Hindawi
Advances in Civil Engineering
Volume 2019, Article ID 4896717, 6 pages
https://doi.org/10.1155/2019/4896717

Research Article

Study of Bridge Demolition DOT Survey and Available Standard Specifications

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Received 12 November 2018; Accepted 13 March 2019; Published 1 April 2019

Academic Editor: Salvatore Grasso

There are many damaged bridges in the United States which are either structurally deficient or functionally obsolete and require replacement or rehabilitation, many using accelerated bridge construction (ABC) techniques. Before a bridge is replaced or rehabilitated, the old structure or component needs to first be demolished. Although the AASHTO LRFD Bridge Design Specification presents minimum bridge design requirements, there is limited information about bridge demolition available for designers and contractors in this field. More study is required to determine best practices in demolition administration and avoid further unintentional events. This study presents the results from a survey prepared and disseminated through a research effort under the Accelerated Bridge Construction University Transportation Center (ABC-UTC). This survey was sent out to all State Departments of Transportation (DOTs). The results of the survey reveal the need for additional guidance in bridge demolition administrations at a national level. According to the results of this study, contractors are the most important part of bridge demolition projects from injuries, fatalities, and responsibility point of view.

1. Introduction

During their design life, bridges may need replacement or rehabilitation for a number of reasons: deterioration of bridge materials, accidents, drainage, debris, vegetation, scouring of foundation, movement of the structure, and condition of approaches [1]. Bridges may also become overcrowded or no longer able to carry heavier trucking loads, making them functionally obsolete. In both cases, before a bridge can be rehabilitated or replaced, the bridge (or portion of the bridge) must first be demolished and removed. Demolition is a critical step in the construction process that has the potential to cause injuries or death, transportation issues, and delay of the future construction tasks. Therefore, investigating the main criteria and choosing the demolition methods are significant. Some of the important criteria for considering demolition techniques were studied previously [2], and some guidelines with specific demolition equipment have been suggested by Anumba et al. [3]. For example, ball and crane, diamond sawing and cutting, hydrodemolition, blasting bursting, machine-mounted pneumatic and hydraulic breaker, and handheld percussion tools are some of the suggested equipment [3]. Some other studies discuss different techniques in the demolition industry [4, 5]. In these projects, safety, time, and the expenses are the priorities. Martin and Does [6] describe the demolition stage of two-span concrete bridge structure in a single 12-hour in Canada. Two different models, analytic hierarchy process (AHP) and analytical network process (ANP), were suggested to evaluate the demolition plans [7]. Bai et al. [8] developed a model for demolition bridges, and it is mentioned that providing a knowledge-based information system is necessary for demolition plans and organizing key elements such as major players, major tasks, and major decisions. In addition, it is significant to assess the bridge condition during the demolition plans [9].

The need for further investigation in this area has been highlighted by two worker casualties occurring during bridge demolition reported in less than one year in two different projects. The first incident was in Orange County, California, on May 18, 2014 [10]. While a team was working to demolish part of an old railroad bridge, a part of the bridge buckled under the weight of the construction equipment and caused a collapse over the CA-91 Freeway in Riverside, which was open to traffic in both directions. Unfortunately, this incident led to the death of one of the construction workers who was on the bridge.

The second incident occurred in Cincinnati, Ohio, on January 19, 2015, during the demolition of the Hopple Street overpass over I-75 [11]. The incident occurred when the concrete slab for the deck was being removed from the superstructure. The day before the incident, the demolition work was stopped due to the steel beams lifting off of the supports during demolition. A plan was developed by the contractor to tie down the beams to the supports the morning of the incident and demolition was continued [11]. Although the initial demolition plan and a later plan revision were signed and sealed by the contractor's Professional Engineers (PE) and submitted to the Ohio Department of Transportation (ODOT), there was no reporting of the issues with the beam uplift or review of the tie down plan.

According to *The Washington Times* report, a 103-year-old bridge in Pennsylvania also experienced partial collapse during demolition in 2015, and three were injured. These fatalities are not just limited to U.S. Recent studies on highway bridge collapses in China have indicated that 15 bridge failures occurred during demolishing operations between 2000 and 2014 [12]. The Hongqi Road Viaduct bridge collapsed during demolition resulting in 9 fatalities, 16 injuries, and 24 vehicles damaged in 2009 [12]. The reason for the collapse was not found, but the blast demolition was being performed by a company without experience in blast demolition, which was likely a contributing factor to the collapse.

All of these incidents created a desire amongst bridge owners to better understand the demolition oversight policies and eventually create a best practices guide for demolition administration. The goal of the research conducted and discussed in this paper was to gain a better understanding of the number of failed demolitions that are occurring but not captured by the media. There is a need to see if there is a bigger problem than just these three failed demolitions, and gather the bridge demolition administration policies from bridge owners, to see the current practice of states and determine successful policies.

