had a damping level of 10%, or perhaps as much as 20%. But they learned that this concrete structure had very little damping, less than 2%. The damping was much lower than what everybody generally had thought, because no one had ever run any tests like this. And less damping means higher forces.

Scott: If you were to interpret this for a layperson, would you say that your previous design criteria had not been conservative enough? In other words, did this discovery cause you to become somewhat more conservative, or maybe quite a bit more conservative?

Meehan: Yes. Because the greater the damping, the more energy is absorbed. With low damping, when the building is shaken, the duration of the motion is also longer. Universities and other groups used these four machines on dams of all kinds, concrete dams, earth dams, and buildings all over the west coast.[10] A lot of buildings in San Francisco and the Bay Area were investigated.

We had just completed the construction of the shaking machines and became concerned with the responsibility of the state when the machines were used. It became very complicated and took much time because we asked for hold-harmless clauses from the people who were doing the testing and from the owners of the structures to be investigated. There was a great deal of paperwork involved, so we decided to get out of the business and give

9 W. O. Keightley, G. W. Housner, and D. E. Hudson, *Vibration Tests of the Encino Dam Intake Tower*, Earthquake Engineering Research Laboratory, California Institute of Technology, Pasadena, CA, 1961.

10 For example, the shakers were used to study the Millikan library at CalTech: P. C. Jennings and J. H. Kuroiwa, "Vibration and Soil-Structure Interaction Tests of a Nine-Story Reinforced Concrete Building," *Bulletin of the Seismological Society of America*, v. 58, no. 3, pp. 891–916, 1968.

the shaking machines to the University of California.

We could give them to the state-owned University of California, but we could not give them to a private university such as Stanford, Caltech, or the University of Southern California. The only thing we asked was that when the machines were used and a report prepared, we would be acknowledged and receive a copy of the report. If any public presentations were made, we would also be acknowledged.

For a time we got quite a few reports, and then they began to dwindle down. The University and others used the machines frequently. I don't know if they are being used anymore now. I know the last time I heard, there were two of them at Cal and two of them down at UCLA. We haven't received any reports, or at least when I retired I had not received any reports for a long time.

We thought it would be easier to let somebody else do the work. However, we did get them back once. We had a contract with Cal to shake McKinley School in San Jose. The site was in the alignment of a future freeway, so the building was slated for demolition. When we learned about it, we asked Caltrans if we could use the building to test. They were agreeable to test to the damage level. We set up a contract with Cal, with Jack Bouwkamp, Dixon Rea, and Ray Clough. We shook the school buildings, but could not do it as strongly as we wanted, because a church group became aware of what we were going to do and offered to buy the buildings. They didn't want us to damage the buildings.

Scott: If they had been of no use to anybody, and were to be demolished anyway, you could have shaken them down.

Meehan: The buildings were much stronger than we thought. They could resist all the shaking that the machines produced. They were post-Field Act wood frame buildings that had been designed under the Act's provisions. We learned a lot from them.

Scott: Then you could not have shaken them down even if you had wanted to.

Meehan: No, we could not. But we learned some significant things about the number of cycles and load levels. A complete report on the McKinley School experiment was written by Rea, Bouwkamp, and Clough.[11]

Grouting of Reinforced Brick and Concrete Block Walls

Meehan: We also did a lot of other good things in research. An interesting project that I got into the middle of was the development of high-lift grouting. That effort started with the 1952 Bakersfield or Kern County earthquake. In the 1952 Bakersfield earthquake, the end wall at Arvin High School developed some serious cracks.

Scott: The wall cracked much worse than it should have?

Meehan: Yes. It cracked and yet the design load was low. The office had some eight-inch cores taken from the wall, and it was obvious that when they placed the grout, it didn't get

11 Dixon Rea, Jack G. Bouwkamp, and Ray W. Clough, *Dynamic Properties of McKinley School Building*, EERC 68/04, U.C. Berkeley, 1968.

compacted and worked in to fill the hollow space between the two wythes of brick. We thought we had inspection, but maybe the inspection wasn't as adequate as it could have been, or the inspector was on the other side of the job while the wall was being grouted. The workmen probably did not work the puddle stick very well. Anyway, the upshot of the investigation was that a lot of voids were found in the grout space.

We've put in a lot of effort to improve the quality and workmanship of masonry. Our regulations now require that if they use masonry construction—concrete block, clay brick, or whatever—they must cut a core, cut a hole in the wall as a test. When a mason knows that a hole will be cut in his wall, and that he will catch a lot of hell if the cells aren't filled properly, that awareness can improve a mason's output in quality and workmanship. If the work is inadequate, the wall may even have to come down.

Arvin High School had been constructed under the provisions of the Field Act. The classroom building had grouted brick walls, using the low-lift process. Schools are probably unique in California in that they use grouted brick masonry. In the low-lift grouting process, a reinforced grouted clay brick wall consists of two wythes of brick on the two outer sides, and a two-and-a-half-inch space between the wythes where the reinforcing is placed, and finally the space is then solidly filled in with grout. In those days, the low-lift process was used exclusively. It consists of laying four or five bricks on top of each other on one side, or wythe, of the wall. Then each time a brick was placed on the opposite side of the wall, that two-and-a-half-inch space is filled with grout almost to the height of the brick, which is about two inches deep. The wall, then, has a lot of little lifts—two-inch to two-and-a-half-inch lifts of grout. We required that the grout be puddled immediately with a stick, not a rod, but a stick that had some size and volume to it. It must be puddled vigorously so as to push the grout into all the little interstices.

Scott: That is done to make sure there are no voids.

Meehan: Right, the wall must be solid, with no voids, rock pockets, cracks, etc.

So what we assumed we had was in effect a reinforced concrete wall about three inches thick with brick veneer on both sides. That's our assumed design. That was the theory.

In the 1950s, concrete block walls would crack a few days after they were constructed. The block gets wet during construction, starts to dry and shrink, then cracks. We found that a certain pumice used to make the concrete blocks had a large amount of shrinkage, so we set a limitation on the allowable amount of shrinkage to reduce the cracking. It is in our regulations today, and the problem cleared up. Shrinkage control is now a common requirement for all concrete block. These were some of these things that we started, and now they have become part of the general tricks of the trade. They were put in the codes, and became part of the general practice.

Scott: As a layman, I have thought of concrete block construction as perhaps intrinsically questionable because of seismic concerns. Are there circumstances or designs where concrete block is quite acceptable?

Meehan: Concrete block is fully acceptable when it's done properly to meet our requirements.

Scott: Say what you mean by "when it's done properly"?

Meehan: We have many requirements of concrete block construction. For instance, we say that reinforcing spacing cannot be more than two feet on centers, each way. It must be evenly spaced to improve toughness. This reduces the cracking, although some cracks will form, because all concrete shrinks.

Scott: Grout is a kind of a concrete?

Meehan: Yes. The grout is made with aggregate not over ⅜ inch. The usual process for constructing a concrete block wall is to pour the concrete foundations with the wall reinforcing dowels projecting upward, clean the concrete foundation surfaces, set the blocks in mortar, set the reinforcing of the wall, clean the cores, and place the grout properly.

We require the concrete core, whether block or brick, to be bonded to the foundation. When a concrete block wall is erected, mortar is applied on the edges of the block, and then the next block is placed on top of it. The mortar will compress and fall into the core space, or bulge into the core space, or fall outside. It is easy to clean the outside of the wall, but on the inside the mason must reach down into the core space, break the projecting mortar off at all the joints off, and dispose of them. We require that all interior mortar projections be removed and the top of the foundation be clean of all debris. Usually a clean-out hole is cut through the block face at the foundation to facilitate the removal of the debris, the bits of mortar broken off that fall to the bottom. Otherwise the grout core will not bond to the foundation, and the lateral force shear cannot be transferred across the broken pieces of mortar or other debris in the core.

The primary part of the masonry wall that carries the lateral load is the concrete grout that is bonded to the foundation. The small amount of load that is resisted through the mortar joint is not very competent, because of the usually poor bond between the mortar and the brick or block. The real working part of the wall is the concrete grout core, and the rebar. We found that Grout-Aid, i.e., an expansive admixture, is needed to reduce grout shrinkage. The grout separates from the face shells without its use.

After the 1952 Bakersfield earthquake, the office started exploring ways of improving construction of reinforced grouted brick masonry. Manley Sahlberg in our San Francisco office, who was the principal structural engineer at the time, worked together with a masonry contractor, Oscar Pearson, and Bob Harrington, with the Masonry Association, who were extremely interested in the same problem. The three of them began the high-lift grouting process. I got in about the middle of the program. The upshot of the project was that they tried pouring concrete in masonry walls in different processes and procedures, which developed into the high-lift grouting process.

High-lift grouting involves stacking up the concrete blocks or clay bricks higher, and having a clean-out at the bottom, which permits grouting to a higher level with a single pour. Block or brick walls can be erected 20 feet or more in height, then they can pour grout up to four feet high in single lifts. Wire ties, bent at

the ends and cast into the mortar, are set across the grout space. They are placed twenty-four inches on center horizontally and sixteen inches on center vertically in running bond and twelve inches on center stack bond. They are placed to resist the outward fluid pressure of the grout, which is basically the same pressure as water, so with four foot of head, there is considerable pressure. The wire ties hold the two wythes of bricks together to prevent the wall from exploding when the grout is fluid.

High-lift grouting was developed to make walls both more reliable and less expensive to build.

Scott: How do you make sure the void space inside the wall is completely filled?

Meehan: Two important features in high-lift are the use of the expansive grout admixture and the reconsolidation of the grout. The grout is placed first, and then a vibrator, a rod or something is used to vibrate it so the grout will settle down and compact. Of course, there's still a lot of water in the grout. The water is then drawn into the concrete block or out into the brick, and leaves a void, so the grout must then be reconsolidated to make it solid.

It is very critical first to consolidate then reconsolidate the grout. They tried all kinds of pouring procedures, different mixes, different sized aggregates, different processes and different ways of vibrating the grout. One of the keys was the use of an admixture called Grout-Aid, which is kind of a retarder. We found that the best grout was composed of pea gravel not over 3/8 of an inch, sand, and cement with the Grout-Aid, but with a lot of water in it with a slump of about eleven inches. It looks like a great big meadow muffin or cow poop when they pull the slump cone. That was the fluid kind of mix that was needed to get it down through that narrow space.

Then we found that by placing grout about four feet deep, putting the vibrator down shortly after it was first poured, and then coming back fifteen or twenty minutes later and re-vibrating the mass, it broke up the voids left by the water and reconsolidated the grout to a solid mass. It was necessary to do this quickly, before plasticity is lost.

Scott: How did they go about developing the technique?

Meehan: The contractor making test walls panels was partially funded by the Masonry Association to do some experimentation. First they built some wall panels in the manner they would like, the easy, cheap way of constructing. Then they laid the wall down, sawed through the wall, opened it up and looked at it. This was really revealing. There were innumerable defects due to shrinkage and improper placement of concrete. Next, they tried different ways of consolidating it. They tried consolidating it with sticks and concrete vibrators. They tried just vibrating the reinforcing, putting the vibrator directly on the reinforcing. That didn't work too well, because the displacement was damped out by the grout. Then they tried reconsolidation, and then on to the admixture. I guess it all sort of went together. First, they built six-foot-high walls, and later built twelve-foot-high walls. There were still many defects if the grout was only partially reconsolidated, which you could see when the wall was sawed apart.

Scott: So they kept trying various combinations?

Meehan: Yes, different combinations of materials and processes, of spacing, pouring, and vibration. They had to get the stinger to the bottom of the pour. When they do that, it works well. It is the same for clay brick and concrete block.

Scott: The vibrator is called a stinger?

Meehan: Yes. In masonry usually a smaller diameter vibrator is used than in concrete. For a concrete wall, it might be about two inches in diameter, but grout vibrators are about ¾ of an inch in diameter. The vibrations are slower than in a regular concrete vibrator, but many contractors use the same motor anyway. Some people feel that a slower vibration works better.

Scott: As a footnote, what was put in the admixture that helped reduce shrinkage? How does it work?

Meehan: It is a trade secret.

Scott: Are you serious?

Meehan: Yes. They would never tell us exactly what was in it. It's some kind of powdered compound of aluminum mixed with other materials. I really don't know what it is. All of these admixtures are trade secrets. Normally we don't go for trade secrets, but we accept Grout-Aid because it works. We also accept other admixtures, depending upon proven tests.

Scott: They don't patent something like that, they just keep it secret?

Meehan: Yes. New Zealand is doing a lot of masonry work, and they tried to determine the ingredients of Grout-Aid, but I don't think they ever did. I think they finally just decided to buy it. It was a lot easier simply to ship it in from the United States.

Scott: Has the history and background that you have reviewed here been written up in the literature anywhere?

Meehan: No, it is not written up, although I have discussed it a number of times in talks I have given. I also know Bob Harrington of the Masonry Association gave presentations on the process.[12]

Scott: I remember something from the John Blume oral history interviews about his participation in the study or restudy of the Arvin High School. Is that correct?

Meehan: That's right. His work was done on the same building, but on a different set of problems. John did an analysis showing the dynamic character of the building. Because of the resonance of the structure, the actual stresses in this wall were probably a lot higher than what we had thought they were. In about 1957 or 1958, we contracted with John A. Blume, who had a lot of knowledge of dynamics, to look at a number of school buildings, and Arvin High School was included. He had gone to New Zealand and worked with someone down there on some dynamics problems using a computer. I've forgotten with whom he worked down there. The upshot of the Arvin

12 O. F. Person, M. W. Sahlberg, and Robert W. Harrington, *Progress Report of Testing Project No. 922: New Method of Reinforced Concrete and Masonry Construction using High Lift Grouting System*, Masonry Joint Industry Board, San Francisco, CA, 1959.

High School problem related to the period of vibration of the roof diaphragm. It was a concrete roof diaphragm. The end walls were the resisting elements. There were no moment frames because the concrete diaphragm carried the lateral load to the end walls.

Our knowledge at that time told us that it was quite all right to span that far, but John found that the period of vibration of the diaphragm became resonant with the earthquake, and therefore threw a tremendous amount of extra loading into the end walls. That was the other reason for cracks in the masonry wall.

Scott: Is this a roof diaphragm you're talking about?

Meehan: Yes.

Scott: Resonance developed and it threw more vibration onto the end walls than was anticipated?

Meehan: Right. In those days, nobody knew how to calculate periods of vibration very well, and that was not even mentioned in the regulations. That started us looking into period of vibration. That's where it all started from, as far as I know. John found that the earthquake had the right input to match the roof diaphragm's dynamic characteristics. It was a two-story building. The roof length of the two-story portion was about two-thirds the length of the ground floor. The building's roof was vertically offset. The damage was below the roof of the second floor at the off-set wall. The damage below the lower roof wasn't as heavy, because there were some additional walls at the ground level.

That was one of the conclusions that John developed on that building. This concern for resonant vibrations was, to my knowledge, the forerunner for some of our current and very important provisions in our building codes.

Updating the Code's Seismic Provisions

Meehan: I got involved in another research project about this time, although not as part of the state activities. The Portland Cement Association employed John Blume, Nate Newmark, and Leo Corning to prepare a book on design of concrete buildings to resist earthquakes.[13] John asked me if I would review it. So I was one of the reviewers of the book.

Scott: Was this review done after it was published, or while it was in manuscript form?

Meehan: While it was in manuscript form. They developed a draft of the chapters and sent them out. Being one of the reviewers forced me to do a lot of extra reading. I learned a lot in reviewing that manuscript and had a chance to talk to the real experts in the field. That was a big learning process for me.

Scott: Say something more about the book by Blume, Corning, and Newmark, and give your interpretation of what it meant, the significance of that whole job.

Meehan: This was, I believe, the beginning of ductile reinforced concrete. The concept of ductile concrete is that, as the concrete frames bend and deflect, there are enough ties in the

13 J. A. Blume, N. M. Newmark, and L. H. Corning, *Design of Multistory Reinforced Concrete Buildings for Earthquake Motions* Portland Cement Association, Skokie, IL, 1961.

columns and beams so that concrete won't fall out. That is, keep the concrete confined in what is in effect a metal basket, keep the concrete within the core of the steel reinforcing, even when the concrete cracks, which it will do. When the concrete falls out, the member cannot resist any loading. The structure will buckle and fail. Another important aspect of ductile frame construction requires the columns to be stronger than the beams. If the beam fails first, it will allow only the area supported by the beam to come down; whereas if the column comes down, it will allow a bigger area, or possibly the whole building, to come down.

This book had a big influence on designs in reinforced concrete. Then, almost simultaneously, the Portland Cement Association did a lot of research on their own on the concept of ductile concrete. John's book dealt a lot with the dynamics and how to analyze buildings, and included a lot of good general information. I think that book was very valuable. During that same era, the first Blue Book[14]—or maybe it was one of its early versions—put a limit on the height of reinforced concrete buildings. This encouraged PCA to research ductile concrete.

A little before the PCA book came out, in 1957, I was president of the Central Section of the Structural Engineers Association, the Structural Engineers Association of California. We went to San Diego to participate in the statewide Structural Engineers Association of California convention. I remember the convention occurred shortly after the 1957 Mexico earthquake.

The Torre Latinoamericana came through the earthquake in fine shape, because the designers were using these later concepts.[15] It also went through this last earthquake in 1985 in very fine shape.[16] One of my functions at the convention was to introduce speakers, and one of the speakers was Adolfo Zeevaert, who designed the foundation, while his brother Leonardo designed the superstructure.[17]

About this time, the Structural Engineers Association of California recognized that our building regulations were not in the greatest shape, so they formed a seismology committee with representatives from the three structural engineer associations: Central Section from Sacramento, the Northern Section from San Francisco, and the Southern Section from Los Angeles. Now there is also a Structural

14 The Blue Book (*Recommended Lateral Force Requirements and Commentary*) was first published by the Structural Engineers Association of California (SEAOC) in 1959. The 1966 edition was the first time reinforced concrete frames in high-seismic areas were allowed to exceed 160 feet in height, as steel frames had been.

