

BY THE COMPTROLLER GENERAL
Report To The Honorable Adam Benjamin, Jr.
House Of Representatives

OF THE UNITED STATES

**Further Examination Of The East Chicago,
Indiana, Highway Ramp Collapse Could
Help Prevent Similar Accidents**

The April 1982 collapse of a highway ramp under construction in Indiana killed 13 workers and injured 17. The ramp is part of a highway construction project receiving 90 percent Federal funding. Several Federal, State, local, and private agencies are investigating the accident. The National Bureau of Standards, assisted by the Federal Highway Administration, is investigating the technical cause of the collapse for the Occupational Safety and Health Administration.

Federal action to begin the technical investigation was prompt, and the Bureau appears well qualified to determine the cause. GAO, however, is concerned that Federal and State agencies were not examining and had no plans to examine systemic aspects, such as Federal and State construction monitoring and inspection. GAO is recommending that this be done. GAO is also recommending that the Congress, in considering the need to grant authority to an existing Federal agency to direct and coordinate investigations, provide that such authority enable the agency to conduct independent investigations of both the technical and systemic aspects of accidents involving Federal and federally assisted construction projects.



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COMPTROLLER GENERAL OF THE UNITED STATES

WASHINGTON D.C. 20548

B-208748

The Honorable Adam Benjamin, Jr.
House of Representatives

Dear Mr. Benjamin:

At your request we reviewed the adequacy of the Federal Government's investigation of the collapse of a highway ramp under construction in East Chicago, Indiana, and whether the investigation is employing all available resources. This letter summarizes the results of our review.

On April 15, 1982, three sections of the ramp collapsed, killing 13 workers and injuring 17 others. The ramp, which was one of four ramps designed to form the Riley Road-Cline Avenue Interchange, is part of a \$261-million Federal-aid highway project to extend Cline Avenue through East Chicago and eventually close to the Illinois State line. The Federal Highway Administration (FHWA), Department of Transportation, is providing 90 percent of the funds for the project and Indiana is providing the remainder.

Three Federal agencies--the Department of Labor's Occupational Safety and Health Administration (OSHA), the National Bureau of Standards (NBS), and FHWA--are involved in investigating the ramp collapse. NBS, with FHWA assistance, is seeking to determine the technical cause of the collapse at the request of OSHA, which in turn is having the investigation done on behalf of the State of Indiana Occupational Safety and Health Administration (Indiana OSHA). OSHA asked NBS to investigate because the NBS Center for Building Technology had previously conducted several major construction accident investigations for OSHA, and OSHA officials believed that NBS has the expertise and laboratory capability to successfully determine the cause of the ramp collapse. Although the ramp was being constructed as part of a Federal-aid highway project, FHWA decided not to conduct its own investigation but to assist NBS, which had already begun its investigation.

Under an agreement with OSHA (many States have similar agreements), one of Indiana OSHA's responsibilities is to investigate work-related fatalities and catastrophes in Indiana. Indiana OSHA, however, because of the magnitude of the ramp accident, accepted OSHA's offer to have NBS perform the technical investigation. OSHA is reimbursing NBS for the investigation's estimated \$177,000 cost, and NBS is reporting to OSHA on its

progress and expenditures. OSHA officials, however, consider the investigation to be a State investigation, and Indiana OSHA will use the results as a basis for determining the need to issue, if warranted, appropriate citations and proposed penalties for violation of occupational safety standards during the ramp's construction.

The Indiana Department of Highways has contracted with the Portland Cement Association's Construction Technology Laboratories to investigate the collapse. Other groups, such as the construction contractor, the contractor's insurance company, and the Lake County, Indiana, coroner's office, are also conducting investigations. Several lawsuits have been filed and others are expected.

Following is a summary of our major findings and conclusions, which are discussed in more detail in appendix I.

- The major objectives of an accident investigation are to determine the accident's cause and prevent future occurrences. Meeting the objectives requires determining the technical cause of the accident, identifying systemic weaknesses that may have contributed to the accident or allowed it to occur, and taking all reasonable actions to prevent similar accidents in the future.
- The major Federal effort with regard to the ramp collapse is the NBS technical investigation for Federal OSHA and Indiana OSHA, whose major concern in the investigation is worker safety. NBS is examining aspects such as the strength of the concrete and other construction materials and the adequacy of the temporary supports used during construction.
- Federal officials acted promptly in the aftermath of the collapse to begin the NBS investigation, and the agencies are coordinating their efforts to determine the technical cause. Furthermore, NBS appears to be well qualified and experienced to determine the most probable technical cause.
- NBS and the other agencies, however, are not examining and have no plans to examine aspects of the project, such as Federal and State responsibilities, standards, requirements, and control and monitoring procedures that may have contributed to the collapse or allowed it to happen. The results of the NBS investigation will help pinpoint weaknesses, but its purpose is not to evaluate systemic aspects.
- No single Federal agency or group has the responsibility for directing and coordinating the total Federal investigative efforts for this accident and similar ones to provide that, in addition to determining the technical cause,

aspects such as standards, requirements, and project control and monitoring procedures are also examined and any needed corrective action is taken. Furthermore, all the Federal agencies involved in the investigation, with the exception of NBS, which is limited to determining the technical cause, had some responsibility. In contrast, the independent National Transportation Safety Board, which has no program or operational responsibilities, by law investigates major traffic accidents, fixes the technical cause, and examines systemic aspects to determine what could be done to prevent similar accidents in the future.

