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The Seismic Safety of California's Freeway System

Assembly Committee on Transportation

ASSEMBLY COMMITTEE ON TRANSPORTATION

HEARING ON

THE SEISMIC SAFETY OF CALIFORNIA'S FREEWAY SYSTEM

NOVEMBER 7, 1989
LOS ANGELES, CALIFORNIA

HON. RICHARD KATZ
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November 7, 1989
Los Angeles, California

CHAIRMAN RICHARD KATZ: The Special Session of the Legislature on the Loma Prieta earthquake was just completed with the Governor signing the twelve bills yesterday in San Francisco. This hearing is what we need to learn from that. Out of the rubble that was the Nimitz Freeway has come the alarming reminder that our freeways can become deathtraps in a major earthquake. Forty-one people lost their lives in that collapse. Up until then, only two people had died on California freeways as a result of earthquake activity. That was an elevated freeway that was built under seismic standards that were established nearly 50 years ago, standards that were applied to the construction of many other bridges, interchanges and overpasses throughout California. While the number of fatalities is small compared to what might have been, we can't minimize their significance.

One of the casualties of the Nimitz collapse is public confidence in the freeways and the highways we travel every day, and whether or not they're safe or as safe as we've come to expect them to be. In fact, much of the confusion and contradiction in statements made by transportation officials immediately after the earthquake has added to the loss of credibility.

Efforts to strengthen our older structures built under archaic seismic safety standards with retrofit programs began after the 1971 Sylmar quake and the 1987 Whittier Narrows quake. But these efforts have lagged, creating additional questions. Have adequate resources and money been made available to retrofit freeway and highway structures? How are the priorities established for the retrofit program? Which structures in Los Angeles may not be safe, if any, in a major earthquake? Perhaps most important is determining now what needs to be done to prevent other deadly and destructive collapses of state and local highway structures, and how to provide money and manpower necessary to ensure to the maximum extent possible the seismic safety of our entire system.

During the Special Session of the Legislature that convened on Thursday and ended Saturday night, I introduced legislation, working with my colleagues around the table and Caltrans, that would earmark $80 million in earthquake emergency spending to match against federal money to result in a $320 million statewide seismic safety retrofit program for state and local bridges. These funds will be used to assess needs and determine priority projects and then to fund the very highest priorities on the retrofit program.

But it's important to add and understand that this is a down payment on retrofitting our streets and roads. This is $300 million on the state system; it's only $20 million on the local system. I think you're going to hear today of a much greater need, particularly on local streets and roads. It's a down payment, and we may have to look at SCA 1 money, if that is successful, as far as additional revenue in order to seismically improve and guarantee the integrity of our highway system. As the lessons learned in the October 17 quake are translated into action, much more will be needed to make our bridges as safe as possible and to restore confidence in our aging freeways and highways.

That's what this is about today. The Committee wants to know what happened, if we can determine that; to what extent we've learned from that; what's going to be done different in the future; and what we're doing now to make sure that everything in Los Angeles and other parts of California are safe so that motorists, when they drive to work each morning and are sitting in bumper-to-bumper traffic and look up at the four-level interchange in downtown Los Angeles, know that it's not going to fall down on them if there's a tremor at that moment. We have to start that process of restoring public confidence in the system. This hearing is part of doing that.

We're not looking to hang anybody today. We're not looking to find a scapegoat or smoking gun. What we're looking to do, I think, is understand what happened at the Nimitz and make sure that it never happens to any other structure in California to the best of our ability, remembering all the time that when earthquakes come, no amount of computer modeling is going to be exactly correct. At some point, that earthquake is going to come, and all we can do is prepare as well as we possibly can for it. That's what we are here for this morning.

Before we start with any of the members of the Committee that want to make any comments, I want to introduce on my far left, which is an unusual position for him to be in, Mr. Wyman, then Mr. Costa and Mr. Roos. And on my right, Mr. Eaves, Ms. Roybal-Allard and Mr. Areias.

There's a published agenda that I need to make a couple of adjustments to. There are a number of people that have planes and are moving around. Bob Best has a plane. Bob, before I get to you, let me take two people. Also, let me say that Assemblywoman Lucy Killea, who sits on the Transportation Committee, is having a hearing of her own on International Trade. That's why she's not here today and asked me to mention that.

Let me first call Ed Avila, who is President of the Board of Public Works for the City of Los Angeles, and Bob Horii, who is the Los Angeles City Engineer. Then we'll go with Mr. Best and Caltrans.

MR. EDWARD AVILA: Thank you, Assemblyman, for accommodating my request to be heard early. First of all, welcome to the Board of Public Works. It's somewhat unusual for me to be standing on this end, as opposed to sitting where you're sitting.

We truly appreciate the State's and your committee's interest in the needs of the City of Los Angeles and the needs of the entire State of California. Without question, the need is one of federal, state and local cooperation/collaboration to deal with what we know is a fact: earthquakes will occur, they have occurred, and will continue to occur in the State of California.

The method of funding for disasters of this nature in terms of recovery is one which we should look at very seriously. We believe that sources of financing should be made permanent, that there should be the development of some source of funds that is literally put in some type of reserve that will be available for what we know will occur. It is extremely important to do that prior to the occurrence so that we are ready for it. Truly, what is being considered today, not only in the city, but in the state is, as you said, the down payment. The need for these funds can almost be said to be a known quantity for the foreseeable future in the State of California.

On November 3, the Board of Public Works for the City of Los Angeles adopted a seismic strengthening of existing bridges report, which has been forwarded to the Mayor and the City Council. I'd like to leave that for your information. For the most part, it essentially shows that we'll probably have to spend approximately $150 million in the city, just for city structures, those which are under our control. The rest of the report essentially is talking about the need for the design capability to accomplish that task. Also, we are talking about another couple of million dollars for a restrainer program, essentially fixing bridges with restrainers that can be done without major structural change.

CHAIRMAN KATZ: The restrainer -- is that the same sort of strapping program that Caltrans did on the state system?

MR. AVILA: I'll let Mr. Horii address that a little more specifically.

CHAIRMAN KATZ: Your estimate though, in the City of Los Angeles alone, just the City of Los Angeles, is $150 million.

MR. AVILA: That's correct.

CHAIRMAN KATZ: Any idea how many structures that is?

MR. ROBERT HORII: We're looking at approximately 136 bridges, at approximately a little over $100 million.

CHAIRMAN KATZ: Bob, please identify yourself for the tape.

MR. HORII: I'm Robert Horii, City Engineer for the City of Los Angeles. Of the amount that we have mentioned, we had estimated in the neighborhood of $100-$110 million. Our preliminary estimate is based on strengthening the columns of our multiple span bridges, of which we have 136. We do have a total of 416 bridges within the city, but not all of them are multiple span. Our major concern is the multiple span bridges. Additional money in our report was talking about going back and correcting the deficiencies in the city-owned public buildings. That's the $40 million in additional funds required. The restrainer program -- we did start after the Sylmar quake, and we have completed 15 projects. We've got 14 more to go, and we have 43 that are of lesser priorities that we're asking funding for.

CHAIRMAN KATZ: Mr. Areias.

ASSEMBLYMAN RUSTY AREIAS: Mr. Horii, what has your department done to prioritize those various structures as it relates to when they were constructed, the types of materials that were used, the types of engineering, the area of the city, and corresponding seismic activity within that particular area, and the risk that that represents? Have you set up a priority system?

MR. HORII: Yes, we have. After the Whittier quake, we have gone through and started looking at our structures. We do have a priority system, which I think will have to be probably a little better fine-tuned. Basically, it's based on the age of structure, the span of the structure, the amount of daily traffic carried. That's basically the criteria that we're looking at. And the type of construction that it is. We do have various types of construction. If you look at the North Broadway Bridge, which is an arch span versus the simple support column-supported bridge. All those factors are being put into the priority system, and we're looking at that right now.

CHAIRMAN KATZ: How do you prioritize between single-column versus multi-column?

MR. HORII: We really don't have single-columns within the city; all ours are multiple columns.

CHAIRMAN KATZ: When was the last assessment done in the city for the priorities? When was the last time they were inspected and a look was taken?

MR. HORII: We have an on-going inspection program, where we inspect the structures for structural stability, roadway surface, as a continuous process. I can't tell you which bridge was last looked at, but we do have a staff that does this continuously year-round, looking at the structures. I think we'll take another hard look at it, saying, are they really up to seismic safety? What you're really looking for on the structural inspection is really whether there's any deterioration, any cracks, or whatever, not just your superficial inspection, which really doesn't get into the structure itself, looking at the structural stability.

CHAIRMAN KATZ: How do you make the determination when you look at the bridges and you say they've got to be retrofitted? How do you determine that, even though they need to be retrofitted, they're still safe enough to keep open?

MR. HORII: Pardon me, I didn't understand the question.

CHAIRMAN KATZ: You were mentioning that you've got 136 structures you've identified that need to be retrofitted. You've obviously made a determination that they could be made safer than they are today, or you could do additional things to them based on new knowledge. What I was interested in, how do you then make a determination that, knowing that we can make them safer, they're still safe enough to operate today, based on what's going on?

MR. HORII: Well, I think that's the analysis we really want to do. With our knowledge that we have today, based on what has happened in San Francisco, is the criteria that we're using to establish priorities correct or not? This is one thing we would want to determine. Based on our experiences, all of these bridges that we've talked about primarily have been in existence prior to the Long Beach quake and also prior to the Sylmar quake and the Whittier quake. They've undergone three major quakes. So we feel comfortable that they probably will stay there. The question is whether we're going to get the major quake on the Newport-Inglewood Fault, what that would do. If we get the major quake on the San Andreas Fault, what would happen? These are things I think we have to look at.

CHAIRMAN KATZ: So you're confident that if a major earthquake hit Los Angeles today, those 136 structures would stand?

MR. HORII: Well, that's very difficult to answer, because it depends on where the epicenter is, what the magnitude of the quake is, and so forth. The only thing we can go on is based on history. They have gone through some major quakes.

CHAIRMAN KATZ: What I'm trying to understand is, you're confident enough that the Board of Public Works hasn't gone to the City Council and said, we need $150 million today or we're not going let anybody drive on these structures.

MR. HORII: No, we have not specified the structures unsafe to drive on. We have not said that.

CHAIRMAN KATZ: So you believe they are safe to drive on?

MR. HORII: I would say, in our estimation, yes, at this time, unless you have a major seismic event. Then we really don't know what would happen at that time.

CHAIRMAN KATZ: Mr. Roos.

ASSEMBLYMAN MIKE ROOS: Mr. Horii, what interested me in this debate that we just finished with in Sacramento is, when Mr. Katz was in a meeting with Ms. Waters, myself and others, trying to press Caltrans with respect to the insurance of safety on some of this double-decking, there was a standard called maximum credible earthquake, or an 8.3 episode. That's what we were trying to nail down. Is there a commonality in the engineering language with respect to what standard you're seeking, and would you attest that the standard for the City of Los Angeles is equal to the standard for the State of California and vice versa?

MR. HORII: We have really not gotten to that stage of the analysis; and based on the testimony Caltrans has been presenting to the City Council and so forth, we really want to sit down with their experts and make sure our programs are compatible. They have a wealth of data that we did not have. And we want to work with them to capture that information and to examine our bridges based on what they're projecting.

ASSEMBLYMAN ROOS: Well, we all know this. When we're trying to make better public policy, we get a group of lawyers in the room, and on the number of lawyers depends how many points of view and recommendations you come out with. Does the same exist in the engineering community? Are there legitimate substantial differences in the evaluation of these structures with respect to whether they're going to hold up under various magnitudes of a quake?

MR. HORII: I don't think there's a difference there. It's really estimating what the magnitude of the quake is going to be and where the epicenter will be and how that energy is transmitted to that location.

ASSEMBLYMAN ROOS: So if someone went outside and hired an independent consulting group, let's say, they would probably come down independently with the same findings that you're making within the city bureaucracy?

MR. HORII: If we assume the epicenter's in a certain location and the soil conditions are such, and so forth. Geology is not an exact science. It's pretty good, but we do not know what Mother Nature's going to do. And that's the difficulty. We, as engineers -- you tell us what that force is going to be, and we can design for that force. The difficulty is to determine what that force is going to be at any given location.

ASSEMBLYMAN ROOS: I understand all that. You have to understand that, from our point of view as politicians, what we're trying to deliver is some degree of confidence that, in fact, the roadways and the highways and other things that we have been responsible for funding to the bureaucracy to build are going to withstand again a respectable blow in the vicinity so that we don't have the same crisis of confidence that ensues in the aftermath of the collapse of the Nimitz freeway. That's what I think this hearing's about and what we continue to search for, is that type of assurance.

MR. HORII: We are searching for the best information. Sure, there's going to be times of questioning, is that seismic event going to occur or not occur; but I think, with the knowledge we all have, we're going to be looking on the conservative side. The other question is, though, can we afford to go to a zero risk? Do we design our structures...?

ASSEMBLYMAN ROOS: We could go to zero risk, but the cost may just be too extravagant.

MR. HORII: Right. So do we set a limit at much less than zero risk that really then would assure that the majority of times or the highest percentage of times our structures would be safe? I could protect all my structures; but if I went to zero risk, I could only protect ten percent of the structures. So what is zero risk in this case? This is what makes it very difficult.

ASSEMBLYMAN ROOS: I don't think that the City of Los Angeles or the State of California could afford to maybe put it in those terms because it sounds awfully reminiscent of a Pinto report -- is the cost benefit correct in developing the Pinto? I don't think that you see any public lawmakers up here who want to run for reelection saying, "Well, it's an acceptable risk," meaning that this freeway may collapse on you under the worst circumstances.

MR. HORII: I'm not saying we will not design -- we're going to design to the best knowledge that we would have regarding what we think is necessary for safety and so forth. We would design for that criteria and not let the dollars control. What I'm saying is there may be another event beyond that. We don't know. I cannot guarantee that that structure, even though I designed it for the 7.7 or the 7.9, that may not be the actual quake that occurs.

ASSEMBLYMAN ROOS: Where are you now? Are you designing for -- what? 8.3? 7.9?

MR. HORII: We would, I think, right now, go back to Caltrans and look at data they have -- they've done the Harbor Freeway based on the Inglewood/Newport Fault -- and take that data, and see whether that is the controlling seismic event on our bridges, or do we look at the San Andreas break at the 8.3 as the controlling point? We have not gone into that extensively at this time. We've done some preliminary work, based on what Caltrans has talked about, strengthening columns. That's where our estimates come from, just going ahead and beefing up the columns. Now, we may want to go back in and do additional work on that and say, "Was our original pass at this an adequate assessment?" And that's the reason, I think, we need to step back and say, "Was our original assessment correct? Should we do more, or do we have to do as much as we have projected?"

ASSEMBLYMAN ROOS: Thank you.

CHAIRMAN KATZ: Mr. Areias.

ASSEMBLYMAN AREIAS: Mr. Horii, are you aware of the work the Japanese have done in terms of their transportation system as relates to earthquake preparedness?

MR. HORII: No, I'm not. I understand they have done quite a bit. I assume Caltrans has been working with them. We're going to go back and try to tap all sources of information that we can now. This heightened our awareness of the problem. Let's go back and find out what the best information is and how do we design our system to accommodate those seismic events.

ASSEMBLYMAN AREIAS: Mr. Horii, in terms of evaluating all of the structures that you've been referring to, were they all built to sustain roughly the same magnitude quake, or is there a variance?

MR. HORII: I'm not sure, because our first bridge was built in 1909; and the majority of our bridges were built prior to the Long Beach quake. So we really would have to go back to see how they were really designed. The unfortunate part of it -- the original designs are not as detailed as what we would do today. So whether we can recreate them or not, I'm not sure.

ASSEMBLYMAN AREIAS: One statement you made bothered me in response to a question by Mr. Katz. It was your conclusion that, because most of these structures had survived three relatively major earthquakes -- I assume it's your conclusion -- that they would probably survive a fourth one. Was there damage to those facilities and structures, and how good a job has your department done in evaluating whether that damage has actually -- I mean, I don't know that I can come to the same conclusion. If there's been three quakes, will the fourth be the straw that breaks the camel's back? Are they in fact weaker as a result of those three, or should we conclude that they're quake-proof? How do you come up with that conclusion?

MR. HORII: That's a difficult question to answer. Assemblyman Katz asked me, "Are the bridges safe to travel on, and would we shut them down today because of our lack of knowledge or our concern about whether they would fail under a major seismic event? I said, "No, we probably would not shut them down. There's a certain amount of comfort that we know, in the type of seismic events that we have experienced since the Long Beach quake, that these bridges will stand up. We did have problems on some of the bridges. We've gone back and made some structural repairs on them. The Sixth Street bridge has had problems. In the Whittier quake, we lost some street lights, stuff like that, superficial damage on it, but not a structural damage so that we had to close the bridge for a gross failure. Talking about a structural failure, I'm looking at the gross failure, the bridge collapsing and not traversable to the public.

ASSEMBLYWOMAN LUCILLE ROYBAL-ALLARD: In response to several of the questions that were asked, you kept saying that we have to go back, and we have to study the issue. We have to talk to Caltrans; we need to know what the latest information is. What I'd like to know is how long of a time frame are we talking about in which you will go back and you'll study it and get all the information before actually we have an answer as to what the problem is and actual work can get started.

MR. HORII: We'll start immediately on some of the work. Unfortunately, we do not have staff to do all the work, so we will step into this as rapidly as possible with the staff that I do have. It's a data bank there that I want to capture. I want to utilize that information.

ASSEMBLYWOMAN ROYBAL-ALLARD: How long a time frame are we talking about in studying the problem before we actually have an answer as to how severe the problem is and what can be done about it?

MR. HORII: I'm not sure. It depends upon availability of staffing, how soon I can put staff on to do the work, what other work I can divert from, put on the back burner, and do this work. We're limited with the number of structural engineers we do have. I can't say tomorrow I'm going to have an answer for everything. But it's a major concern of ours, and we're going to move into it as rapidly as possible.

ASSEMBLYWOMAN ROYBAL-ALLARD: Potentially, could it be a year from now that maybe you're just finishing or getting into it because of lack of staff and these other things you're talking about?

MR. HORII: It's possible, hopefully not. We have a fairly good idea which one of the critical bridges that we really want to look at and systematically approach it and take them one at a time, rather than do them all in this phase. I think we had best take the critical ones and start moving into those in a priority order.

ASSEMBLYWOMAN ROYBAL-ALLARD: Have you established a time frame for yourself that hopefully within three months or six months the problem will be studied and you'll have the information?

MR. HORII: In our report to the Council, which went to the Board, we're asking that we be allowed to retain consultants. Our process in retaining consultants will probably mean that we'll not have them on board before the first of July. It's just that lengthy a process. By the time we send out requests for qualifications, interview prospective consultants, select them, and negotiate contracts, it's a time-consuming process. If we're going to the consultant field, we're looking at next year, the start of the next fiscal year for us, to have them on board.

ASSEMBLYWOMAN ROYBAL-ALLARD: So it could be potentially six or seven months before you'll even be able to have the consultants you need in order to get the information?

MR. HORII: Yes.

ASSEMBLYWOMAN ROYBAL-ALLARD: Just to get the consultants on board will take about seven months. So, potentially, we could be here a year, a year and a half, from now and still not know what the problem is and have all the information.

MR. HORII: Well, I'm not saying that. I'm saying that to do an entire program, we will need consultant help. I do have some staff that can jump on this thing immediately, and we can start analyzing the critical ones, starting today or tomorrow or whatever.

ASSEMBLYWOMAN ROYBAL-ALLARD: But it's going to be done sort of piecemeal as you get a little bit of information, rather than taking care of it from an overall plan and understanding of just what the problem is.

MR. HORII: Yes, well, the data that you gather on what the problems are is going to probably apply to every one of the structures. Now, each of the structures may require a different type of solution. But we're gathering all the information, how they should be analyzed, what are the forces going to be in any given area, geological data, the best information we can get, and then look at our structures, which ones are the critical ones for us to say, "Let's start a program to strengthen that bridge if it's necessary."

ASSEMBLYWOMAN ROYBAL-ALLARD: But right now without the use of the consultants that you say you need, you're doing that without the benefit...

MR. HORII: Part of that work will be done with available staff, yes.

MR. AVILA: We have this as a top priority. I don't want you to misunderstand that. When we're talking about consultants, it means we need more help, as everybody does in the State of California. I would submit that every single city in the state of California is going to require a tremendous amount of help. The process of bringing on consultant firms to assist us in the evaluation is one that we can't avoid, our interview process to make sure we have the quality that we require. That's not to say that we have not already done a significant amount of work. That's where this Board report comes from. We also have a listing, prioritized listing, of bridges in the City of Los Angeles that have been evaluated on a preliminary basis.

I think the technology in terms of earthquakes and seismic safety is evolving in such a fashion that there is information to be learned on almost a daily basis.

But I do want the Committee to understand that there's an absolute commitment here to expedite the process of seismic safety for the City of Los Angeles. We've already done a substantial amount of work in terms of the rehabilitation of the buildings of the City of Los Angeles. Seventy-five percent have been brought up to our seismic standards. The City is committed to that and will continue to be committed to that.

I think the major element here, the major element in this state right now and in this city, is how are we going to pay for it. We're all going to have put our collective heads together and decide that we need to do this. $150 million does not -- that's just the City of Los Angeles -- does not come out of the air. We have to find a way to do that and solicit your support. We thank you very much for your interest. I want to make sure it wasn't something you thought we were going to get to eventually. We're doing it now. We're soliciting support we need to fund the projects at an adequate level, a level that will make you comfortable, make us comfortable, so that when we go to the people of the city, we can say with confidence that we're doing everything possible, everything within our power, to make sure this city is seismically safe.

CHAIRMAN KATZ: Mr. Wyman has one question, and then I have one last question. Then we'll let you get on to your next meeting.

ASSEMBLYMAN PHILLIP D. WYMAN: Thank you, Mr. Chairman. I don't think it's unnatural for a lot of people to be peppering you folks with questions, as is the case with Caltrans as well. I perceive, and I think the legislation that was adopted, parts of some of that legislation that I and Mr. Katz were involved in, perceives that local government needs technical support. They need support as it relates to structural analysis. Caltrans has been specifically given an additional part of $1 million to identify the latest state-of-the-art technology from within the Caltrans lab, from throughout the universities, from throughout the world so that, if there's any additional information that we need to model our structures and to make them safe in the state system, that occurs. But part of that language in that legislation also says that that technology shall be shared with the City of Los Angeles, with local governments, be it county or city. I think that reinforced our obligation as a state to share with local communities so that you can get the best possible answers. I think that others will be discussing that. I think it's important that that commitment is stated, and it is stated. It was signed in legislation by the Governor yesterday, and I hope that will be helpful to you.

One final point. The bench marks that you're using for the quake analysis is the Sylmar and the Long Beach, and what was the third?

MR. HORII: Whittier. Now, those are not the bench marks. Those are historical, and they may not be our design standard.

ASSEMBLYMAN WYMAN: My question is, as we're analyzing bridge structures and as we have new ways to improve technology with computer modeling and the like to analyze bridge structures, what kind of analysis occurred on some of the very old structures in Los Angeles, some of those built before 1915, after these earlier episodes, these earlier earthquakes? Do you have written engineering analyses between those that would show some sign of deterioration or will your analyses basically be starting clean at this point?

MR. HORII: We've done some work based on looking at the structures, looking at some of the damage that occurred on those structures because of the, say, the Sylmar quake. But I think we're really going to go back in and look at new data and new information as to how can the energy be transmitted. Like I say, the puzzling thing to us is that the quake hit down in Santa Cruz and all the damage occurred up in the top end of the Peninsula. Why didn't San Jose get damaged? So just to assume that if we're right next to the epicenter and to the fault, there's going to be a problem, is going to be very difficult.

ASSEMBLYMAN WYMAN: We found as we were trying to redesign and strengthen a dam that was built at the turn of the century in the Little Rock area, right on the San Andreas fault -- we found it's difficult to identify what steel went into the structure, to identify from contractors' plans what is actually in the structure. So I know as you get into the older bridges, there may have to be some dynamic determination of what actually is the level of reinforcement, that wouldn't be a problem with a Caltrans structure, wouldn't be a problem with a later structure.

MR. HORII: The majority of our 136 bridges were designed prior to 1930. How good our records are, how good the detailing was on those -- it's not that good, not by today's standards where we can pull the plans and immediately give you a structural analysis. It's going to be a very difficult job.

CHAIRMAN KATZ: Just one last question. I appreciate your representation in terms of what you're trying to give and the resources you are working with. If you were going to focus all of your efforts only on seismic upgrades, the seismic safety, what would you be taking away from in order to make that happen?

MR. AVILA: We have critical problems in this city, as every large city does. $150 million is a lot of money. We can't take it away from anything. We've got to find new resources. There is no way in the world that we can endanger the health and welfare of the people of the City of Los Angeles by stopping our sewer program or stopping our other municipal facilities programs that are critical to life in the city. We must find a new way of financing for seismic safety. The figures are enormous. There is no way to substitute. We shouldn't. Granted, this is extremely important, and no one is going to argue that, but we must find a way to deal with a problem that will recur. We will have earthquakes through our lifetime and for generations to come. It seems to me this is an ideal opportunity for all of us to get together and find a way to provide some kind of reserve fund that is exclusively set aside for seismic events, since we know that we can predict that they will occur. It seems to me that we, and the people of the State of California, would be willing to provide some source of funding. But I would be irresponsible to say I'm going to redirect $150-200 million from other programs in the city. It just would not be feasible.

CHAIRMAN KATZ: Thank you very much. Bob, thank you also. Next, we're going to hear from Bob Best, Director of Caltrans.

I also want to mention, members, Assemblywoman La Follette left a statement with the Committee. She's chairing a Los Angeles Task Force on Better Education and could not be here today, but wanted it entered in the record. She looks forward to working with us on finding ways to retrofit and upgrade seismic safety. I appreciate that from Marian.

Bob, thanks for coming down. I know you have a budget meeting in Sacramento also.

MR. ROBERT BEST: Thank you, Mr. Chairman. I'm Bob Best, Director of Caltrans. I'd like to just give you a brief opening statement. I have with me today, Mr. Jim Roberts, who is the Chief of our Division of Structures. He is the most knowledgeable about some of the seismic questions you were just asking Mr. Horii and Mr. Avila with regard to the City and can give you more detailed answers to the questions in terms of the fundamental issues relating to structural safety.

I know all the members have received the reports in terms of what happened in Northern California. I won't go over those here today. We're really now getting to the point where we're looking on and saying, now that we've learned some things and we've observed some events, what can we learn from those? What does that tell us about seismic safety elsewhere in the state, and what should we be doing about that in terms of a statewide program?

Certainly, the emergency disaster recovery is underway in the Bay Area and will continue to be a top priority. But at the same time, we need to start immediately in moving forward with a statewide look at seismic safety.

I think the legislation that was passed in the Special Session, where the Legislature has addressed some of the basic questions, certainly with regard to structures on roads and highways throughout the state, has given us the basis to begin some immediate work, both in terms of dealing with the research that's going to be necessary to determine the answers to some of the questions you're asking this morning, and in terms of implementing retrofitting programs for older bridges where we already feel comfortable with the level of research.

We do know that we have a lot to learn from that event. I think the history of seismic safety, as Mr. Horii indicated, has been one where every event teaches us something. We tend to mark changes and progress from certain seismic events. Certainly this state has undergone a dramatic change in past years in its approach to roadway structures as a result of earlier earthquakes, and certainly what we have learned from those has proven not to be enough in terms of what we saw that occurred up in the Bay Area. We're going to have to learn from that event and move forward.

We know very well that the modern engineering tools that we have at our disposal today can provide us with techniques to construct structures that can resist virtually any type of force that can be expected. As Mr. Horii indicated, one of the big problems we're facing is how to predict, with regard to an earthquake, what in fact does occur or will occur in order to try to go through and construct the appropriate design for that.

So as we step off in this program, we're going to be looking at the prioritization that we have given in previous programs where we had developed, on a statewide basis, a retrofit program. We have to look at that retrofit program and decide whether or not what way it should be modified. We now, under the legislation that was signed by the Governor, passed last week by the Legislature, are going to include in that local bridges and have to develop again a new prioritization based upon what we learned and based upon the involvement now of any local bridges in this program, as well as bridges on the state highway system.

The Committee did present to us a number of questions in advance, and we have provided a written response to those questions. Mr. Roberts can go into that in more detail.

Essentially, we're looking at engaging in substantial research programs in order to go forward, both for the purposes of testing the current design standards that are in use and also, of course, to look at the retrofit program, both what we can learn about how to retrofit bridges and how to design an expeditious retrofit program to deal with bridges that were designed in past years and are already in place.

For here in Southern California, we have that dual question of getting our standards up to the most current standards based upon what we learned from the Loma Prieta quake in Northern California, and then also to go back and look at how to adjust and retrofit bridges in light of that knowledge, in addition to the knowledge that we had in past years.

I think we are looking at going forward with what we might want to call a crash program. We do have to realize, though, that when we call it a crash program, we don't have all the knowledge we need to simply go out today and start letting contracts to work on bridges all over the state. We have to do some more research; we have to learn what happened to us up in the Bay Area, understand that event. We will be doing such things as preserving a piece of the 880 Cypress structure that suffered the worst collapse, and testing it in place with devices to simulate some of the movements and forces, try to measure that and measure its response to see what can be learned. We have to do that kind of research. We have to do university-based research to divine how that program can go forward. In addition, once we have that knowledge, the individual structures are just that. They're individual. And then you have to move from that knowledge into the field of designing the exact retrofit that's going to be placed on each bridge. So we have a very, very big program ahead of us.

When we say crash program, that means we're going to be pouring resources into it and moving on a much more expeditious basis than the retrofit program was set up in the past. It also means that part of that crash program is going to be an expedited investment in research to determine the knowledge we need in order to begin to design the appropriate programs.

We're going to learn a lot from this quake in Northern California, and we're going to see a lot of changes introduced into the way we approach seismic safety in the state as a result of that. In looking at the bridges that are in place, we have conducted a review of the bridges down here to determine, based upon what we could learn immediately from that quake in Northern California and the effects that were received, do we have any bridges that we would be concerned about the safety for the traveling public here in Southern California? Our first review of that has indicated, no. In looking at that, we have no structures down here in Southern California that are designed similar to the ones that collapsed in Northern California. That's one of the key factors, of course, in terms of trying to determine what degree of confidence in safety we can have of the structures that are down here.

One major structure that is under construction on the 110 -- we have called in a peer review committee to take a look at the design for that, bringing people in from the private sector and universities to work with an internal review team. We will not start construction of that particular structure until that peer review has been completed and has indicated that either the designs are safe, from everything we know; or if they have indicated certain changes, we've been able to incorporate the necessary changes in that. So those are the kinds of immediate reactions that are going on at the current time while we still have to go ahead and learn some more from what the experience has been in Northern California.

Would you like to move immediately to Mr. Roberts, Mr. Chairman, or do you want to take a few questions now?

CHAIRMAN KATZ: Mr. Best, I'd like to move to Councilman Alatorre, who has a council meeting. Let me take the councilman's testimony, and then I think there were some questions for you, as well as Mr. Roberts. But let me digress for a minute and ask Councilman Alatorre to come forward.

COUNCILMAN RICHARD ALATORRE: Thank you very much, Mr. Chairman and members of the Committee. Last Friday, I held a press conference under the 4th Street Bridge here in Los Angeles, the city's highest priority bridge for seismic repairs in terms of cost, need, and use. Now, we are here at City Hall which is also not entirely up to par in terms of seismic safety. We've all seen pictures of what happened in the San Francisco Bay Area two weeks ago.

I want to make sure that we won't have the same level of human tragedy or the multi-billion dollar loss here when the inevitable big earthquake strikes Los Angeles. It strikes me that the millions of dollars estimated to make our bridges, public structures, housing projects, overpasses, and residential brick buildings safe are worth the collective will and the collective strains of all of us involved.

It's worth it in terms of dollars. We know that it would cost about $62 million to replace the 4th Street Bridge alone, and $9 million, if we did our work as a proactive force, to upgrade it. But it would cost billions to replace all of the unsafe structures that we are talking about.

It's also worth it in human terms. Again, we know that more than 20,000 cars use the 4th Street Bridge every day. Imagine how many people's lives are at stake in all of the other public structures and residential brick buildings in the city. Two weeks ago, I proposed that we put a bond issue on the ballot to retrofit seismically unsafe residential structures. I added teeth to the motion by getting some of the major civic leaders to lead the campaign to get this bond issue on the ballot.

Last Friday, I introduced a comprehensive multi-million dollar measure before the City Council to ensure that Los Angeles City structures, the housing projects, the bridges, the overpasses, and residential brick buildings meet earthquake standards. A piecemeal approach to bringing our city up to earthquake safety standards doesn't make sense. That's why we have to take a comprehensive approach.

You listened to some of the testimony by Mr. Horii. He talked about some of the bridges that we have here in Los Angeles that do not meet seismic standards. Whether we talk about public buildings -- and we have about 128 of them here in Los Angeles that are unsafe out of the 187 city-owned buildings. As far as residential brick buildings, we have more than 23,000 residential units that remain out of compliance. The housing projects -- from information that we have received, all of their structures meet city codes. But much work remains to be done as far as doing some of the work as it relates to the strapping of water heaters and other non-critical issues. The bridges -- you heard that we have 416 city-owned bridges and overpasses, and over 100 bridges need some level of reinforcement.

Along with the measure, we have included homeless shelters, of which we have about 150 shelters in the City of Los Angeles that house approximately 6,000 people every night. I am proposing that $10 million be set aside from the bond proceeds for the expansion and rehabilitation of these shelters that would increase our capacity by 5,000 people that could be served on top of those that we serve today.

It seems to me that a lot of work has to be done in the coming weeks and months so that the situation that we saw happen in San Francisco does not reappear here in Los Angeles. It seems to me that being proactive, as opposed to being reactive, not only makes monetary sense, but certainly it makes sense from the standpoint of prevention and trying to make sure, when the big earthquake hits Los Angeles, our residents are protected to the extent that we can.

The role of the state in the passage of the increase in the sales tax, I think, is but a small measure in terms of the things that we have to do. I think hearings throughout the State of California, not only here in Los Angeles but in other areas, will point out the fact that almost every city has major problems. Every city has limitations in terms of money; and to the extent that we can work cooperatively together to deal with this issue, I think people are benefited by that. Governmental entities working cooperatively probably is the best approach that we can move in during this period of time that analyses are made, not only here in Los Angeles but throughout the State of California.

With that, I'll be more than happy to answer any questions.

CHAIRMAN KATZ: Thank you, Councilman Alatorre. Mr. Areias.