15 Leonardo Zeevaert and Nathan M. Newmark, "Aseismic Design of Latino Americana Tower in Mexico City," *Proceedings of the First World Conference on Earthquake Engineering*, pp 35–1:35–11, Berkeley, CA 1956.

16 Adolpho Zeevaert, "Behavior of the Latino Americano Tower in Mexico City," *Proceedings of the Eighth World Conference on Earthquake Engineering*, pp 363–370, San Francisco, 1984.

17 Adolpho Zeevaert, "Latino Americana Building," *Proceedings of the 26th Annual Convention of the Structural Engineers Association of California*, 1957.

Engineers Association of San Diego. I was one of the representatives from the Central Section. In fact, I was a liaison member for the Central Section, from our local committee. The recommendations that came out of that committee comprised the original Blue Book.

Scott: That was about 1957?

Meehan: That's when it started. The first edition came out in 1959. It was a great learning experience to sit in a room and just bang ideas around, discuss recommendations, and listen to these knowledgeable engineers talk. I learned a lot from that. John Blume came up with a lot of good suggestions. Many of the things he told me back in the earlier days when I was working for him, like, "Make every frame work. Make every frame in your structure capable of resisting lateral load, so if the walls go, at least you'll still have a frame there that will resist the lower level aftershocks. It won't or shouldn't collapse." That same thought is in the regulations today. John had a good deal of input into the Blue Book writing process. There were many good engineers, practical fellows, on the committee who made many excellent contributions.

Scott: What areas of the building code did they work on? Did they work on everything?

Meehan: No. Just the lateral force provisions. In that first Blue Book, we didn't get into the details of structural steel or reinforced concrete design as such. They did develop some things on some of the other subsequent issues, such as placing reinforcing with tighter or closer tie spacing within the beam-column sections. Before, they'd normally just place the column ties up to the bottom of the beam and did not put any ties within the beam-column joint. Then they found that if ties were placed through the depth of the beam, and close-spaced ties were placed below and above the beams in the ends of the columns, much better performance of the frame would be obtained.

Our office always required closer spacing of ties for many years, going back to the 1930s, I guess. I don't know when it first started, but we had photos in our office of concrete column failures at their ends from the 1933 Long Beach earthquake. We always required close tie spacing at the ends of the columns—that is, spacing not over half the spacing of the normal tie spacing, with a maximum of six inches on center. Then the Blue Book came along and it too required more ties in the top and the bottom of columns, plus within the depth of the beam.

Scott: You mean the Blue Book required even more than was required under the Field Act?

Meehan: As of then, yes. Of course, when that happened, we immediately adopted the same regulations.

Shaking Table and Other Research

Meehan: I was very pleased with another research matter in which I was involved. I always thought that we needed a device to do some real seismic testing and asked if I could go down to Cal and talk to them about developing a shaking machine. So I went to Berkeley and met with Joe Penzien, Ray Clough, and others.

Scott: This would be another shaking

machine, entirely different from the one you talked about previously?

Meehan: Yes. I said I wanted them to design a shake table platform about one hundred feet by one hundred feet on which we could build a gymnasium and reproduce earthquake motions that would knock it down.

Scott: In other words, a big shaking table.

Meehan: Right. This was the forerunner of the shaking table at the Richmond Field Station of the University of California at Berkeley. They came up with a suggested design. I wanted all three components of motion, both of the horizontal and the vertical components simultaneously. They worked on it and came up with a design concept.[18] It is basically the concept that is used on the shaking machine that is in Richmond now, except that the proposed "large-scale earthquake simulator facility" was to have a table one hundred feet by one hundred feet, and the one that was built was 20 feet by 20 feet. The state couldn't afford to build it. I think they ended with a tab of $25 million or so to build it. The proposed large table needed its own electrical generation plant powered by a jet engine or a lot of aircraft engines to produce the horsepower to drive all the hydraulics needed.

There weren't any funds, but the design concept was then adjusted back down to what they have now [1988], which is one component of horizontal motion and one of vertical motion.[19] That's what was built and funded by the National Science Foundation, I believe. But the original design study we funded went in three directions. The table was suspended in air to reduce friction, and jacks were installed in two horizontal and the vertical directions. But again, they didn't have enough money to build the big one I wanted to build.

We funded other projects too. I'll go quickly over some of these research projects. We did site characteristics of earthquake recorders, the first such studies that I know of. Dave Leeds and Martin Duke at UCLA worked on that project.[20] We did studies of the shrinkage of concrete blocks. We did a lot of damping studies[21] with Lydik Jacobsen[22] at Stanford, but he didn't do any testing. We later did some testing and damping studies in the 1960s on plywood

18 Joseph Penzien, Jack G. Bouwkamp, Ray W. Clough, and Dixon Rea, *Feasibility Study Large-scale Earthquake Simulator Facility*, Earthquake Engineering Research Center (Berkeley, CA: University of California, 1967), UCB/EERC-67/01. The "01" in the title indicates it was the first report published by EERC, the U.C. Berkeley Earthquake Engineering Research Center, later re-named Pacific Earthquake Engineering Center (PEER).

19 The table was upgraded in 1997 to have three axes of motion.

20 C. Martin Duke, David J. Leeds, *Site Characteristics of Southern California Strong-motion Earthquake Stations*, Department of Engineering, University of California, Los Angeles, Report no. 62–55. This was reissued in 1972 as California Division of Mines and Geology Special Publication 38.

21 L. S. Jacobsen, "Damping in Composite Structures," *Proceedings Second World Conference on Earthquake Engineering*, Tokyo and Kyoto, 1960.

22 J. A. Blume, "Lydik Siegumfeldt Jacobsen, 1897–1976," *Memorial Tributes: National Academy of Engineering*, Vol. 1, pp 132–136, 1979.

damping diaphragms with Ken Maderas at Stanford.

We tried to develop non-destructive tests on masonry. I told you that we required that cores be cut in the finished walls. For aesthetic reasons, core-cutting was not received too well by many people, so we tried some nondestructive tests on masonry construction. We tried X-raying. That was done at Stanford by Jack Benjamin. He found that X-raying in one direction could not catch everything. Besides, it was dangerous to use a lot of X-raying on construction.

Then we tried sonics, which was a fascinating project we did with Aerojet. Aerojet had a fellow who had been doing sonic studies of discontinuities between layered materials. His field was working with rockets. Metals are bonded to other materials, and he developed a technique using sonics to determine whether it was bonded properly.

I heard about this use of sonics and contacted him. I asked, "Do you think you would be able to tell anything in masonry, using sonics?" I explained what the problems were, and we agreed: "Let's try it." He had just finished a project and was available to work on it at the time. We wrote a contract with Aerojet.

It was interesting. He sent a sound wave through the material and picked it up on the other side. If the time interval between two locations on the wall was different, it would indicate a defect was present. The use of microphones was not satisfactory to induce the sound wave into the brick wall and pick it up on the opposite side. So he developed a water coupling. He placed a device like a rubber doughnut on the end of a hose, put the microphones in the water, and pressed the doughnut containing the water and microphone against the wall. The sound waves would go through the water, into and through the masonry construction, and be picked up with a similar device on the other side of the wall. It worked pretty well.

Scott: In other words, the sound was transmitted through water instead of air? Was that the key difference?

Meehan: Yes. That was the contact. A better contact with water on the material to be tested. It worked pretty well, except that it was very expensive, and your water would be all over the project. Also, we really didn't know how to interpret everything that we were recording, because of so many dissimilar materials, and so many ways that hitting a discontinuity or a different material will produce reflections. There are reflections from every boundary of material.

Scott: So it was hard to determine which was a defect.

Meehan: That's right. Or whether a reflection was bouncing off something on another part and did not represent a defect. The process did not work too well, but it was fascinating.

Measuring Snow Loads

Meehan: Aside from earthquake engineering research, I did snow survey work. Although that was not earthquake-related, I think it was extremely important for our office. I did a lot of original snow survey work, on determining snow loads on the roofs of buildings. We

get some heavy snows in the Sierras, and at that time we didn't know how much snow load we really had on the roofs. Both the designers and we were guessing at the loads. We did not know how dense the snow was. There are many variables such as how much rain fell on the snow, did it freeze at night, and other factors. So we really didn't know the roof design load. That was another one of my projects.

I remember the first time I tried collecting a column of snow. I used the office coat tree as a snow tube. Snow surveyors have calibrated snow tubes to measure the snow. They take a snow core, determine its density, and with the scales convert it to inches of water. We didn't have anything like that.

For the first trip, my youngest son, Mike, and I took the office coat tree apart, put it in the back seat, took the postal scales that we had in the office along with my ladder so we could get up on a roof, and took off to the hills to get some snow samples. We got some pretty heavy loads. That was the first snow survey trip I ever made. The first one that I know of by anybody who has ever taken a measurement of the snow on a roof.

Scott: You were testing for snow weight on the roofs. The other snow surveys we read about each winter and spring, such as those done by Pacific Gas and Electric, are somewhat different?

Meehan: Yes, they survey to determine water content and to make estimates of how much water is stored in the snow in a whole mountain valley.

Scott: But they do not test to determine the weight of the snow that may collect on building roofs. When did you do your survey work?

Meehan: It was probably around 1964, give or take a year or two. It was not during a big snow year when we first tried it. We realized that we should get some decent equipment, so we purchased snow survey tubes. These tubes are expensive, a little under $1,000 each, because they have proper ice cutting bits on the end, the proper diameter, slots in the tube to show the depth of snow inside of the tube, proper splices of pieces, a handle to turn the tube to cut through the ice, and a calibrated scale to weigh the tubes containing snow and determine the water content, that is, inches of water in the snow.

Scott: A pretty sophisticated instrument.

Meehan: Yes. It was. We bought three tubes, one in the San Francisco office, one in the Los Angeles office, and one in Sacramento. I later learned that San Francisco and Los Angeles seldom used them, because they didn't have much snow. Actually after a few years they all ended up in Sacramento.

We got a great many snow measurements in 1969 when we had a big snow. It was the biggest since 1952, when the train was stuck in the snow at Donner Lake. A fellow in the office, Dale Rittmann, and I drove all over the Sierras, measuring snow on roofs and the adjacent ground. We got enough information to enable me to prepare a paper and present it to the Structural Engineers Association of California convention.[23]

23 John F. Meehan, "Snow Loads and Roof Failures," *Proceedings of the Structural Engineers Association of California Annual Meeting*, pp. 17–26, 1969.

Then we tried to get the snow surveys group in the Department of Water Resources to do some of that snow surveying for us on the buildings. But that didn't work because they're not funded for that purpose. We had the job, so we had to do it.

It's a little difficult to climb a ladder with snow shoes. Also, an interesting experience occurred: The snow survey tube has a cutting bit on the end of it, to cut the ice to get down to the bottom of the snow pack. We were cutting away on one school roof and thought, "Boy, we must be down to the bottom," and we were. We had cut a hole in the roofing! We pulled the tube out, and there was a piece of roofing in the end of the tube. We told them about it, but fortunately the hole was outside the wall of the building, so the water didn't go into the building. But that was a little embarrassing. We had a lot of fun. We had a lot of interesting experiences doing the snow survey work.

Scott: Before you leave the snow survey, say a little about what you found out and its significance. What did you do in terms of regulations under the Field Act, or was there any other influence that the findings might have had?

Meehan: Yes, regulations were the end result. I was just giving you the research experience. The end result was that we had some actual measurements of roof snow load. Then we had to develop means of extrapolating snow loads for locations without measurements. We tried several equations and graphs to coordinate elevation location and rainfall to determine the load, but we couldn't find a good finite solution. I found a hydrology report by the Corps of Engineers, where they presented probability studies of rainfall in inches in different periods of time, such as the amount of rainfall in a three-day storm with a ten-year probability. I think they had 20-year probabilities, too. I found the best results when taking the value for one three-day storm and one ten-year storm—that's the number of inches of water you would use for the design of the roof on sites between 2,000-foot and 4,000-foot elevations.

Above 4,000 feet we arbitrarily doubled it, which means there would be the weight of two storms on the roof. Some of the water falls as rain, most of it falls as snow, and some will melt, but a lot of it will stay on the roof. Rain will get trapped in the layer of snow. Then at night it freezes, so the water doesn't get off the roof until spring. We used that theory, and that worked out pretty well. It also took care of estimating values on the east side of the Sierras where there is less rainfall. The analysis had to include the rainfall. From all of that, we developed a listing of values for various locations. We would not accept any load less than those. Engineers could use higher values.

Scott: This would be for vertical load.

Meehan: Just for the weight of the snow. Just vertical load. Then we had to estimate how much of the snow is to be expected to be on the building during an earthquake. In the west we have a high probability of snow load, not just a little probability, like in the Midwest where there are just a few inches of snow. It's there for a few days and then it's gone. In the Sierras, it's on the roofs for months. So we said, "We'll take one-third of it, above 5,000 feet." That is, assume a loss of two-thirds of the snow, but keep at least a third as dead load for all locations above 5,000 feet elevation for the purpose

of calculating the horizontal seismic load. We used 25 percent below 5,000 feet. Today, the UBC seismic regulations say you can use 25 percent of the weight of the snow as part of the dead load in calculations for the effective mass on the roof.

We've found subsequently that, under certain design assumptions, or types of framing, this is a very high design load.

Scott: You mean your criterion is too high?

Meehan: Just that it comes out with a heavy design load. I don't know if it's too high or too low.

Scott: But it comes out with a heavy load.

Meehan: Yes. Well, I can't say it's conservative, but I say it's heavier than the Uniform Building Code value in the higher elevations. We had what we called our Snow Load Book. There were no loads in it less than those I had measured. It could go higher, and it probably did go higher. Remember the big snow in Redding where many buildings fell down? I think that was Christmas of 1968. We did not have any trouble with our schools. But up in Redding we didn't use the tributary area reduction for roof snow load. The Uniform Building Code allows a reduction of the roof loading if a member supports a large area, because of the likelihood of not having twenty pounds per square foot over the whole roof. It goes down to sixteen pounds over two hundred square feet, and then down to twelve pounds over six hundred square feet tributary area.

One of our employees who lived near Redding suggested that although Redding is only at an elevation of seven hundred feet, they have snow occasionally, so we keep the twenty-pound minimum. We didn't allow the tributary area reduction for Redding. That is why we didn't have any problems with schools, but several commercial roofs fell in Redding and Anderson.

Scott: Let me ask another question or two. Did what you learned about snow load affect general practice, or did it principally affect just public school buildings under the Field Act?

Meehan: Yes, it went beyond public schools. I think everyone learned a lot after I got those measurements. No one could believe that you could get four hundred pounds per square foot of snow on the roof. But I measured it. I showed the pictures and gave them the results. There was no denying it. So as a result of that, our buildings became much stronger. Of course, we still have some of those old school buildings that were designed by the old method.

But there's a saving grace on snow load. The design load is known, and it can be determined so the load should not get any higher. Snow is not a suddenly applied load without prior notice like earthquake loading. Snow can be removed from the roof before it becomes critical. It's a strenuous and expensive job. It could also be dangerous. Engineers who have cabins in snow areas do not hesitate to use our loads. You have to shovel snow off only one roof to know better.

Glued-Laminated Beams

Meehan: Another research activity we got into concerned glue-laminated beams (glulams). We've had a lot of trouble with delamination problems with glulams. There

was concern with the end joints, the lumber grading, the process of doing the gluing, and other factors. We generated some extra requirements that the American Institute of Timber Construction didn't really always follow. Plus we required continuous inspection by a knowledgeable inspector. What is a knowledgeable glulam inspector? We decided to visit plants fabricating beams in Oregon and Washington to find out. A few beams were made here in California, and some in Idaho.

So we took what we called a glulam tour, and visited all the glulam plants, plywood and lumber mills, testing laboratories, and universities doing work on glulams. We talked to the plant superintendents and the management, explaining what our problems were, and learned of their problems. It was a mutual learning process for all of us. That was very successful and extremely interesting, learning about the wood industry and grading, and some of the defects they don't talk about in many of the books, but that can show up.

An example of an item not mentioned in the grading rules is what they call timber break. When a tree is cut, and lands on a big rock across a gully, the impact of the tree falling and bending will break fibers in the wood. They call that timber break. Timber break is a discontinuity in the fibers, but it takes the eyes of an eagle to see it. It's not in the grading rules. They don't say anything about grading timber breaks. They recognize them as a defect. Timber break appears as a fine line across the grain. The only way you can see it is to look really close. When lumber is graded it goes by the grader several feet per second. A good grader can spot timber break. The light shines on it a little different way, and if something looks suspicious they look at it carefully.

Another unusual characteristic is compression wood. If a tree grows in a bent form, nature tries to straighten the tree. On the compression side, the tree forms a different fiber. When a piece of lumber contains this type of wood, those fibers are not strong and they shrink at a high rate. Those are defects in the lumber, and it's very critical in a glue-laminated beam. This wood is avoided as much as possible. For instance in good wood, if you insert a knife under the grain and try to pop it out, the long fibers try to hold it together. With compression wood, the piece just pops out like it's made of cheese. It doesn't have the fiber. We have some samples at the office that I picked up on the tours. I use them in interviewing prospective glulam inspectors. I developed many questions on what a glue-laminated inspector should do and should know. I questioned inspectors on timber break, compression wood, and the usual things like slope of grain, knots, density, gluing processes, and some other details..

We visited all the plants and talked to the folks to develop a good line of communication. They know that when a California public school building job comes into the fabricating plant, they must meet all the requirements because it's going to be looked at very carefully. We require continuous inspection by an inspector approved by our office. They cannot fabricate a glue-laminated beam unless the approved inspector is in the plant at all times.

Scott: The approved inspector may be a local man from up there.

Meehan: Yes. He'd have to come down to

Sacramento to be checked out and I would interview him.

Scott: He in effect would be licensed by you.

Meehan: Not a license, but it was an approval after I interviewed them. Also on our trips we interviewed inspectors. We worked together with the labs. There were a couple of labs that do the inspection.