In a related development, the Subcommittee on Investigations and Oversight, House Committee on Science and Technology, on August 3 and 4, 1982, conducted hearings on the collapse or failure of public structures such as buildings, dams, and bridges. During these hearings, the subcommittee discussed expanding the authority of an existing Federal agency to have it investigate structural collapses and to help promote safer technology and design. The subcommittee also considered authorizing this agency to act as a clearinghouse to maintain, analyze, and disseminate information on the technical causes of failures. The subcommittee may develop proposed legislation in this regard.

If a Federal agency is given the responsibility for investigating structural failures, that agency needs to also be given the specific responsibility for directing and coordinating the total Federal investigative effort for major accidents on Federal and federally assisted construction projects. This responsibility needs to include determining the technical cause and provide for an appropriate examination of agency responsibilities, standards and requirements, control and monitoring procedures, and other systemic aspects to identify what improvements are needed for future projects.

RECOMMENDATION TO THE SECRETARIES OF LABOR AND TRANSPORTATION

To provide for a complete and effective investigation of the Riley Road-Cline Avenue ramp collapse, we recommend that the Secretaries of Labor and Transportation review appropriate Federal and State responsibilities, standards, requirements, control and monitoring procedures, and other appropriate systemic aspects of the ramp's construction. The objectives of this review should be to determine if improvements are needed for similar projects in Indiana and in other States. The NBS investigation results should help pinpoint specific problem areas that need to be examined. To have a more comprehensive review, the Secretaries should seek the cooperation of Indiana OSHA and the Indiana Department of Highways in examining systemic aspects of the ramp collapse.

RECOMMENDATION TO THE CONGRESS

We recommend that the Congress, in its current deliberations on the need to authorize an existing Federal agency to investigate structural failures, provide that such an agency have the specific responsibility for the total Federal investigative effort whenever a major accident occurs on Federal and federally assisted construction projects. This authority should provide for the agency to conduct independent investigations of both the technical causes and systemic aspects of accidents.

At your request, we did not take the additional time to obtain agency comments, but the matters covered in this report were discussed with agency officials. Their comments are included in the report where appropriate.

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As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of the report until 15 days from the date of this report. At that time we will send copies to the Chairman, Subcommittee on Investigations and Oversight, House Committee on Science and Technology, and the Chairmen of House and Senate legislative committees for action on our recommendation to the Congress. We will also send copies to other appropriate congressional committees; the Secretaries of Commerce, Labor, and Transportation; and the Director, Office of Management and Budget. Copies will also be made available to others upon request.

Sincerely yours,



Acting Comptroller General
of the United States

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ABBREVIATIONS

AFL-CIO	American Federation of Labor-Congress of Industrial Organizations
FHWA	Federal Highway Administration
Indiana OSHA	State of Indiana Occupational Safety and Health Administration
NBS	National Bureau of Standards
OSHA	Occupational Safety and Health Adminis- tration (the Federal agency)

DISCUSSION OF THE FEDERAL INVESTIGATION
OF THE APRIL 15, 1982,
RILEY ROAD-CLINE AVENUE RAMP
COLLAPSE IN EAST CHICAGO, INDIANA

THE COLLAPSE AND ITS AFTERMATH

On April 15, 1982, at about 10:40 a.m., three sections totaling over 400 feet of a Riley Road-Cline Avenue interchange ramp collapsed during construction, killing 13 workers and injuring 17 others. The planned ramp is located just west of the Indiana Harbor Ship Canal in East Chicago, Indiana, and is designed to take Riley Road steel mill and other traffic to what will be the Cline Avenue expressway. The ramp is part of a \$261-million project of elevated highway and bridges that will eventually extend Cline Avenue (Indiana Highway 912) northwest through East Chicago, and almost to the Illinois State line.