2. Methodology: Survey

A survey was prepared and sent to DOT offices in all fifty states in the United States, and responses were collected. The survey was developed with the guidance of several state bridge engineers and other industry experts in bridge demolition. This survey started with the background questions about location and affiliation of the state DOT bridge owners. Then, they were asked if they experienced accidental incidents, unintentional collapses, and other demolition-related events within the past 15 years. Additional details on these events were gathered, including the number of specific occurrences, the location, brief description, etc. The next questions were asked about the liability policies of the agency and their effectiveness. The objective of the next questions was to obtain policies that each agency has related to approval of demolition plans and oversight to ensure the plans were properly executed. The participants were asked about bridge demolition plan submittal requirements and required approvals prior to the beginning of work. The participants were then asked about who is in charge of the inspection and oversight and ensuring the demolition plans are executed as planned. Finally, the last four questions in this survey focus on the administration of bridge demolition to assess national interest. The full survey and a more thorough explanation can be found in Garber [13].

According to the survey, participants were asked 56 different questions. The response of each question was compiled and gathered for analysis. These results provided a better understanding of current practice and recommendations for future research. An extrapolation of some of the survey results was presented to show the national impact. This study confirms the need of developing comprehensive documents or specifications about bridge demolition.

3. Summary of Results: Past Incidents

A total of 28 state DOTs responded to the survey, as shown in Figure 1. According to the responses for the past 15 years, 25 percent of states have encountered an accidental incident (with a total of 16 incidents reported) and 43 percent have observed an unintentional collapse (with a total of 16 collapses reported). As shown by these responses, issues with bridge demolition are not just isolated to a few states.

These accidental incidents and unintentional collapses resulted in a number of injuries or loss of life are shown in Figure 2. Contractor employees were the victim of the injury or fatality in the most in these incidents. Most of the accidental incidents and unintentional collapses occurred in conventional projects over either closed roads or waterways.

The primary reasons stated for the accidental incidents or unintentional collapses included

(1) Crane or demolition equipment overloading the bridge or being used improperly

(2) Removal of span or component of continuous span caused other spans to fail

(3) Deteriorated members had lower strength than expected

(4) Demolition plans were not followed

(5) Deck removal caused collapse

Though in only one of the incidents was a post-incident report developed.

4. Summary of Results: Policy

The states responded to questions on liability, requirement of bridge demolition plans, information required for a bridge

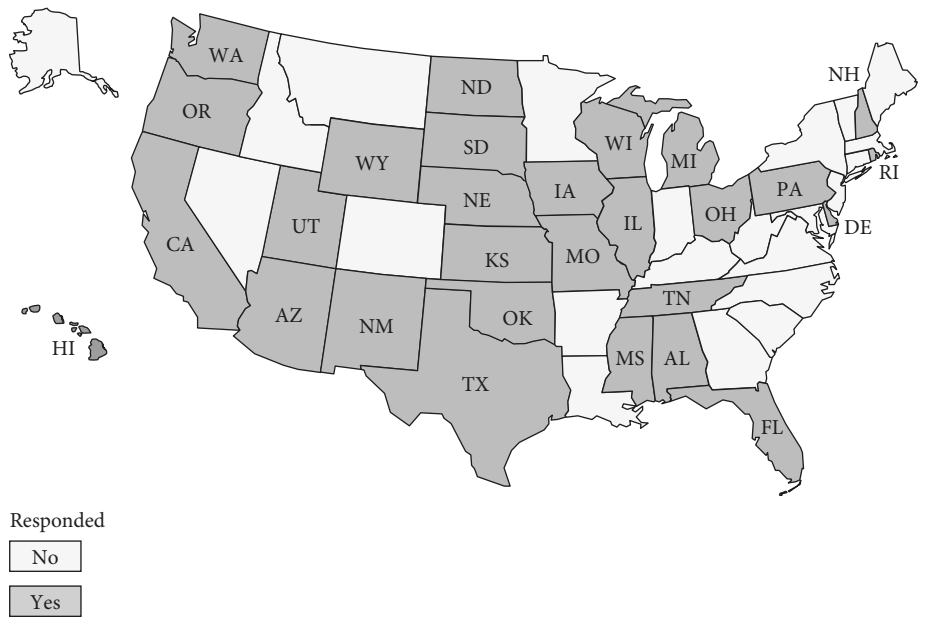

Figure 1: States who responded to demolition survey.