The plant man who does the quality control for commercial work and puts on the stamp is a man paid by the fabricator. In contrast, our inspector is paid by the school district, which is required by the Field Act. Our regulations are prepared so that no inspector is paid by the contractor. The inspector, the architect, and the engineers cannot be an employee of the contractor. They must be hired by the school board.

Scott: That way, you assure a kind of independent review.

Meehan: That's right. This is independent control. In fact, this is part of the Field Act philosophy.

Problems with Plywood

Meehan: Another example of the development of new construction technology needing better quality control has been the use of plywood, rather than board sheathing. We found that plywood manufactured by one particular manufacturer was not getting the proper amount of glue spread.

Scott: This occurred in the actual manufacture of the plywood itself?

Meehan: Yes. The kind of plywood that we require has an exterior grade glue, so the plywood can tolerate a few cycles of being wet and dry. Sooner or later during construction it will probably get wet, so it must have the quality of holding together, at least for a few cycles of getting wet.

But in certain areas we found that if the plywood got wet or damp once, it would delaminate. Bubbles form; pieces of veneers were separating and coming apart. That is completely unacceptable for all purposes, for vertical and lateral load.

Scott: The plywood sheet loses a lot of its strength when it separates that way or delaminates?

Meehan: Right. Like the glulam, it has to function as one integral structural sandwich.

We had our field men go out and pick up samples on the jobs, and had them tested in the state's highway laboratory. That was one of our research projects. Our field men picked up scraps of plywood on the job, usually trying to get one with a stamp on it, and sent the samples over to the highways lab. They ran it through the wet cycle test to determine its performance. As a result, we were influential in changing the qualities of the glue they used. When we started picking up samples down in San Diego, they knew about it in Redding almost the next day. The word got around.

We decided to determine if the Association or the other independent agencies were providing proper quality control. Some of them were, and some weren't.

Scott: What did you do when you found a problem?

Meehan: We told them. We even went so far as to almost reject certain manufacturers. We would require that if plywood was used from that manufacturer, the contractor must run all those tests. Contractors don't want to mess with that. They'll buy the other plywood. It may cost a few cents more, but that's easier than testing. We do these kinds of things to keep quality control up.

The Plywood Association was doing quality control, and also there were certain laboratories whose inspection we would accept. Plywood is a special product. Normally it is a secondary structural product, because it usually only has to span a few feet as a floor or roof component to carry vertical load. But it has to be fairly competent to be in a shear wall to resist lateral loads. It gets much more critical when used in the web of a built-up beam with a web made of plywood. If the composition is not proper, it comes apart. If you have a little hole in a big diaphragm, it doesn't make a lot of difference. But a hole in a beam makes a big difference, because of the percentage of web or plywood lost. We found that some agencies were doing a good job, and some weren't.

They used to drive nails with a hand-held hammer, and then along came nail guns, which shoot the nails into the wood. Again, it was an acceptable and efficient technological development, just like plywood, but it needed quality control. The workers frequently got sloppy, instead of putting nails ⅜ of an inch from the edge of the plywood panel, they might be only ¼ of an inch or ⅛ of an inch from the edge. The edge distance is critical for proper diaphragm performance. The other big problem was that the nail gun frequently drove the nails in too deep, so the nail head is punched through the outer veneer and into the next veneer. When that happens, much nail connection strength is lost. It is called over-driving.

It is hard to over-drive a nail with a hand-held hammer. The hammer head is ¾ of an inch or 1 inch in diameter, and the nail head is much smaller. But the driver in a nail gun is about the same size as the nail head, so it doesn't have the automatic stop that a hammer does. We complained to the architect and contractor and required re-nailing when over-driving was observed, and now most nail guns don't over-drive.

The Wider Impact of the Field Act

Scott: You mentioned earlier that the state's Field Act regulations that pertained only to public schools had a wider effect on design and construction.

Meehan: I've heard many people in the private sector say our operation has improved the general class and quality of engineering and construction that's done for both commercial and Field Act work. The fact that we have a complete review and get a chance to talk to people with a lot of experience in many disciplines, and that we have many people working in the area, makes for a better design.

Scott: I recently interviewed a much older, retired structural engineer, Art Sedgwick, who's now about eighty-five years old. He said the administration of the Field Act influenced not only engineers, but also contractors and people who work on construction jobs. They learned how they had to do things when

working on a public school. They thought, "If it's a good thing on a school, why isn't it a good thing for these other buildings?" He said this was true even though at first they might have resisted these "new-fangled" Field Act ideas. When they got used to the Field Act, they began to wonder why they shouldn't be doing the same thing on other jobs.

Meehan: We call that the ripple effect. I've also heard that a contractor will give a school job a better price, because he knows that all the other contractors are bidding on exactly the same thing, and he also knows that he must provide everything in the contract documents. He knows that there isn't any cutting corners.

Scott: And his competitors would have to provide that, too.

Meehan: So he comes up with an honest, firm bid, knowing that he and his competitors must also meet all requirements of the contract documents. Changes are permitted only by approved change orders. That's a big protection for the school board, though some don't recognize it. The school board gets a much better building, because the contractor must provide everything on the drawings. That is the duty of the inspector; that's why he is there. If he's not doing that, he's not doing his job.

I will not say most contractors or any contractors are dishonest. We all try to do our job. It is somewhat akin to the way we do our income taxes. We try to meet the requirements in the IRS documents, and no more. The way the Field Act is written, and the organization we have, is pretty tight. To the best of my knowledge, it works pretty well.

However, I am sure we will learn a lot of things when a big magnitude eight earthquake arrives. People say, "I went through the earthquake. Fine. I'm home free. My building is strong enough." But they're talking about smaller earthquakes. We haven't had that big nearby magnitude eight earthquake yet. That really concerns me. We're all going to learn a lot from a really big one. I have no question in my mind that it will happen sometime.

The End of the Division's Research Function

Scott: At some point I believe your agency stopped doing this sort of research that you were in charge of.

Meehan: We were not permitted to have any more research funds when Ronald Reagan was governor.

Scott: They cut the funds off?

Meehan: We actually had the money in our fund, but we couldn't spend any money unless the item was specifically approved in the budget.

Scott: For how long was it stopped?

Meehan: For good. They still haven't given us any more money. We frequently tried to apply for research projects, but they'd say: "No, you can't have it. It's not our role to develop and come up with new ideas. We must leave that to industry. The more we do it, the more they'll expect us to do."

Scott: Who said that? The Department of Finance?

Meehan: Yes. They asked, "Where in the

Field Act does it require you to do research? You must follow the law."

A number of school buildings were severely damaged in the 1968 Tokachi-Oki earthquake in Japan. I had been to Japan for the Second World Conference on Earthquake Engineering in 1960 and reported on the glass tests that we ran. One of the fellows in the Building Research Institute over there was very interested in my work, because they wanted to do similar work. They used our project and expanded on it. I still had a contact with him, so I wrote to determine if we could get some drawings and the calculations of the damaged school buildings. He was very cooperative. I told him we would analyze the buildings and would give them a report of our review. So he sent the drawings and calculations on several buildings. I contacted John Blume who said, "Sure, I'd be happy to work on that project. It looks like it would be a very interesting project."

We prepared a contract and took it to the State Architect who would not sign it. He said, "Let industry, architects, engineers, or any others come up with funds. There's the steel industry, the concrete industry, the rebar industry, the Portland Cement Association. Get money from them and let them pay for that work."

So I wrote letters to all of the various industries, and they all responded "No" or did not respond. So we didn't get a nice clean review of the drawings. We had to bootleg the work on the Japanese school damage and did it ourselves. We found some interesting problems that we didn't want to expose, so we just swallowed it. One of the things we found was that they constructed the buildings differently than we did. They didn't have the extra column ties that I mentioned.

Scott: Why did you not want to expose that? Would it have embarrassed some of your friends in Japan?

Meehan: Yes. Fortunately they didn't follow up and ask for our findings. I'm sure when they started going over the drawings they would see the same thing. Losing that project was the beginning of it; from then on we couldn't get funds for any research.

Scott: This is fascinating, if also depressing. In your estimation, why would there be this change now, at this point?

Meehan: To start swinging the other way? Jerry Brown's administration was the same [the first Jerry Brown gubernatorial administration, 1975–1983, not his second administration that began in 2011]. Also, part of it was that at the time we did not have these great research ideas or these new things to investigate. We had already done a lot of them. What would we do next? I think we could probably expand a little more on the glass questions, and expand a little on the glulam. Perhaps more on the dynamic properties of buildings and their sites.

It's nice to have those research capabilities, but what do we really need to know? It appears that now researchers are looking for things to study. They're doing base isolation. That would be a fascinating thing, but the industries are doing the same thing. So this can't be justified to finance and say that it has not or is not being done.

Scott: Are you saying that you had researched out most of the questions?

Meehan: At least as far as some of the original major issues, yes. Though I'm sure we could still generate research projects. Like just the other day I thought, "It would be really great if a shake table could move more than six inches in one single surge. We need a table that can actually displace the same distances within the same time frame or as the actual records indicate. Things like that come up every once in a while. I would also like to see more research on panel anchorage, glass limitations, suspended pipe supports, equipment anchorage, maybe even base isolation and flexible utility connections.

Chapter 5

Post-Earthquake Investigations

My first experience going out to look at the effects of an earthquake was in 1952 in Kern County.

Scott: Would you talk about the post-earthquake investigations you were involved in, starting back at the time of the Kern County earthquakes in 1952?

1952 Kern County

Meehan: My first experience going out to look at the effects of an earthquake was in 1952 in Kern County. The biggest one had a magnitude of 7.3, with others that occurred over the following month or so also causing damage. I was a pretty young guy then and had no experience with an earthquake. The past practice of the Division of Architecture had been that when we had an earthquake, we would send engineers to observe the performance of buildings.

For instance, back in the 1940 El Centro earthquake, the office prepared no reports that I am aware of, although we have photos showing our post-Field Act buildings performed very well. That was way before my time. But I do know that in 1949 there was an earthquake in Seattle, and D. C. Willett and Merle Ewing drove

to Seattle and visited school buildings in that area. I don't think they published a report on it, because people didn't do things like that in those days. They went up on their own expense to see how the buildings performed. That was when I first started with the state, and I remember that D. C. came to the San Francisco office and told us about some of the things he had seen. As I said earlier, when I graduated from Cal, I didn't know anything about earthquakes, but it was a fascinating subject to me.

Then the 1952 Kern County earthquakes came along. There was damage to some school buildings, and Merle Ewing, who was the principal structural engineer in our Sacramento office, immediately dispatched Herman Finch, a supervising structural engineer, to the area. He took off in a state car and drove as rapidly as he could to the area. Herman was a structural engineer with quite a bit of experience. I believe he met with some of our engineers who came up from Los Angeles. They made a quick tour of the area and returned. The office then selected a few engineers in the checking section and me as a field man to go down and visit several school buildings and the Tehachapi State Prison. It was quite fascinating to see some of the damage that was in the newspapers. We were down there for two or three days and looked at everything they told us to look at, or we were aware of.

Scott: That would have been mostly schools?

Meehan: Schools, water tanks, the prison. We didn't go into the railroad tunnels or anything like that. We only looked at buildings. We just drove around, looking at damage. People would tell us about their damage and their experiences. We also had an itinerary that the office put together for us.

Karl Steinbrugge wrote his report on the earthquake, published by the Seismological Society of America.[24] He got information from Merle Ewing and worked up some interesting statistics on comparing pre- and post-Field Act schools. I just traveled around with my eyes wide open, observing how the buildings performed. We did go to the Arvin High School and saw the failures I mentioned previously. The other school buildings, except one other at the high school, site performed very well. The roof x-bracing in that building separated because they used the wrong size turn buckle on the steel rods. Some pre-Field Act school buildings in the area performed very poorly. We looked at those and took photographs.

Scott: Was any kind of a report made on that?

Meehan: We didn't prepare a published report. Ours was an internal type of report, trip notes. Because Karl Steinbrugge wrote the comprehensive report published in the *Bulletin of the Seismological Society of America*, our people didn't feel that it was necessary to do any more.

1964 Alaska

Meehan: The next earthquake I studied was the 1964 Alaska earthquake. In the meantime, there were other earthquake-related activities in the office. In 1956, there was the first of the

24 Karl V. Steinbrugge and Donald F. Moran, "An Engineering Study of the Southern California Earthquake of July 21, 1952 and Its Aftershocks," *Bulletin of the Seismological Society of America*, Vol. 44, No. 2B, 201–462, 1954.

World Conferences on Earthquake Engineering in Berkeley. I didn't go, because at the time I hadn't yet gotten into the research. Two of my bosses, Merle Ewing and Tex Herd, wrote a paper on school construction and the process of the Field Act and presented it. That appeared in the proceedings of the First World Conference.[25]

Along came the Alaska earthquake in 1964, on Good Friday, causing a variety of damage in Anchorage, the only fair-sized city in the state. By then I was doing research, having been given that role in 1957, so I had six or seven years of experience doing research on earthquake matters. Here we had this big earthquake in Anchorage, and I thought I should go up and see what happened. So I asked the Division if they would fund a trip, and they said, "No."

Scott: Because it was out of state?

Meehan: Yes, it was out of state. Also, they said, "It's not *our* function—it's *their* earthquake."

Scott: Did you say, "We might learn something from it that would be beneficial to California?"

Meehan: Of course. I said a lot of things, but "No" was still the answer.

Scott: That would have been when Pat Brown[26] was governor.

Meehan: So then I said, "Damn it, that's not a good enough answer." I went to the National Science Foundation for funds, but didn't get anywhere with them. They were not set up to fund the investigation of earthquakes. At the time, the office was doing the School Construction Systems Development program, which was funded by the Ford Foundation.[27] Under the SCDC program, they were developing standard details for a large number of standard school building and component details. Components could be assembled together into school buildings. For some reason or other, it was funded by the Ford Foundation.

So I contacted the man at the Ford Foundation and told him what I wanted to do. I said "You are going to be investing a lot of money on these school buildings, and it might be a real good idea to go to Anchorage to see how the buildings performed." He asked me to come to their meetings in Palo Alto the following Saturday, which I attended.

25 M. A. Ewing and C. M. Herd, "Criteria for Structural Design in California Schools," *Proceedings of the World Conference on Earthquake Engineering*, Earthquake Engineering Research Institute, Oakland, CA, pp.36–1 through 36–15, 1956.

26 Edmund Gerald "Pat" Brown, Sr., was governor of California from 1959 to 1967; his son, Edmund Gerald "Jerry" Brown, Jr., served as governor from 1975 to 1983 and was later re-elected in 2011, serving another two four-year terms.

27 The School Construction Systems Development (SCSD) program was a project of the Educational Facilities Laboratory, which was established by the Ford Foundation in 1958. See J. Marks, *A History of Educational Facilities Laboratories*, National Clearinghouse for Educational Facilities at the National Institute of Building Sciences, Washington DC, 2009.

We talked for a while, and they agreed to send me and one of their employees. They would provide the funding for the travel and I would pay my per diem.

Meehan: That was on a Saturday, and early the following week we departed. In getting ready, our people and other folks suggested to bring back some drawings. The costs for film and drawings would come out of my own pocket. Merle Ewing said, "You have to plow back a little bit if you want to get something out of your field." I bought a whole bunch of film, because I knew I would take many pictures. So I went pretty much on my own with this fellow from the Ford Foundation.

Frank McClure had gone to Anchorage first, and while he was up there, he called me on the phone and said, "Jack, you have to come up here and see things that you wouldn't believe. It's just like all of these seminars and reports and books that we have been reading. It's exactly the way they say it could happen." So then I was really motivated. Frank met me at the airport. We saw many interesting failures.

I spent about a week primarily looking at school buildings. We crossed paths with a few earthquake chasers, but it was not like it is today. Only a very few people went out to look at earthquake damage. There were many other interesting facilities and geologic conditions to look at, but I spent most of my time on school buildings. I contacted several school architects. They were very cooperative and allowed me to make blueprints of their drawings. So I paid out of my own pocket for the negatives, prints, and shipping a two-foot by two-foot by three-foot box. I didn't know if I would be reimbursed, but I knew I had to do it.

I can't remember who was Chief Structural Engineer then, Merle Ewing or Fred Cheesebrough. Anyway, I came back and told him what I had done, and had the films developed as soon as I could, because I knew they were very important and everybody would want to see them. After I got my slides developed and got them lined up so that I could show them, I asked the Assistant State Architect if he'd like to see the pictures. He said, "Yes. We might as well ask some of our staff, architects and engineers to see what you found."

Meehan: So I went to their office and started to show them the slides. The person who refused my travel request to visit the earthquake was there. He had just written a big "Negative" across the request. Anyway, after I got into the talk, he stopped me, turned on the lights, and said, "I want you to put talks together and I want you to give talks to all of our engineers, and I want the clerical people to see these pictures too. I want you to prepare different kinds of presentations for the architects and mechanical and electrical engineers and landscape people. I want another talk to your schoolhouse people and the structural engineers. I want another talk to tell our clerical and our general office people. I want you to put them on in our office in Sacramento, San Francisco, and Los Angeles." It was a complete reversal. Having photos of all the damage really worked, and I was reimbursed for my time and expenses.

I also showed the slides at all the structural engineering association meetings and also at some presentations for the public. I learned

a lot by going back over the same slides but responding to different questions from different people.

This was the first time I saw earthquake damage to T-bar ceilings, suspended ceilings. I didn't know about ceiling damage before that. I reported it but no one considered such nonstructural damage to be of importance.[28] Even our own people showed little concern for ceiling damage until the 1971 San Fernando earthquake when they and others saw ceiling damage. My slides showed much structural damage, but there was also lot of nonstructural damage. Many buildings were not operable, because the ceilings and the light fixtures and the grillwork had fallen down. That made quite an impression on me. Also it was the first time, as far as I know, that T-bar ceilings were exposed to earthquakes. There were many T-bar ceilings and gypsum board ceilings in the schools up there. I became very interested in T-bar ceilings and why they should fall apart. I worked with the industry on ceilings as a sort of applied research. I didn't mention that in the research discussion earlier, but I worked a lot with industry, developing, I think, fairly competent T-bar ceiling systems. We developed a system of bracing, anchoring, and competent splices and intersections of T-bars. All of the requirements are in the codes now.