ASSEMBLYMAN AREIAS: Yes, Mr. Alatorre, in recognition of those needs and limitations on local government and given your long experience on the state level, what type of mechanism or combination -- say, matching funds, general obligation revenue bonds, some continuance of the sales tax -- what kind of mechanism do you think would be most suitable and maybe the fairest in terms of financing the tremendous...?

COUNCILMAN ALATORRE: I don't know if there's any that's really that fair. The sales tax can be used, being regressive. Almost anything that we do is going to hurt in one way or another; but it seems that a combination of general obligation bonds, the increase in the sales tax for a longer period of time, the use of gasoline tax money -- I think we have to look at whatever mechanisms that we have. The City has certain limitations. Last year, we put a general obligation bond initiative on the ballot. It missed by two percentage points without any campaigning. I would hope that once we drew our analysis as to how much money would be needed to bring some of the overpasses, bridges, public buildings up to code, we could put the general obligation bond measure back on the ballot with an organized campaign to support it and to see that it is passed. I think we have that capacity here in the city. I think that whatever money we invest today is going to be a small token of what we would have to invest if an earthquake hits in the very same manner that San Francisco was. I would hope that we could learn something from that, so that the City of Los Angeles could move in a proactive manner.

ASSEMBLYMAN AREIAS: Richard, what kind of match, assuming that there is some kind of match, do you think the City would be willing to do as it relates to the State?

COUNCILMAN ALATORRE: About one for one wouldn't be bad. I don't know if that's even possible. The State has tremendous obligations, I'm sure, just to take care of their own public buildings, as well as the roads, the freeways, and the like, and the bridges that are state-owned. I think, the State has some problems. Yes, we would like to see some relief. Whether that's realistic remains to be seen. But in the meantime, it seems to me that we have an obligation to move in a proactive manner, so that we can at least stabilize and deal with whatever it is the City has responsibilities over, that we can minimize the possibility of human loss.

CHAIRMAN KATZ: Mike.

ASSEMBLYMAN ROOS: Thank you, Mr. Chairman. I just wanted to note to the Chairman and Mr. Areias how City Hall has obviously mellowed Mr. Alatorre. I remember the day when he would think an equitable formula would be two for one, two state dollars for every one local.

COUNCILMAN ALATORRE: Well, I was really going to talk about five for one.

ASSEMBLYMAN ROOS: That's the Alatorre I'm used to working with.

ASSEMBLYMAN AREIAS: Then was then and now is now.

COUNCILMAN ALATORRE: That's right.

CHAIRMAN KATZ: Richard, thank you very much.

COUNCILMAN ALATORRE: Thank you very much, Mr. Chairman.

CHAIRMAN KATZ: Mr. Best. Do you want to have Mr. Roberts come up and then have committee members ask questions?

MR. BEST: Whatever your pleasure, Mr. Chairman. Do you have some policy questions you want to talk about before we get to the second question?

CHAIRMAN KATZ: My question to some extent goes back to some concerns I had in terms of the length of the Phase 1 retrofit program. It took 16 years to complete Phase 1. $50-60 million is not small change, except when you start talking about transportation. Why so long to do that kind of a program? Why the time into Phase 2? I know you mentioned the need for research on page 2; but going over the Caltrans memos in 1987 and 1988, there's no indication in those memos that more research is needed. In fact, there's one 1987 memo that talks about going out to bid in June or July of 1988; and yet in the first fiscal year following that, while there was $16 million set aside, there were no projects in Phase 1 in the first -- I guess it would be Phase 2, Category A, or however you want to break them down. Those are some of the questions I've got in terms of the movement on this program. It covers two administrations. I'm just trying to get an idea from you as to why.

MR. BEST: I don't have the years of knowledge as to why these decisions were made each year on that. I think what we do know is that the seismic retrofit program was one of many programs in the department. It was laid out as a long-term program. It was laid out from the beginning in a sequential process as opposed to a parallel process. Rather than taking the categories and looking at them and moving with the research and the development of plans for each category, a decision was made that we'll identify first the highest priority bridges, in other words, the bridges that appear to be at highest risk, and do a program for them. When that program was done, we'll go to the next set of bridges that were considered lesser risk, and so forth down the line.

Again, with Monday morning analysis and looking back on that, at that particular period of time, there had been no real catastrophic failure in spite of some major quakes. There had only been two lives lost. And even though we can't say just two lives, in comparison to the fact that lives are lost every day on the road system around the state, there was not a feeling that there was such a threat to the structures in the state that it had to be carried off as a very expeditious program. We have now learned that there is a higher degree of threat from the structures of the state than was expected at the time that program was designed, but we don't know exactly yet the degree of that threat because we aren't through with our learning. In retrospect also, we have to say that, with regard to the identification of the highest priority risk, in setting up a program to take care of that risk, it was indeed an accurate judgment.

We completed Phase 1 during the time that Phase 1 was under work; no structures failed from that. During the major quake we had up there, no structure failed from the phase because of the inadequacy of the Phase 1 retrofit program; and at the time the program was designed, nobody believed that there would be the type of catastrophic column failure, even from a much larger earthquake than was experienced. So the program moved within government, given its priority. Certainly, I think we're all in agreement now that we need to readdress that whole concept of the priorities for this program.

CHAIRMAN KATZ: In terms of the Phase 2, you indicated there's a contract with UCSD. Also, there's an additional contract with UC Berkeley on multi-column phases, but when I looked over the documents that go back in late 1987 after the

Whittier Narrows quake and that column on the I-5 that went down to the rebar, which prompted a lot of the concern about single-column support and wrap-arounds -- in looking at those memos, it indicated a desire to accelerate the funding of Phase 2. Again, I don't see any indication that there was anything to prohibit that from going ahead immediately. Yet, there would seem to be a considerable time lag between those memos, the Whittier Narrows quake, and dollars getting on the street. I'm trying to figure out what happened in that accelerated process.

MR. BEST: Well, I think, when that was proposing an accelerated process, it was proposing a process accelerated as compared to Phase 1. In other words, this was not something that we could take 17 years to get done. Indeed, I think, the response, the funding allegations, the Commission promptly approved the program and authorized it. It was set up as a four-year program. I'd have to ask Jim Roberts to explain a little bit the reasons that some of the projects didn't get going in the first year.

CHAIRMAN KATZ: None of the projects got going in the first year. There was no funding in the first year at all.

MR. BEST: There was funding approved in the first year, but none of the projects were put in. That's right. None of the projects went to construction; but there was work going on, a great deal of work going on in terms of the design of the retrofitting and in completion of the research. So there was a great deal of work going on on the Phase 2 program in the research and the actual design phase, but the first contracts didn't go up for final funding approval until actually just before this quake occurred. That's just a matter of balancing that workload with all the other workload in the Department at the time.

CHAIRMAN KATZ: Balancing the workload of the Department -- I know the four years that I've been chairman of the committee there have been questions over adequate staffing in the Department to meet department needs. Balancing workload sounds to me like not having adequate staff to do what needs to be done.

MR. BEST: Any governmental agency will always say if we had more money and more people, we would be able to get more done on a quicker basis. That to a large degree is true. So decisions are always made based upon what you know at the particular time. We will definitely be adding some capability to the staff of this particular seismic safety program than we had before. But the decision to run the program at that level was not because of an inadequate staff. It was based upon the analysis of the priorities of the program at that particular time. We do have the capability now to engage on a much more expeditious basis than we ever had in the past. We have use of outside consultants; and we will be utilizing that capability to expedite this program, both for state bridges and, of course, for local bridges under the new legislation in order to move that along on a much more expeditious basis.

CHAIRMAN KATZ: Can you give me an idea of how Caltrans is broken down in terms of staffing from a safety or rehab standpoint versus new capacity/new roads standpoint. Where are most of the bodies, and where is most of the work being done?

MR. BEST: No, I can't give you that off the top of my head, primarily because in most of the Department, in terms of most of the projects, many of the safety projects, essentially the same people work on both. We could have a situation where we can have a design team working both on a safety project and a new capacity project in their same workload. The seismic safety area in terms of structural safety is much more of a specialty, so we can actually go in and look at the number of people who are devoted to that. Those are not the only people who are engaged in the design when it actually comes time to actually design a retrofit or a corrective program. A lot of that can be done by general design engineers once the standards and guidelines have been created by the specialists. So we don't have a clear breakdown in the Department of so many people on this and so many people on that.

CHAIRMAN KATZ: I just have a concern when I hear comments like, "We were working it out with the workload," -- and I know what was going on, both from a dollar standpoint over the last many years in the Department and for the road system and the emphasis on new road start-ups and expanded capacity because of the congestion nightmares that everybody's facing -- I just have this fear that at some point folks who could have been doing seismic upgrading or safety rehab, or rehab work, were doing capacity enhancements. When you look at the dollars allocated, even though safety comes off the top and is supposed to be top priority, $16 million a year for four years is a drop in the bucket out of the highway department. $64 million for one year on an expedited basis, if the resources and the commitment are there to do it, is not a tremendous impact on the highway budget.

MR. BEST: You would have to go back more years in advance. In other words, if we were going to spend $64 million in one year, we would have had to start earlier on this phase of the program in terms of getting the research completed to move forward. Again, what we have here is a program that was designed essentially after the 1971 quake and was set forward on initially a crash program to get certain high priority things done and then laid out as a long-term program. That program was reevaluated every year as the process went along, based upon people's perceptions at the time as to the priority to do that versus other programs within the Department. It's easy to second guess all those decisions made many, many years in a row over long periods of time. But again, given what was known at that particular time, there were a lot of safety needs on the state highway system that were clear and evident and immediately apparent that were competing for the same dollars that the seismic program was.

To the best of my knowledge, there was no specific proposal put together asking for additional resources for the seismic safety program that was denied in the process. But within a large institution, the institution itself goes through a process of balancing what it's going to ask for, and the seismic program was developed within the institution to be a long-range program and to be done on a sequential phase basis rather than to be a short-range program with the phases running parallel.

CHAIRMAN KATZ: I have one last question. To your knowledge, are there any single-column structures in the Los Angeles area built pre-1971?

MR. BEST: I have to refer to Jim on that. I assume there probably are. He's nodding his head. Why don't we let him give you more details on that.

CHAIRMAN KATZ: Okay, I'll come back to Jim on that. Mr. Roos, then Mr. Eaves, and then Mr. Areias.

ASSEMBLYMAN ROOS: Mr. Best, I wanted to get back to the questions I was asking Mr. Horii in terms of the degree of certainty about your internal evaluations and would they match up with an independent audit or an independent analysis? Would you attest that there would probably be no variance in what your people conclude versus what an independent engineering firm would conclude?

MR. BEST: I think the answer to your question is, yes, from what I know of the field. I've learned a lot about it in the last couple of weeks, being a lawyer and not an engineer. But when you get to the experts in the field, there isn't a lot of what I would call independence in the sense that most of these people have been working with each other for many, many years now, and that includes on an international basis. Any time there's been a major seismic event, engineers from our department, engineers from foreign countries, engineers from the research institutions work together to analyze what that event was, what happened in that event, and where should we go from there. I don't thing you're going to find, and again Jim Roberts could give you more detail on that, but what I've been able to learn, I don't think you're going to find a situation where you have Code A, B, and C, with one group of engineering professionals subscribing to Code A, another group to Code B and Code C. I think you're going to find that they all have acknowledged more or less what Mr. Horii was saying, and that is, we're just still trying to learn how to predict what the forces are. Once we have agreed upon what the forces are that are likely to have to be resisted in this structure, most of the engineers are going to agree as to what the alternatives are to go about designing for that.

ASSEMBLYMAN ROOS: Could you give a quick picture of what Caltrans is going to look like in the next couple of years in terms of coping with this. What is going to be left undone as men and money and resources are diverted toward shoring up the freeways that, again, are problematical at this time?

MR. BEST: I'll start from the back and work forward because, when you talk about men and materials, shoring up or retrofitting structures, virtually all of that work is done by the private sector under contract. We do some minor retrofitting with our own forces, but not anything that is substantial, certainly given the program that is there.

ASSEMBLYMAN ROOS: But all the engineering is done in-house.

MR. BEST: No longer is all the engineering done in-house. But in terms of moving back into the engineering phase of that, we are already utilizing it. We have the capability right now to expedite our ability to bring on board private engineers. We're already using them on some of the structural analyses in Northern California in putting together essentially a design consortium, including our engineers or theirs, to get these analyses going. There is definitely going to be some degree of competition for resources. At this stage, we haven't really sorted that out, and there is a lot of concern that we not abandon on-going projects for totally pursuing this particular process. It is our understanding right now that, if we can assume for a moment that the independent resources are going to be there, in other words, that the policy decisions with regard to resource allocation do not result in transferring resources from other projects to this program, we will be able to keep both of them on schedule providing, in addition to our own in-house expertise, there are substantial contributions from the private engineering sector specifically on this effort.

ASSEMBLYMAN ROOS: One final question. Have you made a determination what's going to happen to the Embarcadero Freeway yet?

MR. BEST: No, we have not made that determination. The Embarcadero Freeway actually suffered from...

(Due to loss of power to the recorder, the recording was interrupted at this point in the hearing, resulting in the loss of a short period of testimony.)

...There were some initial standards going out. This review will be a very high priority item. We have a lot of people on board looking at this from various points of view, collecting information, taking samples, beginning to run analyses. As I said earlier, we intend to rig a portion that's going to be left standing for the purpose of dynamic testing of the structure in place. We're talking about a matter of weeks of concentrated effort and then, of course, some time to actually look at what that means. We're not talking years here; we're talking months in terms of being able to come up with a large percentage of the knowledge. Actually, I think, and I'm sure Jim would agree with this, in terms of the ultimate learning from this, it'll probably be years that they'll be studying and analyzing what happened with this quake and the ultimate learning. But that's the process that goes on inevitably to fine-tune what you learn in the first effort.

ASSEMBLYMAN JERRY EAVES: Second question -- you talked of the peer review group that studied the Harbor Freeway transitway. What kind of time frame? You said no construction is going to start until that peer review is completed. What kind of time frame are you expecting with that peer review?

MR. BEST: Do you have a date on that, Jim? I know they're already underway. We expect to have it done by the end of the year. Then the construction can start.

CHAIRMAN KATZ: Mr. Costa.

ASSEMBLYMAN JIM COSTA: Yes, back to the funding question. Last weekend when we concluded our work, we passed a number of pieces of legislation that dealt with both the acceleration of the seismic assessment and retrofit program. We also provided funding for sales tax for additional means to help match the federal funds. The cost that this is going to create in terms of dealing with all the retrofit, do you have any handle -- it seems to me it's going to be more than we have provided for thus far.

MR. BEST: Again, of course, the program that we're looking at now is not only a state program, but also includes local structures as well. You heard this morning a kind of eye-ball guestimate for Los Angeles of $150 million. We're looking at what we believe to be a minimum of a $300 million program at the state level and probably higher than that to do the top priority bridges. But, in terms of actually giving a figure on this kind of a program, to give you any sort of a hard figure -- until you have actually completed your design and have a few bids in, it's very hard to give actual dollar amounts.

ASSEMBLYMAN COSTA: And I don't expect you to give me a hard figure, but I think it's safe to say, at least from my perception, that it's going to be larger than the amount that we've given you thus far. My question is, then, what considerations is the Department looking at now in terms of getting additional funds to do the job so that we can have adequate safety in our transportation system?

MR. BEST: We're looking at the federal level. A lot in terms of the amount of dollars we will need here at the state and local level depends upon the degree of federal participation, particularly whether or not the federal government will agree to include the program as part of the emergency relief program that they have approved, like we have included it as part of our emergency program at the state level. There's a big uncertainty there as to where the federal government will come down in terms of helping to support this particular program. Beyond that, if we have to come up with funding totally at the state level -- let me clarify that. It's clear that most of the work on the state highway system and certainly a portion of the work on the local government system will be federally eligible. So the question is whether it is eligible under the special disaster relief program or whether you have to include it in your on-going program and, therefore, would offset other projects that might qualify for the regular on-going program. That's the big question right now.

ASSEMBLYMAN COSTA: Now you're getting to a concern that I have. We're obviously here today to deal with the rehabilitation and the retrofit, the safety questions at hand. The Chairman mentioned in his opening comment -- correct me if I'm wrong -- that potentially the transportation package that we're going to be asking the voters to approve next year might be a source of some additional funding to deal with this problem. Did you allude to that?

CHAIRMAN KATZ: Mr. Costa, one of the things that we're going to consider, coming out of this hearing, is going back in January and earmarking potentially as much as a billion dollars of that $18.5 billion package contained in AB 471 that's going to be on the ballot in June, if that is what the need is on a state and local system. We hope to have better information by January as far as exactly what the need is. I agree with Mr. Best. I don't think the $300 million is going to be enough.

ASSEMBLYMAN COSTA: I don't think it's going to be enough.

CHAIRMAN KATZ: $20 million obviously is not going to be enough on the locals. We may look to earmarking part of that $18 billion package for earthquake rehab and seismic upgrades.

ASSEMBLYMAN COSTA: Then, I think it's important to note that in fact if we do that, if that is the decision that we reach next January or February, there will be potentially $1 billion worth of projects throughout the state that were on somebody's priority list for good reasons that may not receive funding, certainly will be much delayed in terms of their funding, if we determine that in fact we need to designate a certain amount of the funds from the transportation package to go for safety reasons. If that is our decision next year and we determine that the federal government may not provide sufficient funding to meet all of our safety needs, we at the same time have to consider whether or not we attempt to make up that billion dollars, or whatever that number is, in some other fashion because I know you have indicated -- I have and many of us on the Transportation Committee -- that the $21.5 billion transportation package that we're asking the voters to approve next year is probably not enough in itself. It seems to me that if some of these monies are determined to be set aside for safety reasons, we need to get that word out because that would provide additional incentive for the passage of that act in June. Would the

Administration be prepared to make a policy recommendation, Mr. Best, to the Legislature in February as to whether or not, if sufficient funding is not available from other sources, any money should be diverted from the transportation package?

MR. BEST: We would be in a position to make a policy recommendation, but I don't think by February we'll really have the numbers tied down very hard. But we certainly will have better numbers than we're working with today. Let me emphasize that the transportation program that was going to be supported from the SCA 1 measure was a ten-year program; and built into that program, at least on the state highway system, was the continuation of the retrofit program that was underway. So some of the retrofitting dollars were envisioned to be part of that program and were included within that program. Now, from my understanding of the discussions, I don't believe there was any determination made with regard to the local share of that funding package, that any of that would be directed one way or another. But in terms of the basic ideas for the state program, at the time that package was put together, it was expected that Phase 2 would be included within that package and certainly at least the beginnings of Phase 3 as well.

ASSEMBLYMAN COSTA: Will you be prepared in January to let this committee know in what areas there was planned to be retrofitting and in fact that this would dovetail?

MR. BEST: We will give the Committee a report in January, or whatever meeting you wish to schedule that for, Mr. Chairman, as to how we foresee the retrofit program fitting in with the SCA 1 program.

ASSEMBLYMAN COSTA: That would be very helpful. One last question. In the conclusion of the Chairman's statement, they talk about giving assessment to retrofit needs that include not only local road, but rail transit as well. And they also mention bridges. In the area of rail transit, it seems to me that the

Department ought to be looking, when we look at our ten-year package -- and again this alludes to SCA 1, the bond measure for future planning purposes -- when we look at policy considerations, at whether or not there is greater means to provide safety from rail transit in terms of survivability versus other modes of transportation. It seems to me that in the Northern California area, certainly BART, certainly most of the intercity rail transportation held up fairly well. I'm wondering if there are some lessons to be learned out of that in terms of how we plan for the future and how we're looking at spending, particularly, some of the rail transit funds over the ten-year package.

MR. BEST: I think one of the big lessons that we've already learned out of the events in Northern California is the importance of alternative transportation systems in the time of a major disaster. If you are totally dependent on one mode of getting around, that mode may fail you and create very serious consequences as a result. The alternative transportation systems that were in existence and that we were able to put into existence on an emergency basis certainly have gone a long way to keeping that area somewhat close to normal. We can't overlook, however, of the thousands of structures that are in the Bay Area in the road system as well as on the transit system, we're facing a situation where 99.8 percent of them all held up during this process. So what we're dealing with here is an engineering issue, I think, more than a modal issue. Certainly we've learned a lot; and we're hoping that up in the Bay Area in particular, a lot of people who, without their choice, had to find an alternative mode of transportation may conclude from that experience that those alternative modes are very workable and a very good way to commute, in particular, and will continue to use them as we begin to pull out of the damage to the road system.

CHAIRMAN KATZ: Mr. Areias.

ASSEMBLYMAN AREIAS: Mr. Best, getting back to the collapsed freeway, was there ever a proposal to add a third deck to the Cypress viaduct?

MR. BEST: I've heard some talk about that, but certainly nothing that ever got into the design stage or any serious proposal that I know of. We've done a lot of theoretical reviews in the Department over the years. A number of years ago, it began to become very apparent that in certain corridors through the urban areas, we simply couldn't continue to add lanes, add lanes, add lanes and that some alternatives were going to have to be developed for handling the high demands through those corridors. One of those reviews that had been done was to look at the utilization of structures through there from a conceptual standpoint. I heard that there was a conceptual proposal at one time of considering adding another deck, but it was never engineered, nothing was ever given serious consideration.

ASSEMBLYMAN AREIAS: Where did that originate? Did that originate in Caltrans?

MR. BEST: I don't have any idea, quite frankly. I just read about it in the press.

CHAIRMAN KATZ: Mr. Roberts.

MR. JIM ROBERTS: Assemblyman Katz and members of the Committee, I'd like to try to put the Loma Prieta, as the special name for the San Francisco earthquake, into perspective because I know there is concern statewide, especially here in the Southern California area. I'd also like to walk through the written comments we've made.

This is a section of the seismic map that's produced by the California Department of Mines and Geology, which we all use and have used since 1971. There are over 210 faults in the state. We designed all the structures in the state since 1971 site-specific. There were approximately 5,000 bridges in the area of the earthquake, and most of the damage was at the lower two-thirds of this red square. There were about 2,500 state bridges in the section and 2,427 local city and county bridges.

Within 48 hours of the earthquake, forces utilizing both construction engineers and our licensed engineer maintenance inspectors had inspected 1,530 sites in the affected counties. This is a daily report we receive on damage. There is work that we considered very minor, cracking and spalling where joints banged together on 64 bridges. Ten bridges at that time were closed to traffic. Subsequently, one of those bridges has been reopened. Today, there are nine bridges closed to traffic. There are fifteen others with some major damage that requires supporting while the repairs are being made. But essentially, out of 1,500 bridges on the state system, there were only ten closed. Granted one was a major tragedy.

I believe the records will show that the local city and county systems fared equally well.

One area that's been discussed earlier today, and I think deserves a little enlightening, is the relationship of the Richter scale on an earthquake to the complete ground acceleration for which we design structures, utilizing the map I just showed you.

I have a printout here that lists 17 most recent major earthquakes in California, with the Richter scale magnitude and the peak rock acceleration that was recorded. There's no relationship. We can't correlate. These are random events. In fact, the best thing that can be said about the Richter scale is that it's a measure of the energy it relays, so it would obviously relate to the magnitude or the area of the damage. But it does not necessarily relate to the ground acceleration.

For example, in the Gilroy area, the ground acceleration was as high as .65g which is 65% of the weight of the structure, applied laterally. And it was as low as .26g up around the Hayward fault, which is in the vicinity of our worst damage.

I think it's admitted that the Cypress Street structure was a dinosaur in terms of bridges in this state. It was designed by 1949 code, of which I have a copy. At that time, we were the only state in the United States who had a seismic design code. That code required a lateral force of 6%, .06g. Today, we would be using .25-.30g for the same kind of structure.

CHAIRMAN KATZ: How many other structures in the state are built to that same code from 1949?

MR. ROBERTS: Probably half of the system, which would be about 7,500 structures. When I get into the Phase 2 retrofit, that's exactly the process we used to screen and prioritize for Phase 2 retrofit. Seventy-five hundred structures built prior to 1972, or the San Fernando earthquake, is just a gross number. Certainly all those structures are nowhere near the seismic zone, using the map. As you radiate out from an earthquake fault, the energy is dissipated and gets as low as .02g or even 0. So nowhere near all of those 7,500 structures are susceptible to major acceleration.

CHAIRMAN KATZ: You have to consider Los Angeles, though, an area of potentially significant seismic activity.

MR. ROBERTS: Yes, sir. Los Angeles is criss-crossed with major faults. When I go through the report which we gave the Committee, we've listed all the faults that we use in prioritizing. These, incidentally, are the attachments to your report. I have four printouts. That's the Phase 1 structures which have been completed. We gave one to your staff person earlier, but I have four other copies.

Just one last item on the seismic structure. Some calculations were done shortly after the earthquake by many people. I happen to have a report that was handed to me, written by Dr. Priestly, who is on your agenda later, and Dr. Seible from UC San Diego. They did an analysis of structure and they identified a weak joint on the structure which a lot of people have found. They've also done a finite element analysis, and their calculations and those of Professor Farrell from UC Berkeley show that the force in effect that failed this restrained joint was between .17 and .20g, which was three times what the design code was at that time. Granted, there are several factors: ground, soil conditions, this weak detail. We would not use any of those details today, and haven't since 1972. Until the investigating team completes its report, there's a lot of speculation about the causes. There will be many factors that contribute to the cause of that earthquake. We have, of course, closed all of the double-decked viaducts in the San Francisco area. They will not be reopened until we can complete the project to put in some temporary reinforcements, as Mr. Best mentioned.

Shortly after the earthquake, the district director for Caltrans in this area, Mr. Baxter, asked me to put together a Blue Ribbon Committee to look specifically at the I-110 viaduct and Harbor Freeway. That Blue Ribbon Committee consists of two university professors from the Los Angeles area and two consulting engineers from your area. They may have met twice with some of the local officials; and as you heard, their report will be available by the end of the year. I'm certain that, in view of what has happened with the earthquake, we will be using several outside peer review groups such as this. We had, in fact, used a peer review group in our office to look at the Embarcadero for some details we were working on in Phase 1.

I'd like to just quickly run through the responses to the questions, if I may.

CHAIRMAN KATZ: Since you have the advantage of having seen that before today and we haven't, let me ask you something specific. Committee members, you may want to take a look at what we were handed by Caltrans at the beginning of this hearing today.

Mr. Roberts, I want to focus back on Los Angeles. I want to focus back on concerns that you seemed to have expressed two years ago. You expressed the concern at that point over the 605 separation over Highway 5, which I remember viewing the day of the Whittier earthquake because the metal support column had been broken down to re-expose the rebar. You said at that point that if that had been a single-column structure as opposed to a five-column structure, it would have collapsed. You had grave concern about any single-column structure that was designed prior to the 1971 the Sylmar quake experience. Now, you've also told us that there are a lot of single-column structures in Los Angeles that were built pre-1971. My question is, has anything changed in the last few years to change your opinion of that October 19 memo, first of all?

MR. ROBERTS: Yes. This really responds to your first question as to how we prioritized the three phases. As a result of the San Fernando earthquake, it was rather obvious within hours of the earthquake that the hinge joints pulled apart on many structures out from the bent spanner and also at the abutment supports. That caused many single-column structures to roll over when the columns broke. At the same time, there were many multiple-column structures in the San Fernando earthquake where the hinges had pulled away from the supports. While those structures sustained major damage, they did not collapse. That really was the basis for our prioritization that hinges had to be fixed first because they posed the greatest threat to the traveling public. Secondarily, we felt the single-column had posed the second highest threat. What we've seen now since the San Fernando quake on three other major earthquakes -- Palm Springs, Whittier, and Trinidad up north, and even the San Francisco earthquake -- is that the hinge respanner program has been so successful through earthquakes that the single-column structures have held together because the structure acts as a diaphragm, so to speak. Instead of pulling apart laterally, it acts as a unit. It actually reduces the probability of single-column structures keeling over.

You've talked about funding levels here earlier, and I think you're well aware of the funding levels and the internal processes we go through. But after we reviewed the results of the 605 structure, where we had major column failure on a five-column bent, we felt concerned. My seismic analysis people prepared this letter, which I wrote to my boss. I think it's important that we point out that we did say there are fifty fatalities. There are almost fifty. We talked about the probability in earthquakes and the random measure. There could be fifty-some fatalities. We also pointed out in that letter that the Phase 2 program was primarily designed to increase serviceability in a system and reduce damage and any probability of collapse from a major earthquake.

We're concerned about keeping the system open, which we didn't do in San Francisco. We have to emphasize that it's not possible to guarantee that there will never be a fatality from any event. But it's our position today, as a result of the earthquakes we've seen, that the Phase 1 program was effective in greatly reducing that threat. While we did state that there was a serious threat, today we don't see any single structure, based on its location and the knowledge we have today, that we feel should be closed that isn't closed today. And we have closed all of the double-decked viaducts in San Francisco. Obviously, we've learned that our original prioritization was incorrect in that the double-deck, multiple-column structures didn't hold up as well as -- at least the one, Cypress, didn't hold up as we had anticipated. However, the 506 in San Francisco did experience damage, but frankly that damage was isolated to just a few bent constructions that were a mile long. We feel very strongly today that this prioritization of fixing the hinges first was the way to go, and we would recommend that today to the local agencies in their first review.

CHAIRMAN KATZ: I don't think anybody is questioning the strapping program as having been worthwhile. I think some of us may wonder why it took 16 years to do it. The concern is that two years ago you were warning about potential for single-column failure in pre-1971 structures. There are a lot of pre-1971 single-column structures throughout the Los Angeles basin that all of us drive, and I'm not getting a whole lot of reassurance that I want to drive home this afternoon as opposed to walk.

MR. ROBERTS: I think that, quite frankly, we've had to struggle within the Department for this program versus other traffic safety programs. I've been accused by the press of not pushing the program fast enough -- why I waited until 1987 to write those letters -- at the same time, accused of possibly over-stating the case to get the $64 million program. That program was, in fact, approved after I wrote the letter. The California Transportation Commission voted to put the funds into the program in December.

I wrote a letter on January 4, directing my people to get moving on the design and the plan. It did take a year to get that done. We've been working with UC San Diego on the research for single-column retrofits. Most of those tests haven't been completed. We did pursue designs for the projects simultaneous with the research. The money was put in the 1988-89 fiscal year, and the three subsequent fiscal years at $16 million a year. So the projects were ready at the end of that fiscal year. I think the best I can say is, in order to push the program from a $4 million-a-year program to a

$16-million-a-year program, we stated the possibility. The operative word in the sentence is "could".

But in going back and analyzing after this earthquake, I've had people looking at bridges in the Los Angeles area. You asked specifically about the four-level. I've written a paragraph on that in response to your questions. We put a lot of structures, pulled the plans and reviewed them. There are no structures similar to the double-decked structures in the San Francisco area. In about another week, we'll finish all of our review of the 1,500 bridges in the northern area. Then we will concentrate on the Los Angeles area. We did have damage up there, so we have to inspect those bridges first.

I still value the system. I am confident that we could have damage to some single-columns, but they're not going to fall over, because of the hinge program. Even the Cypress structure where the bent collapsed for about 4,000 feet, probably 90 percent, and you can see it in the aerial photos, but the hinges kind of held the bent together. It's really inappropriate to compare that column design of 40 years ago to anything we do today, even pre-1971 single columns. That particular bridge had some horizontal hinge joints at the bottoms of columns and at the top in one place.

CHAIRMAN KATZ: I don't think anybody's comparing the Cypress structure to single-column. My questions are all focused around pre-1971 single columns, particularly in the Los Angeles area. Your reservations about them, which I'm a little uncomfortable about, because you're telling me you're hyping your reservations in order to get more funding, which bothers me a lot. I depend on you to tell me facts about whether something is safe or not. I don't want to have to start looking at every memo I see from Jim Roberts and say, "Well, he said it's not safe and could use the following. Is he just try to hype funding versus funding for blood alley on Highway 120 in the San Joaquin Valley? How do I make those determinations now?

MR. ROBERTS: I think I understand your position, sir, but seismic people agree certainly over and over that, although we wrote this, they don't see the structures today that they feel, from their analysis, are unsafe or should be closed, that we haven't closed. What we want to do is get the Phase 2 program completed so that we won't have the kind of damage that requires shoring them and closing the road either above or below.

CHAIRMAN KATZ: I guess then, just to bring it full circle on the Phase 2, when you wrote the memo in October 1987, you said that you could advertise contracts on July 1, 1988. You didn't seem to think you needed more research at that point. You didn't seem to think there were any problems.

MR. ROBERTS: The contract with the University of California at San Diego was well underway. They had done their theoretical work. Towards the summer of 1988, they had begun building models, half-scale models for their testing, and that testing is still going on. There's a series of about six models. Tests have been completed on three. I wrote a memo to my people to get the plans and the details developed based on the research. They did that. The analysis is not that simple because you're doing an analysis of a structure based on what it's good for in the old codes and then adding to that what you can get from the reinforcement. Then the details to make it work have to be developed. We got about eight projects completed in the fiscal year. They're in line to be advertised. As you know, the first two were approved by the California Transportation Commission. They are here in the Los Angeles area.

CHAIRMAN KATZ: You wrote the memo in October. It went to the agency in October; agency signed off on it in October-November, I guess. Then you came back again at the end of November with the cost-benefit considerations for Phase

2. If everything was moving along, why the need for this subsequent memo? I'm curious as to what prompted that.

MR. ROBERTS: I'm not sure why it was asked for later, but that's typical of any program to show the cost benefits for any program.

CHAIRMAN KATZ: But after it's approved?

MR. ROBERTS: I wouldn't think normally, but that's what happened there. I can't answer why I was asked for it later.

CHAIRMAN KATZ: It concerns me. You highlight the 405, the 110, the 710, the 605, all in Los Angeles. You talked about the Newport-Inglewood fault and the potential. Then you also talked about the San Jacinto fault in San Bernardino. I get the sense sometimes in reading some of this stuff that you knew there was a problem out there, you were trying to get attention focused on it, and folks weren't taking it as seriously as you were. And you could view the memo as an extra kick in the hindside in trying to get somebody to recognize there is a problem here and still stay within channels.

MR. ROBERTS: You asked a question earlier about the number of people that are involved in this program. I have seven people assigned full-time and then a number of designers that work on it. That's from a group of 1,000 people that are involved in design, construction and maintenance. So I think that puts the program into conflict. Also, the history for the first -- even up until this earthquake, the first 80 years on the system, there were two fatalities. Yes, sir, we had to push hard to get the program through.

CHAIRMAN KATZ: Seven folks work in seismic out of 1,000 people doing design, the majority of which I would assume then design increased capacity and new projects?