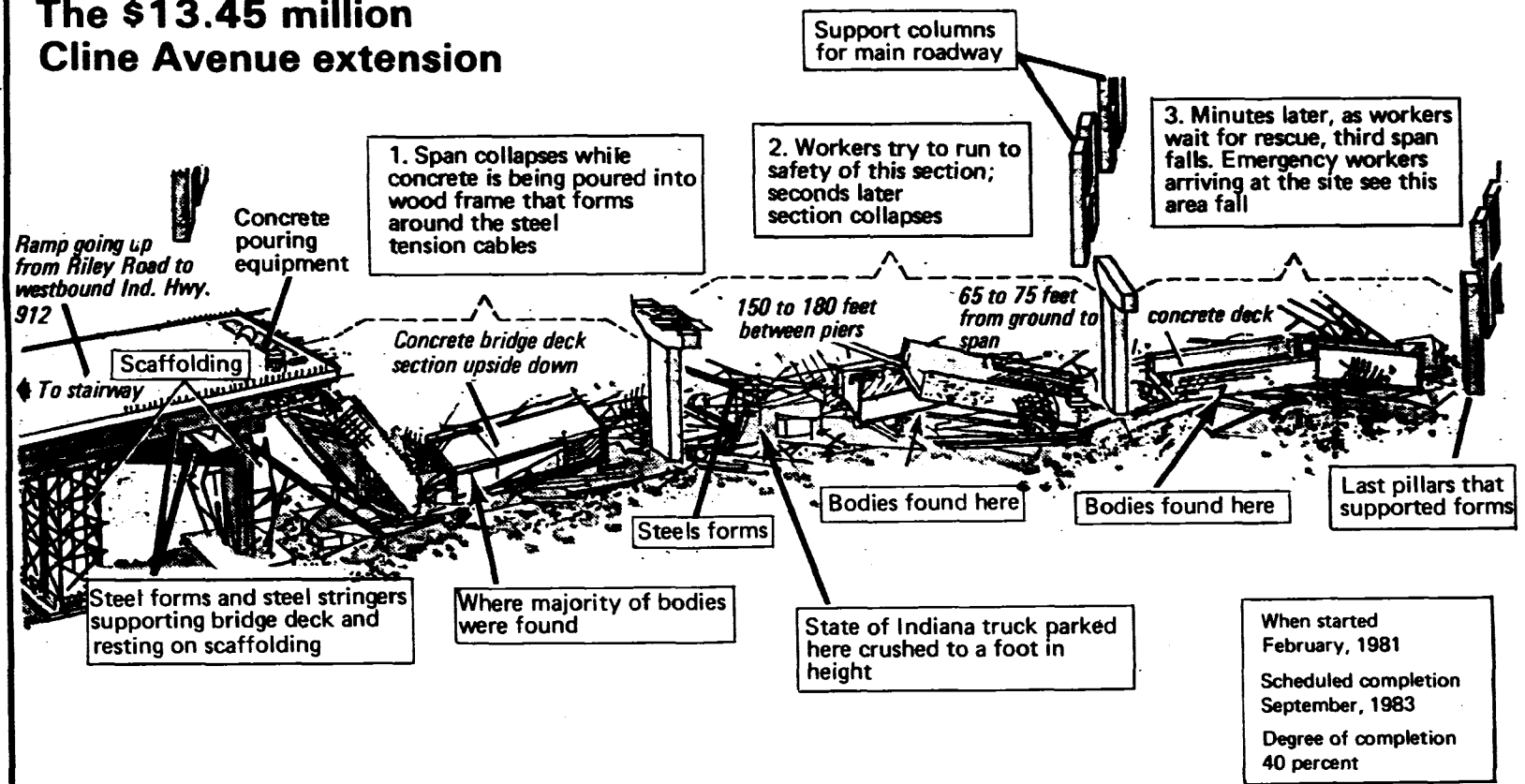
Based on discussions with various Federal and State officials and on news accounts, nearly 90 percent of the concrete for the deck of one section of the uncompleted ramp had been poured or placed using two crane-hoisted buckets. This section, which was about 65 feet high, collapsed first. Before it collapsed, however, most of the workers had gone to part of an adjacent section, which flipped over and came down with the first section. Somewhat later the rest of the second section collapsed. A few workers were able to get to the deck of a third section, which was by then a free-standing island 60 feet in the air, without a means of escape. This section fell about 5-10 minutes later as rescue workers looked on, unable to help the trapped workers. A Chicago Tribune graphic depiction of the collapse is on the following page.

In terms of the type of construction, the ramp that collapsed was a cast-in-place, post-tensioned concrete bridge. In this type of construction, the bridge or ramp is made largely from concrete placed into forms on a system of permanent supporting columns and temporary supports or falsework. The forms or frames shape the wet concrete until it "cures" and are removed later. The concrete is reinforced with steel bars throughout. In addition, steel cables (post-tensioning strands) placed inside conduits in the forms before the concrete is poured are tightened or tensioned after the concrete cures, providing the strength needed to maintain the continuity of the bridge. A critical factor in this type of construction is the temporary support or falsework that must bear the weight of the permanent structure until the concrete has cured and the steel cables are properly tensioned. Early speculation about the cause of the ramp collapse had mainly centered on problems with the falsework, which

East Chicago ramp collapse

April 15, 1982

The \$13.45 million Cline Avenue extension



Chicago Tribune Graphic by Terry Volpp
Sources: Chicago Tribune news reports and Indiana Highway Department

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was providing support to the structure at the time of collapse. This type of construction has not been used much in Indiana but has been used often in California and is considered a safe construction method by FHWA and Indiana highway officials.

The State of Indiana is the owner of the Cline Avenue extension project, including the planned interchange with Riley Road. The Federal Highway Administration is providing 90 percent of the funds for the project under the Special Urban High Density Traffic Program. The program was established by the Federal-Aid Highway Act of 1973 (Public Law 93-87) to construct in high traffic urban areas highways that are less than 10 miles in length and connect with the Interstate Highway System. (The program has since been repealed.) The State of Indiana is providing the remaining 10 percent of the project costs.

The Riley Road interchange ramps are being constructed under a \$13.5 million contract. Construction began in April 1981 and is scheduled to be completed in September 1983. Work on the ramps was about 40 percent complete at the time of the collapse.