We sent the Anchorage school drawings I brought back to our Los Angeles office. They had more people than we had in our Sacramento office. They went over the drawings and found a lot of things. Our review was purely selfish and done for our own purposes. We wanted to know what we would have found if we had reviewed the drawings. Would we have seen things that had later failed? Would we have found the errors in construction?

Scott: In other words, you did a post-earthquake review?

Meehan: Yes, it was a post-earthquake plan check. The West Anchorage High School classroom building was a sizable two-story reinforced concrete building with extensive damage. A review of the shear wall arrangements made it immediately apparent where the problem was.

Scott: Was it a design or construction quality problem?

Meehan: Layout and design. The plan of the building had a bend in the middle, a boomerang shape, and needed a better arrangement of shear walls. It was not a good layout, as shown by the building's performance. When the earthquake came, they said visible waves came down the corridor. They said it looked like shaking a carpet.

We found details we would have wanted to see improved. It was to our advantage that we kept the information to ourselves. We did not expose these things any more than the report I wrote on schools in Volume II of *The Prince William Sound Alaska Earthquake of 1964 and*

28 The report by J. Marx Ayres, T.Y. Sun, and F. R. Brown, "Nonstructural Damage to Buildings," *The Great Alaska Earthquake of 1964: Engineering*, National Academy of Sciences, Washington, DC, 1973, is generally considered to be the first comprehensive post-earthquake documentation of nonstructural damage.

Aftershocks.[29] The attitude is exactly the same today as with any set of plans that comes in on a new job. We don't discuss errors in the plans with others. It's a matter of professional ethics as far as we're concerned.

Scott: In other words, whatever whistle blowing is done, it is done strictly for the people involved in that project, the structural engineer, or the school board.

Meehan: Yes. You can get sued if you start to assign blame. But you can't get sued if you present only the facts. That's what I did. I presented facts when I made presentations and kept away from personal opinion.

The visit to Anchorage, Alaska, was probably one of the more outstanding post-earthquake experiences I'd had. Since then, of course, I've had a lot of others, but Anchorage really brought out a lot of interesting engineering problems.

1965 Seattle

Meehan: The next earthquake that I investigated was in 1965 in Seattle. I went up there alone, drove around and looked at their various public school buildings. I even got some drawings that I brought back that we reviewed. It had already been proven that unreinforced or partially reinforced concrete block masonry walls do not perform very well. There was a lot of damage in that type of construction. Of course, the old masonry construction had cracks in it. Seattle was a small earthquake, so we didn't learn much, but it confirmed many of our beliefs.

I remember Ernie Magg, Principal Structural Engineer in our Los Angeles office, saying, "We've got to place the reinforcing in the wall like a blanket, or closely spaced, to keep the wall tough." Masonry is not tough when the reinforcing is gathered close together in one area and the remaining reinforcing is spread out. Proper and close spacing of the reinforcing vertically and horizontally makes the whole unit tough, and gives it much more ductility and strength.

1966 Parkfield

Meehan: The next earthquake was in 1966, in the Parkfield-Chalome area. There was a small Field Act wood school building sitting right next to the fault. We could throw a rock over the fault from the schoolyard. There was no damage to the building. The building is still there.

Speaking of Parkfield-Chalome and that school building, the Division of Mines and Geology's Strong Motion Instrumentation program now [1988] has strong motion instruments in it and the nearby Shandon High School waiting for the earthquake that is predicted in that area at this time by the U.S. Geological Survey. Of course, there are many other types of instrumentation in that area now, waiting for the predicted earthquake.

29 John F. Meehan, "The Response of Several Public School Buildings in Anchorage, Alaska, to the March 27, 1964, Earthquake," in Fergus J. Wood (editor) *The Prince William Sound, Alaska, Earthquake of 1964 and Aftershocks*, Vol. 2, pp. 219–243, U.S. Dept. of Commerce, Washington DC, 1967.

1969 Santa Rosa

Meehan: In 1969 in Santa Rosa there again we had T-bar ceiling damage in the high school. The light-gauge steel members forming the ceiling structure are inverted Ts, so that there is a small shelf on either side of the webs or vertical parts of the Ts where the ceiling tiles sit. There were some attempts at anchoring the T-bar ceilings, but they did not work too well. The evidence there showed us that we should continue to provide better anchorage. In T-bar ceilings, we now get a competent connection of the T-bars, not only length-wise, but also cross-wise. The T-bar splices in the longitudinal direction and at their 90-degree intersection must be competent connections to carry a tension load. The tension load is based on what the current code requires for each area of a ceiling that is twelve feet by twelve feet. We test for an ultimate tension or compression load of 180 pounds, with a five-degree offset.

Scott: So there could be some wiggling in the T-bar grid if the pieces aren't tied together well?

Meehan: Right. Like you hold one end and pull the other end with 180 pounds straight away, and then 180 pounds at a five-degree offset in the horizontal plane both ways, and then up and then down at the five-degree offset. The five-degree figure is just a number we took out of the air. It puts a little bending in the connection. Some end connections are a snap arrangement that when the ends are brought together, the pieces snap in place. Usually that kind will come apart if bent a little. One manufacturer developed a wire hairpin that penetrates a pair of matching holes in the T-bar web of the cross-T intersections. That performs very well.

It's not a completely scientific design approach, but it does address some of the major problems. Our primary intent is to at least keep the ceiling suspended overhead. We don't care what it looks like after the earthquake, but it must be kept overhead so the panels don't fall down on the kids and cause panic. The lightweight panels may or may not cause injury.

But if the T-bars rotate around, come down and land on their ends, one could penetrate the skin quite easily. In fact, I found one T-bar in an earthquake in Fortuna in 1975 where the T-bar actually penetrated well into the ceiling tile. A piece of ceiling tile landed on the floor first, and the T-bar followed it and almost penetrated through the tile. So T-bar ceilings could cause injury.

Scott: So you've tested the different components of these suspended ceilings?

Meehan: The intersection joints and splice joints. The manufacturer runs tests on them once. The tests are reported by a testing laboratory, and we review the reports. We must assume that the manufacturer will fabricate the members the same as those tested. We do not have in-plant inspection on those items, but we do have the test information in our files, and information on how they are made. We have a record of what we've accepted.

I might as well finish with our discussion of T-bar ceiling requirements. The main Ts go in one way, and they might be in twenty-foot lengths. The cross Ts are between the two main Ts, so their length is usually two feet or four feet. The cross Ts go through the main

runner and then snap or join together. At intersections, about twelve feet on centers each way, we require diagonal splay wires in each direction. In the case of a hospital, we use a higher load factor, and it comes out to about eight-foot by twelve-foot spacing, or 96 square feet, instead of the twelve foot by twelve foot or 144 square foot spacing for schools. That's because the lateral force factor for the hospital is 0.3, and for the school is 0.2. The wires go up and anchor into the structure above. We get involved in details like the number of twists in the wires to make it resist as much load as is needed.

A lot depends on the workmanship. The wire sags if it's not tight, and it is difficult to get it tight because there's no weight to hold it down, unless a vertical strut is installed. We've always wanted a strut, but decided at the time that we did not know how the ceilings perform, and we thought maybe the strut was not needed. We knew we should see how they really perform in an earthquake. Well, we had the 1975 Fortuna earthquake, and the performance triggered support for the strut requirement. According to simple engineering principles, it is obvious it really is needed. Ceilings there in Fortuna had diagonal wires, and they did resist load, because at the diagonal wires T-bars were wrinkled in compression. So they did perform. But in other places, in that same ceiling, the T-bar joints came apart.

We also require a vertical hanger within eight inches of the wall, because that is another place where the T-bar ceilings come apart. At the wall, the T-bar sits on a small ledger angle. The T-bar is pop-riveted to the ledger angle on two adjacent sides of the room so the workmen have something to pull against. The T-bar is not usually anchored to the ledger angles on the two opposite corners of the room. The T-bars fall off the ledger angles and drop the tiles, and sometimes drop the T-bars to the floor even if the T-bar is pop-riveted. We therefore require a hanger within eight inches of all walls or at any ceiling discontinuities. We also require a horizontal member connected to all Ts at the walls or areas of discontinuity to prevent spreading the T-bars.

Those are the things we've incorporated in our requirements, and the Uniform Building Code has incorporated the same requirements. In fact, the Uniform Building Code required the strut in this last code change in 1985. Frank McClure had a lot to say about getting the strut added at the UBC code change meeting. I'm sure that our current requirements have now incorporated that vertical strut. Locating the struts is sometimes very difficult, because there are ducts and other nonstructural items above the ceiling. In a hospital, it's a major problem, because the ceiling space is full of ductwork and all types of pipes.

Scott: Could you say a little more about the Santa Rosa earthquake? It was not a big earthquake in terms of magnitude, only 5.6, but in terms of damage and in other ways, it was a major earthquake.

Meehan: It did a lot of damage in Santa Rosa.[30] Santa Rosa received heavy damage in

30 K. V. Steinbrugge, W. K. Cloud, N. H. Scott, *The Santa Rosa, California, Earthquakes of October 1, 1969*, U.S. Environmental Science Service Administration, 1970. (See the contributions by Jack Meehan and Eugene A. Miller.)

the 1906 San Francisco earthquake because of the deep soil conditions. It relates to the Mexico City kind of soil condition. The soil characteristics probably amplify the seismic waves coming up to the surface, and if buildings have certain dynamic characteristics, they become damaged. In 1969 there was a lot of damage in Santa Rosa for that size earthquake.

Scott: I guess it mostly involved older structures.

Meehan: There was a new structure, too, a county building.[31] It was reinforced concrete, a two-story building, and had a fair amount of concrete cracking.

Scott: Was that of ductile concrete?

Meehan: No, it was built in the days before ductility requirements were in the code. By the way, they also tell me that in the hospital, in the lab, they had cyanide and acid on some shelves. The earthquake threw those things down together. When they joined up, they generated the famous green-room gas, the gas in the green-painted room at San Quentin where executions are carried out. I didn't talk to the hospital people directly, so this is obtained second hand or third hand. Anyway, I talked to somebody who said, "The custodian or somebody was aware of it and they sealed that room off, and they were able to exhaust the gas out of the lab and not pull it back into the hospital." That brings up one other thing: there are still no requirements on proper chemical storage that I'm aware of. We have codes for buildings, but do not have codes for furnishings and the loose materials, installed by the owners. Someday, I imagine, we will.

1970 Peru

Meehan: In 1970 I went to Peru as an EERI reconnaissance team member. EERI funded the trip and per diem, and the state paid my wages. This is the same arrangement EERI has today. Professor Glen Berg from Michigan and I went, and we met up with others down there. Jim Stratta showed up there, too, for a while, and we traveled around together. That was an outstanding event, both as relating to structural earthquake damage, and the influence of a huge piece of a glacier and rock breaking off the 23,000-foot high Mt. Huascarán. We put together an EERI report on Peru's earthquake. It was the first or one of the first EERI post-earthquake reports.[32]

A huge piece of the glacier and other debris broke off the mountain, apparently became airborne on an air cushion formed from the tumbling action of the rocks under the ice and snow. The avalanche just whooshed down the mountain, covering everything in its path. It covered Ranrahirca, a town of several thousand people, and also went over a high ridge

31 W. K. Cloud, D. M. Hill, M.E. Huffman, C. W. Jennings, T.V. McEvilly, R.D. Nason, K. V. Steinbrugge, D. Tocher, J.D. Unger, and T. L. Youd, "The Santa Rosa Earthquakes of October, 1969," *California Geology*, Vol. 23, No. 3, 1970. Karl Steinbrugge raised questions about design provisions and the possibility of "quasi-resonance between the building and the vibrating soils beneath" (p. 50).

32 J. L. Stratta, G.V. Berg, W. Enkeboll, J. F. Meehan and F.E. McClure, *Peru Earthquake of May 31, 1970, Preliminary Report*, Earthquake Engineering Research Institute, Oakland, CA, 1970.

of about 200 to 300 feet and into another town called Yungay. It basically covered the whole town several feet thick with sand, rock, mud, and ice. There was a cemetery in the lower part of the town, on a mound, which didn't get covered. The slide engulfed it, went around the mound, and then went down into the river. That same mass just slish-sloshed back and forth in the river bed, as it flowed down the river. This great mass of material just went down and destroyed and covered everything in its path. We visited that area after the earthquake and it was amazing. I have a lot of slides of it. It was very clear that the speed of the flow was very fast, from two sources that I could quote. The first verification was from a physicist in Lima who was up there at the time of the earthquake. He said he was with a French geophysicist, and they were at the base of Mt. Huascarán, in the town of Ranrahirca. He said they took photographs of the glacier and the mountain. They could see huge cracks at the end of the glacier, and they both commented on the possible avalanche hazard.

Scott: This was shortly before it cut loose?

Meehan: Yes. This was just minutes before the earthquake. He said they both commented on the fact that, "This would be a bad place to be in an earthquake." A similar avalanche occurred at least one time previously on that same mountain.[33] These glaciers in the Andes break off, and come down and just wipe out the cities, the towns. He said after they took the photos, they then got into their car and drove a little farther way. The road curved, and they had to go down and cross the river. He showed me on a map, saying that, "We were right about here when we felt the earthquake, and we both decided to run for that little mound or hill in the cemetery, because that's the highest ground around." He said they parked the car and grabbed some things and ran up the side of this mound, and by that time the debris arrived. He was about sixty or so, not a track man or anything like that, so you can visualize that he could probably run one hundred yards in thirty to fifty seconds, while the dislodged material traveled several miles. Using the distances and estimating the time involved, I came up with an unbelievable speed of something like 250 or 300 miles per hour for the speed of the avalanche. Others have verified that airborne avalanches can get going to those speeds. He said that he was running in front, and his friend was behind him. A lady yelled to him, and he says his friend reached around and grabbed the child from her arms, but couldn't save the mother, who was caught in the sweeping avalanche.

Frank McClure was able to obtain some pictures of the town that were taken before the earthquake. There were some palm trees and a huge adobe church. Afterward there was just a lump of adobe where the church originally was. The palm trees were about two feet in diameter. On the approach side of the trees, the mud went up 15 or 20 feet high, but on the backside, the mud was up only three or four feet. This is the second verification or evidence of the extreme speed of the avalanche, knocking out everything and covering everything. It was just unbelievable.

We drove to Huaraz from Lima in an army truck. We were asked to go to a power plant

33 The town of Ranrahirca was previously damaged and two thousand residents killed by an avalanche on January 11, 1962.

in Huallanca. We were able to get a helicopter ride in a French army helicopter from Huarez to Huallanca. We went to the power plant and landed on the opposite side of the river from the powerhouse. The only way to get over to the plant was by riding a cable across the river suspended in a little cart. Knowing about the earthquake, I didn't have any faith in the anchorage to that cable, so I declined their invitation to cross the river and examine the power plant. It was out of operation, because debris got into the intake tunnels. I don't know what happened inside the power plant.

Four of us went to Huallanca in the French helicopter: Glen Berg from the University of Michigan, Raoul Hasid from Chile, George Plafker from USGS, and me. Raoul remembered his high school French better than the rest of us. The Frenchmen flying the helicopter said that they would come back *apres midi*, which we interpreted as after lunch. So, they dropped us there about ten o'clock in the morning and took off. What an empty feeling to be without communication to the outside world. We looked at a lot of buildings. The tallest buildings were one-story adobe. Where the avalanche went through, there were just little stubs of walls protruding above the ground, because the avalanche wiped out everything. Just cleaned off the buildings slick as a whistle. *Apres midi*, after lunchtime, about one o'clock, we returned to where the helicopter had dropped us off. I remember George found a beer truck that was delivering beer, but it could not get out of the town because of the landslides. We had a warm beer, but at least it was wet. Finally after what seemed like ages, probably around four or five o'clock, the chopper came in and picked us up. We were in a very steep, narrow, deep canyon, and they had to go up and down through that narrow space. I'll never forget that experience.

We saw a lot of damage to school buildings and hospitals in Peru[34]. There was heavy damage in a brand new hospital in Casma. An earth-filled berm for a soccer stadium liquefied and just sloughed away. Amazing.

1971 San Fernando

Meehan: Next was the San Fernando earthquake of 1971. There was a lot of work to do there. I spent about four weeks going through everything that I could find and was very fortunate in being able to visit schools, hospitals, and private facilities, including the power intertie of the Edison company with its electrical problems, and also many other sites, including highway structures.[35] After the San Fernando earthquake, the National Oceanic and Atmospheric Administration published a report, and EERI put together a section in that one. There were quite a few additional reports after that.[36]

34 John F. Meehan, "Performance of School Buildings in the Peru Earthquake of May 31, 1970," *Bulletin of the Seismological Society of America* , Vol. 61, no. 3 pp. 591–608, June 1971.

35 John F. Meehan, "Performance of Public School Buildings, San Fernando, California, Earthquake of 9 February 1971," Supplement 196 to the California Division of Mines and Geology *Bulletin*, 1975, pp. 355–368.

36 John F. Meehan, Public School Buildings, *San Fernando, California, Earthquake of 9 February 1971,* U.S. Dept. of Commerce, Vol. 1, Part B, pp. 667–684, 1973.

Scott: You visited all kinds of facilities, not just public schools?

Meehan: Everything I could get to. Everyone was very cooperative. I took photographs of everything. I was with Don Moran frequently. He and I went around together on that one, as well as Martin Duke and others, including our Structural Safety people.

As you well know, we learned a great deal in San Fernando. That earthquake drew people's attention. Before that, not too many people cared a lot about ceiling damage and nonstructural damage, but finally, San Fernando brought people's attention to nonstructural damage, which is very important. This is because local folks were seeing the damage firsthand, not just the few of us who go off on these crazy trips and then come back to show earthquake damage pictures. Things like that can suddenly drive the point home. That's one of the many advantages of a local earthquake—you get the local people's attention.