MR. ROBERTS: And many highway projects, as Mr. Best mentioned have some safety features. But I think this is the only one where we have people specifically assigned for what's definitely a safety part of the program. In addition to the people we have, we've spent, since the San Fernando earthquake, $2,600,000 at six different universities on various types of seismic research.

CHAIRMAN KATZ: Any other questions? Thank you, Mr. Roberts. Let me get Mr. Leonard up here since he has to get out of here.

ASSEMBLYWOMAN DELAINE EASTIN: Could I ask Mr. Roberts one quick question? Sorry I came late. I wanted to know about your memo that you wrote and then you said you exaggerated it, and now you're in the funny position of...

CHAIRMAN KATZ: Delaine, we just went through this whole thing on this memo.

ASSEMBLYWOMAN EASTIN: Was it an exaggeration or not?

CHAIRMAN KATZ: Mr. Roberts said that he wrote the memo as an attempt to draw attention and get funding. We just went through that whole thing.

ASSEMBLYWOMAN EASTIN: The only point I'm trying to get at, Mr. Chair, is what is the ethic in the Department that causes someone to feel in his own testimony to the press that he's exaggerated a problem after the fact. I need to know whether you exaggerated the problem or didn't exaggerate the problem. If you felt you had to exaggerate the problem, that's a problem. But if, in fact, people had pressured you subsequent to that to say it was an exaggeration, then I think that's a different problem. Which is it?

MR. ROBERTS: I think I need to repeat my statement that it's really not possible to guarantee that there won't be fatalities at any time. We sit here and say what we know today about the bridges in this state; if they're unsafe, they're closed. As a result of the last earthquake, we closed all of the double-deck viaducts in San Francisco. But in this same earthquake, bridges that were designed previous to 1972 and post-1972 performed well in the area of this earthquake. What we're trying to do on this program is reduce damage so that we don't have to close up. The system's not functioning in San Francisco on three major routes because of damage. They can't be opened until that damage is repaired.

ASSEMBLYWOMAN EASTIN: What is your estimate of the need for seismic retrofit in California? If you were the budget director of this state, what amount of money would you put in for seismic retrofit, such that we wouldn't, the next earthquake, have to look at a Cypress or close an Embarcadero.

MR. ROBERTS: The state bridges only -- we've estimated $300-500 million.

ASSEMBLYWOMAN EASTIN: You would say $300-500 million; but sometimes your estimates tend to be a little bit on the lean side, isn't that true?

MR. ROBERTS: They're on the lean side in this area specifically because we have excellent experience on the INS program, and we can certainly provide a lot of good information to local agencies. We don't have experience at all on Phase 2. We have contracts about to be awarded. Until we get some kind of bids in, we really have no basis for estimating like you do on a normal budget. So I'd say, yes, it probably would be lean. I have people in the Department who think it's much higher than that.

ASSEMBLYWOMAN EASTIN: Thank you.

CHAIRMAN KATZ: Thank you, Mr. Roberts. Mr. Leonard wants to make a brief statement from the Chairman of the California Transportation Commission. Then we'll go on with Dr. Priestly from the University of California at San Diego.

<u>MR. WILLIAM LEONARD</u>: Thank you, Mr. Chairman. My name is Bill Leonard. I'm Vice Chairman of the California Transportation Commission. I'm pleased to have the opportunity to appear before the Assembly Transportation Committee on behalf of our chairman, Joe Duffel, representing the CTC. Mr. Chairman, much of my testimony is repetitious. In the interest of the Committee's time and my voice, I'm not going to repeat. My remarks have been put in writing and will be passed out to members. Let me make a few observations though.

On October 17 at 5:04, our fellow Californians experienced a disaster. This event, which we have long dreaded throughout California, brought devastation to one of the loveliest and most historic areas of our state, the San Francisco Bay area.

In spite of the incredible destruction, there was much to give thanks for. The immediate reaction of Caltrans, state and local officials, and our fellow citizens in the Bay area, did much to mitigate the loss and suffering. It is well to bear in mind as we seek solutions to this terrible toll, an earthquake of similar magnitude in Armenia last year caused the lives of 25,000 people. The Nimitz Freeway and the Bay Bridge failure was a terrible tragedy. To keep this tragedy in perspective, we have to be grateful that it wasn't even a greater tragedy. And I give this as an accolade not only to Caltrans, but to make a point.

Rehabilitation of the California highway and freeway system has been always assigned the highest priority for available funding. Seismic retrofit projects are part of the rehabilitation program. As individual projects have been readied by Caltrans for construction, the Commission, without exception, has allocated construction funds so the contracts could be awarded. In recent years of funding shortages, it has been necessary to curtail new capacity projects in order to assure that rehabilitation, including seismic retrofit, come first.

Let me make a personal observation, if I may. The San Francisco earthquake of October 17 is a catastrophe that will long be remembered. No one knows precisely when or where the next earthquake will be centered, though we do know with a high degree of certitude that there will be another. One thing we do know is that there will be frequent and continuing catastrophes that will heavily impact the motoring public. It may be a fire; it may be a flood. It usually is in Northern California. It may be slippage; it may be fog with the resultant multi-car pile-up, or even a single-car accident. Whatever, it certainly is a tragedy to those involved. The Commission is very sensitive to these concerns.

Most every capital project we authorize is a safety project designed to save lives and protect property. We only vote amenity projects, such as sound attenuation walls or landscaping, when it's mandated, or it's the price of getting federal funds for projects that meet the criteria of protecting people and property. The Commission is firmly committed to the necessity of assuring a safe, reliable transportation system, that its maintenance and repair is adequately funded, as a priority over and above other assessments in the system.

One can lead to the inescapable conclusion that, with limited transportation funds, choices must be made as to which future capacity we should attempt to negate. In that event, it becomes a Hobson's choice. It is essential that additional funding be provided to fully reimburse emergency expenditures from the severely limited State Highway Account. We must not only raise sufficient funds to repair the earthquake damage, but to shore up damaged roadways to avoid future failures and to provide congestion relief and accelerate our seismic retrofit program. Caltrans and the Commission are out of money to meet the transportation needs of the rich state and very competitive economy.

Today is election day in my county, San Bernardino. On the ballot is a proposed one-half cent sales tax increase. In support of the adoption of this increase in sales tax, I sent to each of the county newspapers a letter to the editor. Two sentences in my letter are particularly germane for this committee's hearing today: (1) California has one of the lowest gas tax rates in the nation. (2) While inflation has driven the cost of transportation projects skyward, because they bought efficient cars, the cost to the motorist has materially dropped. Measured in terms of today's dollars, California drivers paid $183 in annual gas tax in 1964, compared to the average annual tax in 1987 of $58. In 1964, California was rated as having the best transportation system in the United States. In 1989, we cannot keep up with the repair, maintenance, rehabilitation, plus new capacity, with 30-cent dollars.

If I may expand just a little bit on one of the questions that was propounded to Director Bob Best, were you to take all of our transportation dollars and categorize them into one of three categories, they would become either (1) engineering support, planning, administration and operations, or (2) maintenance and rehabilitation, or (3) capital outlay. As we reported to the Legislature in our annual report of January 1988, maintenance and rehabilitation projects have increased 600%, from $489 million during 1966-70 to $3.4 billion expected during the 1986-90 period. Thereby, overall transportation budgets between 1966-70 was 9%. This has grown to 21% for the recent 1981-85 period and will continue to grow to 32% of expenditures between 1986-90. Despite recent year increases in highway capital outlay expenditures, capital outlay will have decreased as much as 77%, adjusted for inflation, between 1966 and 1990. The increasing maintenance burden, combined with little real growth and transportation expenditures, has left less capital outlay money to expand highway capacity in new areas of rapid growth and to serve real economic growth in California's long-established major urban areas.

Mr. Chairman, thank you very kindly for the opportunity to appear before you. If there are questions, I shall attempt to answer. Bob Remen, our executive, is with me and might be able to field them.

ASSEMBLYMAN COSTA: Thank you very much, Mr. Leonard. You touched upon a comment in terms of the expenditures that dealt with a question that I had asked Mr. Best earlier. Has the Commission met since the earthquake?

MR. LEONARD: We met the day after, sir, yes.

ASSEMBLYMAN COSTA: The reason that I ask that is, I'm wondering what sort of policy considerations the Commission is giving since they've approved a host of projects contingent upon the transportation package funding being passed next year by the voters. It's clear, based upon the comments Mr. Best made in response to my question, that the cost of the repair, the retrofitting, the rehabilitation is going to exceed what we provided thus far. How much of federal dollars we're going to receive remains to be seen. As you indicated, we don't have enough money as it is. In essence, we almost don't have enough money at this point. What recommendations are you going to be making to the Administration and to the Legislature for additional funding, especially if some of these monies are taken out of SCA 1 to deal with the safety questions at hand today?

MR. LEONARD: Well, Mr. Chairman, let me point out that the Commission, number one, is very strongly and actively supporting SCA 1, both individually and collectively. Number two, we, frankly, don't have a handle on the damage; and from Director Best's comments, he doesn't either. It will be some little while before the Department does have a handle. However, we have asked them to provide us at the earliest possible time, possibly the November meeting, a proposal for acceleration of the priority 2 retrofit programs and a proposal for the solving of those bridges and structures that came in priority 3. Priority 3 was a new category for us. We were not aware of that until October 18. There's going to be a great deal of room for the private sector to attack those problems. Director Best made reference to that. I think a great many of our solutions are going to come from the private sector, because the job at this point is overwhelming.

Where are the additional funds going to come from? This Committee was certainly very beneficial and instrumental in getting federal funds in large sums available to California, much larger than the law would ordinarily provide had you not had the law changed. That's going to be very, very helpful. There's the extra quarter of a cent that's going to be very, very helpful. The rainy-day fund is going to be very, very helpful. And here I have to get into a personal opinion. Add them all up, they're not enough. They are just not enough. We've allowed our infrastructure to go downhill. I picked the year of '64 because that was a year we could look back on when California was proud of its infrastructure. We have not put enough of our resources there. Now, that opens up the question for the Legislature to determine whether that means that there should be a curtailment of existing programs, whether there should be additional revenue introduced in the program, or whether it should be accomplished by both.

ASSEMBLYMAN COSTA: Well, ultimately, it is both our responsibility and the Administration's; and since this will probably carry over to the next Administration, we'll hope, whoever they are, they'll be prepared to make some recommendations. But will the Commission, in your opinion, be also prepared to make recommendations as a commission. You have $18.5 billion worth of priorities over a ten-year basis. A lot of those projects have already tentatively been approved, are there awaiting those funds. Will you have to make any decisions in terms of prioritization if a billion dollars-plus is taken from that total sum of money for the purpose of retrofit for safety reasons?

MR. LEONARD: Mr. Chairman, I'm not going to bore you with the chicken and the pig story. But I'm here with a fever because I want you to know that this commissioner is firmly committed to working with the Legislature in any way we can, and we will put our money where our mouth is.

ASSEMBLYMAN COSTA: We appreciate that.

MR. LEONARD: Thank you, sir.

ASSEMBLYMAN COSTA: I have a question by Ms. Eastin.

ASSEMLYWOMAN EASTIN: Yes, Mr. Leonard, I have a lot of regard for you and the members of your commission, but I also have a freeway down in my neighborhood, and I have some very serious concerns about California that I know you share in terms of our long-term investment. I'm trying to get to the bottom of the question: What did we know and when did we know it? You just said something that the CTC was not notified that there was even a phase 3 retrofit program until the day after the earthquake. Is that correct?

MR. LEONARD: I had not heard the term of phase 3 until the day of our meeting, which was the day after the earthquake. That's correct. And, therefore, the Nimitz was not in any of the categories.

ASSEMLYWOMAN EASTIN: And you also did not know that Mr. Roberts, the bridge structures chief at Caltrans, had indicated that there was some serious threat to life if certain other retrofit steps were not taken. Is that correct?

MR. LEONARD: I was not personally aware of it. Whether I should be -- I don't know the date of that report.

ASSEMBLYWOMAN EASTIN: And at no time did Caltrans submit to you a $300-500 million price tag for retrofit in California, did they?

MR. LEONARD: The answer is "no", but, Ms. Eastin, if I might say that they did submit to us a priority 1 project of $54 million, which was fully funded, a priority 2 of $64 million, which has been fully funded, but only $1.2 million has been let. And that's understandable because of the lead time necessary to get the projects going. I would make this observation just from my own seeking of information since the earthquake: I believe the $64 million is going to be much closer to $200-250 million. I say that, not in the sense of challenging the Department, but as they get their project reports back, I think they're finding that their retrofitting is more expensive than they originally believed it would be.

ASSEMBLYWOMAN EASTIN: Have you ever seen anything at Caltrans that wasn't? I'm not trying to make wrong here. What I am trying to do is say that, in the past, I'm not sure any of us have asked the right questions. But I think it's incumbent on all of us to ask the right questions now. We've had a terrible reminder of just how far behind our infrastructure needs are. While it's been sexy to go after the new construction, the new capacity projects and not so glamorous to go after the retrofit projects, it seems to me that ought to become a priority in California and that we ought to move as quickly as possible to fund that and to do so also with a sense of urgency. Clearly, by the fact that you've let $1.2 million, the fact that CTC was told that they could be advertising contracts as early as July 1, 1988, and here it is November 1989, it seems to me there isn't a sense of urgency. This has not been a high-priority project and really needs to be moved up in terms of the sense of urgency for all of California.

MR. LEONARD: Ms. Eastin, in all due respect, don't draw an erroneous conclusion. Looking at the chart, from '76 through '90, maintenance is pretty well leveled out, no change. Rehabilitation, which would include seismic retrofit, has actually increased for the last five-year cycle, '86-'90. The price of holding maintenance level and increasing rehabilitation has been by decreasing capital outlay almost $3 million.

ASSEMBLYWOMAN EASTIN: While I agree that we're spending a lot more money on rehabilitation than we historically did, I would still suggest that the Cypress points out, since it wasn't even on anyone's plate to do in the immediate future in terms of the kind of retrofit we would have needed, it seems to me that we do need to have a greater sense of urgency, more fire in our belly, if you will, about this issue, which has up to now not been a very interesting subject for a lot of people.

MR. LEONARD: I can't quarrel with that. I support it 100%. I feel certain the Commission supports your position on that also.

ASSEMBLYWOMAN EASTIN: Do you as a commissioner believe that the historic north/south split really is useful? We suspended it for purposes of earthquake reconstruction. Do you think it's useful in the long-term insofar as deciding how our resources should be spent, especially where issues of public safety are concerned?

MR. LEONARD: Ms. Eastin, that's a political question that you folks have to wrestle with. From a very technical standpoint, I think, and I speak for myself, I would like to repair what's needed or rehabilitate what's needed worst. I personally drive all of the highways of California, so the north/south split doesn't really turn me on. But I understand the pragmatic politics. That's an issue for you folks to wrestle with.

ASSEMBLYWOMAN EASTIN: The last thing I would ask is that I hope the CTC is planning on making a priority item the reconstruction of those freeways that are out of commission completely, specifically the Cypress Freeway. It would be a shame to see that project have to go through the normal eight-year waiting period that we see in the typical STIP project. I would hope that the CTC would support a policy change that would ensure, not just for the Cypress, but for any other such cataclysmic event in the future, that the total reconstruction would receive priority under state funding.

MR. LEONARD: I understand what you're saying and I, with no hesitancy whatsoever, would support that and I feel very comfortable that the entire Commission would support that position, particularly its chairman, Joe Duffel. Fortunately, he wasn't on the freeway. As a matter of fact, at the time, there were two commissioners that were awfully close to creating vacancies on our commission because of that catastrophe. It's a very sensitive, personal subject with the commissioners. I can assure you it will move forward with dispatch.

ASSEMBLYWOMAN EASTIN: Thank you very much, Mr. Leonard.

ASSEMBLYMAN COSTA: Thank you, Mr. Leonard. Hearing no further questions, we will take the next witness. Dr. Nigel Priestly, University of California from San Diego. Dr. Priestly must have left. We have Dr. David Rogers with Rogers/Pacific, Inc. of Pleasant Hill.

DR. J. DAVID ROGERS: Mr. Chairman, I had originally intended to show slides.

ASSEMBLYMAN COSTA: That would be rather difficult, I think. Why don't you try to be very visual in your description.

DR. ROGERS: Everything that I have to say is in the testimony outline.

ASSEMBLYMAN COSTA: Please sum it up, give us a briefing.

DR. ROGERS: Basically, I worked on preparing a dynamic analysis proposal on the structure while I was in graduate school at the University of California at Berkeley.

ASSEMBLYMAN COSTA: On which structure?

DR. ROGERS: On the Cypress structure -- 1977 and 1978.

ASSEMBLYMAN COSTA: This was a class project?

DR. ROGERS: No, this was an individual research project with Professor Jerome M. Raphael, the reinforced concrete expert. At that time, we identified a number of possible modes of failure of the structure. I've summarized those in my notes.

We were frustrated, at the time, with the paucity of data, especially structural site response spectra data from earthquakes. Basically, all we were using at that time was the 1940 El Centro quake and the new records that were developed from the Sylmar quake of 1971. We did not have the kind of data, strong motion instrumentation data, engineers need to use for the types of earthquakes we expected in the Bay Area. And indeed, when this quake hit, we see a great degree of variation in the types of ground shaking levels we got in downtown Oakland, about four times what we got in San Francisco, the same distance from epicenter. That was something to worry about ten years ago, and I think we're worrying about it now.

There are members of the Seismic Safety Commission, especially Drs. Clarence Allen and Bruce Bolt, who question using the maximum credible earthquake method. You start there, but it isn't going to tell you what level of shaking and structural response you're going to have in any one particular area. That's going to take another generation of earthquake engineering research, probably over the next ten or twenty years.

At the time I prepared the proposal -- you can see in there a cost of between $40,000 and around $100,000, depending on how many phases we had to do. The results of one phase give birth to the necessity or the non-necessity of going to the next phase. At that time, we learned there was no money set aside for the analysis of multi-column freeway structures, even though other major structures at that time were being analyzed by the Department, such as the Bay Bridge and the Golden Gate Bridge.

I've also put in the notes the observations about the earthquake, what we knew about the earthquake. The earthquake was not unexpected. That was the most powerful earthquake we were to have in the Bay Area. It had five times more probability than any other earthquake, and the area was exactly identified in reports prepared under the direction of the Seismic Safety Commission, or at their request, in 1984. I've referenced that in division 2. I've also put there a description of the styles and modes of failure seen on the site, a number of scaled engineer drawings. There's 19 figures in the back of the notes, and you could refer to that for further information. I'll defer from taking any more of your time. I'll be glad to answer any questions.

ASSEMBLYMAN COSTA: Thank you. Why do you think the Embarcadero Freeway, that is a multi-tier structure, appears to have withstood the affects of the quake in better condition than the Nimitz did?

DR. ROGERS: There's two figures I would refer you to in the back, figure 1, figure 2. Figure 1 is from our original 1978 proposal. It shows that the Cypress was a very long, linear structure, probably about 6,800 feet long. It's very straight shot. In straight structures, you can get earthquake waves, shown on the bottom of the figure, reverberating up the structure; and you have a different kind of structural response coming back through the structure so the waves can synchronize. If the waves become synchronous, you can get even much higher levels of vertical motion pounding up and down, which was not even appreciated until after the San Fernando earthquake in 1971. It was not appreciated, period. We were very frustrated. I spent about nine months trying to find vertical records, because we were worried about this mode of failure. You can see on the second deck in on that figure 1, we've drawn a circle around the bottom of the upper supporting columns. That was the area we were worried about in vertical shaking.

On figure 2, on the next page, you see the answer to your other question about the Embarcadero Freeway, the central freeway, the 280. Those structures are curved and they have a lot of ramp appendages. When you do that, you have some natural defense towards having these synchronous dynamic responses, because the earthquake energy wave is hitting the structure at a different point on the structure at any one time, so the waves don't ride up with each other and get reflecting with each other.

Lastly, we look at figure 7, probably the most important one. These are strong motion instrumentation results, a program that was installed in the state, the California Strong Motion Instrumentation Program, after the 1971 Sylmar quake. In there, you can see these are weighted vectors. These are the maximum horizontal accelerations. You can see that Oakland basically got hammered with respect to what level San Francisco got. This points to the fact that even though it's the same earthquake, the same epicenter, the same distance from epicenter, the ground response, the loads on the structures, are going to be very, very different, a five-fold difference across the same area here. So it depends what kind of geology you build your structure on and what the geometry of your structure is as to how it performs.

ASSEMBLYWOMAN EASTIN: Dr. Rogers, if you were sitting here, what would you say the public policy implications for California are, not just at the Cypress, but generally. If you were tomorrow elected to the State Legislature, what would you do to ensure we don't ever have to talk about another failure like this.

DR. ROGERS: Well, we're going to have other failures. It's like having rain records. We only have one record; it shows up about every ten years. Every time we have one of those, we learn a lot. What we've learned in Mexico City and in this earthquake is that you have to look at each site individually. A whole other generation of earthquake engineering research needs to be embarked upon that really looks at these geologic effects, what we call ground enhancement effects. That's very much going to be a concern of Los Angeles when you have a large earthquake because Los Angeles is a large Pleistocene Age basin. And those earthquake waves are going to reverberate through the softer sediments of the basin, and they're going to keel things over in Rolling Hills, Dominguez Hills, Torrance, that area. Actually, even though you're further away from the quake, those waves are going to reverberate down like they're in a big bathtub.

This is what happened in Mexico City in 1985, and it validated that group of people who had postulated this effect for a long time, the ground enhancement effect. That quake was 200 miles away, and it leveled every masonry structure 14-21 stories high.

So there's a type of structure that's going to be vulnerable, and there's a type of geological area that's going to be vulnerable. And just saying, "I'm this far from the quake; the maximum quake might be an 8.3," isn't going to be enough to prevent a large number of failures and collapses. I think we've been too smug in proximity. You say, "Well, I don't live on the San Andreas, so I'm not going to get hurt." This epicenter is down there in Watsonville, and it wipes out a freeway structure 100 kilometers away. It's the structure and the geology.

We really need to fund that and take it seriously. Earthquake engineering funding died when I was in graduate school. It just stopped, and we started hazardous waste in the 1980's. So I think every time you have a major quake, there's going to be new lessons. We don't have enough of them records-wise. The first strong motion data we ever had was El Centro in 1940. The second really was San Fernando because Park Field and Tehachapi were out in remote areas, and we didn't have accelographs in those areas to give us engineering data. See, the seismograph data doesn't help the design engineer. As Mr. Roberts pointed out, that just measures energy release. That's how we get a magnitude. Those magnitudes don't have a lot to do with what gets knocked down and what doesn't get knocked down.

ASSEMBLYWOMAN EASTIN: Would you be available to assist the Legislature in understanding how we should develop funding for that type of research?

DR. ROGERS: Sure, I'd be glad to, and I'm sure there's lots of other people even more well qualified than I am, people like Dr. Housen or Dr. Jennings.

ASSEMBLYWOMAN EASTIN: As I understand from your testimony -- I overheard on the radio in San Francisco that you in fact had a next-phase study for the Cypress, which was not funded by the State of California.

DR. ROGERS: That's correct.

ASSEMBLYWOMAN EASTIN: And you were not terribly surprised, as I understand it, that the Cypress went down.

DR. ROGERS: I was surprised at the amount of Cypress that went down. We were worried about especially bents 105 to 111 in the north end, and that's where the greatest damage was. That's the only section that went completely down. The rest of the failure was a partial collapse, just the top deck going onto the bottom deck. The bottom deck held. Only two bents, 105 and 106, did the entire structure go down as are evidence of pile caps breaking or foundation failure. That's what we were worried about in the '70's. The technology was there in the '70's, but the funding wasn't, to do the analysis. I think it's great that Caltrans is going to the consulting engineering community and getting that kind of help because I think we could really help each other out.

ASSEMBLYWOMAN EASTIN: So you would suggest there are other structures in California, based on what we know today, that are at least of concern to you as a professional?

DR. ROGERS: Yes, very much so. This data, this quake, really points this out. You're going to have to look at each area, a site-specific point of view, and spend a lot more time and money looking at the geology under that structure. If you look at figure 7, it will give you a real graphic representation. There's two stations not even a half mile from each other, Treasure Island and Yerba Buena. Treasure Island is part of Yerba Buena. It's a man-made fill, sand, done with hydraulic fill. You see one gets .06g; the other one gets .16g, almost three times as much. There is a proximity to the fault.

We have to reevaluate ground motion and ground enhancement effects, look at the sites with a lot more sophistication. That's going to happen with more records. This is going to be the most well-instrumented quake in United States history -- over 400 strong motion instruments in the net within 200 kilometers of the quake. And if Los Angeles ever has one, it's going to be even greater because they passed ordinances back in 1965 requiring three accelographs in every building over ten stories high. So Los Angeles is the most well-instrumented site, probably, in the United States if the not the world. Tokyo might be close.

CHAIRMAN KATZ: There's been some talk at one point about a kind of rat-tail affect at the end of an earthquake area. That's not the scientific term; that's what we used to call it in locker rooms when folks with towels would snap them. Is that valid? Is that just talk, or does something like that occur at the end of a seismic area?

DR. ROGERS: There are some new theories that were expounded upon about three or four years ago by a seismologist named Dr. Robert Naylor, who lives in San Francisco -- he used to be with the U.S. Geological Survey -- that waves are reflected down, go along the bottom of the crust, then come up to create damage zones 200 miles away.

There's a lot we still don't know. This type of quake was very different. It was 12 miles down. It was almost all vertical, 70 degree inclination with the Santa Cruz block going up. Beaches are going to rise toward the Santa Cruz side. And it petered out about four kilometers below the surface. So like the Whittier quake, it didn't even come up and break through the surface. What we have on the surface is just bridge spreading fractures due to the bridge being reverberated so much. We don't have a clean fault break like we had in 1906. It was a really different style of motion, but very well predicted with regard to what portion of the fault was going to go and how soon. That was the predicted quake event in that section of that fault.

CHAIRMAN KATZ: So to some extent you can identify what parts of faults are most likely to have events, and then also the kind of event as well? You said this is an unusual event since it was so deep. If someone had looked at this fault and made that kind of a judgment that there was going to be an activity, is there a likelihood they would have come up with this, but it wouldn't have been 12 miles deep and it wouldn't have looked like a vertical movement?

DR. ROGERS: The U.S. Geological Survey has had good survey creep nets on San Andreas, starting around Hollister and going down to Park Field. There was a large quake at Park Field in 1967. They've had a real good net down there. They had expected a quake. I can't speak for them about what style of movement they expected, but we have a section of the fault that's moving and creeping. And this section that moved was called a locked section, a section that wasn't exhibiting movement so that strain built up because there was movement south of it and there was movement north of it. What they can't do is tell you exactly what window the quake is going to occur in. I've studied these things for years, and I got pretty excited after about 20 seconds of shaking because I was resolved to die and never experience a large quake. That was a good probability. These things just don't happen that often. So the awareness isn't there until after the catastrophe happens.

CHAIRMAN KATZ: You don't mind if most of us hope that your big moment never comes. You might be disappointed; we'd all be very relieved.

DR. ROGERS: It'll come in L. A.

CHAIRMAN KATZ: But, as you say, geological windows being what they are, they're a little broader than windows that we're normally used to that term implying.

DR. ROGERS: Yes, we're just starting, even in the last ten years to really understand seismology more. There are large quakes that are going to occur in the Midwest, we know now. The largest fault in the United States runs between Charleston and Yellowstone. The largest quake in U.S. history was epicentered in New Madrid, Missouri in 1810. But those don't happen nearly as often as things on the San Andreas system. It's a very active system.

CHAIRMAN KATZ: If you were sitting where we were in terms of looking at freeways in Los Angeles, what would your thoughts be? Do you think freeways in Los Angeles are safe?

DR. ROGERS: Freeways or bridges?

CHAIRMAN KATZ: Bridges.

DR. ROGERS: You have to take a real hard look at bridges built, especially, before 1930. I was surprised to hear L.A. had so many of those. Just because it went through the 1933 quake at Newport/Inglewood -- that was sixteen miles off the coast. If the Newport/Inglewood moved closer to Baldwin Hills, you might not fare as well.

You have to remember the Cypress structure, when we were studying it, went through a very sizable earthquake right when it was being built. The last concrete and the last section had just been poured. On March 22, 1957, we had a 5.3 event, epicentered only 13 1/2 miles away, very close in. The structure got probably .1g, more than it was designed for. The concrete was wet; concrete gets stronger with age. The structure did fine.

You can get a false sense of security because you went through this quake or went through that quake. No two quakes are the same. You've got to look at every single structure, every single system with that kind of individual eye; and the maximum credible quake might not be the quake that knocks you down. This is what some members of the Seismic Safety Commission, Clarence Allen and Bruce Bolt, have been saying for years.

It sounds like the program Caltrans has devised is a real good one, but you need to fund it at a serious level where you can do the level of sophistication that is required. And that's a site specific -- because I find this or that in the San Fernando Valley doesn't mean it's going to work out at the 7 Interchange in Pomona.

CHAIRMAN KATZ: That, I assume also, is the reason you use a maximum credible earthquake standard, as opposed to saying 7.0 statewide or 8.0 statewide.

DR. ROGERS: MCE says what's the strongest event ever probable for that particular area; but that's just one acceleration, one shock load. It doesn't necessarily mean that the structure is going to be taken out by that one load. Again, duration gets in there, style of motion, up and down versus sideways, things like that.

CHAIRMAN KATZ: As I understand, Whittier Narrows was a new fault. What instructions do we give Caltrans to build freeways, build for the maximum credible earthquake, when it turns out that it's a new fault? You're going to assume that the maximum credible earthquake at some point was going to be 4 or 5, and no one knew the fault line was there. What do you do about that?

DR. ROGERS: San Fernando, Coalinga and Whittier Narrows were all faults that were previously unmapped, some of which didn't even break ground surface. If you go into an oil company's office, you're going to be amazed as a geologist. You're going to find out that 90% of the faults don't break the surface. So we say there's 112-120 active faults in California. That's about 10% of the active faults in California, most likely. The maximum credible event -- what it does is say, will a large event close in on the Newport/Inglewood load my structure worse than a far away event on the Garlock or the San Andreas? You look at those things, and you decide which one's going to put a greater load, a longer load. And the maximum event might be the San Andreas one. Most of L.A., it is, even though it's not as close to other faults, like the Raymond fault, Pasadena, and the Newport/Inglewood. So the MCE is the term to say, of all these faults we can choose from, we're going to choose a big event and hope that designing for that will hold us up in the smaller unforeseen ones like Whittier Narrows.

ASSEMBLYMAN EAVES: I think I want to get back to what you said that Caltrans' program was in the right direction and they needed to do this site-specific; but realistically, if there's 7,000 bridges in Caltrans' system and x-amount wherever, what are we talking about if we're going to look at each one of those individually in the way of dollars? Again, it's this thing that you can design bridges with zero risk if you can afford to do that. When you're starting to retrofit 7,000 bridges, you can't just say, "Here's the standard. We're going to build bridges statewide." What you're saying is you have to do that; and in addition to that, then you have to specifically design them for the location they're at, based on all these varying factors. Could you give me some idea whether it's realistic to think that we can in fact look at all of these bridges, site-specific, or is that something that would be nice if we had unlimited funds?

DR. ROGERS: Following the 1971 Sylmar quake, Caltrans contracted with the Division of Mines and Geology to produce a statewide map showing what the maximum base rock accelerations would be. They contracted for another more detailed map two years ago. That's out now. They map in zones. So the maximum credible bedrock acceleration might be .5g in a whole zone belt through the San Fernando Valley, say. Then they have to take that data and look at the geologic column and see will that bedrock acceleration be amplified in this location or will it be dampened in this location. We see a lot of enhancement and dampening figures in the earthquake. Basically, you try to design for the biggest acceleration which you think is possible over a broad area. So they may have several hundred bridges in the same seismic zone that they design or check or analyze with the same ground loading factor. And that's fine, as long as those loading factors are realistic. If you look at my notes, I put in there a section of what we knew about the Cypress area before this quake; and the ground shaking factors were .5g bedrock, which would give us .2g to .35g, and we got about .28g. The knowledge was there and the quake was within the window of the maximum credible earthquake, so that would tend to validate Caltrans' approach. They just hadn't gotten to that particular structure yet.

CHAIRMAN KATZ: Ms. Hansen, and then Ms. Eastin.

ASSEMBLYWOMAN BEV HANSEN: Thank you for your testimony. It was really informative. I lived in the north bay up in the Santa Rosa area. We experienced quite an earthquake in 1969. I'm real concerned about our overpasses in that area, because they say that we're going to the 8.0-8.2 quake. Is that right?

DR. ROGERS: Well, and Santa Rosa got leveled in 1906.

ASSEMBLYWOMAN HANSEN: Right, they talk about the San Francisco quake, but Santa Rosa was totally leveled during the '06 quake.

DR. ROGERS: Santa Rosa was closer to the epicenter.

ASSEMBLYWOMAN HANSEN: Given the maps that we know and knew prior to this quake, were they fairly accurate now that we're looking at the numbers? This map in front of us, giving the g's -- was it fairly accurate? Did we have a good idea where the strength was going to be?

DR. ROGERS: No. We had no idea we were going to get this kind of distribution. But in design, we look at the MCE event, the maximum credible event, of Cypress. It was a magnitude 7.5 on the Hayward four miles away. If you design for that, that's so overwhelming that something from 100 kilometers away actually is less than that. No, we can't predict exactly how the ground is going to shake in any one area, so we have to pick a big number and see if we can work with that.

ASSEMBLYWOMAN HANSEN: You talked about the problem with bridges and structures built before the 1930's. If you took another date that would be dangerous, going from 1930, where would you place that one?

DR. ROGERS: 1973. Anything before 1973 were using the El Centro records. That's what the designers for Cypress used. That's what we used when I was in college. That was the only good site response spectra we had because it was the first site that had an accelograph on it. The accelograph was born at Cal Tech right about that time, in the late '30's. The seismograph was invented in the mid-1930's by Richter. The first seismograph record we have is the 1933 earthquake in Long Beach. The first accelograph data we have is 1940 at El Centro. At the other quakes I have mentioned, like Tehachapi, which was a 7.6 in July 1952, we didn't have any strong motion instruments up in that area; and two major railroads, Santa Fe and Southern Pacific, got leveled in that quake. They were out of commission for weeks.

ASSEMBLYWOMAN HANSEN: The information that we get from this quake -- is it going to be very helpful in building the next level of technology and the maps that we need to draw from this point forward?