Various Federal, State, local, and private groups are currently involved in investigating the Riley Road-Cline Avenue ramp collapse. Three Federal agencies are involved in the investigations. The National Bureau of Standards, with FHWA assistance, is conducting an investigation to determine the technical cause of the collapse. NBS is performing its technical investigation at the request of the Occupational Safety and Health Administration, which as explained below is acting on behalf of the State of Indiana Occupational Safety and Health Administration. OSHA asked NBS to investigate because the NBS Center for Building Technology had previously conducted similar construction accident investigations for OSHA, and OSHA officials were pleased with the quality of those investigations. The officials further believed that NBS has the expertise and laboratory capability to successfully investigate the ramp collapse. The ramp was being constructed as part of a Federal-aid highway project, but FHWA decided not to conduct its own investigation because the NBS investigation had already begun. NBS is to summarize its conclusions by September 16, 1982, and issue a final report by September 30, 1982.

Under a State agreement with OSHA, one of Indiana OSHA's responsibilities is to investigate work-related fatalities and catastrophes in Indiana. (Many States have similar agreements with OSHA.) Indiana OSHA, however, because of the magnitude of the ramp accident, accepted Federal OSHA's offer to have NBS perform the investigation. Federal OSHA is reimbursing NBS for the estimated \$177,000 cost of the investigation, and NBS is reporting to Federal OSHA on its progress and expenditures. Indiana OSHA, however, has assisted NBS in collecting data and is following the progress of the investigation. It will use the NBS investigation results as a basis for determining the need to issue, if warranted, appropriate citations and proposed

penalties for violation of occupational safety standards during the ramp's construction.

The independent National Transportation Safety Board, which by law investigates aircraft, railroad, highway, and other traffic accidents, is not investigating the ramp collapse. Safety Board officials considered the accident outside their jurisdiction because it was not a traffic accident. The ramp was not complete and not open to traffic.

The Indiana Department of Highways has contracted with Construction Technology Laboratories, a division of the Portland Cement Association, to determine the collapse's technical cause. The Lake County, Indiana, coroner is also conducting an investigation. The coroner is not only determining the medical cause of death but is also examining duties and responsibilities and safety precautions that should be taken on future projects. Construction Technology Laboratories provided its preliminary report to the Indiana Department of Highways during the first week of August, 1982, and the final report is scheduled for September 1, 1982. The coroner completed his investigation in late July 1982 but at the end of our review had not made a final ruling.

Several firms associated with the project have hired their own investigators. The principal firms include Superior Construction Company, the prime contractor for the ramp project; Commercial Union Insurance, the insurance carrier for the prime contractor and the Indiana Department of Highways; Midwest Steel Erection Company, Inc., the steel-reinforcing and post-tensioning subcontractor; Anthes Industries, Inc., the falsework manufacturer; and Figg and Muller, Engineers, Inc., the designer of the ramp. According to an official of the AFL-CIO, although some of its members were killed and injured in the collapse, the union is not conducting a formal investigation. However member organizations--particularly the local carpenters' union and the Indiana State Building Trades Council--and the national headquarters are monitoring the Federal and State investigations.

The Federal and State investigations and the roles and responsibilities of Federal and State agencies will be discussed in more detail in later sections.

OBJECTIVES, SCOPE, AND METHODOLOGY

The overall objective of our review was to determine whether the Federal investigation of the ramp collapse on the Cline Avenue extension project is correct and reasonably employing available resources. Our review included identifying and determining (1) the purpose of the various Federal, State, local, and private investigations, (2) the role of the Federal agencies in these investigations and also the ramp construction project, and (3) the basic objectives for accident investigations of this type. We evaluated the Federal investigation's adequacy in terms of

whether it is likely to meet the basic objectives of an accident investigation--that is, determine the cause of the collapse and prevent future occurrences. We examined the qualifications and experience of the primary NBS investigative personnel and compared their planned investigative approach with that of other groups, such as the National Transportation Safety Board, that conduct similar investigations. We also discussed the qualifications and experience of the personnel and the quality of the research laboratories available to them with various Federal, State, and private officials, including sponsors of their previous investigations. Further, we compared the stated NBS objectives for its investigation of the ramp collapse with the usual broad objectives for National Transportation Safety Board accident investigations of this type, taking into account the various other investigations and activities that are underway. The National Transportation Safety Board investigations usually include determining the technical cause of the accident and identifying systemic weaknesses that may have contributed to the accident or allowed it to occur.

Our review was conducted in May and July 1982 at FHWA's Washington, D.C., headquarters, Homewood, Illinois, region 5, and the Indianapolis, Indiana, division offices; at OSHA offices in Washington, D.C., and in Chicago, Illinois; and at the National Bureau of Standards in Gaithersburg, Maryland. We held discussions with appropriate officials and reviewed pertinent documents.

We also held discussions with and reviewed documents of appropriate officials of Indiana OSHA, the Indiana Department of Highways, Construction Technology Laboratories, the Lake County coroner, and the ramp project's prime contractor. We also interviewed officials of the National Transportation Safety Board and the office of the Mayor of Kansas City, Missouri, where a similar NBS investigation previously took place. In addition, we visited the site of the collapse and talked to Indiana and Federal OSHA and State highway department officials located at the site.