Scott: What about the laws that came out of the earthquake?

Meehan: In 1971, I was on the EERI-NOAA earthquake committee that coordinated the reporting on the San Fernando earthquake, and I was on an ad-hoc sub-committee on instrumentation location in northern California. That was the beginning of the strong motion implementation program (SMIP) we have now.

Scott: That was also an outgrowth of the San Fernando earthquake and the Alquist committee of the state legislature?

Meehan: Yes, the Alquist committee recognized that the need for strong motion instrumentation was very critical. We had several meetings and discussions on instrumentation. Also, I had a state-funded research project with Martin Duke and Dave Leeds of UCLA on sites. We were trying to understand the wave propagation, coming up through the different layers of soil. Prior to that time I had some strong motion instruments installed on the roofs of several school buildings under our research program. The SMIP program followed. I was on the advisory committee from 1972 to 1986. I am now on the building and ground motion subcommittees.[37]

Meehan: Starting in 1973, I was on the Governor's Interagency Committee on Earthquakes. Once the Alquist committee got going, the governor also set up a parallel committee. I don't quite understand why the governor appointed this second committee, but it was done. I was also on that.

Scott: Governor Reagan had a Governor's Earthquake Council for a time, and I think Jim Stearns chaired it.

Meehan: Stearns was Secretary of Conservation. Then in 1979, there was the Governor's Emergency Task Force on Earthquake Preparedness, when Jerry Brown was in his first term as governor.

Scott: I never knew much about either

37 E. E. Cole, C. V. Tokas, J. F. Meehan, "Analysis of Recorded Building Data to Verify or Improve 1991 Uniform Building Code (UBC) Period of Vibration Formulas," *SMIP92 Seminar on Seismological and Engineering Implications of Recent Strong-Motion Data*, California Division of Mines and Geology, pp. 6–1 - 6–12, 1992.

the Governor's Earthquake Council or the interagency committee. I never knew too much about what they were doing. I just knew that the Reagan administration had something going on at the same time as our advisory groups under the Alquist legislative committee.

Meehan: It seemed to be a duplication of effort. Their effort didn't seem as strong as the Alquist group. They followed along and nothing really significant came out of it that I'm aware of. Except, that is, for one very significant thing: it just kept driving the point home that earthquakes are very serious business. Anything that would get more people involved in recognizing the dangers and hazards of earthquakes was good. As far as I'm concerned, that was the biggest plus that I could see out of the total effort.

Scott: Let me make an observation, and see what you think. Jim Stearns was involved in chairing the Governor's Earthquake Council, and he did seem interested and supportive.

Meehan: Oh, yes.

Scott: That may also have had a good deal to do with the Reagan administration's attitude. Even if they didn't take a positive view, at least they did not take a negative view toward going ahead and setting up the Seismic Safety Commission.

Meehan: I think Reagan was down there when they were digging people out of the Veterans Hospital building in the 1971 San Fernando earthquake. I remember seeing it on television.

Also, now that I recall it, Jim Stearns was very supportive of my going to Managua and Veracruz, Mexico. The State Geologist at the time was Wesley B. Bruer. He was knowledgeable, supportive, and a very astute geologist. In fact, through Stearns effort we were able to have a beautiful letter with seal and ribbons signed by the Governor, requesting support for our activities in Managua.

Scott: It must have looked impressive.

Meehan: Yes, it was very impressive. I have it hanging on my "recognition wall." After I retired, I got all my plaques and hung them up. It's an ego wall, I guess.

Of course, I was the unofficial representative of the State Architect to the Seismic Safety Commission. There's nothing recognized formally as such, but as you well know, I attended almost all of the meetings.

1972 Managua

Meehan: The Managua earthquake in 1972 was similar. I went down to Managua with Henry Degenkolb; Henry's son, Paul; and Don Moran. Henry was very concerned with the structural damage. I was too, but I was also concerned with the nonstructural damage.

The damage clearly showed the importance of proper diaphragm design, continuous and proper diaphragm chord locations, and the problem of discontinuous diaphragm chords. There was one building—a telephone building—where the diaphragm had a discontinuous chord, and a tremendous amount of damage occurred at the discontinuity where an

engineer would expect the damage to occur.[38] It was very vivid.

1973 Veracruz

Meehan: The Veracruz, Mexico earthquake was in 1973. It was an interesting experience, seeing their construction. Again, the damage pointed out the problems with discontinuities. The earthquake really found the discontinuities in stiff, brittle building materials.[39]

1975 Fortuna

Meehan: The ceiling problem was repeated in the 1975 Fortuna earthquake, but the structural aspects of the school buildings in Fortuna performed very well.[40]

1975 Oroville

Meehan: The Oroville earthquake, also in 1975, was an earthquake that I even felt here in Sacramento. In fact, I happened to be talking to Everett Blizzard at the Office of Emergency Services as we had the earthquake. I went up there the next day and went through the schools. We had pretty good performance of all of our school buildings, and of the hospital building that the Office of the State Architect had approved.[41]

Prior to the Oroville earthquake, EERI had been talking about setting up a clearinghouse after earthquakes. Before I went to Oroville, the California Division of Mines and Geology had set up the clearinghouse, and I knew it was located in the firehouse. We had previously agreed that the clearinghouse would be at the nearest Division of Forestry firehouse. I went by there early in the morning when I arrived in Oroville, but they were not yet aware of the clearinghouse operation. So I just visited around town, and again on my way home stopped back by the firehouse. But nobody was there. Later on, the clearinghouse activity did develop, but I was not involved in that. I had to get home that evening for other purposes.

Scott: You mean that later on a post-earthquake headquarters or clearinghouse was developed for the Oroville earthquake?

Meehan: Yes, they did develop one, but it was used as a clearinghouse only for a day or so. The clearinghouse was established primarily so that all of the people who were going to investigate earthquakes could come in and report what they were going to do, and what kinds of structures they would visit. Also, they would have a place where they could meet

38 John F. Meehan, H. J. Degenkolb, D. F. Moran, K. V. Steinbrugge, L. S. Cluff, G. A. Carver, R. B. Matthiesen, C. F. Knudsen, *Managua, Nicaragua, Earthquake of December 23, 1972*, Earthquake Engineering Research Institute, Oakland, CA, May 1973.

39 John F. Meehan, "Reconnaissance Report of the Veracruz, Mexico Earthquake of August 28, 1973," *Bulletin of the Seismological Society of America*, Vol. 64, No. 6, pp, 2011–2025, 1974.

40 John F. Meehan, "June 7, 1975 Fortuna Earthquake," Earthquake Engineering Research Institute, Oakland, CA 1975.

41 John F. Meehan, Observations of Earthquake-Related Building Damage, *Oroville, California, Earthquake, 1 August 1975,* California Division of Mines and Geology (now California Geological Survey), Special Report 124, pp. 75–83, 1975.

together and discuss what they had seen or learn about some of the other things that other people observed. That was the general purpose of the clearinghouse.

Scott: It was a communications checkpoint.

Meehan: Right. But it didn't get started off real well in Oroville, because Oroville wasn't much of an earthquake. Like the Fortuna earthquake, it was a little over magnitude 5.

1978 Santa Barbara

Meehan: After that came the 1978 Santa Barbara earthquake—another magnitude 5 earthquake. That was where we saw the University of California's building performance. They had a fair amount of damage to their facilities.

I also looked at one of our approved hospitals there and found only a few plaster cracks. There were some T-bar ceilings in a school building that were installed according to the old regulations, which had practically no lateral resistance, and they did not perform very well.

At the University of California, there were ungrouted concrete block cells. Those cells should have been filled with grout as we've discussed, because there was reinforcing in the cells. I understand this was corrected later, but I didn't follow up on it.

Scott: That occurred in one or more University of California buildings?

Meehan: Yes. These were in dormitories, I believe. But other people got into that much more than I did.

1979 Imperial County

Meehan: After Santa Barbara came the Imperial County earthquake of 1979, with a magnitude of 6½. I was in Europe at the time. When I got home, I went to El Centro and saw the county services building that had soft-story damage. That damage verified our concern that we should not use laterally displaced shear walls. They should be in-line, continuous all the way down. There should not be side-stepped shear walls. There are a lot of reports on that building. I didn't get involved. Again, there was very little damage in school buildings. We just lost the usual cabinets that toppled over and things like that. There was a hospital building that had been reviewed by our office, and it came through fine. There was no damage to it at all.

1979–1980 Mammoth Lakes

Meehan: Then there were the 1980 Mammoth Lakes earthquakes. I think the largest one had a magnitude a little over 6. The district called and said their school building was in a shambles. When we got there, we found a lot of nonstructural damage. Ceilings, light fixtures, vents, and so on, in one of the rooms had fallen, but the structure itself had performed just as it was supposed to. It had performed according to our basic concept that the building should stand up, but that some structural and nonstructural damage might occur. A hospital that had gone through our office was also there, and it had no problem. By that time, the state had set up within the Office of the State Architect the Office of Statewide Health Planning and Development (OSHPD), specifically

for hospitals. I think one pipe cracked and developed a leak, but it was a minor thing.[42]

1980 Livermore

Meehan: We had the Livermore earthquake in 1980 and saw the kinds of building damage it produced. There was very little damage in schools and in the hospital, but there was an interesting sidelight on the hospital. They had an emergency radio with a transmitter and had emergency power. In hospitals, in most instances they only put necessary equipment on emergency power. They don't light the whole hospital and try to do everything with the emergency generator, but only provide power for equipment that is needed critically. They have special red electrical outlets for emergency use, so the plug is always supposed to be hot. But in Livermore, they found that their emergency radio plug didn't work. Somehow or other they did not test it on the emergency power.

Scott: Emergency power sources should be checked out regularly, so they are ready when emergencies occur.

Meehan: Of course, I agree with you. Once a checker, always a checker, as the old saying goes.

1980 Eureka

Meehan: Also in 1980 there was a little earthquake in Eureka. There was no significant school damage. That was the earthquake in which a highway bridge fell off of its supports. We had some ceiling and light fixture damage in the College of the Redwoods. There was a small hospital up there, but there were no problems. It was an old hospital, and so it did not go through our office.

1983 Coalinga

Meehan: Then came the Coalinga earthquake in 1983, where again we saw the importance of continuous inspection in public school buildings. Generally, our school buildings performed very well.[43] While there were some problem areas, we were fortunate. We almost lost part of a roof and part of a wall. Reinforcing ties around the anchor bolts, which were needed to anchor a roof truss, were omitted, although shown on the drawings. A part of the truss bearing had cracked away. It was repaired. In another school there were to be ties around the anchor bolts, but again, the ties were not installed on top of some shear walls.

Scott: What did you do? Send a little circular around to all the inspectors?

Meehan: Yes. We requested that our field people discuss the importance of ties with all the inspectors. Of course, that's something we've been looking at for years, but some will probably be missed in the future. It's

42 John F. Meehan, "Reconnaissance Report of the January 1983 Mammoth Lakes Earthquake Swarm," *EERI Newsletter,* 17,2, pp. 75-71, March 1983.

43 John F. Meehan, "Performance of the Public School Buildings to the 1983 Coalinga, California, Earthquakes," *The 1983 Coalinga, California Earthquakes*, J. H. Bennett and R. W. Sherburne, eds., California Division of Mines and Geology Special Publication 66, pp. 37–54, 1983.

something most people don't get concerned with until they've had the experience, but the experience is growing, too. Probably the next one will come out much better.

The hospital in Coalinga was not under our jurisdiction. It essentially had no damage to speak of. We had some damage in schools, such as some roof tiles were displaced, which showed where tile nails had been omitted. Leave a nail out of the tile, and the earthquake finds that tile and shakes it loose. It drives home the need for continuous, competent inspection that covers everything. Inspection is critical. It doesn't do any good to have a fine set of drawings and a fine bunch of regulations if a building doesn't conform to and meet all of those requirements.

We had major glass damage in the library of a junior high school. The longitudinal lateral forces were resisted by wood posts extending out of short diagonally sheathed walls. The posts deflected, or drifted, causing the glass to explode. This building was constructed prior to the time we had drift limitations in our code. The building was strengthened.

1984 Morgan Hill

Meehan: In 1984, we had the Morgan Hill earthquake and saw similar kinds of ceiling problems with the old ceilings and anchorage of equipment.[44]

1987 Superstition Hills

Meehan: The Superstition Hills earthquakes, two of about magnitude 6, were the last ones I looked at.[45] It was two days before Thanksgiving. By then I was retired, however, so I went down under the EERI Learning From Earthquakes program. A number of other people and I wrote a report for the EERI newsletter. That's what we in EERI are doing now, trying to get people to write quick reports for the newsletter, to get information out on these small earthquakes.

I thought we came out with a pretty good short report in the EERI newsletter.[46] One new observation did not involve damage, but was interesting. The farmers grow a lot of hay and stack up the hay bales in the fields. The earthquake shook down bales of hay that had been stacked up ten to twelve bales high. The shaking was enough for the outside bales to fall off the pile. A bale of hay is pretty stable until you get several of them piled up. They are put one on top of the other, but also are stacked next to each other. I know they purposely intertwine bales, but once in a while they don't, and the earthquake finds vulnerabilities wherever they are.

44 John F. Meehan, "The Morgan Hill Earthquake of April 24, 1984—Effects on Hospitals and Public School Buildings," *Earthquake Spectra*: May 1985, Vol. 1, No. 3, pp. 575–577.

45 These interviews took place in 1988. In fact, Jack participated in reconnaissance after the 1989 Loma Prieta earthquake and is a coauthor on the Loma Prieta Earthquake Reconnaissance Report that is published as a supplement to volume 6 of *Earthquake Spectra*.

46 John F. Meehan, Earl Hart, Anshel Schiff, "Superstition Hills Earthquakes, November 23 and 24, 1987, Imperial County, California," *EERI Newsletter,* 22, 2, pp. 1-8, February 1988.

Sponsorship of Earthquake Field Work

Scott: On these trips, were you operating mostly on behalf of the Division of Architecture, or of EERI? What capacity did you consider yourself to have?

Meehan: To tell you the truth, I really didn't worry about it too much. I had the opportunity to go and I went. I was funded for California earthquake inspections by the state. It's easy to travel in-state. As soon as you cross the state border, everyone looks at the request. In fact, even the governor's approval is required for out-of-state travel.

The request goes up from the Chief Structural Engineer to the State Architect. In my case, the Chief Structural Engineer was always supportive, and the State Architect usually was. Then it went to our department, and sometimes the requests were stopped there. That happened with the 1976 Guatemala earthquake, when they said, "No, you can read the report of that earthquake, as two or three other people are down there looking at it. You can read the report when it comes out."

Then, from our department an out-of-state travel request went to the Department of Finance, and then to the governor's office. There were clerks who said, "No, no, no. That's a junket. Forget it. We don't have earthquakes in Sacramento." There are always those kinds of people who try to shoot you down. With Peru, I just went. Since I didn't have to charge any state funding for travel, it was all right. The San Fernando earthquake was in-state and I got funded. The office did the typing and made copies of the reports when I got home from an earthquake visit.

The Federal Department of Commerce supported reports for Anchorage and San Fernando. Other agencies also put together San Fernando earthquake reports. EERI funded the Managua report. Believe it or not, the California Office of Emergency Services funded the transportation for the 1973 Veracruz, Mexico earthquake.

Chapter 6

Conferences and Organizations

The permit applicants didn't want to follow the code. They would much rather prepare only a very sketchy outline of what they wanted and give it to the contractor and let the contractor build what he thought should be done.

Scott: Now talk about some of the conferences you went to and organizations you belonged to.

The World Conferences on Earthquake Engineering

Meehan: I attended the Second World Conference on Earthquake Engineering in Japan in 1960 and presented a paper on the window research Jack Bouwkamp and I did. I also had a paper for that conference co-authored with John Blume on the dynamics aspects of school buildings.[47]

47 John A. Blume and John F. Meehan, "A Structural-Dynamic Research Program on Actual School Buildings," *Proceedings of the Second World Conference on Earthquake Engineering*, Tokyo and Kyoto, pp. 1297–1325, 1960.

Then I went to the Fifth WCEE in Rome in 1974 and the Sixth in New Delhi in 1977. On the way back from India, I stopped in Japan and visited with engineers there. I visited Tsukuba when the city was in its early stages and they only had a few buildings.[48]

Scott: Is that their science city?

Meehan: Yes. It was when they were building it and had a few of the facilities constructed. They had one fairly large shaking table, larger than Cal's. It had two components of motion, one horizontal and one vertical. They had a big water tank with water on it, and ran a shake test on the water tank. They also had a tunnel where they ran fire tests on automobiles in the tunnel.

They had a programmed bus system that I rode. The idea was to program the bus to pick up passengers in outlying areas and bring them to a central train station. They had an automatic system in the roadway that was unbelievable. The bus had no driver, and it ran along an electrical system. I understand that it is still there.

I went to the Eighth World Conference on Earthquake Engineering in 1984 in San Francisco and presented a paper there.[49] Now I have just returned from the Ninth WCEE in 1988, which was held in Japan again.

USAID Trip to Managua in 1974

Meehan: I was a consultant to the U.S. Agency for International Development (USAID). They sent me to Managua in the latter part of March and the early part of April, 1974. The Managua earthquake had been in 1972, and they were in the process of issuing building permits. The local people in the building agencies were having real problems with the people coming for permits, so they asked me to look at the building department, to look at how and what they were doing, to see if there was some way to get agreement on their operation.

Scott: Could you say more about the problems they were having? What do you mean by "agreement?"

Meehan: The permit applicants didn't want to follow the code. They would much rather prepare only a very sketchy outline of what they wanted and give it to the contractor and let the contractor build what he thought should be done. Whereas under the process here in the United States, the designers prepare documents telling the contractor the details of construction, and

48 Although Meehan did not mention the Third World Conference in New Zealand, he wrote a paper: John F. Meehan, "State of California, Office of Architecture and Construction Earthquake Research, "*Proceedings of the Third World Conference on Earthquake Engineering*, New Zealand, pp. IV-400-IV-413, 1965.