DR. ROGERS: You bet, because we did get at least a San Andreas event. It wasn't a major San Andreas event. It was only a moderate one, and we have 400 instruments. In 1940, we had three. We have 400 instruments that are close in to the quake. It's going to give us a lot more data to work with and synthesize from loading the structure to the style of loading. When I was in graduate school, we were really frustrated by that, even going after this proposal, just a paucity of data out there to use in predicting. It just wasn't much.

ASSEMBLYWOMAN HANSEN: Thank you.

CHAIRMAN KATZ: Ms. Eastin.

ASSEMBLYWOMAN EASTIN: Just one more quick question, and I, too, want to express my gratitude because you are very knowledgeable and you speak English. For those of us who are not engineers, it's most appreciated.

You know, we're better off than Armenia and Mexico City. I think that's fair to say; but I've heard said, and I don't know much about it, that the Japanese have moved to the next generation of planning for earthquakes. Would you speak of that just briefly.

DR. ROGERS: Sure, anybody that works in earthquake engineering goes to Japan. Japan has, on the average, one earthquake per day. They're right on a quake boundary, between the Eurasian plate and the Pacific plate, a very tectonic reactive area. They've had the most people ever killed in an earthquake in this century. In 1922 in Tokyo, several hundred thousand people were killed. That's the first place where earthquake-resistant design starts. It starts in about 1924, emanating out of Tokyo; and it picks up over here at Carnegie Institute, which became Cal Tech, just a few years later, if you go back to the earliest literature. They were the first to apply earthquake loads to structures after that devastating 1922 earthquake.

The Japanese have funded enormous amounts of money -- the government has -- in earthquake research. They have one firm over there that's put more money in earthquake research -- company, now, that's donated -- than the entire United States of America budget, including California. They have a lot more to lose. You have to realize that Tokyo surpassed Los Angeles as the largest metropolitan area in the world at 29 million people in Tokyo, and they have very high probabilities of having a major quake in the next half century. We'll see how they do. They've put a lot more money into it, and they've had a lot more deaths than we've ever had. We've been extremely lucky, in '71, Sylmar, and this last quake, when you look at how many people were on the highways and the Norman Reservoir was only less than two feet from breaking. We could have had a lot more deaths. Someone is watching over us up there.

CHAIRMAN KATZ: Good, thank you very much.

Before I bring up Dr. Iwan, I'd like to ask Councilman Holden to come forward. He's the chairman of transportation.

COUNCILMAN NAT HOLDEN: Thank you very much, Mr. Katz. I'm very glad that you're holding this hearing. I just want to share with you just briefly information that I was able acquire about two weeks ago when I had a hearing on the very same subject as it relates to I-105, the Harbor Freeway. The community felt that this construction going on right now was going to be double-decked, but it was not going to be double-decked. It was going to be an elevated freeway. They wanted to know whether or not it would be safe and would withstand the highest magnitude of an earthquake in this general area.

We had come back to discuss this subject matter with us, Mr. Sammy Newel, who is the chief of the Office of Structural Design, Mr. James Gates, who is the Structural Mechanical Engineer in the Seismic Analysis Division, Caltrans, and Mr. C. J. O'Connell, the Deputy District Director of I-105 Project Management.

We learned quite a bit. In fact, I think people who were in the room and heard the testimony -- their confidence level was raised. For example, we talked about the fact that the columns that are going to be elevated on I-105 will go 70 feet into the ground. The I-105 is being separated, has been expanded on each side, building a new lane on each side, which would maintain the same traffic flow that we have right now, which you're all familiar with. It's designed for a g-force of about .5 at the base.

We talked about what maximum earthquake they thought that the elevated freeway could stand. The problem they thought would give us the most g-force would come from the Inglewood Fault. The Inglewood Fault is adjacent to that area; and it is designed site specific, which you probably heard a lot about today. The San Andreas fault would generate about a 7 or 8 on the Richter Scale, and the Inglewood Fault about a 7. So they figured a worst-case situation developing from the maximum number at the Inglewood fault. And that's where we are. But I'm satisfied that this perhaps will be a good design, given further that the experts who have testified before the Committee have already put together a blue ribbon committee of scientists throughout the State of California to review their design from the standpoint of the standards and design criteria that have been set. So they can report back after their complete viewing of findings. In about six weeks, they will share that information with us. I might say, however, that they went on to say that on the freeway elevations that were built prior to the earthquake in 1971, phase 1 retrofit is complete. Phase 2 yet has to be done, which is another technique using a sleeve in order to increase the safety factor.

The problem is that the money is not available to do all of this work simultaneously, so we're going to be counting on you and the other members of the Legislature to put up enough money so they can do their job completely. What they need for us to do at the local level is to allow them to close down some streets in order to take care of the retrofitting. That which we can do we will do. We made that commitment to Caltrans. But what we will need is the money.

I'm satisfied with the elevation that we have going down I-105. I think it's going to be OK. They think it's going to be OK. Based on the information given by the members of the committee, we will await with anticipation the report from the experts. The Caltrans team have strong reason to believe, however, that their design criteria will be validated by this new blue ribbon commission. That's where we stand; I just wanted to share that information with you.

CHAIRMAN KATZ: Councilman, I appreciate it, and we will work with you. As you know, the Governor signed the $320 million yesterday. That's a start. We will work closely with you and try to come up with the rest of what's needed for the city and work out a way to do that. Thank you very much.

I'd like to call Dr. Bill Iwan, who is a member of the Seismic Safety Commission. I appreciate your hanging in with us. After Dr. Iwan, we have Mr. Noyes from the County of Los Angeles to give a county perspective.

DR. WILFRED IWAN: Thank you, Chairman Katz and committee members, for giving me the opportunity to address the Committee on behalf of the Seismic Safety Commission. My name is Wilfred Iwan. I'm a member of the Commission. I'm also a faculty member at Cal Tech. I'd like to give you some prepared remarks. I'll try to abbreviate them due to the lateness of the hour and just make the main points of what we wanted to say.

Each strong motion earthquake that we experience is a full-scale real live test of our engineered structures. And somehow that test always seems to find the flaws and the weak links in the structures. In past earthquakes, we have seen very graphically that unreinforced masonry structures, both bearing wall and non-bearing wall, underreinforced structures, structures with soft first floors, inadequately tied tilt-up structures, mobilehomes, houses that are not tied to their foundations represent a significant seismic hazard.

In the 1971 San Fernando earthquake -- we've referenced many times the year 1971 -- we saw that there were some flaws in the design of the highway structures and, in fact, that the current design codes and practices were not adequate. As a result, many programs of retrofit were begun. We've heard reports on what Caltrans has been doing since that time.

On October 17, we learned some of the old lessons from past earthquakes, learned a few new lessons, but unfortunately, the lessons that we relearned were the difficult ones. We saw again that unreinforced masonry buildings were in terrible shape because of ground shaking. And we learned again that the highway structures were still hazardous, not only the structures that were known to be hazardous, but some of those even newer structures that experienced some distress. And now it's a sad thing that we find that most of the lessons that we learned in this earthquake are lessons that we probably should have learned in earlier earthquakes.

We've heard much this morning about the Cypress viaduct structure, and certainly the collapse of that structure, and the associated loss of life, tells us that we still have a long way to go in achieving an adequate level of seismic safety for the State of California.

We knew in 1971 that we had a problem with our highway structures. We knew that the codes that existed at that time were inadequate. Yes, steps were taken to correct those deficiencies, but now 18 years later we find that we still have not taken adequate steps to correct this problem. From the seismic safety policy point of view, this is simply unacceptable.

The highway structures were clearly a problem in this last earthquake, but I think it's important we put that problem in perspective and in the proper context. First of all, the highway system in California is only one part of the overall transportation system of the state, which includes not only highways but also rail transportation, air, sea, and even pipe lines. I think we need to realize that that's an interdependent system and that the failure of any one element of that system will effect the other elements as well. We should be just as concerned, and I'm sure that this committee will be as concerned, with the failure of a control tower at SFO or backup electrical generators at that airport, as well as damage to a runway in Oakland that shortens the runway. We see these kinds of failures for an earthquake which really had levels of ground shaking, particularly at SFO, which were not very large. And it leads one to wonder what types of damage we might experience at these other transportation systems with the groundshaking larger. We must also look at rail transportation, at docks, piers, and other forms of transportation. So the first point is that we must realize that the highway system is only one element of our overall state transportation system.

We also need to realize that the transportation system itself is only one element of our aging infrastructure statewide, which needs a great deal of attention in order to make it seismically safe. This ranges from unreinforced masonry buildings, of which we have a great number in the state, to unreinforced buildings of various heights, under-reinforced buildings, including many state-owned buildings. This represents a serious problem.

We also have potentially hazardous dam structures. It's the total of all these problems that we need to be addressing, and it's within that context that we see that the highway problem is a particularly perplexing problem because it's only one facet of a much larger issue. The Seismic Safety Commission has learned that the seismic safety program needs to have three elements, which are essential. One is an identification program, another is an effective mitigation plan or strategy, and the third is an action plan.

First comes identification. We need a program that would identify the weak links in our infrastructure. In every case of an earthquake that we've experienced, there is usually a surprise. We find there was some element that was not as strong as it should have been. That's not acceptable. We need to be able to identify those elements of our infrastructure which are weak and which need to be strengthened. The Cypress structure has been identified now by nearly everyone who has looked at it as a very weak structure. Many people have also asked the question: Why wasn't this structure identified previously as a weak structure? Were we blinded by accepted practice? Have we been asking the wrong questions? Have we been asking the wrong people? Why can't we identify hazardous structures?

I don't mean to be judgmental in that regard. I think it's a very difficult problem, but it's a problem that we must resolve. We must find thorough and effective techniques for the identification of hazards, and we may need to do this on more than just classes of structure. We may need to identify specific structures, individual structures, that are hazardous. One of the problems I think we had to date is that we've tended to categorize structures as being hazardous, and that's making it difficult to prioritize the greatest hazards. If we can get to the place where we can identify hazardous structures more specifically, it will be easier then to prioritize just which structures need to be addressed first, whether they be highway structures, airport structures, or building structures.

I think it's interesting to note that as part of Mr. Roberts' testimony, he indicated that two major universities completed studies of the Cypress structure within less than three weeks after the event and that these studies indicated that there was a strong probability of collapse with an acceleration level of .17g. One wonders then how difficult it would have been to have determined this prior to the earthquake. I know that hindsight is 100%; but these questions, I think, need to be asked.

The second element we need is a strong, ambitious plan for mitigation. Caltrans has and has had such a mitigation plan involving, as we've heard, the various phases of retrofit for the structures. This strategy tended to treat those structures on a general basis as a class, not specifically or individually; and perhaps it's time that we need to look more carefully at the individual structures and their specific nature, the nature of the local site and so on, rather than just on a code basis. As one of the committee members indicated during this hearing, he wondered what would have happened if a group of experts had been asked to look specifically at the Cypress structure to see what needed to be done to that structure to make it seismically safe, rather than applying the phase 1 retrofit to that structure, which was developed for really a different type of engineered structure. We must come up with effective mitigation strategies, even if it requires, I believe, a case-by-case analysis of some important structures. If we don't have the technology, we need to develop that technology.

Third, we need an action plan; and this is, of course, a very difficult part because it involves money. We simply cannot wait another 18 years to solve the highway problems or other seismic safety problems that we know we have in the state. We must find ways to move ahead more quickly. I believe this is going to cost a great deal of money. A site that could cost tens of millions of dollars is going to cost hundreds of millions of dollars, probably is going to cost us billions of dollars to do the job right. That's a lot of money, but we have a choice. We can either spend some money now, or we can defer that and spend a lot more money in the future. It's clear that there has not in the past been the commitment to the kinds of funding that we need to really make a significant impact on seismic safety. This is partly a problem of public apathy, and maybe it's a problem with those of us who are pushing seismic safety. Maybe we have not been good enough advocates, but we need to do a better job. We need to find ways to fund it. Unfortunately, I can't think of a way to fund public structure retrofits, except with public money. And that's going to be a problem. In the private sector, though, we can be more creative. We can try to find methods which will provide incentives for private individuals to do the retrofitting that needs to be done of many of our private structures.

One way to speed up the process may be to let the citizens of California know what enormous cost is involved for not doing something. The Seismic Safety Commission has, as part of its five-year seismic safety plan, an element to determine the true economic cost of a significant earthquake in California. And that's not just the cost of rebuilding freeways or rebuilding buildings, but it's the cost of unemployment, dislocation, the problems of lost productivity, which we think will be very, very substantial. The Commission has never been able to get this particular study carried out.

Finally, I would just like to mention two things that the Commission has found to be central to the whole process of identification and mitigation. These are research and independent review. We've heard a great deal about research this morning, and I'm pleased that that's the case. Research provides the basis for safe, economical, and efficient design and retrofit of structures. I'm very happy to see that Mr. Best expressed a commitment to research. California has traditionally led the nation, and some feel the world, in seismic safety research. However, most of the support for this research has come from the federal government; and recently, quite frankly, that support has waned. We are now receiving less research monies than we have in the past, and our research programs in California universities are severely impacted. The State of California simply must take a stronger role in seismic safety research if we are to solve our seismic safety problems. We are going to need to work hand in hand with research and education. We can do many things in research; but unless we educate the next generation of researchers, we will lose that capability. Right now, many of our programs in California are shrinking. We're not educating the scientists and engineers as we did in the past. I'm concerned at what's going to happen in years to come if we don't have the basis of educated scientists and engineers to tackle the problems that we face.

The next thing I would like to briefly mention is the idea of independent review. The Commission has found that this is a very important element of any seismic safety program. Again, I am pleased with the statements that have been made and actions that have been taken by Caltrans in this regard. We need independent review to assure a high level of seismic safety and design in construction. The use of independent review is not a sign of weakness or inadequacy on the part of the organization using this approach. On the contrary, it's a prudent thing to do and shows a desire to do the best possible job. We applaud the steps that Caltrans has taken to review past and present plans for highway structures, and we hope that this emphasis on independent review will continue. We think this is an extremely important part of the program.

I might just add a side note, a technical note, to comment on some of the previous comments. Mr. Roberts commented that there's no direct relationship between the Richter magnitude of an earthquake and the peak acceleration that can be experienced at a particular site. I would like to also indicate that research has found that there is no direct correlation between the peak acceleration experienced at a site and the damage to a structure. This is a very complex, technical problem, and the damage involves such things as the frequency content of the acceleration. It also involves the duration of the acceleration, and it may even involve the number of times the particular structure has been subjected to shaking. In fact, damage may be accumulative. These are all questions that we need to look at. They are research issues which need to be addressed.

In conclusion, I would like to plead that we do not treat the lessons of the October 17, 1989 earthquake as we treated the lessons of the 1971 San Fernando earthquake. At that time, we clearly saw the problems with our highway structures and with many other structures that we were building. We didn't solve those problems for eighteen years, and they came back to haunt us last month. It won't be easy, but we must find the commitment and the resources to fix the system now. We can't afford to wait any longer.

Thank you. I'd be happy to answer any questions.

ASSEMBLYWOMAN EASTIN: Have you in the past had as your charter giving us a figure for retrofit and for replacement?

DR. IWAN: No, we have not.

ASSEMBLYWOMAN EASTIN: Do you require legislation to give you that charter at this time?

DR. IWAN: I don't know if it would require legislation. We probably could try to put together those kind of figures without that legislation. I think it's not something that we ever have even been asked to do.

ASSEMBLYWOMAN EASTIN: I don't think any of us want to see this politically driven. We don't want anybody to tell us what we want to hear, because it's a nice, low number. We need to fully understand what the problems are in this state and go about finding the resources to fix them. I don't know what those all are. It might be a whole host of different ways. But if we don't have a target -- someone once said it's better to set your target too high and miss it, instead of too low and hit it. California has been more or less saying that it's been setting its sights too low and hitting it. But I think we need your help to understand the scope of the problem.

DR. IWAN: I certainly would like to do that; and as I say, I'm afraid that when we write the bottom line, it's going to be a very large number. It's going to be in the billions of dollars.

ASSEMBLYWOMAN EASTIN: At the Senate hearing, Mr. Best apparently -- the Bee reported -- said that after a survey, as the state stands, Caltrans concluded about the state's bridges that none is at a risk of collapse in what is known as a maximum credible earthquake. That is not your testimony today, is it?

DR. IWAN: I'm really not testifying on the details of the engineering analysis of any particular bridge. I'm not capable of doing that because I haven't reviewed each one of those bridges. I feel that we were very fortunate in the earthquake that occurred on October 17 that the ground shaking in the area that severely damaged the freeway structures was not really as high as it could have been. I think we need to continuually remind ourselves of that. Just because certain structures there did not collapse with this kind of ground shaking, doesn't mean that we would consider them to be seismically safe. The ground shaking there could have been more like it was in Santa Cruz, and I think we would have seen something much more severe.

ASSEMBLYWOMAN EASTIN: I guess the thing I would say is, when we use these large numbers -- Caltrans today used $300-500 million, which -- I would question that figure because Caltrans does tend to give us low numbers on all their early estimates. But the bottom line is the repair of the freeways in California just from this moderate earthquake will be three or four or five or six times that. If we just took the money we're going to spend right now to clean up after our messes and spend it on retrofit, redesign and replacement, I think we'd be money ahead over what we'll have to pay if go through another earthquake.

DR. IWAN: We absolutely agree. We feel that the money that we spend now, although it may be high, will save enormous amounts of money in the long-run when we have to try and clean up the mess that we created.

ASSEMBLYWOMAN EASTIN: But the specialists are going to have to stand up to the real reality. You guys are going to have to say that the bridges are going to fall down. Everybody's so nice, you know. Everybody's being very nice, and nobody really wants to say that this is going to happen. And we do spend the money after the earthquake and say, gosh, we should have known that thing was going to fall down. But apparently there were graduate students ten years ago and more that had some concern that parts of it would fail. Maybe they didn't realize it would be as cataclysmic as it was. But I guess what I'm getting at is, we all have to muscle up; and if the people at the top, even the people who appoint you, say they don't want to hear the answer, I still believe that you all have to give us the answer.

DR. IWAN: We agree with that, and it goes back to what we said first. It's that question of identification; it's a very important one. Right now we tend to identify things in rather broad categories and probablistically. It will take more money, but maybe we need to start looking at specific structures and try to identify those that are hazardous.

ASSEMBLYWOMAN EASTIN: But if you only speak in probablistic terms and in engineering terms, then we will not be able to convey the realities of what we're talking about when you see the Cypress close up. So, at some point everybody's going to have to come step to the plate and say, "All right, this is my turn at bat." I have to say, I really believe that, to some extent, this is a measure of failure of the scientific community, the state bureaucracy, and the state policy makers. It was hear no evil, see no evil, and speak no evil. So, in fact, if we are going to fund these things, somebody is going to have to put it into English and not say, "Well, none of these bridges is ever going to fall down," because the truth is that we clearly know some of them are capable of falling down.

DR. IWAN: That's correct. I'm sure the Commission will try to make that point as forcefully as possible, and try to give you the information that you requested.

CHAIRMAN KATZ: I appreciate it. Thank you.

The next witness is Jim Noyes from the County of Los Angeles. One of the things that comes out of this, though, something we need to think about, is we tend to rate everything within categories. You prioritize based on seismic safety, then you prioritize based on water quality, and prioritize based on hazardous materials; and the lowest funded project on hazardous materials may be a lesser risk than something that's not getting funded on the seismic list. They're all different lists kept in different departments and different agencies.

ASSEMBLYWOMAN EASTIN: And it becomes very topical. That's really what I was getting at with Dr. Iwan. I really believe that we have to begin to frame these issues in a way that the public and the policy makers can both understand. There aren't many of us who really get it until you guys translate it for us.

CHAIRMAN KATZ: Let me ask the County of Los Angeles to briefly translate it for us.

MR. JIM NOYES: Mr. Chairman, I am Jim Noyes, Deputy Director, Los Angeles County Department of Public Works. I just have a very brief supplement to what Mr. Horii told you this morning about what the rest of this town looks like with respect to its bridges.

Our department routinely inspects 1,435 bridges. Five hundred forty of these are in the unincorporated area, with the remaining 895 in 81 cities in this county. We have 134 of those bridges that are supported by columns that were built since bridge design criteria were strengthened in 1972. Because of what happened up in San Francisco and Oakland with the Nimitz Freeway, we have begun a review of those bridges because of the fact that they are supported by columns. We estimate it could cost as much as $50 million to retrofit those 134 bridges.

CHAIRMAN KATZ: How about before '71.

MR. NOYES: That's what I'm saying. These 134 are pre-1971 bridges. Forty-six is the number that have been built since that time, built to a higher standard.

CHAIRMAN KATZ: I know the county until recently had done all the inspections for the smaller cities as well. I understand that's slowly but surely going back to the cities.

MR. NOYES: Correct. For these 134 bridges, a portion of those are in the cities; and we are notifying the cities of our concern about these kinds of bridges.

CHAIRMAN KATZ: So you're essentially talking about everything other than the City of Los Angeles at this point.

MR. NOYES: There are also seven other cities that we do not do bridge inspections for. We will have to notify them somehow of our concerns.

CHAIRMAN KATZ: Which are those?

MR. NOYES: I have a list in my briefcase.

CHAIRMAN KATZ: So we've got $250 million roughly in the County of Los Angeles with four or five smaller cities yet to be heard from.

MR. NOYES: Correct.

CHAIRMAN KATZ: That helps put that $20 million we got for local assistance in perspective. Thank you very much.

I don't know if Mr. Marsh is still here. Do you want to make a brief summary, Mr. Marsh?

MR. JAMES W. MARSH: Mr. Chairman, ladies. I'm Jim Marsh, Regional Engineer with the American Institute of Steel Construction. I don't know if you realize that at the end of World War II, probably 95% of the bridges in this state were steel-framed. By now, it's just the reverse; 95% are concrete. Conversely, we look at high-rise buildings. Today, 95% of the high-rise are steel-framed. This isn't by accident. I think, if you talk to any structural engineer today who's designing high-rise, he'll say he has a greater confidence in the material with the ability to absorb the energy. But what took place in this period of 40-45 years is very interesting in the sense that I think Caltrans became locked in on the bottom line of the cost per square foot of the concrete, and so they gradually transitioned over into that and left this state without one fabricator in the steel bridge business any longer. In the '50's, there were probably six still in existence, Pacific Murphy up in the Bay Area which designed and erected some of the bridges up there and the Coronado Bridge in San Pedro.

What I'm getting at is this: I think the time has come for Caltrans to start shifting their views and looking at all of the designs again. As you know, you cannot do one development without getting an environmental impact report. I think it would be good if Caltrans were to, say, not only use all the designs, which would give you the present cost which they've been locked into before, but say, let's look at the total cost of all these designs, whether it be steel, concrete or composite systems. Look at the maintenance cost through the life of the structure and then add to that the retrofit cost, the site-specific earthquake near that bridge and say, what is that going to cost if this bridge is of steel or if this bridge is of concrete? What is it going to cost in time, dollars and everything else to the public for that bridge in the long run? Maybe we can get a little different design than we are experiencing today in the bridge field.

CHAIRMAN KATZ: All right. Thank you very much. Anybody else? Members, thank you, and I appreciate people in the audience who stuck around and participated in the hearing. Thank you.

STAFF REPORT

ASSEMBLY TRANSPORTATION COMMITTEE
INTERIM HEARING ON
THE SEISMIC SAFETY OF CALIFORNIA'S FREEWAY SYSTEM

November 7, 1989
Los Angeles, California

INTRODUCTION

The collapse of a major portion of the Cypress viaduct of the Nimitz Freeway (Route 880) during the October 17 Loma Prieta Earthquake has focused the attention of the Legislature on the structural integrity of thousands of bridges statewide, particularly those located in high-risk earthquake areas, such as the San Francisco Bay Area and the Los Angeles area.

That freeway structures (which include diverse facilities such as overpasses, interchange flyovers, doubledeck roadways, and "conventional" bridges) could be threatened by a major earthquake was confirmed during the February 1971 Sylmar quake which caused substantial damage to a number of highway facilities. The need to improve structural engineering practices for new facilities was recognized, as was the need to "retrofit" existing ones.

Phase I Retrofit Program

The Department of Transportation (Caltrans) developed the so-called "Phase I Retrofit" Program based on what it learned from the 1971 Sylmar earthquake. In essence, the Phase I program generally involved tying together bridge decks with supporting columns using cables, to avoid separation and collapse that might occur during an earthquake. A structure would still have flexibility to move, but the amount of motion would be constrained within acceptable parameters.

Ultimately it would take until 1987 (16 years) for Caltrans to complete Phase I retrofits as part of the Highway Rehabilitation program. Information obtained from Caltrans indicates 1,262 structures were retrofitted, at a cost of $54.2 million ($47.3 million on state highways, and $6.9 million on toll bridges). At an average expenditure of approximately $3.4 million per year, Phase I could not have been considered a major financial burden on the highway program.

Just to take one year as a representative example, in 1983-84, total state highway resources were in excess of $1.8 billion, of which $413 million was allocated to highway maintenance and another $350 million was allocated to highway rehabilitation (support and capital outlay). An additional $70 million was budgeted during that year for safety capital outlay projects, to be spent on high-priority projects forecasted to reduce accidents and reduce the state's liability exposure. As part of the process of prioritizing capital outlay projects each year through the STIP (State Transportation Improvement Program) process, the California Transportation Commission and Caltrans first set aside funds for maintenance, rehabilitation, and safety before programming most remaining resources for new construction.

Phase I, as its name implies, was not viewed as the end to seismic retrofitting. Caltrans engineers were also concerned that bridge columns could fail in the event of an earthquake, resulting in bridge collapse. The Phase I solution was primarily designed to tie bridge superstructures together at hinges and supports, but would do little if bridge columns sheared and collapsed.

Caltrans has offered two explanations for deferring action on column failure: first, columns performed well during the 1971 Sylmar Quake, and second, developing engineering solutions for column retrofits was more of a challenge than the Phase I program. To assist in research and development, a $418,000 contract was awarded to the University of California, San Diego, late in 1987.

The Whittier Earthquake and Phase II

The Whittier Earthquake of October 1, 1987 provided a new impetus to "get moving" on Phase II. The focus was on the damaged Route 605/5 interchange in Los Angeles County, where Phase I improvements averted a major collapse but where columns were found to be vulnerable. According to a October 19, 1987 Caltrans memo, "if this structure had been supported on single column bents, rather than the 5-column bent, it probably would have collapsed" (Memo of W.E. Schaefer, Deputy Director, Project Development to Caltrans Director Leo Trombatore). Phase II, then, was to be a retrofit program for single-column structures consisting of steel jackets surrounding weak columns; later, Phase III was conceptualized (but has yet to be developed) as a retrofit program for multi-column structures -- such as the ill-fated Nimitz freeway.

In late 1987, Caltrans requested the California Transportation Commission (CTC) to set aside $64 million for Phase II retrofits over a four-year period (an average of $16 million per year), and anticipated that, "contracts can be advertised as early as July 1, 1988." (Memo of W. E. Schaefer, Op. cit). While the CTC agreed and approved this funding level, Caltrans did not submit any projects for funding in 1988-89. In the current year (89-90), Caltrans has had only two projects (total cost: $1.2 million) ready to go as of last month ($724,000 for the Route 57/60 interchange in the City of Industry, and $433,000 for the Route 405/710 interchange in Long Beach). The CTC advises that an additional $1 million will be requested in December. Thereafter, the next group of Phase II retrofit projects is unlikely to be ready "for advertisement" until the summer of 1990. The delay in this project schedule has been questioned.

The cost estimates to complete Phase II have also risen sharply. Caltrans has identified approximately 700 structures requiring a Phase II retrofit; it is now clear that the 100 largest projects alone will consume the $64 million originally requested for the entire Phase II program.

Phase III - No Engineering Solution In Sight?

Phase III, as conceptualized, was to retrofit bridges with multiple-column supports, such as the double-deck sections of the Nimitz Freeway (Route 880) in Oakland, and the Embarcadero Freeway (Route 480), the Southern Freeway Extension (Route 280), and the Central Freeway (Route 101) in San Francisco. Portions of the San Francisco double-deck structures were severely damaged during the Loma Prieta Earthquake, and it is not yet clear that all of these structures can be repaired or when they will reopen. Most of these structures are on relatively unstable Bay fill. Caltrans officials, responding to post-earthquake inquiries as to why this phase was not yet underway, stated that appropriate engineering solutions have not been developed.

Most attention has been focused on the state highway system. There are also many older bridges owned by local agencies; the City of Los Angeles alone is responsible for 416 bridges and is developing a $112 million seismic upgrade program at this time.

Special Session Developments

At the just-concluded special session, the Legislature approved AB 38X and SB 36X, which provide emergency funding for an accelerated statewide bridge seismic assessment and retrofit program. The temporary sales tax will provide $80 million in state funds: $60 million to match an additional $240 million in federal funds for the state highway system and $20 million for local agencies for a total of $320 million, with highest priority given to assessment of retrofit needs (including local road, rail transit, and pedestrian bridges). To highlight the importance of this issue and to guard against fund diversion for other highway purposes, these new revenues will be deposited in a newly-created separate account, the Seismic Safety Retrofit Account in the State Transportation Fund. While Caltrans will seek federal matching funds, additional state resources will undoubtedly be needed as well to reassure the people of California that our bridges are as safe as engineers can make them.

LOS ANGELES DEPARTMENT
OF PUBLIC WORKS

ADOPTED BY THE BOARD OF
PUBLIC WORKS OF THE CITY
of Los Angeles, California
AND REFERRED TO THE MAYOR
NOV 8 1989
AND REFERRED TO THE CITY COUNCIL

J.A. Gibson
Secretary

DEPARTMENT OF PUBLIC WORKS

BUREAU OF ENGINEERING
REPORT NO. 1, Section 1

November 3, 1989
CD# ALL

SEISMIC STRENGTHENING OF EXISTING BRIDGES

RECOMMENDATIONS

Adopt this report and forward it to the Mayor and City Council requesting that:

1. Appropriate action be taken to provide funding for the strengthening of existing City bridges to provide protection against major seismic episodes, with an estimated cost of $150,000,000.

2. Authorize the addition of 15 structural engineering and geologist positions in the Bureau of Engineering to do the necessary design work and that $350,000 be appropriated from salary savings to fund these positions for the balance of the fiscal year.

3. Authorize the Bureau to issue Requests for Proposals (RFPs) for the hiring of consultants to assist the Bureau in analysis and design preparation. Funding for the work to be included in the 1990-91 budget.

4. Authorize $2,100,000 for accelerating the design completion and construction of the restrainer program.

TRANSMITTALS

1. Copy of letter from Mayor Tom Bradley dated October 24, 1989, asking that all bridges in the City be inspected and recommendations for strengthening be presented.

2. Priority List of Future Seismic Strengthening Projects.

3. Earthquake Priority List of Multi-Span Vehicular Bridges Owned by City of Los Angeles Only dated October 27, 1989.

DISCUSSION

The City's infrastructure is a fragile system that can readily be affected by major seismic events. The Santa Cruz earthquake on October 17, 1989, re-emphasized this condition by causing major damage to bridges almost 60 miles from the epicenter. For this reason a new urgency as expressed in the Mayor's letter has developed to extend and complete the City's Seismic Strengthening of Bridges program (Transmittal No. 1).

After the 1971 earthquake, a re-evaluation of design criteria was made to determine what changes would have to be made to protect the City's bridges. As a result of that study it was determined that seismic restrainers be added to certain bridges. These restrainers essentially tie the structure together so that the bridge does not pull apart. This work has proceeded slowly because of funding limitations. The status of this work is as follows:

Projects completed:	15 bridges	Cost:	$3,621,810
Projects approved for Construction:	14 bridges		1,238,000
Projects not Scheduled: (Transmittal No. 2)	43 bridges	Est. Cost:	$1,631,000

Within the City there are 1,014 bridges of which 416 are City owned. In addition, there are 15 vehicular tunnels, 221 pedestrian tunnels and numerous other structures.

These structures are inspected on a regular basis to assure that they are structurally sound. It is to be noted that not all of the bridges are major structures.

The first modern bridge constructed in the City is the North Broadway Viaduct which was built in 1909. During the next 23 years 17 bridges were constructed. These bridges are generally those that cross the Los Angeles River.

The longest bridge is the 6th Street Bridge which is 3,584 feet long, built in 1932 and carries about 12,100 cars per day.

The most heavily traveled bridge among these bridges is the Glendale Hyperion Viaduct over Riverside Drive and Los Angeles River. This bridge carries 41,200 vehicles per day.

The most critical bridges owned by the City of Los Angeles are those crossing the Los Angeles River located between Washington Boulevard to North Broadway. These bridges carry an average daily traffic of 21,300 vehicles per day.

Additional studies have been made by various agencies to further analyze the stability of bridge structures subject to seismic events. The City staff has been and will continue working with Caltrans in doing our bridge strengthening studies and will be using their resources in pursuing this program. As a result of these studies, staff has made a preliminary list of bridges requiring further work and also a preliminary cost estimate of seismic strengthening.

The Earthquake Priority List of Multi-Span Vehicular Bridges owned by the City of Los Angeles only (Transmittal No. 3) includes 136 bridges which may require strengthening. Multi-span bridges are usually more critical in major earthquakes than the typically smaller single span structures. The current estimated cost of strengthening the 136 multi-span bridges is approximately $111,000,000. The estimate for strengthening the remaining City bridges is not expected to exceed $40,000,000. The estimates have been made without detailed analysis and the actual costs could increase significantly if some bridges require total replacement. The converse is also true that the dollar amount could be less if the bridges, after examination, are found to meet current codes.

Financing could be accomplished by either an increase in the gas tax, general obligation bonds, or possibly revenue bonds.

On the basis of $150,000,000 estimated cost and with construction spread over 10 years an increase in the gas tax of three cents would be required for the City to generate $15,000,000 per year of revenue under the present program. However, proposals to greatly increase the scope of the program will reduce the funds available for this activity. If the modifications to the program are approved it is expected that it will require six cents per gallon of gasoline to fund the $15,000,000 per year seismic strengthening program for bridges.

Thirty year General Obligation bonds sold over a ten year program would cost the City an additional $1,200,000 per year the first year increasing to approximately $13,100,000 after the tenth year with 20 years to pay. This assumes concurrent retirement of debt principal.

If the bonds are revenue bonds funded by gasoline taxes and issued over ten years the first year will require approximately 0.5 cents per gallon, increasing to 4.75 cents at the end of ten years. The proposed new gas tax allocation is assumed in these figures.