Several lawsuits have been filed and others are expected. As a result, representatives of the Indiana Department of Highways, Construction Technology Laboratories, and the prime contractor were unwilling to discuss certain aspects of the collapse and the investigation, especially those concerning duties and responsibilities. Thus, we could not completely establish their responsibilities for the project. (See the discussion of responsibilities on pp. 12-15.) In addition, NBS officials would not discuss the details of how they are proceeding on their investigation. It is their policy, and that of OSHA, not to discuss their ongoing investigations. We also did not review the NBS investigation plan. NBS officials told us that because of the nature of the investigation, the actual plan is developed as the investigation proceeds and they are using the general approach they have used in the past for similar investigations. As a result, our evaluation of the adequacy of the NBS investigation

was limited to a review of the qualifications and experience of the NBS investigative personnel and prior NBS collapse investigations.

Our review was made in accordance with generally accepted Government audit standards.

FEDERAL AND STATE AGENCY ROLES IN INVESTIGATING THE COLLAPSE

No single Federal agency has the responsibility for directing or coordinating the investigation of the Riley Road-Cline Avenue ramp collapse, such as the National Transportation Safety Board would have in an aircraft accident investigation. The Federal agencies that are involved--OSHA, NBS, and FHWA--however, are coordinating their efforts to determine the cause of the collapse.

OSHA and Indiana OSHA

The Occupational Safety and Health Act of 1970 (Public Law 91-596) was enacted to assure safe and healthful working conditions. The act requires employers to comply with occupational safety and health standards and eliminate recognized workplace hazards. One of OSHA's primary means for assuring compliance is investigating work-related fatalities and catastrophes. Such accidents are investigated to determine whether (1) a violation of Federal safety and health standards contributed or may have contributed to the occurrence, (2) the accident could have been avoided had proper safety and health regulations been enforced and followed, and (3) OSHA standards should be revised to remedy the hazardous working conditions which led to the accident.

In many States such as Indiana, these investigations have been delegated to the State occupational safety and health agencies under the State plans concept. The 1970 Occupational Safety and Health Act provided for States to assume responsibility for developing and enforcing occupational safety and health standards by submitting a State plan for OSHA's approval. OSHA gave the Indiana State plan initial approval on February 25, 1974, and certified it on September 24, 1981. On October 22, 1981, OSHA entered into an operational status agreement with Indiana OSHA whereby the State assumed responsibility for all occupational safety and health standards enforcement in Indiana except those for maritime occupations (ship building, ship repairing, etc.) and longshoring.

Under the terms of the operational status agreement, Indiana OSHA is required to

"* * * make appropriate response to all notifications of fatalities and catastrophes and complaints about workplace safety and health conditions * * * where State standards are in effect and operational."

Under this requirement, Indiana OSHA decided to conduct a "full-scale" investigation of the Cline Avenue ramp collapse but accepted OSHA's assistance because it did not have the resources to conduct such a large and complex investigation. In response, OSHA entered into an agreement with NBS for it to determine the most probable cause of the collapse. Since October 9, 1973, OSHA and NBS have had an interagency understanding for NBS to provide technical assistance and perform research for OSHA in carrying out its responsibilities.

OSHA is reimbursing NBS for the cost to conduct the investigation and, along with Indiana OSHA, is following the progress of the investigation. Indiana OSHA has assisted NBS in collecting data, such as samples of materials from the accident, and interviewed workers and other eyewitnesses to the accident. An OSHA official has been located at the collapse site to assist the Indiana OSHA site coordinator. Under its State plan, Indiana OSHA will be responsible for issuing any citations and proposed penalties for violations of State occupational safety standards that may have contributed to the accident. Indiana OSHA officials plan to use the results of the NBS investigation as the basis for any ensuing citations.

FHWA and Indiana Department of Highways

FHWA is not conducting its own investigation of the collapse but is assisting the NBS investigative team. It has made one of its bridge engineers available and has offered to provide expertise and conduct tests for NBS as needed. As previously mentioned, the Indiana Department of Highways contracted with the Portland Cement Association's Construction Technologies Laboratory in Skokie, Illinois, to determine the probable technical cause of the collapse. FHWA division office officials in Indiana told us that the Indiana Department of Highways has given the division office full access to its investigation, including weekly progress reports from Construction Technology Laboratories. The division administrator said that highway department officials indicated from the beginning that they welcomed FHWA participation in the investigation, and the division office has offered assistance in any way possible. FHWA regional officials told us that they are monitoring the NBS investigation through contacts with FHWA headquarters and division personnel assigned to directly monitor the investigation.

FEDERAL AGENCIES ACTED PROMPTLY AFTER THE COLLAPSE

The OSHA regional staff was notified of the collapse within 2 to 3 hours after the accident occurred. They immediately notified Indiana OSHA and OSHA headquarters. The day following the accident, OSHA reached agreement with NBS to perform the investigation to determine the cause. An Indiana OSHA official was at the collapse site by 3 p.m. on the day of the collapse. The

following day the Indiana Commissioner of Labor, who is in charge of Indiana OSHA, was at the site. The same day, the commissioner accepted OSHA's offer to have NBS investigate the collapse. That day and the following 2 days, four NBS engineers were at the site to document the collapse and collect data.

According to the Administrator of FHWA's Indiana Division, the Indiana Department of Highways district office in LaPorte, Indiana, notified his office within a half hour of the collapse. A division official immediately contacted the FHWA regional office and the State highway department. Regional officials in turn immediately notified FHWA headquarters. Two headquarters bridge experts and the regional bridge engineer visited the collapse site the next day. FHWA also offered its assistance to NBS and the State.