49 John F. Meehan, "California's Hospital Seismic Safety Act," *Proceedings of the Eighth World Conference on Earthquake Engineering*, San Francisco, pp. 731–738, 1984.

those documents are approved by the building department. In the U.S., there is agreement over the authority of the building department.

It seemed it was mostly the contractors who objected, although the engineers also did not like to be told how to design their buildings. It all basically centered on code enforcement. Since our office enforces codes, they asked me if I would go down and see what they were doing.

They didn't want to be told, for instance, that they had to specify the amount of weld on an angle of a truss. They felt it was insignificant. They felt: "You don't have to show that because the contractor knows how to build a truss." It was that kind of attitude. Then the agency didn't issue the building permits, because the engineers didn't always follow the code, so the agency held up the building permits, so they couldn't build anything.

There was an impasse. I don't know if I did much good, but I brought a check set of drawings for a typical building that our office had approved. The check set is the first set of drawings submitted. We review that set, mark it up for code compliance, and return it to the architect and engineer for correction. So I took down a check set for a one-story steel shop building—a project that is usually relatively clean. We showed them the number and kinds of things that we had marked. That was a surprise to them.

Scott: They were surprised at the number of things that you had found to mark, in a design done by a registered California structural engineer?

Meehan: The marks referred to things that had not been done correctly, or at least hadn't been done according to the adopted Field Act regulations. It caused quite a stir for them to realize how many things were marked. "I had heard California engineers were the greatest. You mean they make all of these mistakes?" We never characterize what we find, we keep away from finger pointing. It's not pertinent. I just pointed out that plan checking always spotted needed improvements.

I did what I could and talked to a lot of people. I even spent an hour and a half with President Somoza, in a one-to-one conversation with him. I talked to him about the buildings. He had taken engineering at West Point. We had a very interesting conversation. He understood what I was trying to do.

We discussed things like how a member is connected when the wind blows, or when the earthquake pushes against it. How does that member resist the load? First of all, it has to be big or strong and stiff enough. Second, it has to have connections at the ends, to transfer the loads elsewhere. This could be seen easily on the set of drawings I brought. I don't know exactly what happened after my visit, but that was one of my interesting experiences.

1975 Trip to Tashkent for U.S.I.A

Meehan: In 1975, I went to Tashkent in the U.S.S.R. The U.S. Information Agency, U.S.I.A. sent four of us to talk about earthquake construction. In addition to me, there was Joe Penzien, U.C. Berkeley; Walt Hayes, U.S.G.S.;

and Charlie Culver, from the U.S. Bureau of Standards. I showed them school construction and a lot of slides of earthquake damage that I had picked up in my travels.

The slides showed how it should be done, along with damage in other parts of the world that I was sure they had never seen. I had all the earthquake pictures I had taken up to that time, including Anchorage, Peru, San Fernando, and Managua.

My primary role was to show damage and to explain how we operate under the Field Act. I learned that they had nothing quite like the Field Act. In fact, there's nothing in the world I know of that operates the way we do.

Scott: Was the Tashkent activity undertaken in response to an earthquake there? What triggered sending the team over? Was it interest on the part of the Russians, or at least the engineers in Tashkent?

Meehan: It was part of detente. At that time, as part of detente, U.S. had an exhibit that travelled in Russia called the U.S. Home Exhibit. They put this exhibit together to show the Russians what American homes were like, and it travelled to various cities. This American home exhibit was in Tashkent when we were there, March 10 to 14, 1975.

In 1966, I think, they had a fairly large earthquake in Tashkent.[50] Much of the town received a considerable amount of damage. So part of the detente activity was to put together some sort of earthquake presentation. I felt very fortunate to be included in such a group.

Of course, there were also a lot of little hardships, like sitting in the Moscow airport for 36 hours because of fog conditions, waiting to get a flight out. We had a chance to see the real Moscow airport. We were in the Intourist section of the airport but could wander into the other side, in the main part of the airport. It was interesting, all the different kinds of people in there, different clothing and behavior.

Scott: You mean people of all the various ethnic or nationality groups that were coming through the airport?

Meehan: Yes. Just the differences in types of people. The little kids are so well behaved, whereas most of our kids would be crawling up the walls. They were all sitting there, waiting to go, feeling they would be lucky if they could fly out in a day or two. It was a fascinating experience. I like to extend my trips when I can, and the extended portion was on vacation time after they paid me while I was doing those five days in Tashkent. I took my wife, Liz, paying her way, of course. We went to Samarkand and Bukhara, then back to Moscow, then to Leningrad, and on to Sweden to visit some of Liz's relatives. It was just the two of us, back in 1975, when things hadn't been opened up very much in Russia.

Scott: That was a pretty good tour for the two of you. And being left unattended sounds unusual.

Meehan: That was very unusual. I wanted to extend the trip, and they told me, "Wait until

50 On April 26, 1966 in Tashkent, Uzbekistan, 28,000 buildings were destroyed, 10 people were killed, 1,000 people were injured, and about 100,000 people were left homeless by an earthquake of approximately magnitude 5.

you get to Tashkent and make arrangements with the travel people who are connected with this exhibit." The people put together a nice visit for us. They picked us up at our hotel in an automobile, drove us to the airport, put us on the airplane.

We'd get to our destination and there would be somebody at the airplane waiting for us. They picked up the bags, took us to the car, and off we went to the hotel. They'd meet us later and take us on a tour with an English-speaking guide. This happened in three places: Samarkand, Bukhara, and Leningrad.

When we returned to Moscow, somehow or other they didn't know that we were coming in. So we landed there all alone, we weren't greeted. We landed at night and didn't know exactly where we were. Fortunately, we walked through a door where we recognized that we were in the main airport. We then knew our way to get back to the Intourist section.

When we walked in, our Russian hosts were surprised to see the two of us walk in by ourselves, and there was a lot of jibber-jabber going on. Of course, we speak no Russian, but do speak pretty good sign language. They brought our bags and took us to our hotel.

We were there for a couple of days. They arranged another tour. Liz and I had a little private tour in Moscow, but we also had time for ourselves. We went to Red Square. I couldn't get enough photographs of St. Basil's, the most outstanding structure I'd seen in a long time. We got some nice pictures. There were different colors in the clouds. We walked through the streets of the city, just the two of us, saw the people, the big stores. We had a great time. Kids wanted chewing gum. We knew that before we left, so we had stuffed our pockets with chewing gum and gave it to the kids. They loved it. That was a great trip.

Other Conferences and Organizations

Scott: Say a few words about some of the other conferences you attended.

Meehan: I presented a building seminar in Hawaii in 1977. Dan Shapiro and I put on a seminar on the design of small buildings. I also gave a number of talks at Sacramento State University. I gave a paper at the First National Conference on Earthquake Engineering, at the University of Michigan, in 1975.[51] I was chairman for a portion of the EERI annual meeting in Nevada in 1982. I also gave a paper at the East Bay Geologic Hazards Conference in 1982.

I presented papers in Washington in 1978 and Tsukuba, Japan in 1979. I'm a member of the U.S.-Japan National Resource Panel on Wind and Seismic Effects. The state of California funded those two trips. I was on the advisory panel of a project called Investigation of Dynamic Behavior of Buildings and Partitions, which had tests run at California Polytechnic State University by Satwant Rihal, a professor there who did many tests on ceilings and on partitions, i.e., nonstructural walls.

I was a member of the Seismic Safety

51 John F. Meehan, "California's Seismic Safety for Hospitals," *Proceedings of the U.S. National Conference on Earthquake Engineering*, pp. 357–366, Ann Arbor, Michigan, 1975.

Commission's Committee on Private Schools from 1981–1985. Legislation came out of that, but it was not equivalent to the Field Act.

Scott: That was Bruce Bolt's committee.

Meehan: Yes. And I was a member of the Seismic Safety Commission workshop on California Earthquake Hazards Reduction in 1985. I was a participant in the in U.S.-Japan Workshop on Urban Earthquake Hazards in 1985 and again in 1988. I just got back from that last one. It was one of the preliminary workshops before the 1988 World Conference in Tokyo.

I was a speaker at the First International Earthquake Conference in Los Angeles in 1983. Just last year, I reviewed some books by FEMA on schools, hospitals, and hotels. There are three different books.

I was a participant in a U.S.-Japan workshop on the improvement of building and structural design and construction practices, in Tokyo and in Hakone, Japan in 1988.

Scott: Mention some of the positions you've held in the various organizations.

Meehan: I was president of the Central Section of the Structural Engineers Association of California in 1957, and in 1967, I was state president of the statewide SEAOC. When I applied for membership in EERI in 1966, Martin Duke sponsored my application. This was at a time when candidates were elected to membership based upon significant contributions to earthquake engineering. In 1970, I was vice president of EERI. I am currently [1988] project manager of the EERI Learning from Earthquakes Project. My primary function is to obtain reports of damaging earthquakes worldwide. In 1976, I was President of the Applied Technology Council.

As far as memberships go, I'm a Member of the Seismological Society of America, fellow and life member of the American Society of Civil Engineers, honorary member of the California Inspectors Association, member of the Geologic Hazards Advisory Committee of the Western States Conference of Structural Engineers Association.

Scott: What about awards?

Meehan: In 1979, I was a recipient of an award from the Engineering Council of Sacramento Valley for service to the profession. In 1982, I was a recipient of recognition of appreciation for outstanding contribution, California Council of Construction Inspectors.

Chapter 7

The Alquist Committee

Because Governor Brown had my keys with the Guinness screwdriver-knife, scraping out mortar at various places in the Capitol, I had to stick pretty close to him to get my keys back.

Scott: Let's talk about the Joint Legislative Committee on Seismic Safety, or Alquist Committee.

Meehan: The Engineering Considerations and Earthquake Sciences Advisory Group to the Joint Legislative Committee on Seismic Safety, 1969–1974, chaired by Senator Alfred Alquist, was a good committee. The Joint Committee prepared many good pieces of legislation, including the establishment of your Seismic Safety Commission.

Scott: The Hospital Act, for example, came out of that committee and its advisory groups.

Meehan: The Hospital Act, the Alquist-Priolo Act, the Strong Motion Instrumentation Program—all those came from this committee. A very significant and important amount of work was done through that group.

Scott: Say more about that period and that committee, and about your own observations and participation. This is a good place to give it some attention.

Meehan: As I said, I was a member of the Advisory Group on Engineering Considerations and Earthquake Sciences. Karl Steinbrugge was chairman, and a lot of the people we both know were members of that committee. The early discussions of that committee showed that they were quite aware that the best time to get earthquake-related legislation passed is right after an earthquake had occurred. That is, if earthquake legislation is needed, it should be prepared and ready to introduce immediately after the next earthquake.

In that group's early discussions, we cast around for the kinds of things that should be covered in such legislation. Everybody agreed that hospital buildings were not very well controlled. Plans did go through the state, through the Department of Health, but they did not look at structural aspects. They looked only at the health-type aspects.

The Hospital Act of 1972

Meehan: One of my assignments from Karl Steinbrugge was to work on a hospital bill, to draft legislation for hospital construction based on the Field Act. I was asked to use Field Act concepts and controls, adapted as I saw fit.

When I finally got around to doing this, believe it or not, I had taken a copy of the Field Act home the weekend before the San Fernando earthquake, and marked it up and added a few other important things.

Scott: Adapting the Field Act to hospitals?

Meehan: Adapting the Field Act philosophy to hospital construction and placing enforcement in the Department of General Services, just like the Field Act. I also put in the requirement that a structural engineer must do the structural design. The Field Act allows either an architect or a structural engineer to do the design. But in the hospital bill, I put in the provision that since these buildings are more critical, a structural engineer must do the structural design.

Scott: And that provision stayed in the bill?

Meehan: Yes. The other thing I put in was that the reviewer of the design also had to be a structural engineer. That also stayed in. There were some other things that I put in, such as increasing the fees, because I knew that hospital buildings would be more complicated than schools and more costly to check. Charlie De Maria and I became a committee to prepare the bill. We, together with Gordon Oakshott, added requirements for a geologic study of the sites and a review of those site reports by the Division of Mines and Geology and a plan review by the State Fire Marshall. The hospital building bill was first introduced in 1971, went through a committee or two, but was killed.

Scott: That would have been right after the San Fernando earthquake.

Meehan: I did the first hospital bill draft the weekend before the earthquake. The earthquake was on February 9, 1971. The morning of February 9, I heard about the earthquake on the radio. I heard that some freeways were down and highways closed. So I went to work that day with my suitcase, knowing that I'd

probably go right on down. That is what happened. I didn't take the hospital draft, but of course, I didn't know anything then about the hospitals being damaged. The first thing I did when arriving in San Fernando was to get together with one of the people in our O.S.A. office. We went as close as we could get to the epicenter, or where we thought the epicenter was. We knew it was near Saugus.

We looked at school buildings around the Newhall-Saugus area, but didn't see a great deal of damage. On our way back toward town, we came by Olive View Hospital because of my hospital legislation assignment. Then we saw the extensive damage there.

The fellow I was with had a Polaroid camera and took a couple Polaroid pictures of the hospital. He took photographs of those big 1-½ inch rebars sticking up in the air outside of the reinforcing cages and of the building.

The next day or so, word got to me that Senator Alquist was holding a press conference in San Francisco, and I was asked to be there. Henry Degenkolb was at the meeting but had not yet gone to San Fernando. I showed to Henry the Polaroid pictures of the damage. He immediately made arrangements to go down the next day.

I understand Olive View Hospital had just been approved through Los Angeles County in December 1970, and the damage occurred February, 1971.

Scott: It was a brand new building.

Meehan: Brand new, and they were still moving into it. Nearby was Holy Cross Hospital. It was also heavily damaged. And there was Pacoima Lutheran Hospital with damage. Olive View was evacuated. Holy Cross was evacuated. Pacoima Lutheran was evacuated after a period of time. Then, quite a bit later, I looked at Kaiser Hospital. Then, of course, there was the Veteran's Hospital, where they had the forty or more deaths.

Scott: Those were older structures at the VA Hospital.

Meehan: Those were older buildings, yes, whereas the other hospitals I mentioned, especially the main Olive View buildings, were designed and built under recent codes.

At that time, Senator Alquist introduced the hospital bill based on what Charlie De Maria and I had worked on as a committee of two. Of course, we had input from the other advisory committee members. It was introduced and adjusted a bit here and there, but later it was killed. I think it was probably killed by the hospital association, because they had an active legislative committee. And the engineers weren't as well organized. Sure, the engineers supported the bill and could see the advantage of it, but it was killed, nevertheless.

The next year, 1972, the hospital legislation was passed and became effective March 7, 1973. Instead of placing the enforcement under the Division of Architecture, like the Field Act and like the original 1971 Hospital Act draft, they put the enforcement under the Department of Health. This law required the Department of Health to contract with the Division of Architecture to do the structural plan review for the hospitals.

Scott: That was a very important early

outcome of the work of the Alquist committee and the advisory groups.

Meehan: As far as I know [1988], any hospitals that have been processed through the Hospital Act and have since gone through earthquakes have had practically no damage, hardly even a few little plaster cracks. So this shows that we've been doing it right, at least for the earthquakes we've had so far. But, of course, we haven't had any of the big, eight-plus magnitude earthquakes yet. Still, I think our hospital buildings will perform quite well.

Scott: Do you have any other observations about the work of that advisory group, the one on engineering considerations? How it operated or what the discussions or controversies involved?

Meeting the Earthquake Challenge

Meehan: A good report came out of the Joint Legislative Committee on Seismic Safety, *Meeting the Earthquake Challenge.*[52] Much good legislation came out of the Joint Committee. It made the California legislature much more aware of the hazards of earthquakes.

It's so difficult to try to convince a person what an earthquake can do, unless they have personal experience. To see it on television is like seeing the floods in Bangladesh. It's terrible for the people who are there, but it's easy not to be concerned, because it's not close to home and not a personal thing. When something gets personal, it gets attention. Again, it's like the Field Act. When the school board members became aware of their personal liability, they went into action and the school buildings were corrected. It's that basic philosophy that gets things done—bring the issue home and put it on an individual basis or individual liability.

Scott: Say a few more words about the Joint Committee.

Meehan: What else can I say about that committee? It was a great group. I think it really helped earthquake engineering worldwide. There were many good people on those advisory groups, something like seventy to seventy-five people.

The Alquist-Priolo Act, which established means for the Division of Mines and Geology to prepare detailed maps of earthquake faults in California, was another good piece of legislation that came out of the committees.

Prior to the formation of the Joint Committee, we got a special law for school buildings that said they cannot be built over faults. That was a good piece of legislation. Prior to that law, we had no authority with regard to locating school buildings on or near earthquake faults.

It was first introduced to say that you couldn't put a school building "over" a fault. Well, a fault can slope as it goes downward and can slope down fifteen miles. Picture a fault plane that is oriented forty-five degrees from the vertical. Therefore, a literal interpretation would not permit a school building within about twenty miles of the fault trace, because you would be "over" the fault. So we had to clean it up with the Joint Committee. It now says a school building cannot be placed on the surface trace of a fault. It also requires that other

52 Joint Committee on Seismic Safety, *Meeting the Earthquake Challenge,* Final Report to the Legislature, State of California, 1974.

geologic hazards must be addressed. It is a separate piece of legislation for public schools.

Scott: It is unlikely anybody would build a significant hospital across a known fault.

Meehan: The Structural Safety Section of the Office of the State Architect will not accept that. But the law doesn't say it quite as firmly for hospitals as it does for schools. On the other hand, all school sites do not require a geologic survey to be made, whereas the hospital legislation says there must be an in-depth study. With public schools, we can accept a statement that there is no need to address a geologic hazards problem, but with a hospital, a study must be made by a geologist, and the report must be reviewed by an engineering geologist.