It is recommended that the following 15 positions be approved to do the necessary design work and construction management:

<u>Structural Engineering</u>

1 Structural Engineer
4 Structural Engineering Associates
3 Civil Engineering Assistants

2 Civil Engineering Drafting Technicians
2 Civil Engineering Associates
1 Clerk Typist

<u>Soils and Geology</u>

1 Assistant Engineering Geologist
1 Engineering Geologist

Consultants will be needed in the first three years of the program to give an early surge to the evaluation of the critical bridges and to provide a backlog of construction documents. Funding for the consultants will not be required until the 1990-91 fiscal year because of the time required to develop, circulate, receive and evaluate the RFPs; hold interviews; negotiate and execute contracts; and start work. The process takes a minimum of six months. The consultant services will cost an estimated $2,000,000 per year.

If it is determined that general obligation bonds are to be the source of funding, it is recommended that additional funds in an estimated amount of $50,000,000 be included to reinforce existing City building facilities. These projects are not eligible for gas tax financing.

(RKH RHK)

Report prepared by:

STRUCTURAL ENGINEERING DIVISION

Rodney K. Haraga
Division Engineer
Ext. 53871

Respectfully submitted,

ROBERT S. HORII
CITY ENGINEER

RKH:RHK:dmd/BRDRPT10.RPT

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STATE OF CALIFORNIA—BUSINESS, TRANSPORTATION AND HOUSING AGENCY GEORGE DEUKMEJIAN, Governor

DEPARTMENT OF TRANSPORTATION
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November 6, 1989

The Honorable Richard Katz, Chairman
Assembly Transportation Committee
State Capitol, Room 3146
Sacramento, CA 95814

Dear Mr. Katz: Richard

The following is in response to your letter of October 20, 1989 requesting information relating to our seismic retrofit program. Responses are in the same sequence as the questions on page two of your letter.

1) The process to determine retrofit priorities has been based to a large extent on our experience in previous earthquakes (primarily the 1971 San Fernando event). These earthquakes told us that our largest problem was keeping the bridges together at their expansion joints (i.e., primarily hinges and abutments and intermediate bents).

   This conclusion was derived from a thorough investigation of the San Fernando earthquake after 1971 and has been supported by our experience in subsequent events such as the 1980 Trinidad-Offshore earthquake, the 1986 Palm Springs earthquake and the 1987 Whittier earthquake.

   All of these past earthquakes showed us that bridges constructed prior to 1971 were most vulnerable from their joints pulling apart and that this type of failure could endanger lives and cause serious property damage. After the 1971 earthquake, a survey of our bridge inventory identified about 1,300 bridges which contained narrow, unrestrained expansion joints. These factors caused us to make the retrofit of our unrestrained expansion joints our number one priority. This effort is now complete and all vulnerable joints throughout the State have been restrained.

   Analysis of past earthquakes identified that the <u>second most critical</u> area of concern was the integrity of the single vertical column members which support the bridges. The 1971 San Fernando earthquake showed that our narrow single column bridges were more vulnerable to damage than our wider multi-column type bridges. Since that time no earthquake (including the 1987 Whittier earthquake) has indicated that any of our single column bents were in danger of collapse. Modern computer analysis, however, is beginning to provide us with insight into the extremely complex performance of the single column type bridge and our conclusions are that retrofitting to improve the ductility of single column bridges is prudent in order to increase the serviceability of the bridge.

All remaining bridges (primarily multi-column type structures) were designated to be included in Phase 3 of our retrofit program. These bridges sustained damage in previous earthquakes but did not collapse. At the completion of Phase 3, every bridge within the highest seismic zones of the State will have been screened and evaluated and these bridges will have the same factor of safety as all bridges constructed to modern seismic standards.

2) Bridge Retrofit Prioritization

Phase 1 -- Bridges were identified by screening the approximately 15,000 bridges on the State system for vulnerable expansion joint details identified as a result of the 1971 San Fernando earthquake. Vulnerable details included narrow support lengths, weak bearings, etc. These bridges were placed on a needs list and prioritized based on the following considerations:

- o Seismic Potential
- o Replacement Cost
- o Replacement Cost Relative to Retrofit Cost
- o Available Detour Length
- o Average Daily Traffic
- o Defense Route On or Under the Bridge
- o Major Route On or Under the Bridge
- o Facility Crossed (State Route, Federal Route, Railroad)

Projects (contracts) were developed by combining several of the prioritized bridges based on geographic proximity to each other. Project priorities varied but every attempt was made to include the highest priority bridges in the earliest projects.

Phase 2 -- By this time we had a better understanding as to where earthquakes would most likely cause damage to bridges, thus the list of bridges to be screened and prioritized was limited to those within the 0.5g contour lines surrounding high potential faults.

High potential faults included in this screening were: Whittier, Elsinore, Whittier-Elsinore, Newport-Inglewood, Malibu Coast-Santa Monica-Raymond, Simi-Santa Rosa, Northridge, Santa Ynez, More Ranch-Arroyo Parida-San Cayetano, Red Mountain, Pitas Point-Ventura, Oakridge, San Andreas (South), San Jacinto, Mission Creek, Brawley, Brawley South, Clark, Coyote Creek, Superstition Hills, Superstition Mountain, Imperial, White Mountain North, White Mountain South, Fish Mountain, Owens Valley, Independence, Sierra Nevada, Hayward, Rodgers Creek, San Andreas (San Francisco South), Sargent, Zayante-Vergales, San Andreas (South of Cape Mendocino), Little Salmon-Yager, Mad River and Patricks Point as defined on the Division of Mines and Geology Map Sheet 45 (1987).

This resulted in a list of about 2,500 single column type bridges. Prioritization of these bridges was based on:

- Fault Proximity (Ground Acceleration)
- Age of Bridge (pre- or post-1971)
- Length of Bridge
- Average Daily Traffic
- Route Type Crossed (Interstate, Federal, State, County, City)
- Available Detour Length
- Skew of Bridge

Over 500 bridges have already been identified from the list of 2,500, however, screening is still underway and it is anticipated that about 700 bridges will comprise the final Phase 2 list. The screening process includes a review of portions of the original plans by at least three engineers who recommend inclusion or exclusion from the program based on our past damage experience combined with our recent analytical knowledge.

Projects (contracts) are being developed by combining several of the prioritized bridges based on geographic proximity to each other. To date approximately 100 bridges have been assigned a project status and work is currently underway to assemble the remaining bridges into projects. Project priorities vary but every attempt is being made to include the highest priority bridges in the earliest projects.

Phase 3 -- The prioritization of the remaining bridges inside the 0.5g contour surrounding the high potential faults has just begun and will be modified based on what we are learning from the effects of the Loma Prieta earthquake. All multi-level viaduct structures will be given the highest priority in this effort and work will proceed immediately on preparation of retrofit contracts for these bridges. Concurrent with the retrofit of these multi-level viaducts, we will be receiving input from our contracted research at the University of California at Berkeley in order to verify the effectiveness of the retrofit measures and techniques. All prioritization of the Phase 3 program will be similar to the Phase 2 effort except that the multi-level facilities will be given the highest priority. Completion of the Phase 3 program will mean that every bridge inside the 0.5g contour of the high potential faults will have been given a detailed scrutiny and retrofit when required.

3) Phase 1 seismic retrofit projects were submitted as candidates for financing as rehabilitation projects and competed with other highway safety projects for funding. The Department spent about $54 million on these projects at a rate of $3 to $4 million per year. In all previous earthquakes, there had been two deaths related to State highways and bridges. The retrofit program process was considered as part of the total highway safety package. This included fixes to "blood allies" that claimed hundreds of lives annually in traffic accidents. Obviously, Caltrans' priorities are now being revised.

4) We presently have an initial four-year Phase 2 program of $64 million which is included in the 1988 State Transportation Improvement Program (STIP). This program will retrofit single column bents. Detail design is underway on 30 projects and the first two were funded by the CTC during their October 1989 meeting. Construction will commence in a few months. Substantial additional funds will be necessary to complete work on all prioritized single column bridges.

   The CTC first allocated funding for Phase 2 in December 1987. The needed research contracts (testing of 1/2 scale models) were underway early in 1987 but actual model testing was not begun until mid-1988. Design was commenced in the Spring of 1988 with plans completed later that year.

5) Phase 1 -- Attachment A is a list of bridges where Phase 1 retrofit was accomplished, sorted by districts. Southern California could be defined as districts 7, 8, and 11. The recently established District 12 is not segregated.

Phase 2 -- Attachment B is a list of Phase 2 candidates sorted by District, County, Route.

Phase 3 -- In addition to the two-level structures, Embarcadero Viaduct, Central Viaduct, Southern Viaduct and China Basin Viaduct in San Francisco, all other multi-column bridges are candidates. We have identified 5,000± (Attachment C) such bridges on the State System.

From experience gained at the San Fernando earthquake, we clearly felt that keeping bridges on the bearings was the most important retrofit we could perform. We immediately proceeded with this program on a statewide basis while continually improving our analytical technology and construction details. We feel this program has saved many bridges during subsequent seismic events.

The single column bent program lacked the analytical technology until 1987. Without that and the retrofit research and model testing, we would have been shooting in the dark for techniques to use for retrofitting columns.

Phase 1 is complete.

Phase 2 -- Research is approximately half complete
-- 95 percent of needs identified
-- 25 percent programmed by project and in various stages of design
-- Two projects voted by CTC -- construction to start in early 1990

Phase 3 -- Just starting to identify needs list
-- Research is commencing immediately

6) Yes, the Department is preparing an expedited program for retrofitting structures. We are nearing completion of Phase 2 retrofit research. Funding for the first contracts has been approved and construction should be completed by the end of 1992. We are initiating immediate research with UC Berkeley for Phase 3, the multi-column bents, which will identify failure modes and details requiring retrofitting. We anticipate that many of the retrofit techniques developed in Phase 2 will be used in the Phase 3 program. In essence the old concepts of Phases 2 and 3 are being changed. We are expediting review and analysis of bridges identified for Phase 3. Phase 2 and Phase 3 will overlap as much as possible; however, the Phase 3 research will take a couple of years. Meanwhile we can get some projects underway by the middle of 1991. Until we have a better idea of the retrofit actions that will be necessary, no accurate cost estimates can be made. Completing all high-priority bridges will cost several hundred million dollars.

7) In a maximum credible earthquake, we expect that our structures will sustain damage but will not collapse. We are reviewing our bridges with the new knowledge that we are acquiring, and at this time we have no reason to believe that any one of the structures is unsafe.

All of the highway structures constructed since 1971, including the Harbor Transitway, were or are being constructed using the details which evolved from the San Fernando earth-quake and have been designed using the very latest seismic design criteria. In conjunction with District 7, in Los Angeles, we are conducting a peer review of the Harbor Transitway plans prior to the start of construction on the structure itself.

The "4 level" interchange has been retrofitted with catcher blocks at the abutment to keep the structure on its supports. The substructure is of the multi-column type with several additional diaphragms connecting adjacent frames. This interchange experienced no identifiable damage in either the Whittier or the San Fernando earthquakes. We do not expect any damage such as occurred at Cypress Street to occur at this location. This bridge is safe for public traffic.

We will certainly include these bridges in our review for the Phase 2 and Phase 3 retrofit programs as we will all other bridges. Multi-level structures will receive the highest priority.

Sincerely,

ROBERT K. BEST
Director

Attachments

TESTIMONY
WILLIAM LEONARD, VICE-CHAIRMAN
CALIFORNIA TRANSPORTATION COMMISSION

ASSEMBLY TRANSPORTATION COMMITTEE
NOVEMBER 7, 1989 INTERIM HEARING
LOS ANGELES

I AM PLEASED FOR THE OPPORTUNITY TO APPEAR BEFORE THE ASSEMBLY TRANSPORTATION COMMITTEE ON BEHALF OF OUR CHAIRMAN, JOE DUFFEL, REPRESENTING THE CALIFORNIA TRANSPORTATION COMMISSION.

ON OCTOBER 17TH AT 5:04 PM OUR FELLOW CALIFORNIANS EXPERIENCED A DISASTER OF IMMENSE PROPORTIONS. THIS EVENT WHICH WE HAVE LONG DREADED THROUGHOUT CALIFORNIA BROUGHT DEVASTATION TO ONE OF THE LOVELIEST AND MOST HISTORIC AREAS OF OUR STATE -- THE SAN FRANCISCO BAY AREA. IN SPITE OF THE INCREDIBLE DESTRUCTION THERE WAS MUCH TO GIVE THANKS. THE IMMEDIATE REACTION OF CALTRANS, STATE AND LOCAL OFFICIALS, AND OUR FELLOW CITIZENS IN THE BAY AREA DID MUCH TO MITIGATE THE LOSS AND SUFFERING. IT IS WELL TO BEAR IN MIND AS WE SEEK SOLUTIONS TO THIS TERRIBLE TOLL, AN EARTHQUAKE OF SIMILAR MAGNITUDE IN ARMENIA LAST YEAR CAUSED THE LOSS OF LIFE TO 25,000 PEOPLE.

ON OCTOBER 18TH, THE DAY FOLLOWING, CALTRANS BRIEFED THE COMMISSION ON THE EVENTS OF THE PREVIOUS DAY AND THEIR ASSESSMENT OF THE SITUATION. AT THAT MEETING THE COMMISSION ADOPTED TWO POLICIES REGARDING EMERGENCY REPAIR FUNDING WHICH WERE IMMEDIATELY COMMUNICATED TO THE GOVERNOR, THE LEGISLATIVE

LEADERSHIP AND THE CONGRESSIONAL DELEGATION. IN SUMMARY THOSE POLICIES ARE:

1. ANY STATE FUNDING FOR EMERGENCY REPAIRS AND RESTORATION OF THE STATE'S TRANSPORTATION SYSTEM SHOULD COME FROM THE GENERAL FUND EMERGENCY RESERVE FUND RATHER THAN THE STATE HIGHWAY ACCOUNT. THERE IS FRANKLY NO OTHER CHOICE FOR PRIOR TO THE EARTHQUAKE WE HAD ALREADY ADVISED THE APPROPRIATE OFFICIALS THAT THE STATE HIGHWAY ACCOUNT WOULD LIKELY BE DEPLETED BY THE END OF THE CURRENT BUDGET YEAR.

2. THAT THOSE RESTRICTIONS ON FEDERAL EMERGENCY REPAIR HIGHWAY FUNDS BE EASED TO PERMIT AN APPROPRIATE FEDERAL RESPONSE. THOSE RESTRICTIONS INCLUDE THE FOLLOWING FIVE POINTS:

   (1) CURRENT $100 MILLION CAP BE RAISED
   (2) MORE REVENUE SHOULD BE ADDED TO THE EMERGENCY REPAIR FUND
   (3) CURRENT 90 DAY WAIVER OF STATE MATCH SHOULD BE EXTENDED
   (4) EMERGENCY REPAIR FUND SHOULD NOT BE CREDITED AGAINST A STATE'S GUARANTEED MINIMUM RETURN OF FEDERAL FUNDING
   (5) TOLL FACILITIES SHOULD BE ELIGIBLE FOR EMERGENCY REPAIR FUNDS

WE ARE PLEASED THAT THIS COMMITTEE PLAYED A MAJOR ROLE IN BRINGING HOME THE BACON. AS YOU KNOW FOR THIS TRAGEDY THE FEDERAL GOVERNMENT DID

1. PROVIDE $1 BILLION THAT HAS A SHELF LIFE OF TWO YEARS.

2. THAT THE 90 DAY WAIVE OF STATE MATCH HAS BEEN EXTENDED TO 180 DAYS.
3. TOLL ROADS ARE ELIGIBLE FOR EMERGENCY REPAIR FUNDS.
4. THESE FUNDS WON'T BE CHANGED AGAINST FUTURE APPORTIONMENTS TO CALIFORNIA.

IF CALIFORNIA IS TO MAXIMIZE THE FEDERAL BENEFITS THAT HAVE BEEN MADE AVAILABLE IT IS INCUMBENT THAT WE NOW MOVE WITH DESPATCH.

AT THE COMMISSION MEETING ON THE 19TH, WE MADE THE NECESSARY FINDINGS TO PERMIT EMERGENCY FERRY SERVICE TO OPERATE WITHOUT VIOLATING ANY COVENANTS ON THE TOLL BRIDGE BONDS.

REHABILITATION OF THE CALIFORNIA HIGHWAY AND FREEWAY SYSTEM HAS ALWAYS BEEN ASSIGNED THE HIGHEST PRIORITY FOR AVAILABLE FUNDING. SEISMIC RETROFIT PROJECTS ARE A PART OF THE REHABILITATION PROGRAM. AS INDIVIDUAL PROJECTS HAVE BEEN READIED BY CALTRANS FOR CONSTRUCTION, THE COMMISSION WITHOUT EXCEPTION HAS ALLOCATED CONSTRUCTION FUNDS SO THAT CONTRACTS COULD BE AWARDED. IN RECENT YEARS OF FUNDING SHORTAGES IT HAS BEEN NECESSARY TO CURTAIL NEW CAPACITY PROJECTS IN ORDER TO ASSURE THAT REHABILITATION INCLUDING SEISMIC RETROFIT COMES FIRST.

LET ME QUICKLY SUM UP THE BRIDGE SEISMIC RETROFIT PROGRAM. FROM THE LESSONS LEARNED FROM THE SAN FERNANDO EARTHQUAKE CALTRANS WAS AUTHORIZED TO DEVELOP A RETROFIT PROGRAM ON SELECTED BRIDGES THAT EITHER HAD NARROW BEARING SEATS OR TALL UNSTABLE BEARINGS IN AREAS OF HIGH SEISMIC POTENTIAL. PHASE 1 IS 99% COMPLETE. THERE WERE 1262 BRIDGES IN THIS PROGRAM WHICH HAS COST SLIGHTLY IN EXCESS OF $54 MILLION. CURRENTLY 13 ARE UNDER CONTRACT

AND THE LAST KNOWN ONE IS UNDER DESIGN. THIS LAST PROJECT IS AN UPGRADE OF A PREVIOUS HINGE RESTRAINER PROJECT.

PHASE 2 WAS APPROVED BY THE COMMISSION FOR INCLUSION IN THE 1988 STIP IN DECEMBER 1987. THIS SECOND RETROFIT PROGRAM WAS TO CORRECT THE LESSONS LEARNED FROM THE 1987 WHITTIER EARTHQUAKE. THIS PROGRAM ENTAILED THE STRENGTHENING OF SINGLE COLUMN STRUCTURES THROUGH THE USE OF METAL JACKETS. A TOTAL OF $64 MILLION WAS PROGRAMMED FOR AN ESTIMATED 767 BRIDGES TO BE COMPLETED OVER A FOUR-YEAR PERIOD. NOW THAT PROJECT REPORTS ARE COMING INTO HEADQUARTERS IT IS MY PERSONAL BELIEF THAT THE $64 MILLION WILL PROVE TO BE MOST INADEQUATE AND THE FINAL COST FOR THESE BRIDGES WILL MORE THAN LIKELY BE IN THE NEIGHBORHOOD OF $200 MILLION. IN FACT, CALTRANS NOW ESTIMATED THAT THE ENTIRE $64 MILLION ALREADY PROGRAMMED WILL BE CONSUMED BY THE FIRST 100 OF THESE BRIDGES. THE FIRST TWO OF THESE PROJECTS TOTALING $1.2 MILLION WAS APPROVED AT OUR OCTOBER 1989 MEETING. AS IS TRUE ON ANY NEW PROGRAM, PROJECT REPORTS, THE NECESSARY RESEARCH, TESTING, AND DESIGN ALL REQUIRE A GREAT DEAL OF LEAD TIME. THE COMMISSION HAS ASKED THE DEPARTMENT FOR AN UPDATED SCHEDULE AND COST AND TO ADVISE THE COMMISSION WHAT EFFORTS CAN BE MADE TO ACCELERATE THIS PROGRAM.

AT THE OCTOBER MEETING THE COMMISSION WAS ADVISED OF A PHASE 3 CATEGORY WHICH INCLUDES THOSE HIGHWAY BRIDGES WITH MULTIPLE COLUMNS THAT REQUIRE SEISMIC RETROFIT ATTENTION FOR WHICH THERE IS NO SPECIFIC ENGINEERING SOLUTION YET DECIDED ON. THE NIMITZ IS AN UNFORTUNATE EXAMPLE OF THIS CATEGORY. PHASE 3 IS CERTAINLY A NEW CATEGORY. THE LESSONS LEARNED FROM BOTH THE SYLMAR AND THE WHITTIER EARTHQUAKES DID NOT INDICATE A POSSIBLE FAILURE INTO THE

MULTI-COLUMN STRUCTURES THAT THIS PHASE WILL DEAL WITH. THE COMMISSION HAS ASKED TO BE ADVISED OF THE SPECIFIC LOCATIONS THAT FALL WITHIN THIS CATEGORY.

IN CONCLUSION LET ME MAKE A PERSONAL OBSERVATION. THE SAN FRANCISCO EARTHQUAKE OF OCTOBER 17TH IS A CATASTROPHE THAT WILL LONG BE REMEMBERED. NO ONE KNOWS PRECISELY WHEN OR WHERE THE NEXT EARTHQUAKE WILL BE CENTERED, THOUGH WE DO KNOW WITH A HIGH DEGREE OF CERTITUDE THAT THERE WILL BE ANOTHER. ONE THING WE DO KNOW IS THAT THERE WILL BE FREQUENT AND CONTINUING CATASTROPHES THAT WILL HEAVILY IMPACT THE MOTORING PUBLIC. IT MAY BE FIRE, FLOOD, SLIPPAGE, FOG WITH THE RESULTANT MULTI-CAR PILE UP OR EVEN A SINGLE CAR ACCIDENT. WHATEVER, IT CERTAINLY IS A TRAGEDY TO THOSE INVOLVED. THE COMMISSION IS VERY SENSITIVE TO THOSE CONCERNS. MOST EVERY CAPITAL PROJECT WE AUTHORIZE IS A SAFETY PROJECT, DESIGNED TO SAVE LIVES AND PROTECT PROPERTY. WE ONLY VOTE AMENITY PROJECTS SUCH AS SOUND ATTENUATION WALLS OR LANDSCAPING WHEN ITS MANDATED OR ITS THE PRICE OF GETTING FEDERAL FUNDS FOR A PROJECT THAT MEETS THE CRITERIA OF PROTECTING PEOPLE AND PROPERTY. THE COMMISSION IS FIRMLY COMMITTED TO THE NECESSITY OF ASSURING A SAFE, RELIABLE TRANSPORTATION SYSTEM WHOSE MAINTENANCE AND REPAIR IS ADEQUATELY FUNDED AS A PRIORITY OVER AND ABOVE OTHER INVESTMENTS IN THAT SYSTEM.

IT IS ESSENTIAL THAT ADDITIONAL FUNDING BE PROVIDED TO FULLY REIMBURSE THE EMERGENCY EXPENDITURES FROM THE SEVERELY LIMITED STATE HIGHWAY ACCOUNT. WE MUST NOT ONLY RAISE SUFFICIENT FUNDS TO REPAIR THE EARTHQUAKE DAMAGE, BUT TO SHORE UP DAMAGED ROADWAYS TO AVOID FUTURE FAILURES AND TO PROVIDE CONGESTION RELIEF AND ACCELERATE OUR SEISMIC RETROFIT PROGRAM. CALTRANS

AND THE COMMISSION ARE OUT OF MONEY TO MEET THE TRANSPORTATION NEEDS OF THIS RICH STATE AND VERY COMPETITIVE ECONOMY.

OUTLINE OF THE TESTIMONY GIVEN BEFORE
ASSEMBLY TRANSPORTATION COMMITTEE
STATE OF CALIFORNIA

CITY HALL
Los Angeles, California
7 November 1989

By

J. David Rogers, Ph.D., P.E., G.E.
Rogers/Pacific, Inc.
Pleasant Hill, California

QUALIFICATIONS

A. Ph.D. in Geological and Geotechnical Engineering from the University of California, Berkeley.

B. Registered Civil Engineer, Geotechnical Engineer and General Engineering Contractor in California. Registration in Geology and Engineering Geology currently pending.

C. Principal author of numerous articles and publications dealing with engineering geology of the San Francisco East Bay and consultant to 25 Bay Area governmental agencies and municipalities.

D. Co-authored a proposal for studying the seismic safety of the failed Cypress Structure section of I-880 with Professor Jerome M. Raphael at U.C. Berkeley in 1978. Received earthquake engineering education while at Berkeley.

E. In private practice for the past 10 years and frequent lecturer for five universities and numerous government agencies.

BRIEF HISTORY OF THE CYPRESS STRUCTURE

The failed Cypress double-deck freeway structure was constructed in 1955-57 in two main contracts as part of then State Route 17, or Eastshore Freeway. Route 17 was conceived by the State Division of Highways in the late 1940's. The highway's northern terminus was in the Oakland Distribution Structure, a complex interchange connecting four freeways/expressways with the Oakland-Bay Bridge. The southern terminus of the highway was at its juncture with the Bayshore Freeway (U.S. 101, in San Jose). Actual construction of the route began in 1949 and was completed some 10 years later, whereupon it was renamed the "Nimitz Freeway", after Fleet Admiral Chester W. Nimitz, whose family had long resided in nearby Berkeley. The Nimitz retained its nomenclature as State Route 17 until 2-1/2 years ago when it was redesignated as Interstate Route 880, or I-880.

A structural kingpin of the Nimitz was the Cypress double-deck viaduct at the freeway's junction with the Oakland Distribution Structure. Design by the Division of Highway's Bridge Department in Sacramento began in 1951, with the final plans being issued in late 1954. In the early 1950's, commuter and commercial traffic traveling up the East Bay toward the Bay Bridge or points north swung around the congestion of downtown Oakland, along a broad, 6-lane boulevard named Cypress Street, which had been widened and improved in the mid-1930's and late 1940's. The Cypress corridor was then carrying approximately 50,000 vehicles per day (on a 24-hour basis during weekdays).

The Bridge Department design team was headed by the late Stewart Mitchell under the direction of Chief Bridge Engineer Frederick W. Panhorst. This duo was very experienced, having designed the Oakland-Bay Bridge, the graceful concrete arch spans on the Big Sur Highway, over the Arroyo Seco in Pasadena, and virtually every freeway project since the first, the Pasadena, which was opened in 1940. A younger engineer, Clayton R. Giroux, had joined the Bridge Department in 1948, and he eventually became the Project Designer and a specialist in double-deck freeways, later designing San Francisco's similar Central and Embarcadero freeways. Giroux retired from CALTRANS in 1986 (and does not need to be bothered by the Press; he is actively co-operating with members of the various investigating teams).

Design concepts for a modern freeway, running through what was then (1951) a pricy heavy industrial area, were extremely complicated. Over a 1.3 mile distance, the proposed route had to cross 24 existing city streets, 3 railroad spurs serving industry, miss the Oakland Army Base railroad yard, access to the Southern Pacific Railroad Depot, and just skirt the largest sewage treatment plant in the East Bay, with dozens of incoming sewer trunk lines. In addition, the 6 existing lanes of the Cypress commuter corridor must necessarily remain open during freeway construction so as not to create intolerable (not to mention politically unacceptable) congestion.

The compromise reached by the bridge design team was to create an extended double-deck structure, not to unlike those emanating from the San Francisco anchorage of the Bay Bridge (built in 1934-37). A doubly-supported deck structure possessed a number of important advantages:

A. It required the least amount of right-of-way, thereby saving the State land acquisition money. At this time, the heavy industrial properties in that area, such as steel fabricating plants, would have been very expensive to condemn and relocate.

B. An elevated freeway would create the least disruption to the neighborhood's well-established infrastructure (railroads, commuter rail lines, streets, trolley lines, buried utilities).

C. A double-deck structure could be built with a minimum of disruption to the existing commuter corridor by buying only enough land (some 75') to create two three-lane streets on either side of the freeway while it was under construction (a 2-1/2 year process). In this way, Cypress Avenue was split, with the north-bound lanes paralleling the east side of the freeway and the south-bound lanes on the west side. These streets were left in place to improve traffic mobility in the affected area, and the contractor could stage his work in the 75' strip of land between the two streets.

The double-decked freeway section would be a little over 6,800 feet long and was to be California's first. The two 52-foot-wide roadways were to be of the concrete box girder type, supported on multiple column reinforced concrete bents. Bent spacings were from 70 to 80 feet, with 124 bents in all. The upper deck would be supported some 50 feet above the ground, and many of the upper supporting girders were reinforced with post-tensioned rods, an early form of the pre-stress concrete method routinely employed in concrete structures today. The finished structure would be able to handle 200,000 vehicles per day, which easily met the 20-year projections routinely applied to such projects during that time period (1951-54).

A BRIEF HISTORY OF SEISMIC DESIGN CONCEPTS IN CALIFORNIA

Reinforced concrete and steel structures technology evolved markedly during the post-World War II boom years as increasingly larger and larger structures were built. By the late 1960's, the entire concept of reinforced concrete design changed over from the traditionally-employed *working stress design* approach to the current *ultimate strength design* procedures (American Concrete Institute, 1971). Other significant code changes included the employment of continuous spiral reinforcement in load-bearing columns which came about around 1968.

Most of these changes emanated from the consulting structural engineering community who were continuing to press the limits in designing larger and more complicated structures.

Earthquake loading was a source of great concern to California's civil engineers whose awareness was piqued during Magnitude 6-1/4 quakes which damaged Santa Barbara in 1925 and Long Beach in 1933. Santa Barbara's municipal water system had been severely crippled in their quake, and Sheffield Dam, a hydraulic fill structure, had been destroyed (Engineering News Record, 1925). The 1933 Long Beach event occurred in close proximity to a more highly developed area and numerous structural collapses forced major changes in the Uniform Building Code and mandated special professional registration for structural engineers.

But, what followed was a paucity of seismic tremors. Seismographs at Cal Tech in Pasadena recorded the 1933 Long Beach event (which was epicentered offshore on the Newport-Inglewood fault), with one station recording a peak acceleration of 0.13g, or 13% of the force of gravity applied laterally.

In 1940, a Magnitude 7.1 tremor rocked the El Centro area (Johnson and Hill, 1982). Strong motion recorders in the area were located inside structures located on deep alluvium (in lieu of bedrock). The May 18, 1940, El Centro quake was the largest quake of record in the new era of seismography which began in the mid-1930's, having a maximum recorded acceleration of 0.33g. The raw El Centro strong motion records were synthesized into *structural response spectra* which were widely disseminated to the engineering profession for use in structural design. This data included time histories of simple motion and response to single degree of freedom systems, structural response characteristics critical to seismic design. The synthesized El Centro data was the first of this kind to be employed in California, and it was the strongest motion data (but not necessarily the greatest acceleration data) available until the San Fernando Quake in 1971. Subsequent measurements at Parkfield in 1967 (0.50g) and San Fernando in 1971 (1.25g) suggested that much higher accelerations were possible than previously realized. The designers of the ill-fated Cypress Structure utilized a 0.06g horizontal acceleration from the 1940 El Centro quake in their 1951-54 design.

The first major structure actually designed to account for earthquake loading in the United States was Morris Dam, a concrete gravity structure, built on the San Gabriel River in San Gabriel Canyon by the City of Pasadena in 1932-35. A fault was discovered in the dam foundation during excavation work, so the dam was designed for 6-1/2 feet of tectonic offset and a lateral load of 0.10g was applied *pseudostatically* upon the dam, causing its design to be thickened (Morris and Pierce, 1934; Engineering News Record, 1938). Pseudostatic loads were applied to designs to simulate lateral earthquake loads, but these assume that such a load is constant when, in fact, it is quite transient.

In July 1952, California was rocked by a major tremor of Magnitude 7.6 near Tehachapi on the White Wolf fault zone. Major highway and railroad closures over the Tehachapi Pass resulted, but no strong-motion instruments were located close to the shock's epicenter and the quake was completely unexpected.

A new awareness of seismic loading and structural response of modern, well-engineered structures came about with the 1964 Good Friday quake in Anchorage, Alaska. The event measured in at a whopping 8.4 on the Richter Scale, the largest quake in America this Century. The destruction was extensive, with ground shaking lasting some 3 to 4 minutes (the 1906 San Francisco quake shook for 52 seconds and is estimated to have been Magnitude 8.3). Large scale ground failures abounded in the Alaska quake, with the entire suburb of Turnagain Heights being liquefied and flowed out to sea, destroying some 75 homes. The tidal wave created by the Alaska Quake damaged California port facilities, particularly at Cresent City. Damage assessments by structural and geotechnical engineers sent to Anchorage triggered research moneys and programs to explore seismic design considerations and building code amendments in the late 1960's.

THE SAN FERNANDO EARTHQUAKE OF 1971

At 6:15 a.m. on February 9, 1971, the Los Angeles metropolitan area was awakened by a sharp jolt of Magnitude 6.4, centered beneath San Fernando, adjacent to a highly-populated area along the northern side of the San Fernando Valley near Los Angeles. Two hospitals fell, one dam crumbled, and three freeway viaduct sections collapsed; interchanges fell where Highway 14 joins the Golden State (I-5), five spans fell where the Golden State (I-5) crossed the Southern Pacific Railroad, and the newly-complete, but unopened, interchange between the Foothill (I-210) and Golden State (I-5) freeways. Twenty other spans experiences hinge connection failures of varying degrees. The collapse of a not-yet-opened, state-of-the-art structure gained widespread notoriety and caused serious concern amongst the Division of Highway's Bridge Departments in Sacramento and Los Angeles.

California's first freeway (the Pasadena) had been constructed shortly before World War II, but the interconnecting system of highways really began to take off in the mid-1950's with the passage of the Interstate Highways Act in 1955. The highway building boom crested in the late 1960's, and then died a fast death in the early 1970's as the Federal Highway Trust Fund moneys were impounded to help balance the Federal deficit, and post-Vietnam inflation made new construction three times as expensive. In 1975, CALTRANS laid off 15,000 employees and, basically, quit building freeways.

The largest freeway system in the World had been constructed between 1947 and 1973. It had been designed to accommodate anticipated growth trends and the Division of Highways had risen to a position of national, if not world, eminence in setting design, safety, and landscaping standards for highways.

But, the first sizable earthquake to test the system was at San Fernando in 1971. The collapse of the Highway 14 connector viaducts onto the Golden State Freeway (I-5)miraculously only killed two men heading for work in a pick-up. Their heirs sued the State, trying, in vain, to prove negligence on the behalf of the Division of Highways for designing such structures (the courts eventually determined that the State is immune from actions alleging design negligence when state-of-the-art engineering precepts are used, even if these standards are subsequently superseded.)

Shortly after the San Fernando collapse, the Legislature appropriated sufficient moneys to study the various failures and the Federal Government followed suit with its own program of research through the National Science Foundation, Nuclear Regulatory Commission, Corps of Engineers, and the U.S. Geological Survey. Cal Tech and U.C. Berkeley headed the list of institutions accorded moneys to research the safety of highway viaducts, dams, hospitals, and nuclear power plants; this topic being of major concern in the 1970's.