State highway department officials said that they were informed of the collapse within 15 to 20 minutes after it had occurred. Some of their personnel located at the project were at the ramp when it collapsed and one of them was killed in the accident. Other personnel arrived within hours.

THE NBS INVESTIGATION--THE FEDERAL EFFORT TO DETERMINE THE CAUSE OF THE COLLAPSE

NBS appears to be well qualified to determine the most probable technical cause of the ramp collapse within the time frame that has been established for the investigation. OSHA officials are confident that NBS will produce an independent, thorough, and timely report because of the capabilities of its staff and laboratories and its past experience on similar investigations. During its investigation, NBS is examining elements of the construction, such as the strength of the concrete and other construction materials and the adequacy of the temporary supports used during construction.

NBS has made available as needed six staff members from its Structures Division, Center for Building Technology, to carry out the investigation. All have doctorates in structural or civil engineering, and four are registered professional engineers. As a group, they have published many technical articles and belong to various engineering societies and construction associations and institutes. They have been employed at NBS for an average of about 10 years. Previously, many of them taught at universities.

The team leader for the investigation is the Chief of the Structures Division. In addition to having a Ph.D. in structural engineering and being a registered professional engineer in several States, he is a noted authority on structural engineering, building systems, performance design, and building research. He is Vice Chairman of the Reinforced Concrete Research Council, Chairman of the Joint U.S.-Japan Panel on the Design of Structures to Resist Wind and Seismic Forces, and Chairman of the

Technical Activities Committee of the American Concrete Institute. One of the team members is Chairman of the American National Standards Institute Task Committee on Safety in Concrete and Masonry Construction.

In recent years, NBS has conducted several major investigations of structural failures. The most recent was the July 17, 1981, collapse of two suspended walkways in the atrium lobby of the Hyatt Regency Hotel in Kansas City, Missouri, that killed 113 people and injured 186. In terms of loss of life, this was the most devastating structural collapse ever to take place in the United States.

The Hyatt Regency investigation, which was done at the request of the Mayor of Kansas City, took 7-1/2 months from the time of failure to the final issued report, which was 254 pages with supplemental material contained in a separate document. The report is available to the public.

One of the critical techniques NBS employed in this investigation was to create a physical model or mockup of critical parts of the walkway in its laboratory for testing. Computer models were also developed to predict the walkways' response to various weight loads. The tests and other data gathered revealed that one of the walkway's hanger rod connections had insufficient load capacity. The original design for the connection was inadequate, and a change in the hanger rod arrangement during construction essentially doubled the load on the connection. The NBS investigation team leader told us that they would perform similar tests for the Riley Road-Cline Avenue ramp investigation, if warranted.

NBS has also performed several recent investigations for OSHA. These were:

- The March 27, 1981, collapse during construction of the Harbour Cay Condominium in Cocoa Beach, Florida, which killed 11 workers and injured 23 others.
- The April 27, 1978, collapse during construction of the Willow Island Cooling Tower in Willow Island, West Virginia, in which 51 workers lost their lives.
- The March 2, 1973, collapse during construction of the Skyline Plaza apartment building in Bailey's Crossroads, Virginia, in which 14 workers were killed and 34 were injured.

Most of the NBS staff on the Cline Avenue investigation worked on at least one of the above prior investigations. The results of these investigations are available to the public.

We did not evaluate NBS' methodology for carrying out the Cline Avenue investigation. Because of its policy not to reveal the details of ongoing investigations, NBS was unwilling to discuss the specifics of the investigative approach and methodology. We were not able to review the investigation plan to determine that all reasonable possibilities for the cause of the collapse are being investigated. The NBS Director of Administration and the team leader for the investigation told us that because of the nature of the investigation, the actual plan is being developed as the investigation proceeds; however, the general plan is the same as that used in the Harbour Cay Condominium investigation.

The Harbour Cay investigation and the others previously mentioned followed a similar general plan:

1. Investigate the site through visual observation, measurements, and photographs; removal of materials for testing; eyewitness accounts and weather reports; review of site records; and so forth.
2. Reconstruct conditions at the time of collapse, based on the physical evidence obtained during the site investigation and knowledge of the construction process. The team recreates the construction techniques or procedures being used and establishes where all the workers were and what they were doing.
3. Through laboratory tests, establish the properties of the materials used in the construction, such as the strength of the concrete.
4. Perform structural analysis, using mathematical models to determine the structural strength under various construction loads.
5. Determine the most probable cause of the collapse, using the data gathered in the above phases.

We discussed the general investigative approach with the Directors of the National Transportation Safety Board's Highway Accident and Aviation Accident Investigation Divisions and a private consulting engineer who has conducted accident investigations. For example, the consulting engineer investigated the collapse of the suspended walkways in the Kansas City Hyatt Regency for the hotel owners. From these discussions and a review of several of their investigation reports, we found that the NBS general approach and plan is very similar to theirs. The Safety Board does involve representatives of private industry, such as aircraft manufacturers, in its investigation. NBS does not do this but it does obtain from them information such as design drawings and specifications.

We discussed the quality of NBS' prior investigative work with OSHA officials and a representative in the office of the Mayor of Kansas City, Missouri, for whom the Hyatt Regency investigation was conducted. These officials were very pleased with the quality and timeliness of NBS past investigations. The Director of the National Transportation Safety Board's Highway Accident Division told us that the division used NBS services during the Safety Board's investigation of the December 1967 collapse of the Silver Bridge in West Virginia that killed 46 people crossing the bridge.