Scott: There are controls in both cases, but the two laws kind of slice the cheese in different directions.

Retrofit of the State Capitol

Meehan: We should probably mention the seismic repair of the State Capitol, which was done through the efforts of Senator Alquist.

Scott: That work was certainly closely related to the Alquist committee, though I don't know if there's actually anything in *Meeting the Earthquake Challenge* about retrofitting the Capitol Building.

Meehan: Karl Steinbrugge was probably the person who initiated it. He encouraged Senator Alquist to ask for an investigation. I think the investigation was a no-cost, casual walk-through that Karl was able to arrange. Frank McClure, Karl, and I believe Henry Degenkolb made the casual review. The Division of Architecture later prepared a more comprehensive report on the Capitol. When money for funding the Capitol repair was up for consideration, and Governor Jerry Brown was to the point of either signing the appropriation or not signing, a committee led by the State Architect including other state officials and the press went through the Capitol with the Governor to observe the deficiencies.

Karl called me and said he could not attend and asked if I could go. I told him I must be invited to participate. He called the State Architect, John Worsley, who said, "Yes, you can go, but if any member of the press asks any questions, you refer them to me." That was all right with me.

The group started the walk-around survey of the Capitol building. We went down to the basement and were showing them the construction, the old bricks and the mortar in the walls. There were television cameras there, and Jerry Brown and others were up there in front of the group. They tried scraping the mortar out, but they could not scrape it out very well with just their fingers. The Governor asked if anyone had a knife or a screwdriver. I had a little pocket key-holder from the Guinness brand of stout, with a screwdriver in it. One blade is a combination screwdriver and bottle opener, and the other is a little short knife. So I said, "Here, try this." But my keys were tied to it too, so he took the whole thing and scraped the mortar out of the joints. It poured out like sand. He kept my keys and scraper and went scraping all over the building. They went all over the capitol, up to the roof, the attic, and into the dome.

Scott: He had your keys and knife?

Meehan: Because Governor Brown had my keys, I had to stick pretty close to him throughout the Capitol to make sure I got my keys back. He used that little gadget to help convince himself that the Capitol needed strengthening. He signed the appropriation.[53]

Scott: The tour had made a believer out of him.

Meehan: Yes, with a little help from my little Guinness screwdriver-knife.

53 A $68 million restoration of the California State Capitol started in 1975 and was completed in 1982. The project included restoration of the many unique artistic and architectural features of the building.

Chapter 8

The Field Act and the Hospital Act

If the checkers can understand the designer's presentation of the information on the drawings, then the contractor can probably understand it as well, and a better job gets done.

Scott: Start with your observations of the Field Act experience.

The Field Act *[see also the appendix]*

Meehan: First, some observations of standards of professional practice. I mentioned earlier that I have heard, and observed too, that the enforcement of the Field Act has a tendency to improve engineering practice because of the in-depth plan review that we do for conformance to the code. Many local agencies probably don't get into the plan review as closely as we do.

Scott: The real focus is earthquake resistance, but that also means checking almost everything related to the structural quality and integrity of the of buildings, doesn't it?

Meehan: Earthquake resistance is very important, but the building must also resist other forces, such as wind and snow loads. The statutes now say buildings must be designed according to Title

24. Title 24 is a collection of building regulations adopted by the state. It includes all types of building regulations, such as plumbing, mechanical, and electrical. We don't specifically enforce those others that are not part of earthquake safety, as such. Usually the school district employs an architect, who in turn employs consultants such as the structural, mechanical, and electrical engineers.

The Hospital Act

Meehan: The Field Act does not specifically state that the structural design of the school must be done by someone with California registration as a structural engineer. For a hospital, in contrast, the structural design must be done by a structural engineer. That was one of the first things I put in when writing the Hospital Act, and we were able to keep it in there. At one time, way back when they were developing the Field Act, they considered requiring a structural engineer for public school design. They thought that was a little too strong, however, and probably would have had difficulty getting it through the legislature.

Scott: Why did you want to get that provision requiring a structural engineer into the Hospital Act when you were originally drafting it?

Meehan: A structural engineer registered in California is trained as a structural engineer with a specialty in earthquake design. A California-licensed civil engineer can, however, sign all kinds of drawings for almost any kind of building or other construction, but may not have very good training for structural work and, in particular, seismic design. In fact, you can now become a licensed civil engineer without writing a single exam problem on structural engineering. In general, I understand that the registration board feels if you get a license, you will not practice in areas where you're not competent.

Scott: It is like relying on an honor system, isn't it?

Meehan: Yes. I'm not sure that still exists today, but it was true a few years ago. Having seen a number of plans where a structural engineer was not involved, I think it really leaves some things to be desired. Structural engineers are much better trained in structural design, of course.

Plan Checking

Scott: The plan checker is not designing. The designer is doing the designing, is that right?

Meehan: That's right. Our reviewers cannot take the attitude "This is the only thing I will accept." Responsibility for the design must remain with the private sector engineers or architects, because they must sign the drawings. That's the philosophy, keep the responsibility on the right person. The designer can't say, "That's not my job, I didn't get paid for that, it is somebody else's job."

Scott: In short, the reviewer is critiquing the design and drawings, but the responsibility stays on the designer.

Meehan: The plan checker should say "It doesn't meet the code" or "It doesn't meet the regulations." Then the checker should go on to explain the deficiency or the applicable code section. This includes explaining specifically

the reason why it is not acceptable. For example, the plan checker should say "The shear is too high," or "The bolt is overstressed," or whatever is deficient. The reviewer must be specific. We try to train our people to make specific notes so that the other person can understand them. Just like your editing of a manuscript. You have to transmit your concern to the engineer clearly, so that he's not on the phone complaining or asking for more explanation.

Scott: Could you comment on the critiquing of plans, especially with regard to the amount of detail. I've heard architects or structural engineers who have done a fair amount of work on public schools say that for various reasons the plans reviewed come back with a great many red marks. They also say "It takes us a lot longer now than it did." I don't know for sure what time span they meant, but surmise that they were contrasting the present with their experience some ten, fifteen, or twenty years ago.

In any event, they say that things are critiqued in greater detail now than in the past. I have heard this underlying complaint, although they also seem really to support the Field Act and acknowledge that it is a good thing. Nevertheless, when it comes to getting specific jobs approved, the detailed checking gives them a lot of aches and pains.

Meehan: I've heard that too. Some of the complaint may relate to the fact that we are more knowledgeable now than we were a few years ago. Once in a while, somebody will find something on the standard details on a structural sheet that has been approved many times, but we will mark up some little detail, or, as you say, give it a much more detailed review and call for a much tighter detail. We know it happens occasionally. We try to encourage the fellows not to get into so much detail, unless it is really needed. It's difficult. We recognize we have this problem. We also recognize that some private-sector personnel have very long memories and bring up historical events.

A checker reviews and marks up the plans. Before the drawings are returned, another employee, usually a supervisor, reads all the comments to see if they make sense and are appropriate. At times, within our own staff we have had some pretty strong arguments on how to approach a problem. That is not as true now [1988], but we used to have some pretty strong arguments. If the review is done properly, we dispose of a lot of those problems.

Scott: One of the people I talked to mentioned having to provide calculations on many things.

Meehan: Such as standard joints and connections that have been used for years. Complete analysis to justify all of the joints that have been used for years just can't be done. The simple connection of two angles connected to a beam that used to be rivets, now it's welds and bolts, is extremely difficult to analyze completely. If the joint works and gives satisfactory service, accept it. You have to be practical. I think it boils down to using engineering judgment. We keep working on engineering judgment. I recognize that we occasionally have that problem. Good judgment comes from broad experience, logical thinking, and openly discussing problems with competent engineers.

Scott: If the private sector architect or engineer complains about being checked too strictly, how are those differences of opinion aired and resolved? How does the process work?

Meehan: The checker is assigned to do the plan review. We try to have the same checker back check the work. The "back check" is done when the private-sector engineers and our representative come together face-to-face, to review the tracings and the checked set of drawings and determine how the tracings have been changed to accommodate the comments made on the drawings by the checker. When the checker agrees, then they proceed. But maybe they don't agree; maybe the engineer feels that what was done was adequate. If they cannot agree, it is standard practice to call in the office supervisor for a three-way discussion among the checker, the office supervisor, and the private-sector person. If there is still an unresolved problem, then the principal structural engineer is called in.

Scott: Thus going one more step up the ladder.

Meehan: Right. Keep going up a step. Thus, if there is still a problem we go to our Field Act advisory board. That's the last appeal.

Scott: You mentioned that Board before in connection with general advice on the Field Act, but in this case it functions in effect as an appellate court? If the Field Act advisory board says, "Look, this really does comply with the spirit of the regulations," the private-sector engineer is home free. Is that correct?

Meehan: No. To do that, we as staff still must agree with the board decision, because the advisory board is just that: "advisory." The legal responsibility is still with us, with the Department of General Services. The Structural Safety Section of the Office of the State Architect has been delegated the authority to enforce the Field Act. If we don't agree with our advisory board, we will not go along with them. However, the Board's views are taken very seriously. There is only one time that I can remember that the Advisory Board recommended something that we didn't go along with. Even then, a few meetings later, the board members changed their minds and agreed with us.

It is seldom that two trained engineers talking about a specific matter are unable to reach an agreeable resolution. They can almost always resolve the problem right there within the office. Of course, the principal structural engineer gets involved frequently, but very seldom does it go beyond the principal. What I've described is the standard process we've had ever since I've been there.

Construction Inspection and Observation

Meehan: Our structural engineers, as well as the private-sector professional, observe the construction for errors and conformance to regulations. As further assurance, we get verified reports from the architects and the engineers responsible for observing the construction, indicating that the building is being or was constructed in accordance with the approved construction documents. These reports are required during and at the completion of construction. The final report must be

received before our final letter is issued. False reports carry a felony charge.

Scott: So the state's engineers and the owner's engineers both inspect the construction?

Meehan: Our field engineers do not inspect, although people sometimes say they are "inspectors." They are not inspectors. Remember, the owner must employ their own construction inspectors, and the owner's architects and engineers sign the drawings and take responsibility. Our field people visit and observe the construction sites as an extension of the plan check, to make sure that the building is being constructed according to the intent of the drawings and the regulations.

Scott: You consider the O.S.A. field review more an extension of the plan check, than an on-site inspection?

Meehan: Yes, I do, although some of our people sometimes tend to act as inspectors, verifying detailed conformance with the construction documents.

Scott: What should they be doing?

Meehan: They should look at construction as a structural engineer, looking for design errors, making sure that the building is being constructed according to the approved plans and the details, that inspectors and contractors are sending in their reports, and that the construction is in conformance with the regulations.

Scott: It's a matter of judgment as to how far they should go in doing this?

Meehan: Yes. The field staff is a little different than the plan checkers in the office. The plan checker can simply reject a calculation or detail and refuse to approve it. The field man doesn't have the authority to stop a job, to tell the contractor that he must do something differently. That would be taking responsibility.

If our field man finds that there is a serious error, he will discuss it with the checker, to see if there is something that the checker has overlooked, or if some kind of justification had been made somewhere along the line. Plans seldom conform completely to all the regulations. There are always adjustments. If they agree that something is wrong, then the field man contacts the architect or the structural engineer and requests that corrections or revisions be made. The private sector architect and engineers are the ones who have the field responsibility, and we try to keep it with them.

Our field engineer would mention it to the inspector and to the contractor. In cases where he can see that something is obviously wrong—for instance when the drawings call for something different than what was constructed—then he tells the contractor and inspector. That supports the inspector and points out to the inspector how to operate. There is a kind of interplay.

The public schools and hospitals must be "continuously inspected." That does not mean an inspector has to be on the job eight hours a day, watching them repeat the same operation over and over that he can see later. He has to be there enough to make certain that the construction conforms to the approved documents.

For example, with a wood frame building, the inspector doesn't have to watch them put in all

the two by fours, all the nails, count every nail, and make sure the nails are all the right size. He can walk around later and in a short time see whether they have the right member sizes and whether the nailing is proper. He doesn't have to watch them drive every nail. That type of inspection can be done any time up to when that phase of construction is covered up. On certain operations, however, an inspector must be present continuously, such as when they're pouring concrete.

Scott: In those cases, such as pouring concrete, "continuous" does mean being right there on the job watching the operation?

Meehan: Right. Because the rebar will be irrevocably covered up. The arrangement of bars can be knocked out of place, things can happen when concrete is poured.

Administering the State's Office

Scott: How do you try to deal with these matters in the O.S.A. administration? How many staff employees are we talking about? How many professionals?

Meehan: We had some sixty to eighty structural engineers, statewide. It's probably more now [1988].

Scott: How do you try to get uniformity in their plan checking and decision-making? How do you try to bring the lax ones up a little, and simmer down the ones who are a little uptight and tend to nitpick?

Meehan: That goes on every day in the office. Usually the office supervisor reviews the checkers' comments on the drawings before they are returned for correction. However, sometimes we have the "super senior" review the plans. We have used that term, although we have been told that we should not, because of what it means in terms of personnel titles. Anyway, we are talking about a fellow who has more experience than a new employee. We try to pair the engineers up. When new employees come in, we try to pair them with one of the older engineers who has been around a while.

There are frequent discussions in the office. Our engineers generally work in cubicles, but there is a lot of banter back and forth. They consult with each other within the staff. There is communication both laterally and up to the office supervisor, to the principal, and to the chief. These consultations occur in the office daily. We have staff meetings periodically, usually every couple of months, when we bring in all our questions and anything else we want to discuss.

Scott: When you have a staff meeting, does that mean the entire professional staff?

Meehan: No. It consists of the chief, the three principals, usually the three office supervising structural engineers for the plan checks, and the administrative office supervisor. At alternate meetings we bring in the field supervising engineers.

Occasionally, we switch personnel from one area to another for a short time, such as when we moved some of our administrative staff from Sacramento to San Francisco to help out on the workload. When Jim Wong retired, we moved one of our engineers to San Francisco for a while to assist them and to introduce some of the headquarter's methods of operation. Each office operates a little differently.

Just because we are the headquarters office in Sacramento, we do not dictate to the local offices that they must do everything exactly as we do it, provided that, when it goes outside the office, it is seen from the outside as being the same. We try to get the same outside appearance. But there are certain things that differ, such as the way they file materials. One office may file a little differently than others do. It is not a major problem.

Scott: Say more about shifting staff from one office to the other. What are the main reasons for this?

Meehan: That happens very rarely. When someone wants to move, we try to accommodate them.

Scott: Are there other reasons for shifting someone?

Meehan: To show the other office the difference in operation. That's also what our staff meetings are supposed to do. We will send some of our staff to another office to assist in the workload, particularly in administration or on the clerical side. We have temporarily transferred some of our engineering personnel, as after a flood disaster, when we are required to verify the reconstruction of public property. If paperwork piles up in one office, we'll send clerks from another to help. Usually two clerks are sent for security reasons because they are usually women. We don't want to send them alone to the other office for a few days.

Effect of the Field Act on the General Practice of Engineering

Meehan: As I said earlier, I think the very fact that we do the Field Act review has a tendency to improve the drawings that are received. The review of drawings involves an interpretation of the regulations, and that interpretation also influences the other designs done by the same engineers and the architects in their private work. This has a tendency to upgrade the whole process.

The Field Act projects require more diligence, but the efficiency and quality of the overall job is improved. If the checkers can understand the designer's presentation of the information on the drawings, then the contractor can probably understand it as well, and a better job gets done.

Another thing I've heard discussed related to the efficiency of the construction contracting is the fact that we do not allow changes, unless covered by approved change orders. A change order must be approved by the architect, the engineer, and by us. Frequently, the owner also gets involved with approving all change orders. There aren't any other changes allowed from the drawings, so that when a contract is written for a hospital or a school, the owner gets everything on the drawings and specifications. Also, the fact that there won't be any changes tends to bring a better contract price. It is more competitive because the contractors are all bidding on exactly the same work.

Scott: In other words, among the contractors who are bidding, everybody's operating on a level playing field.

Meehan: Exactly.

Scott: There are fewer surprises for everybody concerned, because of the sign-off, not only on the original document, but also on any changes.

Meehan: That way everybody knows what's going on.

Peer Review

Scott: Let me make an observation about the general subject of peer review and see how you react. It seems that various kinds of peer review are used more and more, at the state and local levels. One kind is peer review of an office, that is, review their procedures and their standards of practice. I gather there is more and more of that, partly because of insurance premium costs. Peer review is a way to improve standards of practice in the profession, reduce claims, and lower insurance costs. The other kind of peer review is project-specific peer review.

Meehan: While it's not called peer review, our plan checking and observation of construction is basically peer review. I think it's a case of getting a second or third opinion. You may tell a doctor "Before I have that surgery, I want another doctor to give an opinion on it." Or maybe you even get a third opinion. At O.S.A., we have always thought of our kind of review as a completely independent peer review. We're not being funded by anybody but the school or hospital through the fees they pay the state. The statutes establish how much we get to do our job. The statutes establish the job we have to do, and we have to do it, whether we're making money or losing money. If we lose money, then a few years later we may have to adjust our fees.

Scott: Do you have to go to the Legislature to adjust fees?

Meehan: We must go to the Legislature to increase the fees established in the statutes. We can reduce the fees charged without legislative approval, but the regulations must be changed to reflect the reduction. We must conform to the statutes increasing fees and the regulations lowering fees.

The state may employ consultants to review the operations of agencies. For instance, we frequently have different kinds of groups going through our office, to determine what we do and whether it can be improved. Like a Price-Waterhouse team that came through a while back.

Scott: Who sent them?

Meehan: I don't know, come to think of it. The Department of Finance pays for it.

Scott: There is also a state Little Hoover commission that sometimes scrutinizes the operations of other agencies.

As I understand it, the 1981 Hyatt Regency disaster in Kansas City was caused by a design error related to a change made during construction. That set the stage for the disaster.