By 1977, the results of investigations into San Fernando-caused failures were complete. In 1973, major amendments to Building Codes were made to account for better resisting the *observed modes of failure* in the San Fernando quake. Earth dams, built before 1940, using hydraulic filling techniques, were replaced or buttressed by new, mechanically-compacted embankments. Public schools were evaluated, retrofitted (if possible), and condemned or sold (for non-school use) if they could not be brought up to adequate levels of seismic safety. The Alquist-Priolo Special Studies Zone Act was passed by the State Legislature in 1973. This Act required local entities to prepare a Seismic Safety Element of their General Plan, and required the preparation of special geology reports for proposed construction in known fault zones. Unfortunately, California's active real estate lobby axed the additional provisos about any sort of professional *review of the adequacy of such reports.*

CALTRANS RETROFIT PROGRAM

Immediately following the San Fernando quake, CALTRANS began retrofitting their older bridges. In the following years, CALTRANS received the results of the university research and began to implement major procedure changes which included the evaluation of each area's Maximum Credible Earthquake (MCE) and the corresponding highest levels of ground shaking such MCE's would cause on any site. CALTRANS contracted with the State's Division of Mines and Geology to prepare a *Maximum Credible Bedrock Acceleration (Map) from Earthquakes in California* in 1972 (Greensfelder, 1974).

Five weeks after the 1971 quake, CALTRANS embarked on a hinge restoration program to prevent future pull-out at such connections. Soon, a 3-phase retrofit program was put into motion to analyze and amend CALTRANS's pre-1971 structures. Phase 1 of this program consisted of replacing hinges, bearing assemblies, and connectors with seismically-resistant designs. Restrainer cables were used to tie girder sections together to prevent out-of-phase side sway, excessive opening and "hammering" into each other after opening. This program was accomplished on the Cypress Structure in 1979, and the Phase 1 program was completed by 1987. The Phase 2 retrofit program consisted of retrofitting concrete and steel "jackets" on single column supports to increase shear capacity and confinement so that compressive failures like those seen at San Fernando would be prevented. This program was being funded at $3 to $4 million per year until the 1987

Whittier Earthquake, when the I-5/I-605 interchange was damaged. Suspended sections would have failed, closing the freeways for weeks if not for the Phase 1 restrainers emplaced between 1971 and 1987 at a cost of $54 million (Zelinski, 1987). The Phase 2 column support program was accelerated to a funding rate of $16 million per year ($65 million total). CALTRANS felt they would have lost the I-5/I-605 interchange if it had been supported on single columns in lieu of a 5-column bent (Trombatore, 1987).

The Phase 3 retrofit program was intended to apply to more complex, multi-column structures like the failed Cypress Section of I-880. Research contracts for this phase had been initiated with U.C. San Diego in 1987. According to Jim Roberts (1989) of CALTRANS, plans for Phase 3 retrofit were begun in January 1988, but funding levels are currently too low for Phase 3 retrofits to go to contract (approved funds are all slated for Phase 2 retrofits). No Phase 3 retrofits had been accomplished prior to the Loma Prieta Earthquake, but there is CALTRANS's correspondence suggesting that the agency was beginning to take a critical look at such existing structures in San Francisco as late as August of this year (Gates, 1989; Klein, 1989).

A LOOK AT THE CYPRESS STRUCTURE BY U.C. BERKELEY

From 1976 to 1981, the author was enrolled as a graduate student in civil engineering at the University of California at Berkeley. In 1977-78-79, I was engaged in a series of individual study projects in structural engineering with the late Professor Emeritus, Jerome M. Raphael, a mass concrete and reinforced concrete specialist and former Chairperson of the Department's Structural Engineering and Structural Mechanics (SESM) group. Raphael had received his Masters degree at MIT in 1935 and had worked on the construction and instrumentation of Shasta Dam in the early 1940's while with the U.S. Bureau of Reclamation. He joined the Berkeley faculty in 1953, shortly before receiving the Moissieff Medal from the American Society of Civil Engineers for his research in concrete stress distribution.

The elevated Cypress structure section of then-State Route 17 was of much interest to the late Professor because it was such a massive and rather unique structure. The Cypress Structure had not been designed to account for creep (or sagging) of the concrete, a favorite topic of research at Berkeley, going back into the 1930's. Raphael knew the designers and spoke to me of them (Panhorst, Mitchell) and the early connection problems associated with mixing post-tensioned pre-stressed girders with conventionally-reinforced columns and girders.

My individual research project for the upcoming quarter (Summer, 1977) would be to research the Cypress Structure, with special attention to the foundation system and subsurface soils - this being "natural" for me as a geotechnical engineering major (I was minoring in structural engineering).

I spent a lot of time making phone calls and trips to the structure to make measurements and observations of the creep and shear cracking in the supporting girders. I also researched what I could from CALTRANS via the phone without spending too much time or money tracking down the construction records. These were things we intended to do if the project were funded.

The purpose of the project was to take a preliminary look at the Cypress Structure, then prepare a research proposal for performing an in-depth analysis, which other members of the SESM faculty were then embarked. Some of the items took a long time to track down or wait on the response.

We knew from CALTRANS design history that the structure was probably designed for a lateral soil acceleration of 0.06 g, typical of that period (which I believe came from the 1940 El Centro record). The newly-published bedrock acceleration map by Greensfelder (1974) showed a probable bedrock acceleration at the site of 0.50g, emanating from a Magnitude 7.5 quake on the nearby Hayward fault, just 4 miles away. *We also discovered that the structure had withstood a Magnitude 5.3 shock only 13-1/2 miles from epicenter while nearing completion on March 22, 1957* (see C.D.M.G. Special Report 57, 1959).

This 1957 quake had done noticeable damage to the west San Francisco area, and exerted Modified Mercalli scale intensities of at least VII on the Cypress Structure. This intensity would likely have corresponded to a maximum horizontal acceleration on the order of 0.10g (Murphy and O'Brien, 1977). Professor Raphael felt that the structure could easily sustain the 0.10g load without much damage due to the redundancy of old working stress design concepts and the increasing strength of the concrete with age (3500 psi mix originally specified). We did not attempt to run a dynamic analysis on the structure, we only prepared a proposal to do so.

When finished, the proposal included just about everything we had the ability to do in those days. The northern portion of the structure (north of Eighteenth Street, or at around Bent 66) was founded upon old fill, placed on top of an old marine embayment (Radbruch, 1957). Borings in this area revealed soft Quaternary and Holocene-age sediments to a depth of around 60 to 70 feet up in the vicinity of Bents 105 to 122. The freeway's supporting bents were founded upon concrete piles, but some of these pile groups pierced what appeared to be old estuary infillings and sinuous sloughs, some of which were filled with sand or gravel.

That knowledge was enough to make us worry about two potentialities:

1. Partial liquefaction of the slough sands or fill could remove passive support of the nearby piles and pile snaps could occur just under the pile cap footing; or

2. The presence of deep muds at one end of a long, linear structure, and stiff sandy materials with more shallow piles at the other, could react differently to incoming shock waves; and/or could serve to amplify or damp the incoming waves, thereby complicating the structure's response.

Having been originally trained as a geologist, I emphasized to Professor Raphael what I had been learning downstairs in geotechnical engineering - that the presence of loosely-consolidated materials within a stiffer "bedrock" depression could generate deadly energy refraction problems. But, we also knew that the soft marine clays, or so-called "Bay Muds", near the structure's northern terminus, could also serve to "damp" or lessen the incoming earthquake shock wave (which was something of a comforting thought). Either way, we ended up concluding that the structure was going to respond differently at one end versus the other in an earthquake of extended period (something greater than 15 seconds).

Professor Raphael decided that I should research the costs and possibilities of performing some on-site dynamic excitation tests to get the structure's periods and modes of vibration (which he believed would be fairly simple to do), and to perform seismic excitation tests of the foundation, particularly at the north end, atop the estuary deposits. The only rig I could find to perform such work was a geophysical testing truck called a "Vibroseis", which actually stuck large prongs into the ground and input a constant rate and amplitude of shaking. Geophones, inserted into or on top of the ground at varying distances away from the Vibroseis truck, were to measure seismic refraction arrivals.

I remember quite vividly Professor Raphael being concerned about the tapered columns supporting the Cypress's upper deck. Our proposal had two figures which targeted the base of these columns as the "weak link" in the supporting load path. Raphael was also concerned about the top connections in certain cases, but I cannot remember in what context.

Vertical acceleration was seen to be a potential problem at the column bases due to excessive shear, and the general knowledge at that time was that 1950 structures were generally underdesigned for shear stresses induced by compression (it had recently been recognized that a substantive vertical component of earthquake-induced accelerations had been involved in the San Fernando quake collapses). At the Professor's prodding, I searched high and low for some historic records or predictions of what vertical accelerations would be in effect in West Oakland. I spent considerable time in this endeavor and had access to many experts, but came up with *nothing*. The frustration of this exercise cannot be too strongly stated. It was soon apparent that we had very little *strong motion* data from actual earthquakes in similar geologic settings. Strong motion accelographs can record base input accelerations (horizontal and vertical) as well as structural response. We knew from the records at Pacoima Dam in 1971 that the location within the structure or above the ground surface could mean a 10-fold difference in input motion (such as on a sharp ridgeline) and in response (such as atop a building). I ended up with a new appreciation for why engineers use acceleration records of "incorrect" magnitudes or irrelevant geologic settings, such data are oftentimes the only records available! We concluded that we would have to use the San Fernando records in our analysis (provided it was funded), even though the '71 quake style and type (reverse faulting) would not replicate motions on the Hayward or San Andreas (which are strike-slip faults).

It was our general feeling, at the time, that the Cypress would be most vulnerable to three types of ground shaking:

1. Large horizontal accelerations from a close proximity source, running across the structure (from east to west). This would be a Magnitude 6.5 to 7.5 event on the nearby Hayward fault. Shaking levels of 0.30g to 0.55 g could be expected; or

2. A lower level, but *sustained* acceleration of 0.15g to 0.30g, emanating from a large event to the south and propagating up the length, or axis of the structure. Being very straight and a mile long on different foundation materials, this seemed a likely scenario for possible vibration phase synchronization, or resonance; which is any earthquake engineer's nightmare. This phenomenon is shown schematically in Figure 1 (from the proposal);

3. A moderate to long duration event which would input high *vertical accelerations* (0.05 to 0.20g) which would serve to lift the bents up and down, thereby promoting a progressive compression failure of the upper columns. This thinking was influenced by some of the failure modes seen at San Fernando. We were afraid of Rayleigh waves generating such vertical loads, but lacked sufficient data to take this idea much further.

The linearity of the Cypress bothered Professor Raphael; his feeling being that some unknown portion of seismic energy waves traveling up the axis of the structure were sure to be reverberated back, through the structure, where they could interact with later, incoming waves. The curvature and bifurcation of the double deck at either end could conceivably damp some of the return motion, but we felt this was too difficult to model, hence the perceived need for some on-site vibration testing. Curved freeway viaducts with numerous on/off ramp appendages serve to damp incoming seismic waves, as shown schematically in Figure 2. These types of structures are also very hard to analyze for earthquake response behavior, especially if they become cracked.

My study of the Cypress dragged on for months. It was the early fall of 1978 by the time the proposal was complete.

The estimated costs were, as I recall:

Phase 1:

a. Preliminary dynamic analyses	$10,000
b. Site-specific work	
Cone penetrometer testing at north end	4,500
Subsurface sampling, lab testing	6,500
Vibroseis work	8,000
Determination of structural periods /modes of vibration	5,500
c. Specific dynamic analysis	
Original plans and maintenance records retrieval	900
Meet with 1 to 3 members of original design team or CALTRANS staff (as appropriate)	2,200
Preparation of longitudinal and bent sections for dynamic analysis; set up and run	8,200
FLUSH program runs to obtain 2-D soil behavior in earthquake set up and run north-south motion and two sections with east-west motion	4,000

Phase 2:

d. Evaluate above analyses; decide if structural modeling required (elastic to model static modes of vibration; or plastic to model failure modes)	22,000 to 48,000
e. Devise retrofit measures, as deemed appropriate; could include physical testing of scaled structures in SESM lab	10,000 to 50,000

Totals (in 1978 dollars) $49,800 for Phase 1
$32,000 to $98,000 for Phase 2

These are the figures we arrived at as nearly as I can recall from my file notes. After I turned the project in, I went on to work on another study of the heightening of Shasta Dam with Professor Raphael. I recall speaking to him about the status of the Cypress proposal in the fall of 1978, whereupon he replied that, "there weren't any research funds allocated for that type of structure", or words to that effect. I knew that the Cypress had received a Phase 1 retrofit with cable ties and and neoprene cushion blocks at the expansion joints in the late '70's and early '80's. However, even with all of my trips out to the structure, I hadn't appreciated the pervasiveness of the hinge joints nor that such joints negated moment connections to transmit bending or twist-type loads. I had assumed that the main reinforcing steel ran through the columns, much like the modern structures I had observed being built in the 1960's and 1970's.

EXPECTED LEVELS OF SHAKING AT THE CYPRESS STRUCTURE

By the time Greensfelder's (1974) baserock acceleration map was released in 1974, Bay Area civil engineers had a good idea that expected shaking levels were a lot higher than the 0.10g pseudostatic loading we all had routinely employed. Greensfelder's map only predicted baserock acceleration levels as high as 0.50g, over a very large zone within which the Cypress structure lay.

But, a 0.50g acceleration is very tough to design large heavy concrete structures to withstand. The earthquake-induced bending moment on an elevated structure is proportional to the structure's overall stiffness, mass, and height above the ground to its center of gravity. By supporting a heavy box girder 50 feet in the air, the seismic loads are greatly heightened. The upper supporting girders weighed something like 165,000 pounds apiece, and these supported about 80 feet of box girder roadway likely weighing around 850,000 pounds. The widespread use of pre-cast concrete reduces the required beam size (and hence, weight), while the additional employment of lightweight concrete aggregate halves the mass weight. By utilizing modern construction practices, a structure like the Cypress would probably weight only 40% to 45% of that structure, with a notable lessening of the seismic loads.

Toward the early 1980's, an abundance of geotechnical engineering and planning-level documents were available to predict levels of ground shaking from specific MCE's, which varied from area to area. On the East Bay coastal plain, the MCE event was a Magnitude 7.5 event on the Hayward fault (C.D.M.G. Special Publication 78, 1987). This fault runs through the Berkeley campus, actively creeping and off-setting the Memorial Stadium, built in 1912. The Hayward is thought to have spawned Magnitude 7.0 tremors in 1836 (near Richmond) and 1868 (near Hayward).

The Hayward fault lies a scant 4 miles from the I-880 Cypress Structure. Greensfelder's 1974 baserock acceleration map had been updated by C.D.M.G. and CALTRANS in 1987 (Mualchin and Jones, 1987) and now shows the Cypress Structure to be just within the 0.50g acceleration. The 1987 C.D.M.G. Special Report-78 shows the northern half of the Cypress Structure receiving a Modified Mercalli Intensity of VIII and the southern half getting IX (on the Merritt Sands, See Figure 3). Using correlations published in Murphy and O'Brien (1977), Mercalli Intensities of VIII to IX would correlate with accelerations of 0.25g to 0.50g (see Figure 4).

Published correlations, by Seed and Idriss (1982) are commonly used to back out actual near-surface soil accelerations from predicted bedrock acceleration values. Such estimates can be made by first going to their chart relating horizontal distance from fault, quake magnitude, and peak horizontal acceleration, reproduced herein as Figure 5 (top). In the case of a Magnitude 6.5 to 7.5 tremor on the Hayward fault, 4 miles from the Cypress Structure, peak accelerations of 0.50 to 0.55g are predicted.

Actual site response can then be estimated by utilizing another, more approximate relationship between rock acceleration and surface acceleration on particular types of soils, reproduced in Figure 5 (bottom). In the case of the Cypress Structure subjected to its MCE on the Hayward fault, we could expect maximum accelerations of between 0.27g and 0.39g, depending on soil type.

C.D.M.G. Special Publication 78 (1987) went on to warn about the potentialities for ground failure on artificial fill areas, such as the northern half of the Cypress Structure (see Figure 6). The report warns that the Cypress Structure would likely be damaged enough to prevent the passage of traffic "for several days" in the event of a major quake.

ACTUAL LEVELS OF SHAKING EXPERIENCED DURING THE LOMA PRIETA EARTHQUAKE

The Loma Prieta Earthquake occurred at 5:04 p.m. on Tuesday, October 17, 1989, just as the third game of a San Francisco Bay World Series was getting underway at Candlestick Park. Initial reports pegged the quake at Richter magnitude of 7.0. This was downgraded to a 6.9 several days later, then recast at an official magnitude of 7.1 some 10 days later, based on energy release data recorded by far-away stations. Strong motion (source) shaking was recorded for approximately 15 seconds, although site response shaking was estimated to be as much as 30 to 40 seconds in some areas.

The quake came as no surprise to those familiar with California seismicity. In 1984, the Division of Mines and Geology (Real, 1984; p. 2-3) had predicted "odds better than 1 in 2 (>50% probability) that a major earthquake would occur on the San Andreas Fault between San Jose and San Juan Bautista (see Real, p 28). The quake was forecast to be a magnitude 6.5 to 7+ event (Real, 1984, p 3). The next most likely quakes had odds of only 1 in 10 (10%) and 1 in 20 (5%), suggesting that the Loma Prieta event was 5 times more likely than any other major event in the Bay Region.

The Loma Prieta Quake will likely be the most well-instrumented quake in the United States' history. The U.S. Geological Survey expected the quake sometime soon, so an elaborate network of recording stations (over 400) was within 200 km of the epicenter. The style of slippage was unusual however for the San Andreas. The quake's focal depth was quite deep, 10-12 miles, instead of the usual 6 to 8 miles. The Pacific Plate (Santa

Cruz side) *rose* 1.7 meters (5.6 feet) on an inclination of 70 degrees from horizontal, suggesting mostly dip-slip movement in lieu of the San Andreas' more usual strike-slip motion (with the western plate heading north). The rupture energy petered out about 4 km below ground surface. The theoretical surface rupture would be 5.25 feet vertical and 1.92 feet horizontal if the offset had propagated all of the way to the ground surface. Geologists have found no such break, only a ridgetop zone of about 9 left-stepping en-echelon breaks across the tope of Santa Cruz Mountains, just east of the summit of State Route 17. The largest of the ground scarps is about 2.3 feet high and exhibits left-lateral motion, suggesting clockwise rotation and possible ridge spreading. Geologists are now postulating that the fault rupture is disseminated over a broad zone, 1/2 to 1 mile wide with significant "ridge spreading" serving to obscure any "clean" style of surface rupture.

One of the other benefits to come out of the 1971 San Fernando quake was the creation of the C.D.M.G.'s Office of Strong Motion Studies which manages the California Strong Motion Instrumentation Program (CSMIP). At the current time, several hundred strong-motion records are generated for any sizable earthquake. In this manner, localized *ground amplification effects* can better be appreciated and MCE's and planning-level documents annotated to reflect areas of increased concern. It is only by having an adequate number of records that site-specific seismic analyses can be generated and tested for validity (the acid test of any analytical procedure is to see if it will accurately predict previously-recorded or observed behavior).

The Cypress Structure was located almost exactly 100 km (62 miles) from the quake's epicenter. A preliminary evaluation of the available CSMIP data suggests a marked component of so-called *ground enhancement* effects, seen in the recorded acceleration arrivals. Simply put, Oakland got hammered much worse (.18 to .29g) than any other area close in range to the quake (and on the north side of the fault). San Francisco averaged 0.10g over 8 reporting stations, with the Presidio skewing even that average with a 0.21g reading. These strong-motion data (for horizontal accelerations only) are presented graphically in Figure 7.

Ground amplification effects are very apparent in some adjacent stations. For instance, the recorder on Yerba Buena Island on colluvial sands, but adjacent to Cretaceous-age bedrock, measured only 0.06g, while the station on Treasure Island, a man-made appendage to Yerba Buena, registered 0.16g, or more than 2-1/2 times the acceleration! In nearby Oakland, vertical accelerations of between 0.04 and 0.16g were measured, also suggestive of ground amplification. In the downtown Oakland area, a cover of young (Pleistocene and Holocene-age) alluvial and marine sediments is over 400 feet thick in places, lying upon the much older Franciscan Assemblage bedrock (Jurassic-Cretaceous-age). The actual topographic profile of this marked bedrock interface and the consistency and dynamic properties of those soft geologic fills overlying it needs to be probed more deeply in the next round of earthquake engineering research (hopefully in the 1990's).

FAILURE OF THE CYPRESS STRUCTURE SECTION OF I-880

What follows is a brief description of the observed modes of failure of the elevated Cypress Structure. These observations were all made within 48 hours of the structure's collapse. The explanations offered are necessarily *preliminary* in nature, and could, therefore, later be modified or discarded, depending on what the various investigative teams discover during razing of the structure.

Eye-Witness Accounts

Eye-witness accounts will be of much value in sorting out the sequence of failure. Preliminary accounts, several of which are by civil engineers who were driving on the structure's upper deck, are summarized below:

1. The structure was unusually empty at the time of failure (5:04 p.m. PST). Traffic speeds on the upper, southbound deck were unlimited (up to 70 mph). Traffic on the lower deck was similarly unencumbered, but somewhat slower (reported at 65 mph, but likely closer to 55 mph).

2. The earthquake shock waves rolled through the structure's longitudinal axis, from south to north. Like giant ocean waves, the structure lifted and dropped. Driving became difficult and some people slowed, some stopped, and some sped up to get off of the structure.

3. Drivers and passengers of vehicles on the upper deck describe seeing intermittent "puffs" of concrete dust at the supporting bents, indicting explosive crushing, spalling and flexure at those locations. It is not yet known exactly at what point the puffs of dust occurred with respect to the seismic wave crests or troughs. Eye witnesses/survivors of the lower deck have not been interviewed and their observations could be of critical importance.

4. The structure survived shaking long enough that one car of civil engineers from the Alameda County Public Works Department (Danehy, personal communication) first noticed the quake while somewhere in the Oakland distribution structure, drove onto the Cypress, saw and experienced the ground roll "waves" reverberating up through the structure, the concrete "puffs", and sped up, surviving the trip. They describe a progressive failure of the upper deck, starting at its north end, about the time they reached the south end (presumably across Bent 62, near Eighteenth Street). If this description is ac-

curate, a distance of approximately 1.05 miles was traversed at 55 to 70 mph, beginning at the onset of shaking. At an average speed of 62 mph, this trip would take 61 seconds (to reach the relative safety of the southern half of the structure). This preliminary account would suggest that the failure was progressive and may have initiated from north to south *after* the relative cessation of strong motion ground shaking. Certainly, more accounts need to be analyzed with respect to timing.

Failure Mode with Hinge Joints at Bottom of Columns

As mentioned at the outset, the Cypress Viaduct's designers had inserted structural *hinges* or joints at the top or bottom (or both) of the upper supporting columns. The hinges were placed at the bottom of the columns on the conventionally reinforced bents, shown in Figure 8. The 20 No. 18 (2-1/4 inches diameter) reinforcing bars within the upper columns were stopped just above the hinge joints. A shear key approximately 18" x 26" with 4 No. 11 dowels and a 4"-diameter copper drain pipe comprised the connection. The dowels appear to have extended 24" into either side of the joint. Expansion joint building felt provided the bond break for the hinge. These were applied as two 9"-wide strips parallel to the structure's axis and two 5"-wide strips on the opposing sides (north and south).

Just below the hinge, a critical reinforcing detail (shown on Figure 8) was utilized which provided discontinuous reinforcing steel in the lower column area above negative moment reinforcing steel coming up the lower column and turning into the lower supporting girder.

U.C. Berkeley Professors Jack Moehle and Stephen Mahin have identified this area as the zone of a critical crack" which sheared off in the failure sequence (see Moehle, 1989). We can infer that the region of the "critical crack" was an area of potentially high shear stress, noted by the structure's designers because they called for No. 4 ties at 12" spacings in this area and in the lower half of the upper column, just above the hinge joint.

In Figure 9, a diagram illustrating a possible mode of failure at the lower hinges is shown. As the structure bent lifts and falls with each earthquake load cycle (combined with the structure's own modes of vibrational response), a high compressive load is concentrated at the joint because there is insufficient tensile reinforcement across the joint to hold the column together in "negative gravity". Side-swaying motion could induce the same separation (as shown in Figures 14 and 15). On a down or compressive cycle, the outside wedge of discontinuous reinforcement is spalled off in excessive shear. This outside block (just below the hinge joint) was consistently found beneath the failed columns as a block approximately 12" thick and about 36" square. Four No. 18 bars, *only 48" long*, were consistently noted to be attached to such blocks. The bars had been cut prior to placement.

Of the 51 bents that were damaged or failed, 28 of them were of the design shown in Figure 8. All 28 of these bents failed with the upper deck falling onto the lower deck, as depicted in Figure 10. The upper column toes failed in shear and kicked outward, with the "critical crack" normally emanating from the inside of the hinge joint downward, on an approximately 60 degree inclination.

In collapsing outward, the columns caught and dragged the outer two rows of No. 18 rebars reinforcing the lower columns. The upper sections of the failed columns were pushed inward, ripping their upper moment connections in compression and exposing the steel and connection details with the upper supporting girders.

Hinge Joints At Top of Columns

As mentioned previously, the Cypress Structure was designed during the early days of pre-stressed concrete technology. In instances where slightly greater spans were needed for skewed railroad/street crossings or accommodation ramps, the designers had opted to utilize post-tensioned rods to pre-stress the upper supporting girder and in certain instances simply added a third base column for the lower supporting girder. In this manner, the upper girder could be maintained at a constant size, but span greater lengths or be extended for anticipated expansions. This size constraint was important to maintaining adequate clearance for the lower traffic deck.

One complication of this system was that it mixed different types of reinforced concrete members. In Figure 11, a conceptual view of the post-tension pre-stress is shown. If the upper columns were structurally attached to the upper supporting girder, the expected 1" to 3" of pre-stressed compression could deflect the supporting columns inward, breaking or overstressing them. The structure was being constructed from the ground up. As a consequence of this dilemma, the designers deleted continuous reinforcement through the supporting connections and installed hinge joints.

Hinge Joints at Top and Bottom of One Column and Top or Bottom of Opposing Column

In most instances where pre-stressed girders were used, a third hinge was added at the bottom of either of the upper columns within the supporting bent. These "doubly-hinged" columns appear to have been emplaced with an eye toward a planned expansion of the structure, shown diagramatically at Bents 72 (Figure 12) and 76 (Figure 13). Hinges at the top and bottom of the western columns would have more easily facilitated their removal during the planned expansion. The post-tension rods within these bents were threaded and capped with an eye toward splicing onto them later (see Figure 13).

Failure Modes of Bents with Three-Hinge Joints

In retrospect, a three-hinge supporting system possesses several deleterious traits during sustained seismic loading. As shown in Figure 14, upon lateral loading by an earthquake, the structure will sway to the side of the advancing wavefront. The amount of sway and the loads induced by such ground motion are a function of the structure's stiffness, mass, and height above ground. In the Cypress Structure, the heavy upper deck was placed some 50 feet off the ground, raising the structure's center of gravity to a level nearly coincident with the lower hinge(s). As the bent deflects in response to primary ground motion (Figure 14), translation or bending is more easily accommodated at the hinges, therein concentrating deflection-induced stress at the area of the adjacent column without such a hinge (as no bending moments are transmitted across the hinges). Large bending-induced stresses will occur at this juncture which is the only unhinged point on the upper deck load path (Buckle, 1989; Mahin, 1989).

Localized crushing of the concrete on opposing sides of the hinges could also occur at excessive deflections, giving rise to the concrete dust "puffs" noted by eye witnesses. After this primary sideways deflection, the structure would deflect back in an opposing direction, provided it maintained some degree of elasticity.

The structure could be expected to become more plastic and more sluggish in its response with increasing cracking. The corresponding reaction cycle of an undamaged bent is depicted in Figure 15. Localized crushing could occur on the opposing sides of the hinge joints on the reaction cycle and the sense of loading would be reversed on the unhinged section of column (the lower right portion of the upper supporting column, depicted in Figures 14 and 15).

Observed failure modes of the three-hinged bents were more complicated than others described previously. In the vicinity of Bents 71-74 (Grand Avenue), the viaduct made a 15 degree turn to the north, following the original trend of Cypress Avenue. The traffic decks were super-elevated, with the easterly side up-going through the turn (as shown in Figure 13). In Figure 16, the failure mode in this turn is depicted schematically (but the super-elevation is not shown). The easterly column on the "high side" failed in shear with the top, hinged end of the column, impacting on the street. The failed column pulled off significant reinforcing steel from the lower base column, suggesting a shearing or tearing motion downward, before the column head toppled over. Some of the post-tensioned rods snapped in the partial collapse of the upper deck. The west side of these partially-collapsed bents simply leaned over at the upper and lower hinges with some minor compressive spalling of the inside top of the column. This spalling likely occurred during collapse of the upper supporting girder and may not have been induced by side-sway during the earthquake. The surviving hinged columns in this area are relatively undamaged, which suggests that breakage was focused on the area of large bending-induced stresses depicted in Figure 14.

Another heretofore unseen failure mode occurred in the vicinity of Bents 64 to 74, towards the southernmost end of the failure. In this area, the failure appears to have been rapid and catastrophic. As depicted in Figure 17, the doubly-hinged columns on the west side of the bents were blown clear of the structure, consistently landing on their upper ends. These columns were found to be virtually intact with the 4 No. 11 dowels and 4" copper drain pipe cleanly sheared off at either end. In some instances, however, the dowels are gone and the dowel holes in the column are opened, suggesting complete and rapid pull-out.

The single hinge supporting column on the opposing (east) side exhibits the consistent mode of failure described previously. The column base has sheared off and taken off about 20" of the lower outside portion of the base column. This shearing proceeded for 7 to 8 feet downward, then the hinged upper end of the column toppled over, impacting the street below.

Survival of Three-Column Base Bents

A universal observation at the failure site was the apparent survival of the longer three-column base bents (shown in Figure 18). The failure sequence stopped abruptly at Bent 62, the second bent south of Eighteenth Street. Bent 62 is the first in a series of 16 three-column base bents proceeding south which withstood the quake (the Phase 1 restrainer cables pulling out of the upper box girder deck). Within the failed sequence (bents 63 through 112), four 3-column base bents (nos. 95-98) were used on a skewed crossing over a Santa Fe Railway spur in the center of Twenty-Sixth Street. Bents 95 and 98 lost their upper decks, but 96 and 97 did not, providing a delicate sanctuary to those motorists luck enough to be there.

Much can be learned from studying bents 96 and 97. They were hinged at the tops of the upper columns (to carry a post-tensioned girder, but had a thicker section at the column bases (because of the skew) and were continuously reinforced (with lap splices on the No. 18 bars). Bents 96 and 97 carried the maximum skew of 27-1//2 degrees while 95 and 98 provided the transition at skews of only 14 degrees. The greater skew imparted significantly increased shear area to the base of the upper supporting columns, which were noticeably cracked, but not failed. The less severe skew on bents 95 and 98 were failed in shear at the base of the upper columns in the manner described in previous sections.

Another factor which remains to be explored is the increased stiffness of the 3-column bents. By their very design, the side sway and center of gravity somewhat lowered; even though most had upper and lower hinge joints (bents 62 and 95 through 98 did <u>not</u> have lower hinge joints). This increased cross-sectional stiffness of the supporting bents needs to be explored in dynamic, non-linear modeling and then compared to the 2-column base bents.

Possible Ground Motion or Ground Failure Effects

Only two sections of the failed Cypress Structure experienced total collapse, or failure of the upper and lower decks. This occurred between bents 105/106 and 106/107, just south of the Thirty-second Street overcrossing. The west base column of bent 106 was noticeably tilted toward the west. This tilt could be ascribable to foundation failure or it could have been pushed outward in the collapse of the two decks, in which case it broke at the pile cap. In this section, the viaduct was super-elevated and the upper column bases were both hinged. This is in the area where an old slough channel parallels the west side of the viaduct (Radbruch, 1957). Confined channel deposits of saturated granular materials could have lurched or partially liquefied. No overt evidence of liquefaction or ground failure was noted, but such evidence may lie underneath this anomalous failure area, and this should be examined. During demolition of the viaduct, sonic velocity tests could be run on the pile cap at bents 106 and 107 to see if the column footing , pile cap, or piles are damaged. At the present time, this area cannot be inspected.

Another curious anecdote mentioned by many of the survivors interviewed is the description of a so-called "ground wave" rolling through the structure "just like being in the ocean". This is sketched diagramatically (and not to scale) on Figure 19. We may find that Professor Raphael's insights about excessive vertical accelerations and Rayleigh-induced ground waves have merit in retrospect.

The worries about ground enhancement of incoming quake accelerations certainly seems validated (as it was in Mexico City in 1985). Looking at base rock accelerations alone does not appear to be adequate in the analyses of extensive structures founded on different foundation materials.

CONCLUSIONS

A great deal of work remains to be done on the Cypress Structure if the engineering community is to glean what lessons there are to be learned from its failure. The Cypress was an extremely long and complex structure, designed in an era which did not fully comprehend seismically-resistent design. The greatest reason for this view was the paucity of seismic response data, particularly strong motion records and site response spectra from earthquake-loaded structures.

A number of new, and heretofore unseen, modes of structural failure were observed in the collapse. The Cypress was the State's first double-decked freeway and the first to fail in an earthquake. Three similar freeway viaducts in the San Francisco area sustained varying levels of damage, but none failed. It is very likely that CALTRANS' Phase 3 retrofit program will be awarded increased levels of funding to accelerate this program, just as the Phase 2 program received a boost after the Whittier quake in 1987. Had the Loma Prieta quake struck 10 years later, CALTRANS' planned retrofits might have saved the structure.

It is important to appreciate that virtually all of the modern structures built since 1968 survived the Loma Prieta quake with little or no damage. Any quake of a magnitude 7.0 will cause some damage, but well-engineered structures possess enough redundancy to survive. There's nothing inherently wrong with double-deck freeways so long as then are designed to modern (post 1973) standards with proper seismic-loading considerations. The Cypress was not designed for anything close to the loads that were impacted on it.