PREVENTING FUTURE OCCURRENCES

An accident investigation's major objective and the principal reason for determining cause is to prevent future occurrences. This includes determining the technical cause and also identifying and correcting any institutional or systemic problems that may have contributed to or allowed the accident to occur. An example of this type of investigation is the National Transportation Safety Board's investigation of the May 25, 1979, crash of a DC-10 soon after takeoff from the Chicago-O'Hare International Airport, Illinois. A total of 273 people were killed in the accident.

In its investigation, the Safety Board not only determined that the technical cause of the crash was the stall and roll of the aircraft after the engine and other parts of the left wing fell off, but it also examined systemic aspects. The inspectors determined that the separation of the left wing section resulted from damage by improper maintenance procedures. They also found several other problems that contributed to the accident: the vulnerability of the parts' design to maintenance damage; deficiencies in Federal Aviation Administration surveillance and reporting systems which failed to detect and prevent the use of improper maintenance procedures; and deficiencies in the practices of and communications among the aircraft operators, the manufacturer, and the Federal Aviation Administration which failed to determine and disseminate the details regarding previous maintenance damage incidents. The Safety Board made several recommendations to correct these problems.

The purpose of the NBS and Construction Technology Laboratories investigations is to determine the most probable technical cause of the accident. The results of the investigations will help identify systemic problems that need to be examined but will not, in themselves, prevent future occurrences. During our review, however, we found no indication that Federal and State agencies are planning to fully examine and address systemic problems that may exist. For example, FHWA officials told us that they will probably take some action after the NBS investigation has been completed but they do not know yet what that will be. They said there is some concern about jurisdiction between FHWA and the State highway department in what actions FHWA could take.

The stated purpose of OSHA accident investigations is to determine whether (1) a violation of Federal safety and health standards contributed or may have contributed to the occurrence, (2) the accident could have been avoided had proper safety and health regulations been enforced and followed, and (3) OSHA standards should be revised to remedy the hazardous working condition which led to the accident. OSHA officials, however, consider the investigation of the ramp collapse and the enforcement of occupational safety and health standards in Indiana to be an Indiana OSHA responsibility, and they have no plans to examine their standards or other systemic aspects. In comparison, the National Transportation Safety Board's Director of Aviation Accident Investigations told us that the Safety Board's investigative teams often include a group whose purpose is to investigate systemic problems and these investigations go beyond determining the technical cause to include a study of how such a situation could occur.

In our opinion, the NBS investigation is an important phase, but it is only the first phase of a complete investigation. In the case of the Riley Road-Cline Avenue ramp, the system in place failed. It may have been a "one-in-a-million" occurrence or it may be a symptom of a broader problem. Those agencies--FHWA, Indiana Department of Highways, OSHA, and Indiana OSHA--with at least some responsibility for, interest in, and concern about the accident and project need to examine the system for weaknesses and reasonable actions that can be taken to prevent a recurrence. An examination to identify systemic weaknesses or contributing causes should not be viewed as an admission of guilt for the past accident but rather as an effort to improve for future projects.

The team leader for the NBS investigation told us that examining systemic aspects of the ramp collapse is not a part of the NBS agreement with OSHA to determine the technical cause, and none of the other agencies are conducting such an examination. He said that systemic aspects are an important but often overlooked part of an accident investigation. He also said that these aspects should be examined with regard to the ramp collapse.

Several agencies have project responsibilities and interests

On the Riley Road-Cline Avenue ramp project, OSHA, Indiana OSHA, FHWA, the Indiana Department of Highways, and the contractors share responsibilities and interests to varying degrees. These responsibilities, with an emphasis on project monitoring and inspection, are discussed below.

OSHA and Indiana OSHA

As pointed out earlier, OSHA has the primary Federal responsibility for workplace safety and health through the establishment of standards and inspection of work locations. OSHA has

delegated much of this responsibility to its counterpart State agencies in those 24 States that have State plans but retains oversight responsibility. (One of these State plans covers State and local government employees only.)

Many of OSHA's safety and health standards for the construction industry (29 CFR 1926/1910) deal with personal worker safety such as first aid and medical attention; fire protection; safety training; wearing of helmets, goggles, and safety belts; the safety of equipment; and precautions for working over water and off the ground. However, subpart Q contains several standards on concrete, concrete forms, and temporary supports. For example, the standards require that:

"(1) Formwork and shoring shall be designed, erected, supported, braced, and maintained so that it will safely support all vertical and lateral loads that may be imposed upon it during placement of concrete.

"(2) Drawings or plans showing the jack layout, formwork, shoring, working decks, and scaffolding, shall be available at the jobsite."

Formwork, shoring, scaffolding, and working decks are all part of falsework, with the shoring the major support for the uncompleted structure.

After NBS had completed its investigation to determine the technical cause of the collapse during construction of a Willow Island, West Virginia, cooling tower, OSHA had NBS expand on its technical investigation by reviewing OSHA's existing safety and health regulations for general concrete construction and develop guidelines for OSHA's use for safety evaluation of reinforced concrete cooling tower construction. The introduction to the NBS report ^{1/} stated that the construction of cooling towers and other reinforced concrete structures in which the partially completed structure plays a key role in supporting construction workers and other construction loads, presents special challenges to providing a safe working environment. The Riley Road-Cline Avenue ramp could be viewed in this same light because workers were on an uncompleted structure whose support affected their safety.