Meehan: I mentioned having worked in the Midwest. I have seen great differences in the Midwest drawings and those produced for California schools and hospitals. Yes. We also see that in hospital work. Certain hospitals tend to employ consultants from the Midwest. When we first deal with one of the hospital architects or engineers who have not done much California work, we see that their product is different.

Scott: You see a difference, then?

Meehan: On their first few jobs.

Chapter 9

Code Forces and Observed Accelerations: A Big Difference

We have not had any large 8¼ or 8½ magnitude earthquakes of shallow focal depths under buildings here in California. So I don't know for sure how our buildings are going to perform in such events.

Meehan: Another topic you suggested is the nature and significance of the gap between code forces and actual observed peak accelerations.

Scott: I've heard you say that there is a classic problem in earthquake engineering going back through the years: the gap between code design forces and actual measured accelerations.

Meehan: And it continues.

Scott: Despite the highly mathematical and theoretical seismic

and earthquake engineering research being done worldwide, we still have not resolved that problem?

Meehan: There is certainly a big difference between the loads the strong motion records show and the loads we use in design. In other words, we design a building for, say, 13% or 18% gravity. But in most earthquakes, accelerations of 50%, 90%, or 125% or more are recorded. Thus these are huge differences. Sometimes damage occurs and many times it does not. Nevertheless, it is quite obvious that the proper designs that we are producing have performed pretty well in the earthquakes with which we are familiar. So far in the earthquakes we have experienced, the public school buildings and hospital buildings have performed quite well. Many commercial engineered buildings have also performed well.

Scott: In short, the designs have worked reasonably well in the real earthquake experience we have had, although the lateral-force resistance designed for is a great deal less than the actual peak accelerations observed.

Meehan: Yes, the time displacement records show that the peak accelerations have a duration of only an instant. If such loads were to be applied continuously over a significant period of time, we certainly would have different problems. But the load is only there for an instant. That's part of it. I can't come up with a very good answer to this gap issue, except that the designs seem to work the way we are doing them.

The academicians have said that in larger-magnitude earthquakes, about the same level of force is generated, but it is generated for a longer period of time—for many, many cycles. Instead of acting for only four or six or eight seconds, the larger-magnitude earthquake may go for several minutes. That produces a lot of energy. As John Blume said, a building is like a boxer who can take a couple of heavy hits, but if he keeps on getting hit by that same load, pretty soon he's out, and down he goes. There is still that big unknown out there, in terms of probable building performance in a very large earthquake.

Testing Buildings in Actual Earthquakes

Scott: That is another reason why post-earthquake studies, as in the 1985 Armenia or 1985 Mexico City earthquakes, are very important, especially when modern buildings are involved.

Meehan: That's the only way we have to test them. Actual full-scale earthquake forces are not recreated in the lab. The forces that we do recreate, like on the shaking table, don't fully represent a real earthquake. While they say they recreate the acceleration records, it still bothers me. I don't really fully understand it. The 1940 acceleration records of El Centro showed a peak acceleration of about 0.3 g, but there was twelve inches of total displacement with about four inches one way and eight inches in the opposite direction.

There is not eight inches of displacement capability of the shaking table at Berkeley—only about six inches, plus or minus. An earthquake could move the foundation of a building ten inches or more in about a second. Ground displacements in the 1906 San Francisco earthquakeare reported to have been about

twenty feet near Olema. The shaking table does not have that capacity. It's impossible to reproduce such actual earthquake motion without expending large amounts of money, and it has not yet been available. That's why it's so important to get out and look at the actual performance of real buildings in earthquakes. The gap seems to be an accepted standard that we have been using, but there is no reason why it's necessarily going to continue after the next big earthquake.

Scott: You mean the existing code-required lateral-force resistance may be changed?

Meehan: Yes. The Japanese use a higher load level, though I can't tell you what it is. I know from last summer when we were there at the Ninth World Conference on Earthquake Engineering that they use a higher load level than we use.

I can't come up with a very good answer to this gap issue and what the design levels should be, except that the designs generally work the way we are doing them. We have not had any large 8¼ or 8½ magnitude earthquakes of shallow focal depths under buildings here in California. So I don't know for sure how our buildings are going to perform in such events.

Appendix

D.C. Willett on the Origins of the Field Act[54]

I think it was Saturday morning, about 9:00 or 9:30 am [March 11; the Long Beach Earthquake occurred at 5:55 pm on March 10, 1933, the day before.]....I think [Assemblyman] Don Field was the one that was mainly disturbed about what had happened, the buildings collapsing and everything, so he called Mr. McDougall [the State Architect] over to the Assembly Chamber, and Mr. McDougall took me along. [Field] was the ringleader in the [state legislature] group and he didn't know what he wanted. All he knew was that he wanted a State Code to protect the buildings of the state. [Willett then contacted several engineers over the weekend for advice.]

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54 This appendix provides excerpts from the interview of D. C. Willett with Frank Durkee, which occurred October 21, 1957. The interview, and related information such as the original text of the Field Act, comprised an appendix published in the report by John F. Meehan and Donald K. Jephcott, "Task 4: The Review and Analysis of the Experience in Mitigating Earthquake Damage in California Public School Buildings," pp. 152–251, in *Seismic Mitigation Strategies for Existing School Buildings Which Are Subject to Earthquake Risk Throughout the United States*," David Harris, ed., Building Technology, Inc., Silver Spring, MD, 1993. D. C. Willett was a supervising structural engineer working for the California Division of Architecture at the time of the March 10, 1933 Long Beach Earthquake.

Monday [March 13] at noon, we were sitting at the desk eating lunch, and Fred [Green] said "you ought to have a law governing school construction." "Well gee," I said, "Fred, you've given me an idea." So I immediately went upstairs to the Division of Water Resources. They had an act regulating the design and construction of dams [because of the catastrophic failure of St. Francis Dam in Ventura County in 1925.]...I went up and got the Dam Act and as soon as I finished lunch, I went over to the Assembly and got hold of Don Field.... [He] wanted a general code and I frankly told him he could not enforce a general code throughout the State. I said, "Don, I've got another idea,"....I showed him the Dam Act; I showed him the pictures of the schools [damaged in the earthquake] and I said, "if you'll make a law to make school buildings safe, we can enforce it....the schools were public money...and it was the safety of the children, and the people would go for that where they wouldn't go for spending their own money for other safety measures"....So Don said, "This is just what we want." He grabbed it immediately.

I came back [to the Division of Architecture] to see Mr. McDougall [the State Architect.] I went in and said, "Chief, I've just been over talking to Don." I just got that much out when the phone rang. Governor [James] Rolf wanted Mr. McDougall to come to his office immediately....I gave him the papers, explained to him what I'd told Field and the things that Field wanted, so he grabbed them up and went to the Governor's office....He came back and said, "Now we've got to get up a law. You work with the Legislative Counsel. Assemblyman Field would like to have this complete so he can present it to the Legislature tomorrow...."

We took the Dam Act as the foundation and applied it to schools...We worked on it the entire day and took it to the Legislative Counsel....So after we got the thing assembled, roughed out and typed, we presented it to Mr. Field....he said.... "We won't have time to have this printed. I want you to have mimeographs made and put on every Senator's and Assemblyman's desk so we can take up the first thing tomorrow morning."

It was passed [Tuesday, March 14] with a unanimous vote in the Assembly. Then it was tied up [in the Senate]....Of course, you understand, the preparation of the bill was all done without the knowledge of anybody so you can see why they would be suspicious....Earl Cope was President of the Structural Engineers Association of California at the time... Quite a few of them came up representing the engineers of the state and they wanted to know what the devil we were pulling on them. [I said] "If you can find anything wrong with it, I would like to know." Mr. Cope read [the bill] and the statements and he said, "Well, I'm for this....This is just what we should have and I'm for it, and I think the Association will back you to the limit on it." But the architects didn't like it....It forced them to hire structural engineers. Not that it was required [in the law] and not that they couldn't do structural engineering if they wanted to, but there are very few architects that are qualified to handle the structural design of a building....But, this bill, the way it was set up, more or less forced them to....As we went along, the final hearing, a Senate hearing, was called. And prior to the Senate hearing—now I wasn't present but I know of the facts—... the newspapers of the state got the architects together and they told them they would blast

them in the headlines of the papers if they didn't go along with this bill....So, as a result, the next morning, when the committee met, John Donovan, a prominent architect, gave one of the finest talks I have ever heard....He was more or less a spokesman for the architects, being an excellent speaker and a prominent architect. He was appointed to talk [at the Senate hearing].

....[T]he thing that startled everybody...is that there would have been at least 6,000 children killed had this happened during school time. That statement was made by the head of the [state] school department after examining the buildings in Long Beach....

[Violations of the Field Act] would have been a misdemeanor. That was in the Dam Act and we put it in this bill as being adequate. So a tall, dark complexioned fellow...with the Hearst newspapers, the Los Angeles Examiner, demanded that it be made a felony....I was sitting next to Don Field at the time...He agreed to the change and I can say now that that was one of the greatest things that ever happened to the Field Act....Everything that was done helped the bill because the first draft had been done so fast. The way it finally came out, it was really a marvelous piece of legislation.

[The Field Act was passed by both houses of the state legislature exactly one month after the Long Beach Earthquake, on April 10, 1933, signed by Governor James Rolf, and as an emergency measure went into effect immediately. The detailed engineering regulations were separately adopted by the Division of Architecture and were substantially derived from the model seismic code provisions developed by the California Chamber of Commerce after the 1925 Santa Barbara Earthquake.]

Photographs



A grouted reinforced brick wall of Arvin High School, damaged in the 1952 Kern County earthquakes.

(NISEE-PEER U.C. Berkeley)

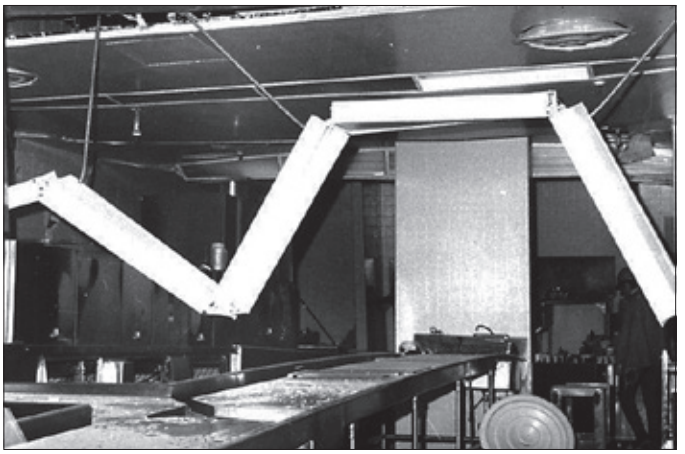


West Anchorage High School, 1964 Alaska earthquake

NISEE-PEER
U.C. Berkeley









Jack Meehan inspecting buildings after the 1971 San Fernando earthquake.

Top: Olive View Hospital;

Middle, a school;

Bottom, L.A. County Juvenile Facilities.

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Jack Meehan in the Banco Centrale after the 1972 Managua earthquake.



Jack Meehan arriving by helicopter in Huallanca, 1970 Peru earthquake.



The Imperial County Services Building, damaged in the 1979 Imperial Valley earthquake.

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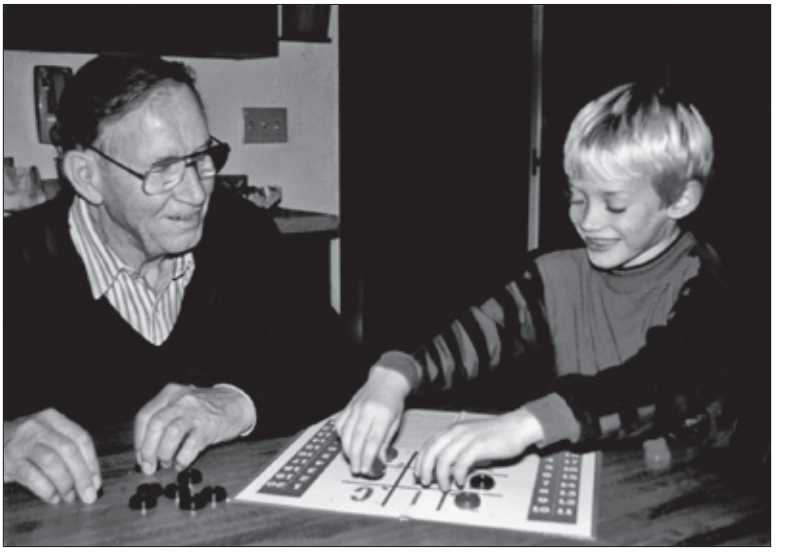


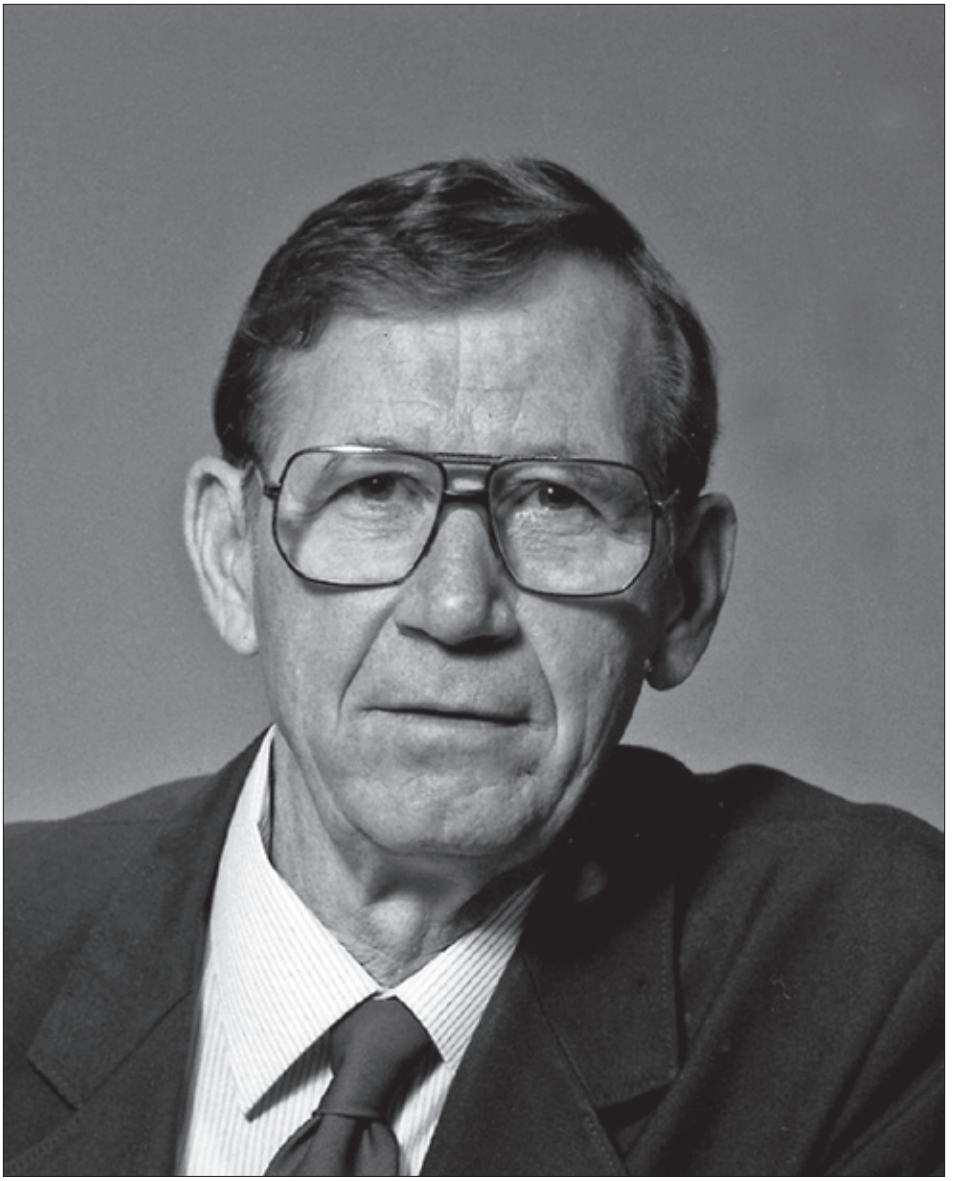
Jack playing tic tac toe with his grandson Andy Meehan.



Liz Meehan, Jack's wife, and Jack Meehan, at Jack's retirement party, 1987.



Jack Meehan at his retirement party, 1987.



Jack Meehan, 1982

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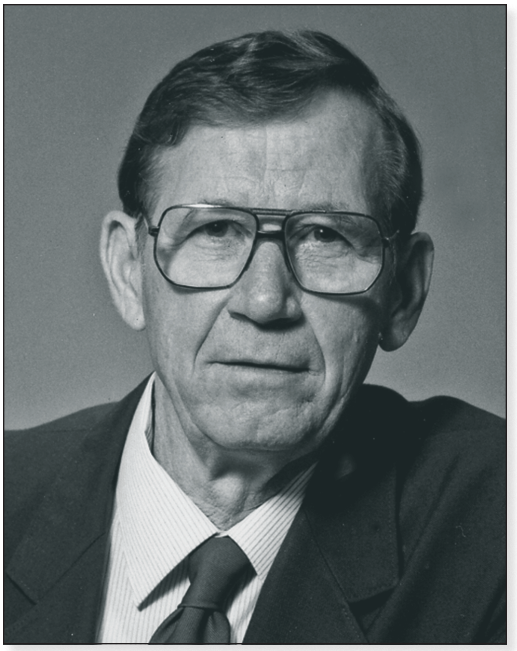

Today there are many individuals who are engaged full-time in earthquake engineering research to improve seismic design practices and codes. In the 1950s, when John (Jack) Meehan (1920–2011) began his long tenure with the California agency overseeing Field Act (public school) construction, he was almost alone in that effort. This EERI oral history documents his early years in various engineering jobs, including working for John Blume, and his later career identifying and managing needed research on nonstructural components, reinforced masonry, damping values, quality control in wood construction, and forced vibration and shake table equipment development, as well as field studies of twenty earthquakes and their effects on buildings.

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