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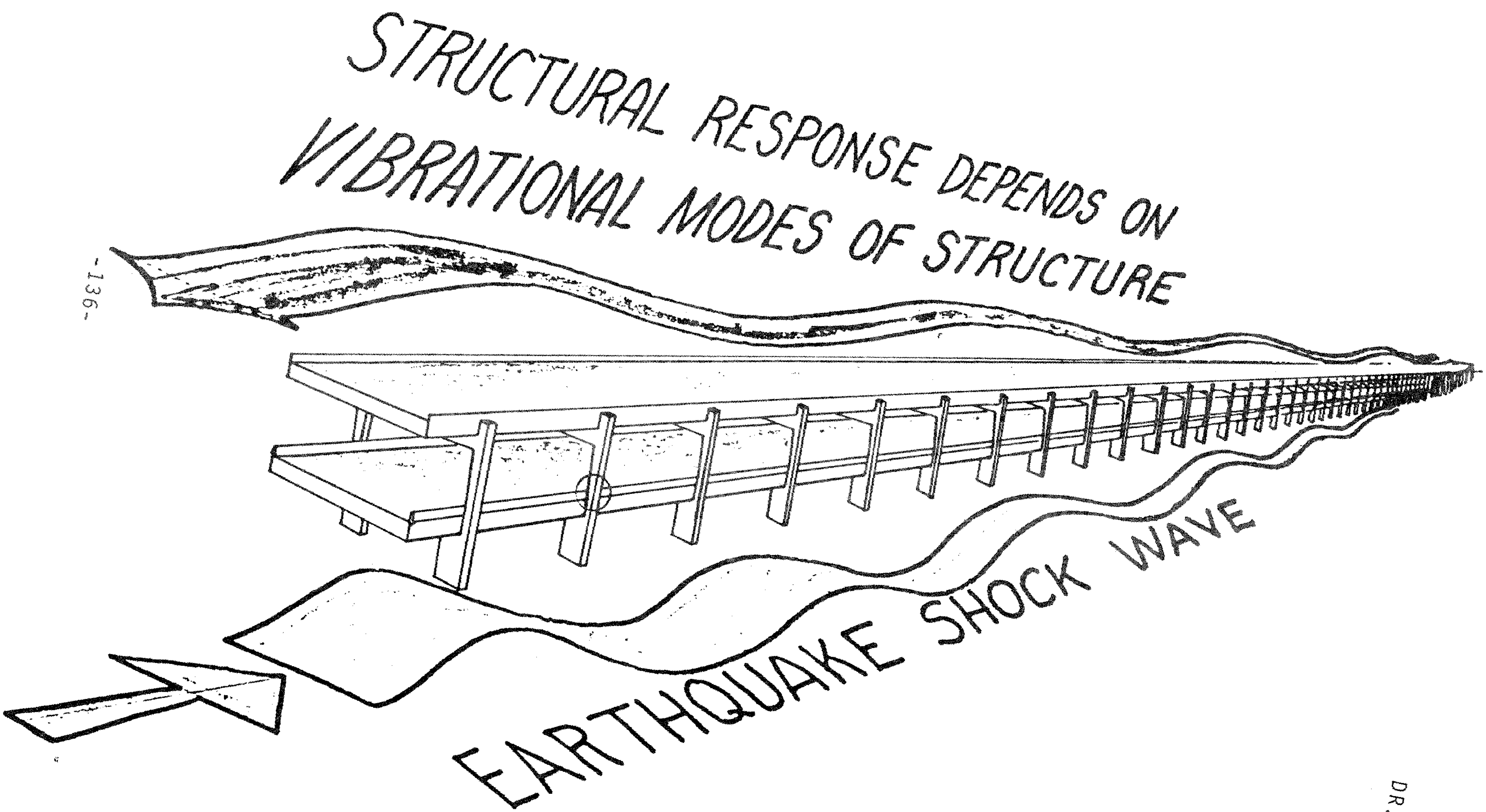
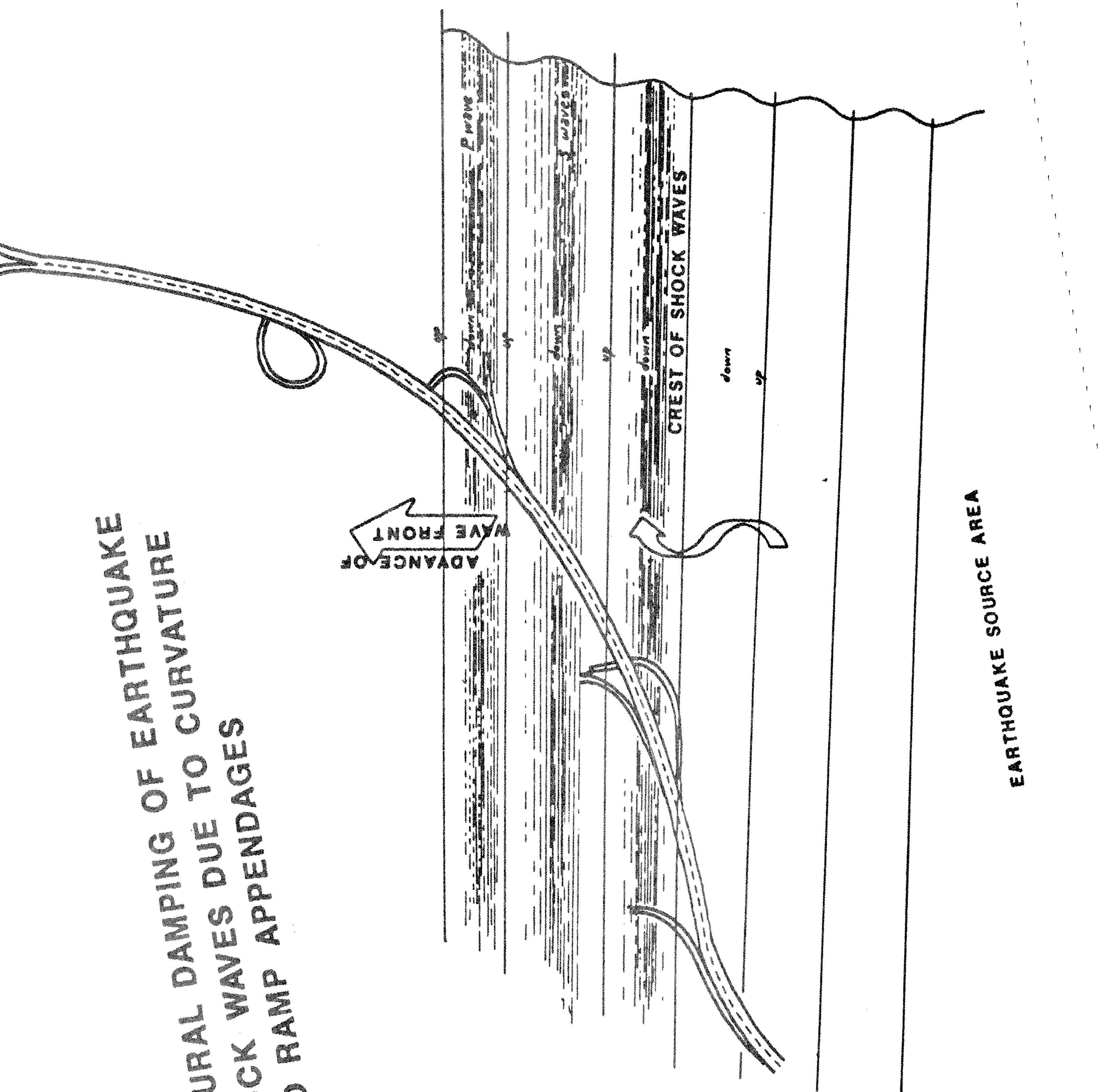
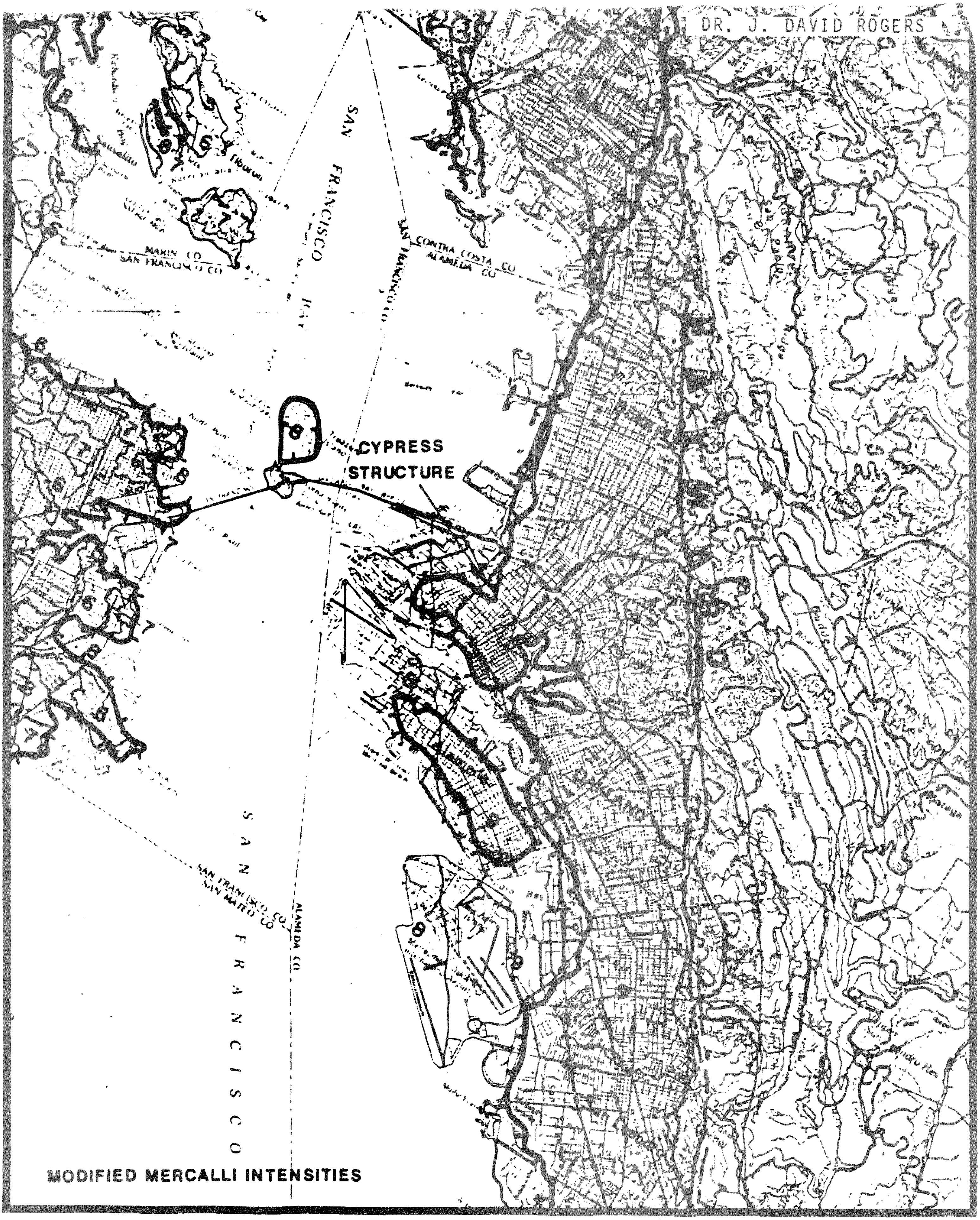

STRUCTURAL RESPONSE DEPENDS ON
VIBRATIONAL MODES OF STRUCTURE
EARTHQUAKE SHOCK WAVE



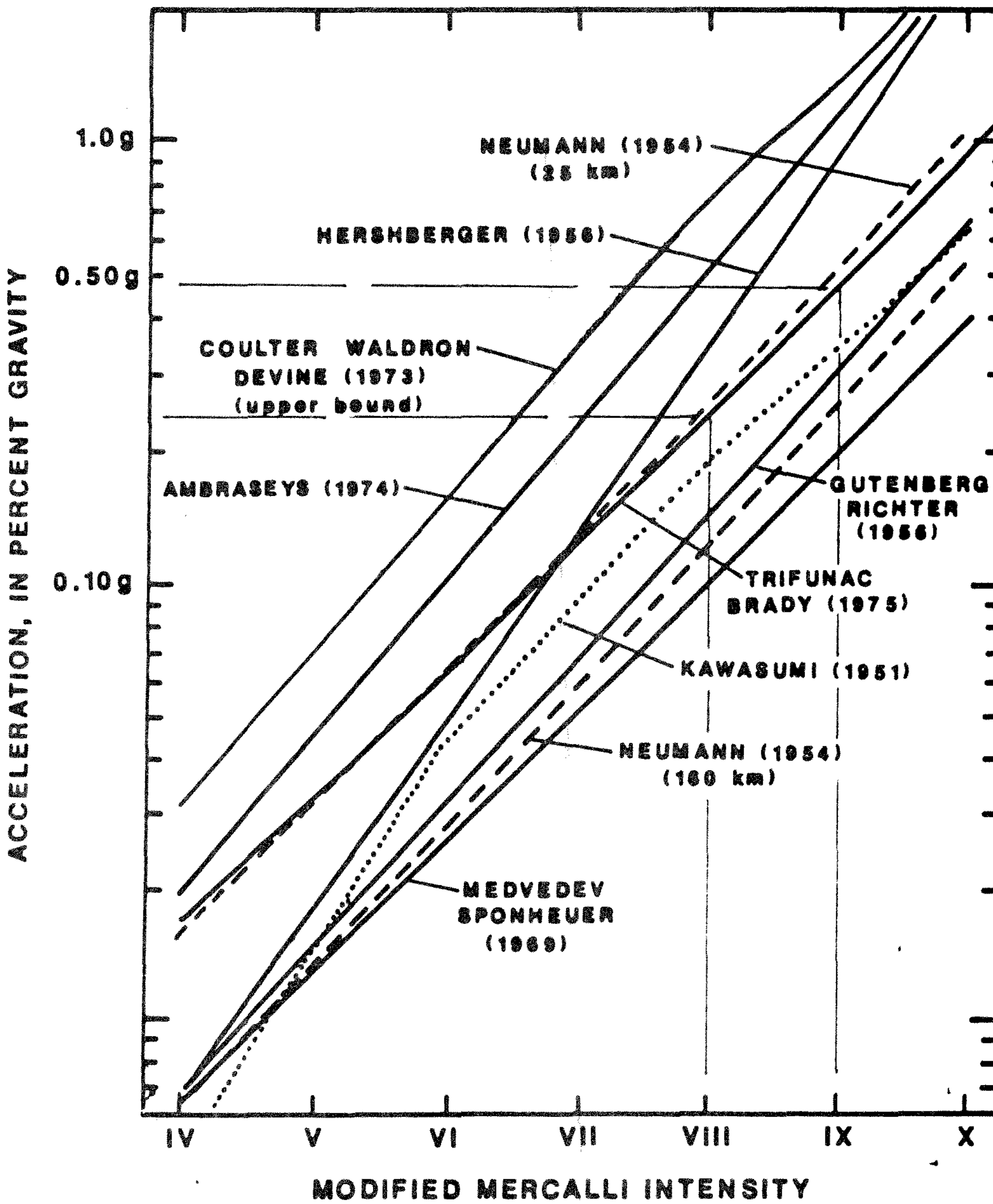
NATURAL DAMPING OF EARTHQUAKE SHOCK WAVES DUE TO CURVATURE AND RAMP APPENDAGES

Fi



Source: C.D.M.G. Special Report 78 (1987)

Figure 3



taken from J.R. Murphy and L.J. O'Brien
Bull. Seismo. Soc. Am. v.67(3) pp. 877-915
June 1977

Figure 4

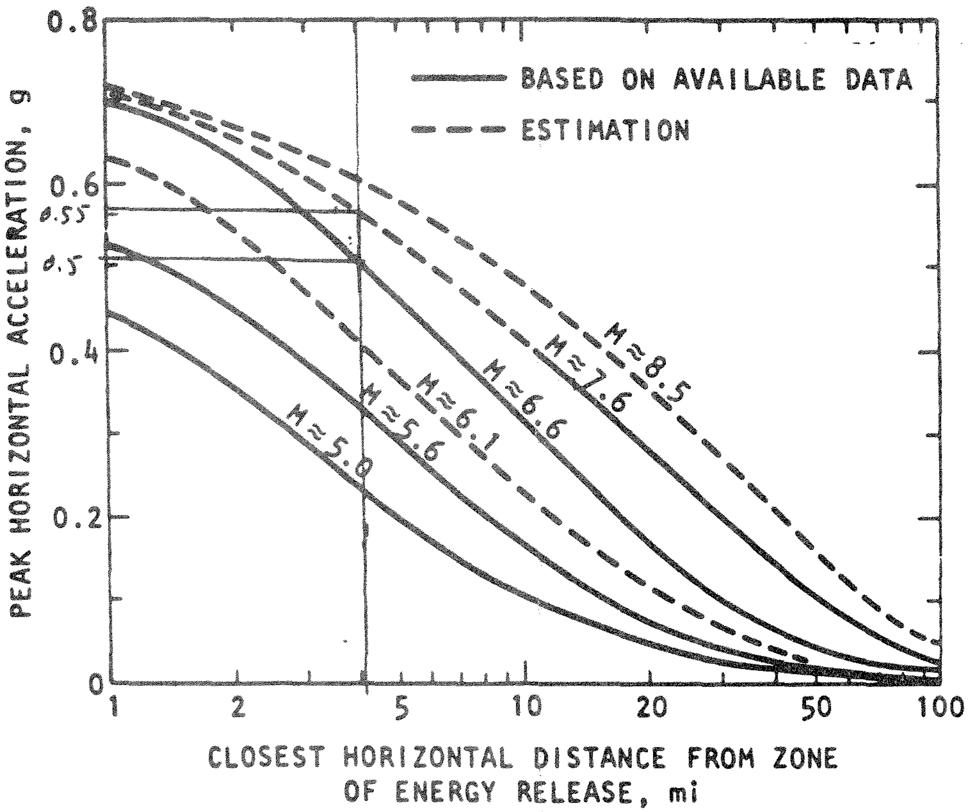


Figure 5 Average values of maximum accelerations in rock.
(taken from Seed and Idriss, 1982)

THE CYPRESS STRUCTURE IS LOCATED APPROXIMATELY 4 MILES FROM THE HAYWARD FAULT. ESTIMATES OF PEAK HORIZONTAL ACCELERATION ARE BASED ON A QUAKE OF BETWEEN MAGNITUDES 6.6 AND 7.6.

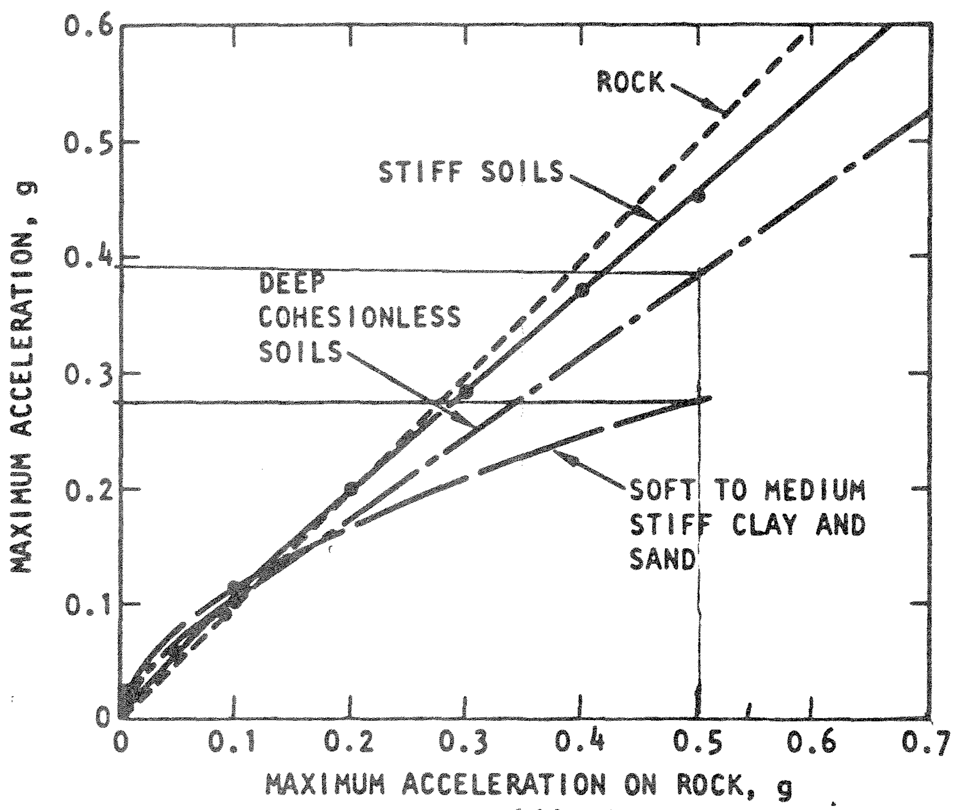
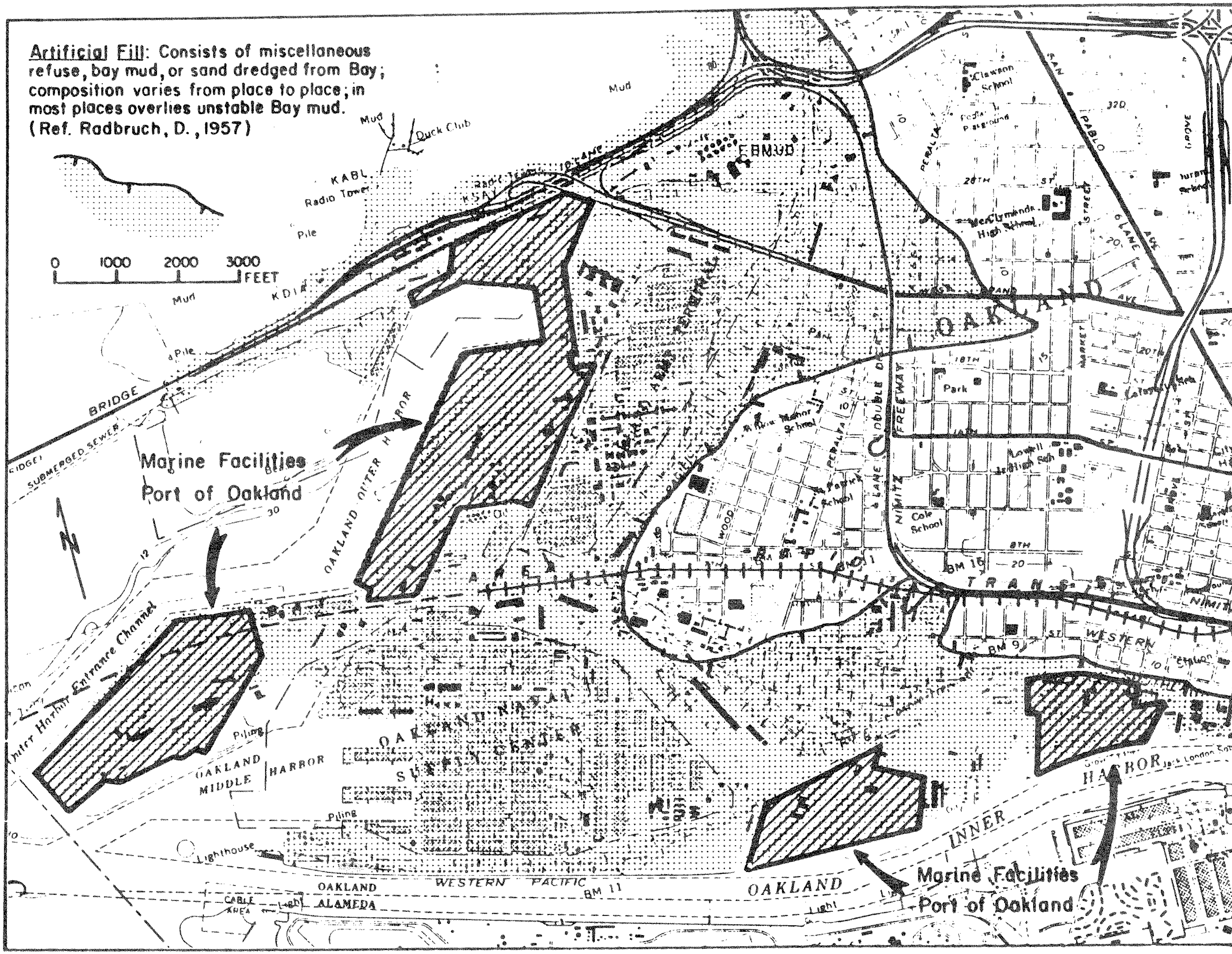


Figure 5

Source: C.D.M.G. Special Report 78 (1987)



Topographic Base Reduced from U.S. Geological Survey 1:24,000-Scale Map Series.

Major transportation and utility lifelines located on artificial fill in west Oakland.

Figure 6

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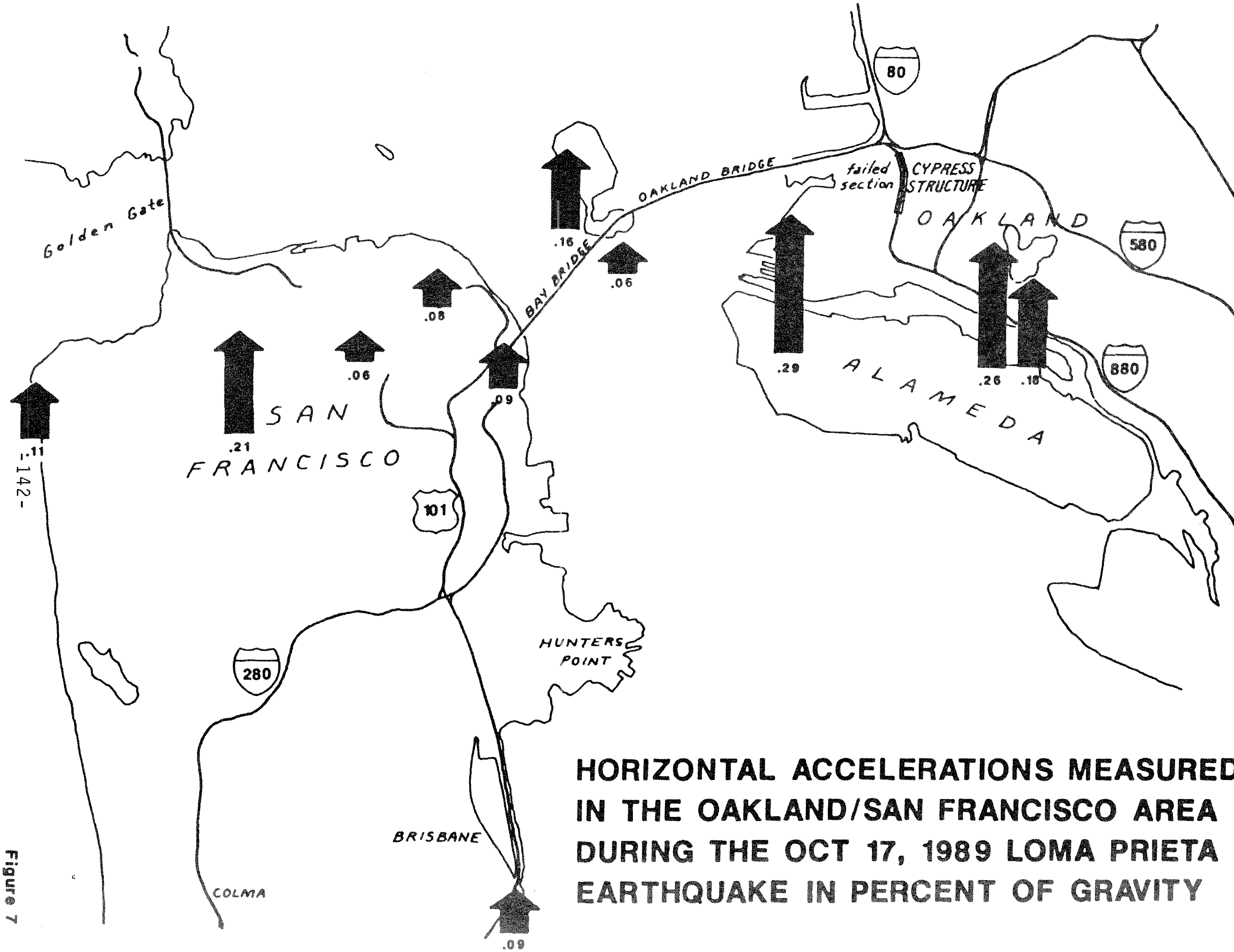

HORIZONTAL ACCELERATIONS MEASURED IN THE OAKLAND/SAN FRANCISCO AREA DURING THE OCT 17, 1989 LOMA PRIETA EARTHQUAKE IN PERCENT OF GRAVITY

Figure 7

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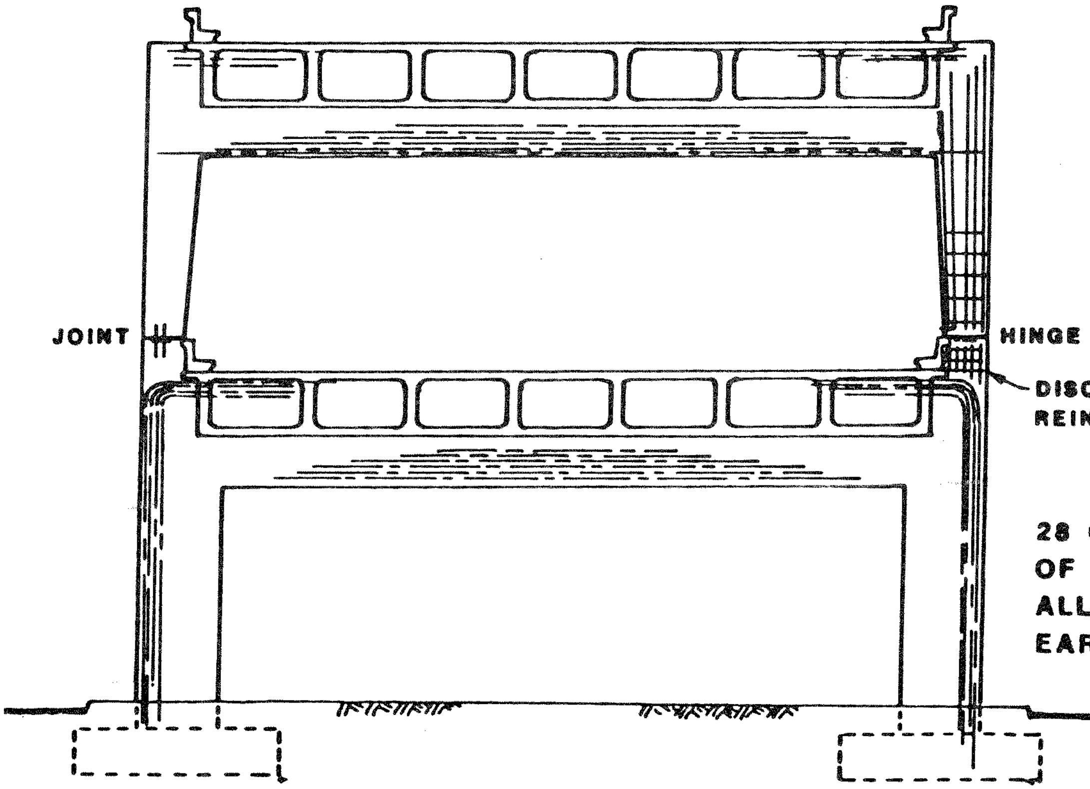
HINGE JOINTS AT BOTTOM OF COLUMNS



28 OF THE 124 SUPPORTING BENTS WERE OF THIS DESIGN. THE UPPER PORTION OF ALL 28 FAILED DURING THE OCT 17, 1989 EARTHQUAKE