We discussed monitoring and inspection responsibilities with OSHA and Indiana OSHA officials. Indiana OSHA officials, including the Commissioner of Labor and the Deputy Administrator, told us that they are primarily concerned with the employer-employee relationship as it relates to individual worker safety on the job site, and this is their primary concern in the

^{1/}"Recommended Guidelines for Safety Inspection of Construction of Concrete Cooling Towers," NBSIR 80-1964, Jan. 1980--issued Feb. 1980.

investigation of the collapse. OSHA headquarters and regional officials told us that Indiana OSHA is responsible for carrying out the OSHA program in Indiana. OSHA headquarters officials told us that OSHA and those States with State plans are authorized to inspect aspects of construction projects such as the design of and the specifications for construction of the falsework for the ramp that collapsed; however, the 1970 Occupational Safety and Health Act clearly envisions that such inspections be conducted on a spot-check basis with the employer responsible for compliance with the standards on a continuing basis. The officials said there are about 5 million workplaces and OSHA inspects about 2 percent of them.

Indiana OSHA officials said that they have less than 100 inspectors responsible for inspecting the workplaces of about 93,000 employees to enforce safety standards. The agency randomly selects industrial construction sites using building permits. The Riley Road-Cline Avenue ramp project was not selected, and the site was not inspected before its collapse.

The Director of Safety and Occupational Health for the AFL-CIO's Building Trades Council told us that the 1970 Occupational Safety and Health Act clearly makes employers responsible for worker safety. He said OSHA cannot have its personnel continuously at construction sites, but the act does give OSHA the authority to ensure that employers comply with its standards. He also said that each year an average of about 2,500 workers die from construction accidents, and it would be beneficial to have at least one of these accidents fully investigated, including the worker safety systems and procedures. The Safety and Occupational Health Director does not anticipate that changes will occur as a result of the ramp collapse unless a systemic review is also performed.

FHWA and Indiana Department of Highways' responsibilities

FHWA has a program called certification acceptance which is very similar to OSHA's State plan concept. Indiana, however, is not a certification acceptance State, and FHWA has a greater role in approving plans and inspecting construction.

According to FHWA policy, its personnel are to review or inspect Federal-aid highway construction activities to assure completion according to approved plans and specifications. The FHWA Division Administrator in Indiana told us that FHWA is responsible for the final product but reviews noncertification acceptance States more frequently during work in progress. The administrator said that the State is the contract administrator and it has authority and responsibility to see that work is progressing satisfactorily according to plans. The division office visited the ramp construction site at least four times before its collapse.

FHWA headquarters officials told us that FHWA is primarily concerned with the design of the ramp and the quality of the final product. They said that unless the investigations of the collapse show that there was a bridge design problem, they consider the cause of the ramp collapse to be a problem with the contractor, and the Indiana Department of Highways as the contract administrator is responsible for the project. The officials added that they would like to inspect construction projects more often but do not have enough personnel.

FHWA's policy directive on Federal-aid construction project inspections does not specifically address whether falsework plans are part of the plans and specifications that it is required to review. Although FHWA officials reviewed the original falsework plans, they said that they generally do not review them and did not review the revised falsework plans actually used in constructing the ramp. According to the Regional Director of Construction and Maintenance, the responsibility for falsework was between the State and the contractor, since the FHWA manual has no requirements on falsework. FHWA division officials also said that the State highway department as contract administrator, has total authority and responsibility to assure satisfactory work progress according to plans.

Indiana Department of Highways officials and the contractor would not discuss their responsibilities with regard to falsework because of current and potential lawsuits over the collapse. However, State highway officials let us review their standard specifications manual. The manual states that falsework plans shall be furnished by the contractor bearing the seal of a registered professional engineer. The State engineer's approval of the plans relates only to requirements for designed strength and detail, and he will assume no responsibility for the strength of the falsework when constructed and in place. The manual further states that approval will not relieve the contractor from responsibility for the adequacy or safety of falsework. Overall, the State's specifications, like Federal highway requirements, are primarily concerned with the quality of the finished product, including workmanship and materials.

RECENT CONGRESSIONAL HEARINGS ON STRUCTURAL FAILURES

On August 3 and 4, 1982, the Subcommittee on Investigations and Oversight, House Committee on Science and Technology, conducted hearings on the collapse or failure of public structures such as buildings, dams, and bridges. The purpose of the hearings was to obtain a better understanding of the actions that either take place or fail to take place during a building project which eventually result in structural failure. The subcommittee is concerned about the number of failures and believes a better understanding of these actions will help determine measures which could reduce the number. During these hearings, the

subcommittee discussed expanding the authority of an existing Federal agency to investigate structural collapses and help promote safer technology and design. The subcommittee also considered authorizing the agency to act as a clearinghouse to maintain, analyze, and disseminate information on the technical causes of failures. The agency's authority would be similar to what the National Transportation Safety Board has for traffic accidents. The subcommittee is continuing its deliberations and may develop proposed legislation in this regard.

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