CONVENTIONAL STEEL REINFORCEMENT IN UPPER AND LOWER SUPPORTING GIRDERS

Figure 8

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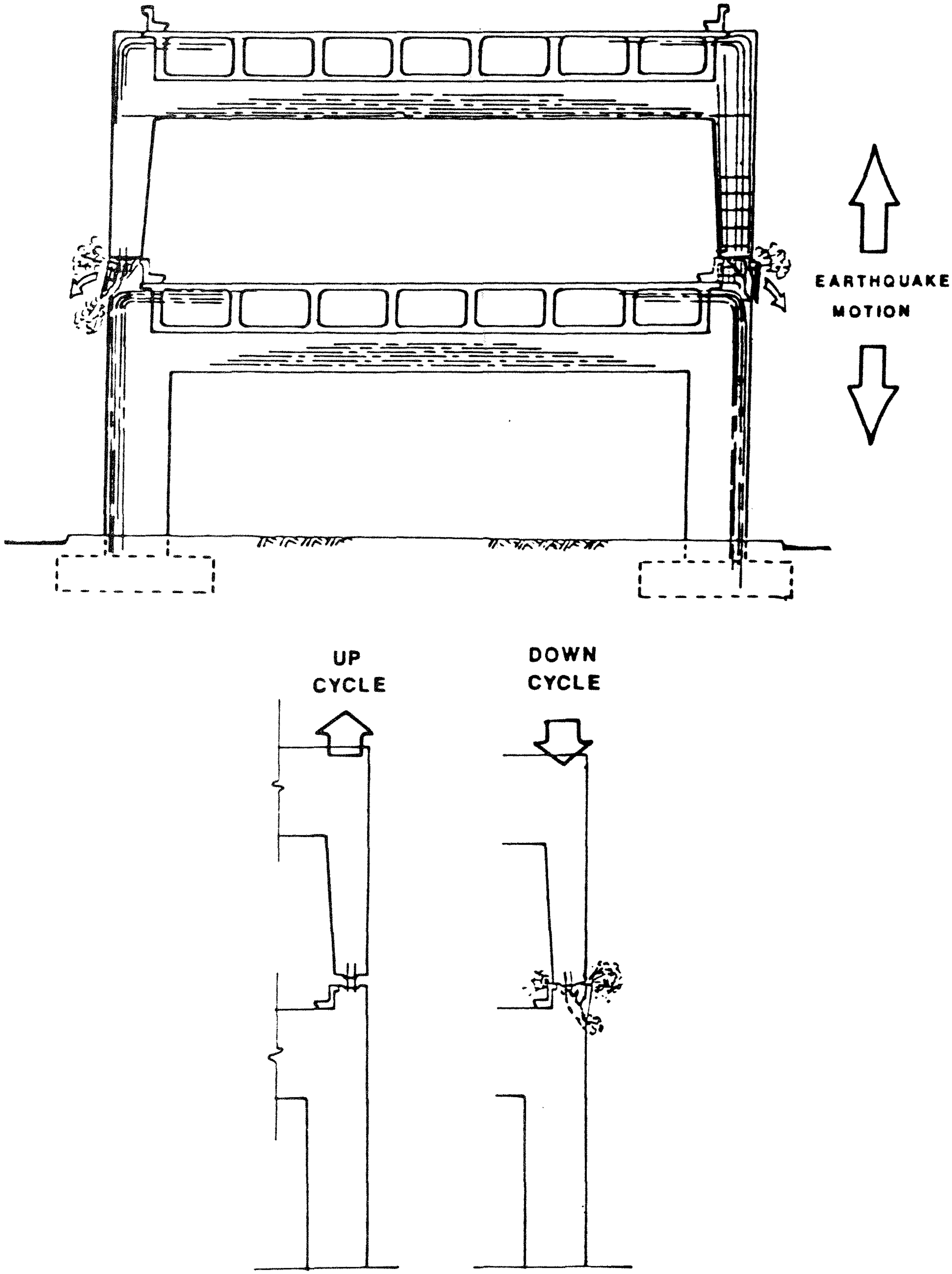
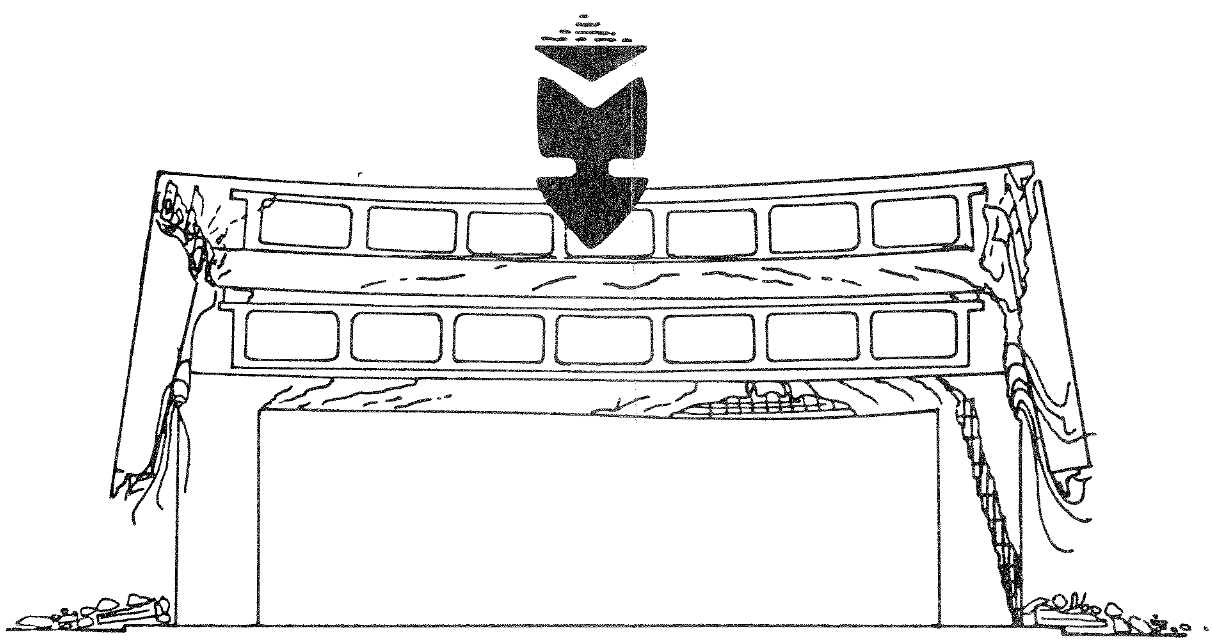
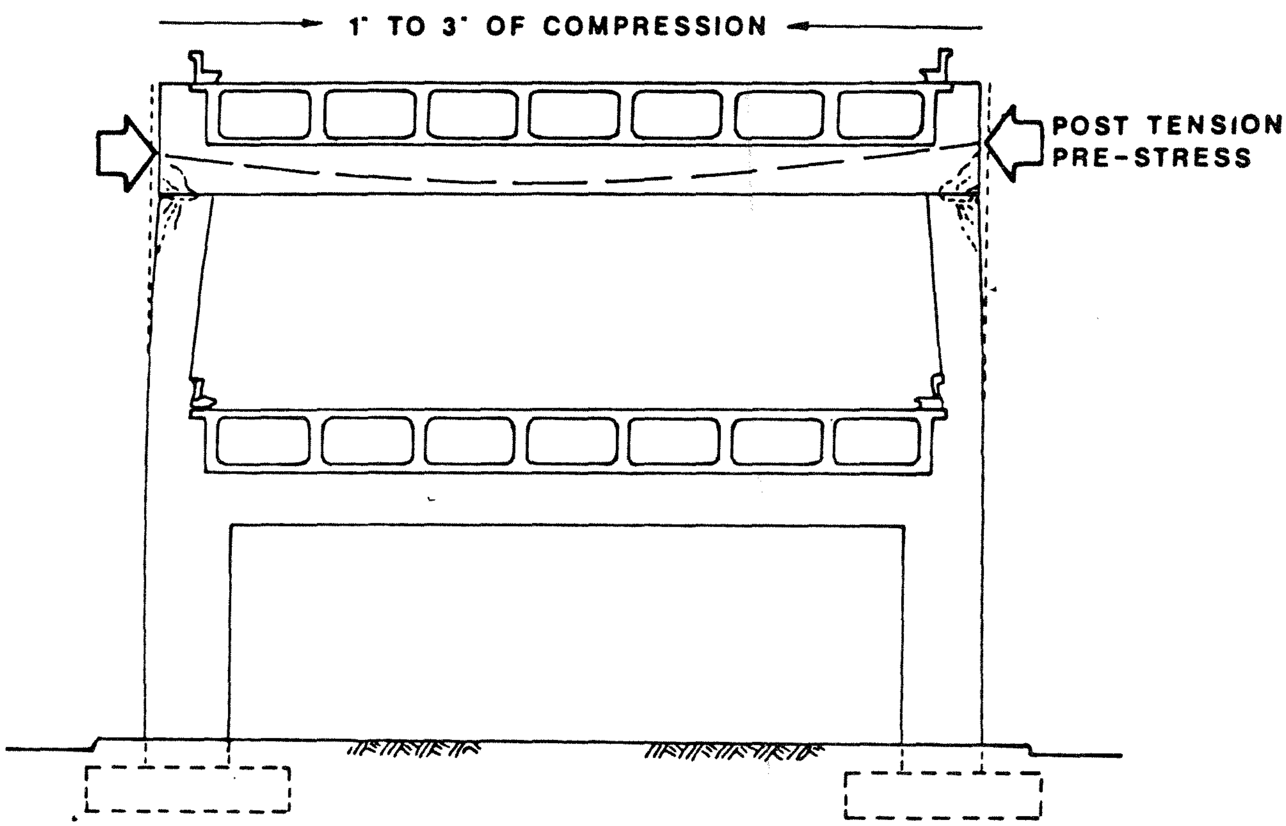

EARTHQUAKE
MOTION
UP
CYCLE
DOWN
CYCLE



COLLAPSE OF UPPER DECK ONTO LOWER DECK

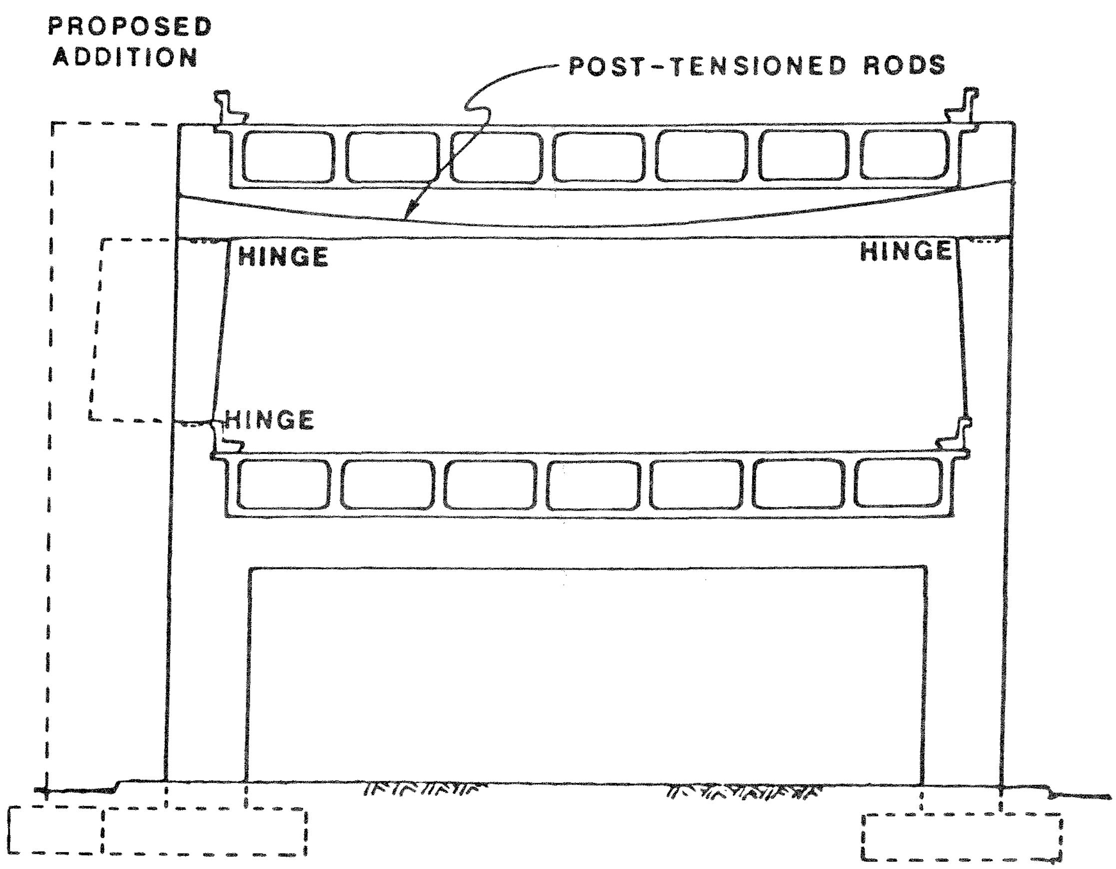
RATIONALE FOR HINGES ON UPPER COLUMN CONNECTIONS TO POST-TENSIONED GIRDERS



TOP OF COLUMNS SUBJECT TO HIGH COMPRESSIVE STRESSES

Figure 11

HINGE JOINTS AT TOP AND BOTTOM OF ONE COLUMN; TOP OR BOTTOM OF OPPOSING COLUMN



CROSS SECTION AT BENT 72

Figure 12

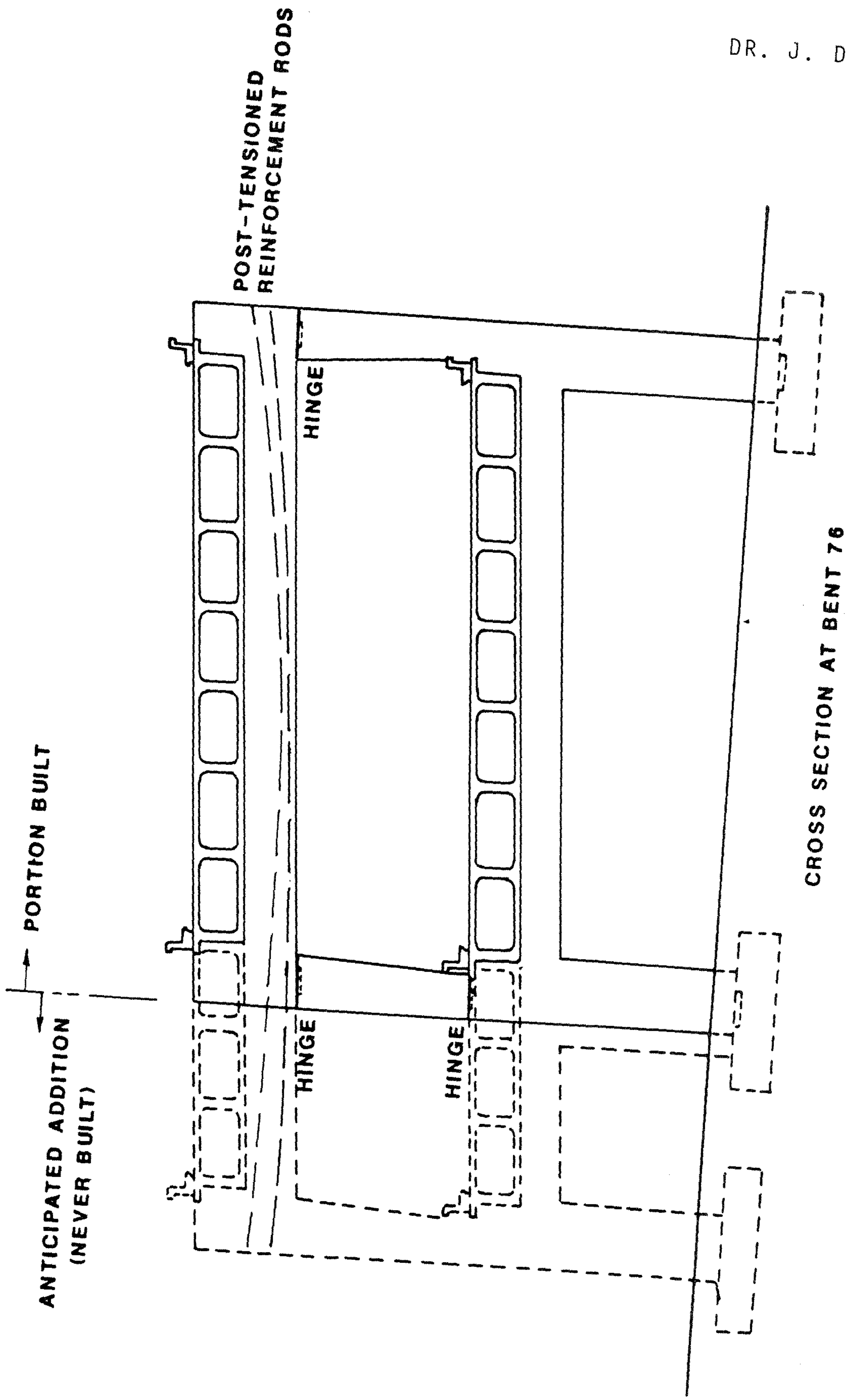
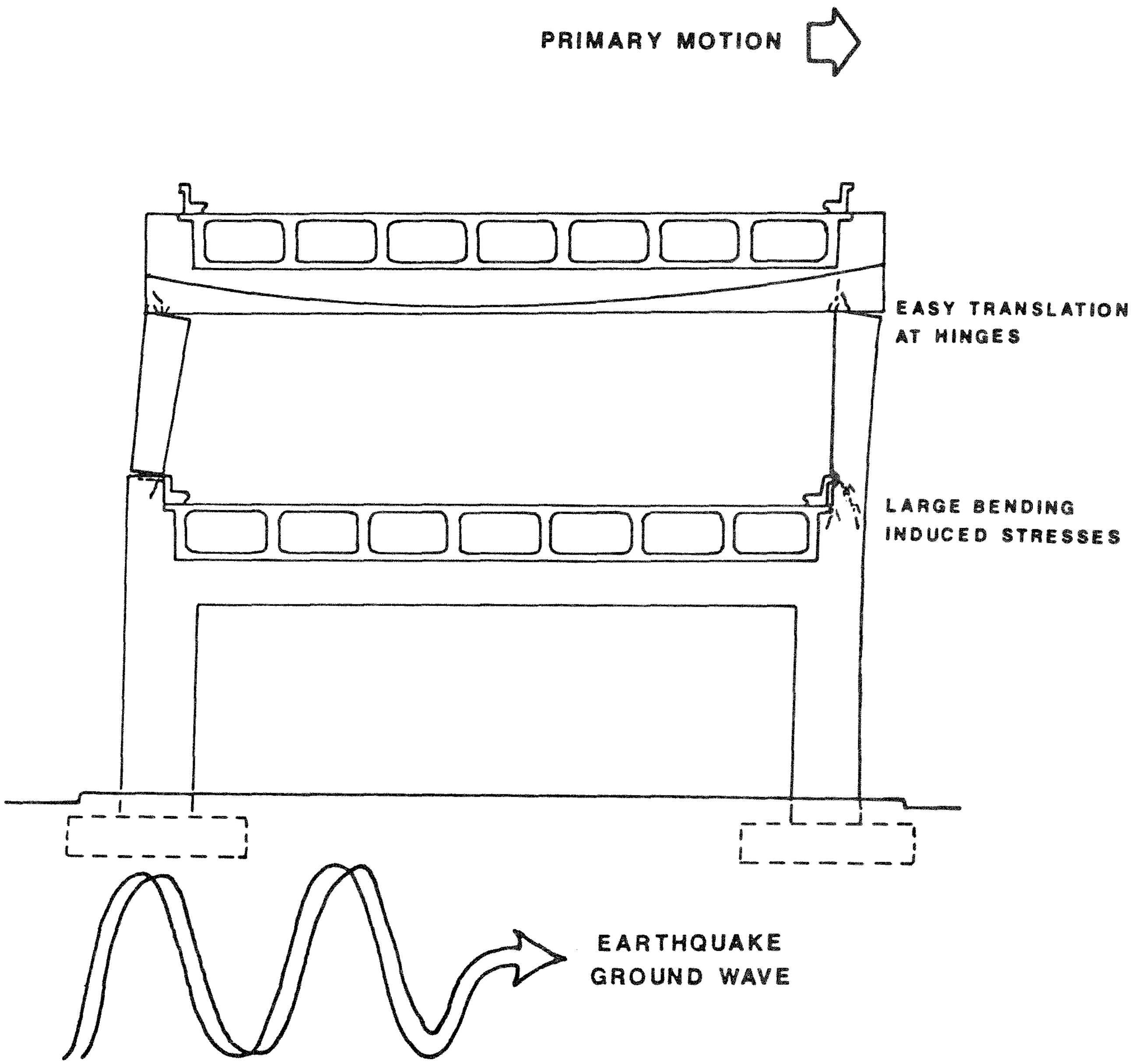

POST-TENSIONED
REINFORCEMENT RODS
HINGE
PORTION BUILT
ANTICIPATED ADDITION
(NEVER BUILT)
HINGE
HINGE
CROSS SECTION AT BENT 76

Figure 13


PRIMARY MOTION
EASY TRANSLATION
AT HINGES
LARGE BENDING
INDUCED STRESSES
EARTHQUAKE
GROUND WAVE

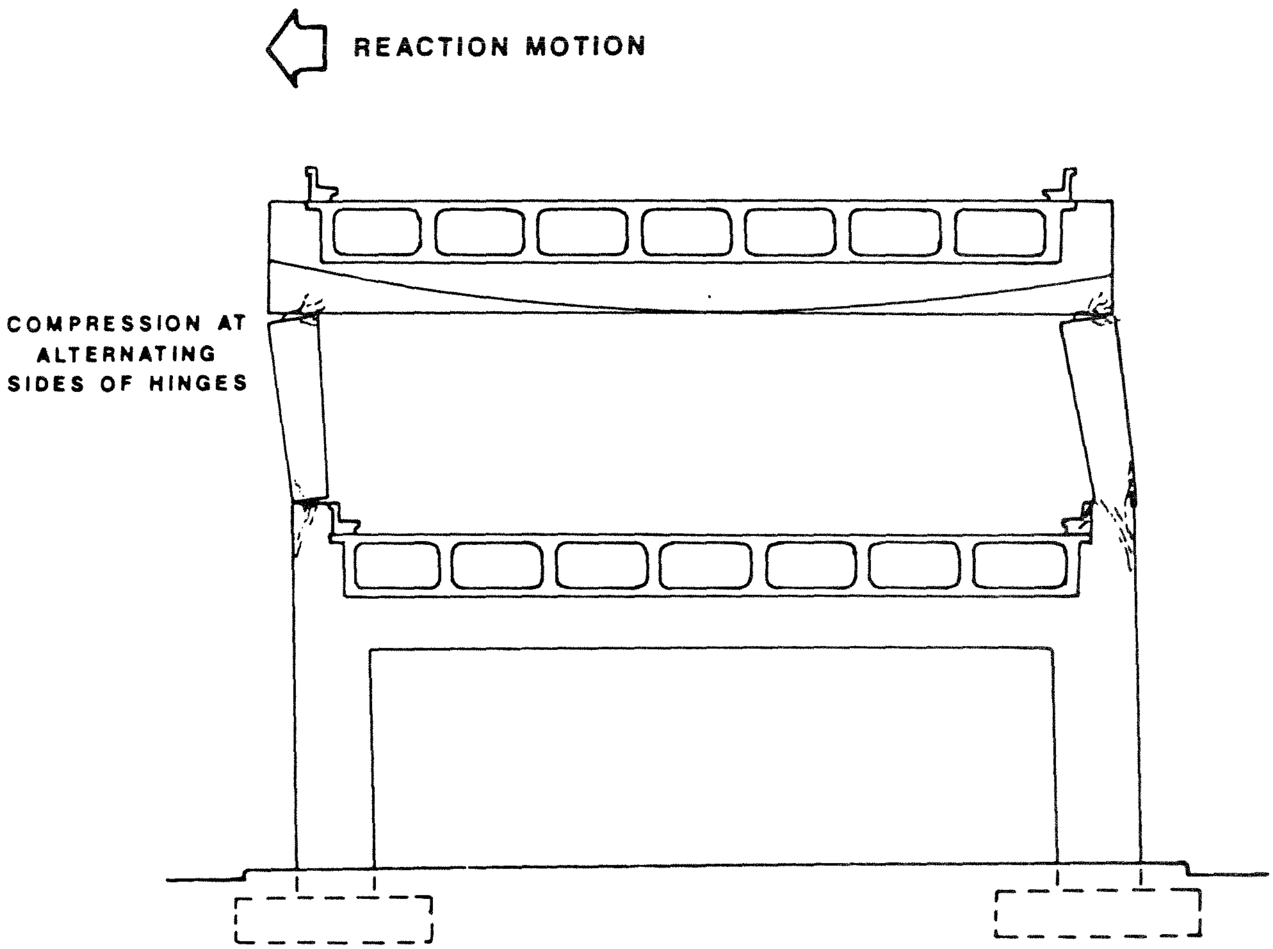
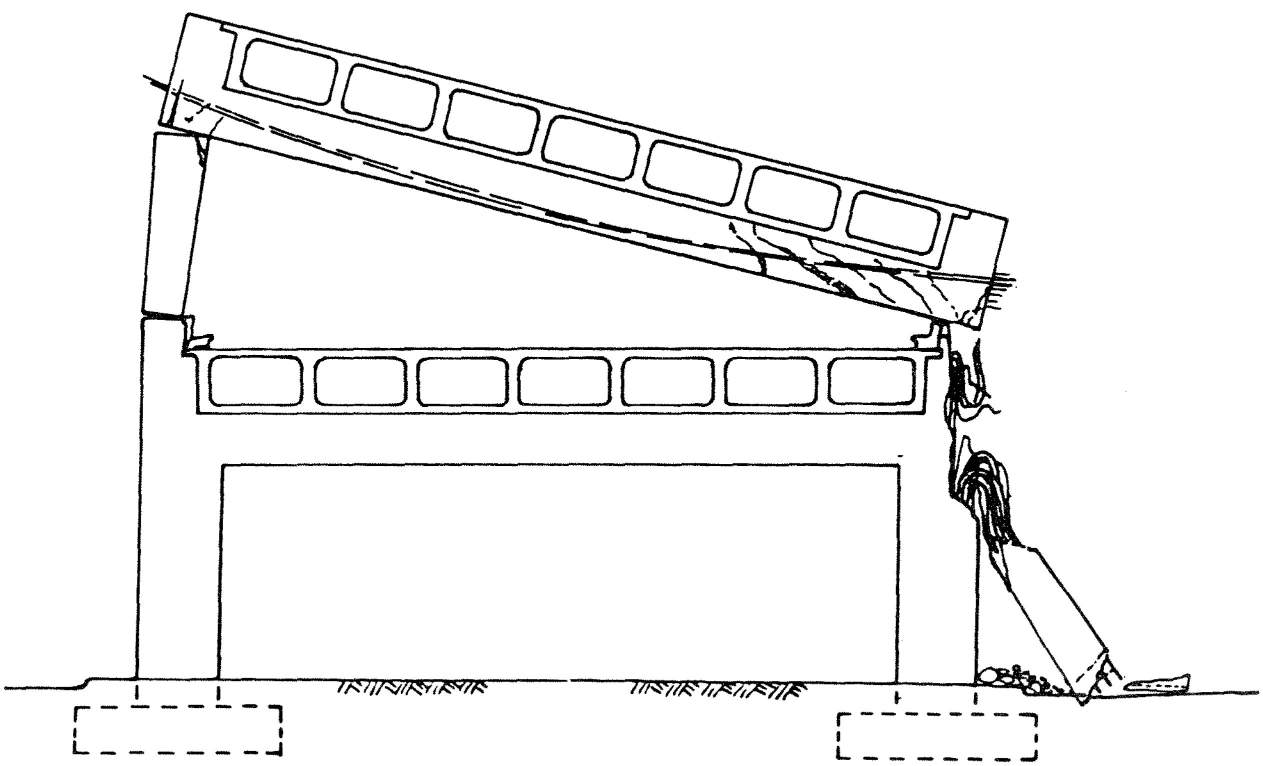
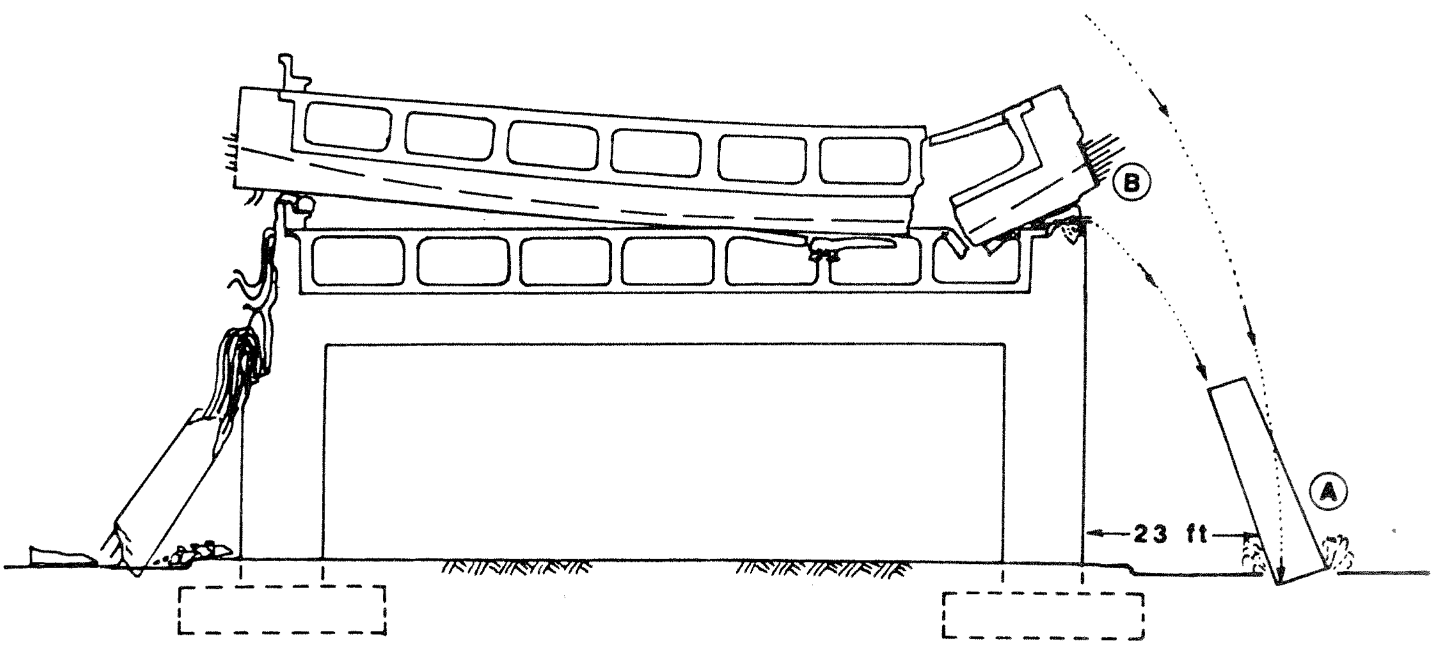

REACTION MOTION
COMPRESSION AT
ALTERNATING
SIDES OF HINGES

Figure 15



FAILURE MODE IN VICINITY OF BENTS 76 - 80

Figure 16



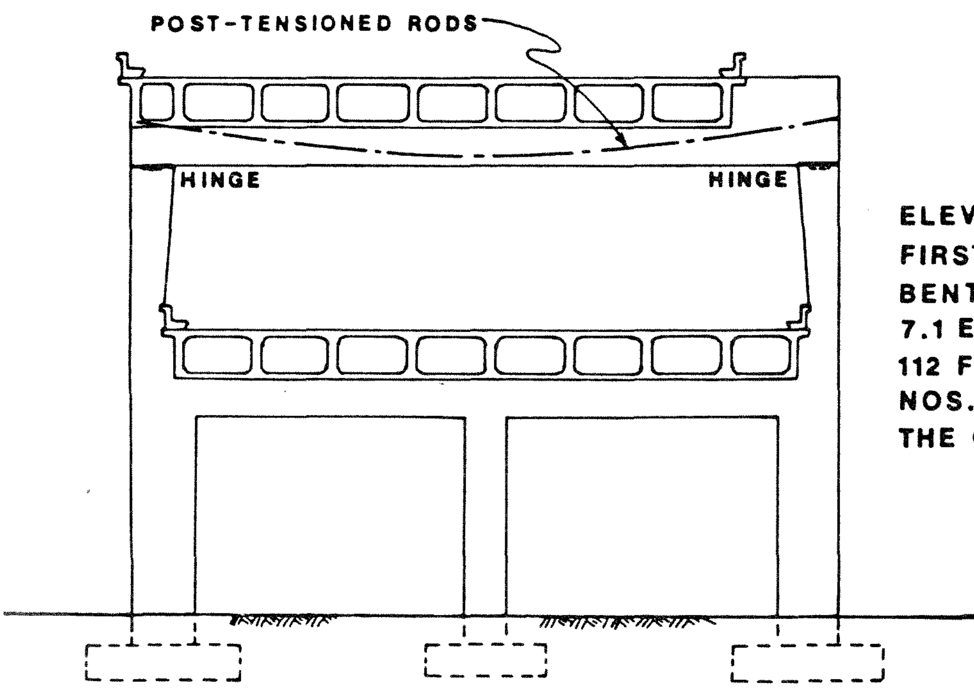
FAILURE MODE IN VICINITY OF BENTS 71 - 74

(A) COLUMNS WITH UPPER AND LOWER HINGE JOINTS BLOWN OUT INTACT

(B) POST - TENSIONED RODS SNAPPED AND POPPED OUT OF BROKEN CROSS GIRDERS

Figure 17

3-COLUMN BASE BENTS



ELEVATION VIEW OF BENT 62, THE FIRST IN A SERIES OF 17 3-COLUMN BENTS WHICH SURVIVED THE MAG 7.1 EARTHQUAKE. BENTS 63 THRU 112 FAILED, WITH THE EXCEPTION OF NOS. 96 AND 97, WHICH SURVIVED THE QUAKE.

THE 3-COLUMN BENTS APPEAR TO POSSESS GREATER STIFFNESS WHICH ENHANCED THEIR SURVIVAL.

Figure 18

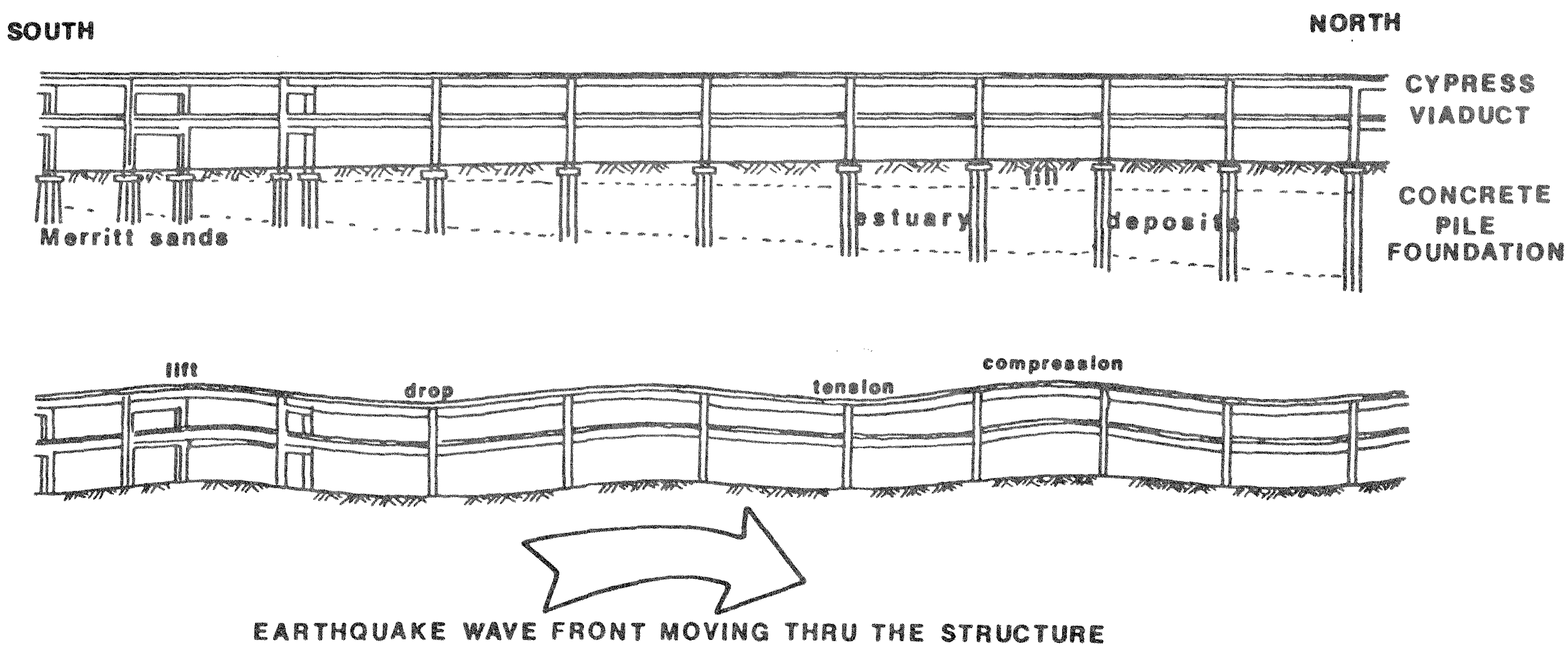


Figure 10

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