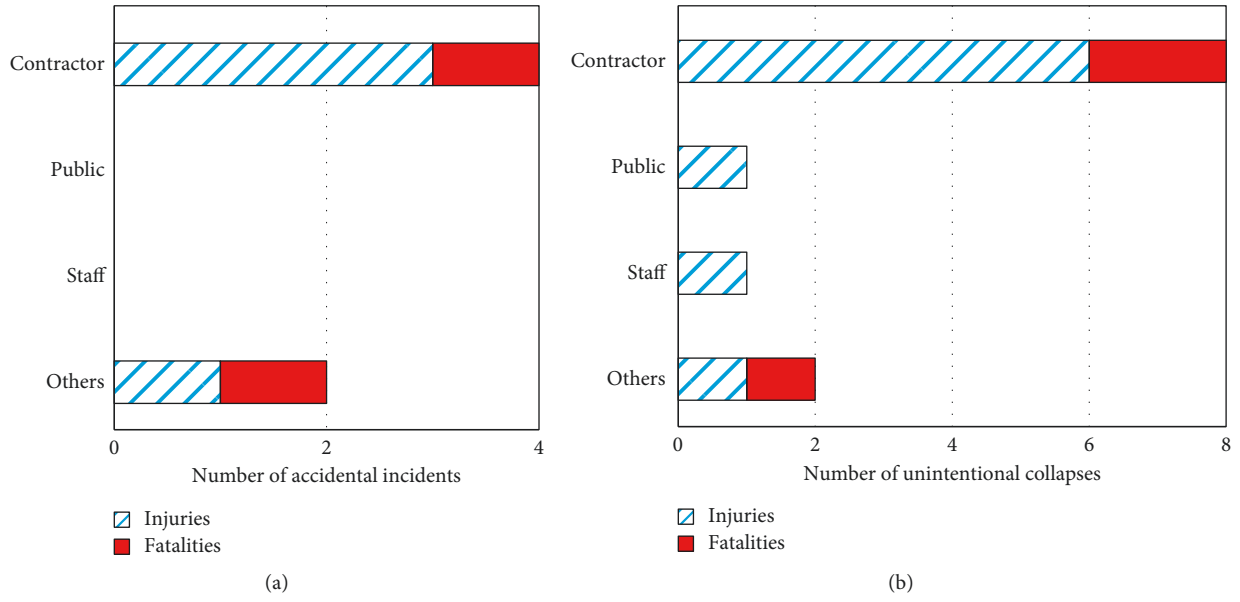

Figure 2: Number of (a) accidental incidents and (b) unintentional collapses caused injuries and fatalities.

demolition submittal, approval of bridge demolition submittal (prior to work), and construction engineering inspection and field oversight (during work). The highlights from these pieces of the survey are summarized in this section.

Over 50 percent of responding states do not have criteria, guidelines, or procedures for when a set of contract plans require the inclusion of a demolition plan, as shown in Figure 3. Thirty eight percent of responding states do have criteria or a formal policy. Among those states with policies, six states provided their formal policies with the researchers. These policies will be reviewed in the next section.

When demolition plans are required, only a third of the responding states either sometimes or always require a design engineer be involved in the development of the plans. These engineers are generally hired by the contractor and involved in the construction phase to either create or review the contract plans. The majority of states (62 percent) do however require demolition plans to always be signed by a PE. There are various levels of owner approval and demolition plan review required by the agencies, as shown in Figure 4. While most states have some form of review system in place (86 percent), half of these do not accept or reject them.

Many of the accidental incidents or unintentional collapses were a result of demolition overloading the bridge. The majority of responding states (77 percent) do not specify any parameters for demolition equipment. These loads are

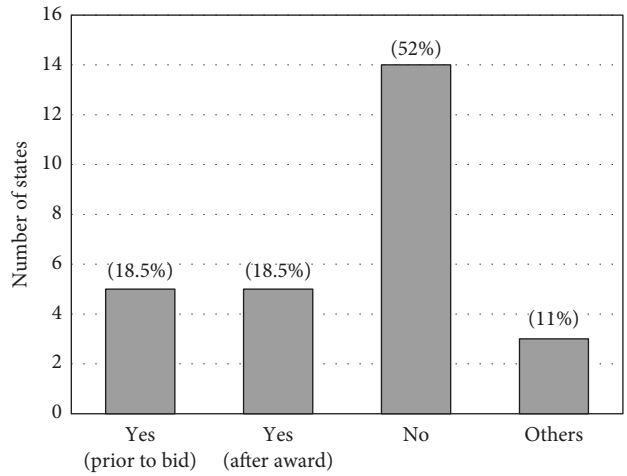

Figure 3: Number of states answering if agency has criteria, guidelines, or procedures for when a set of contract plans require the inclusion of demolition plan.

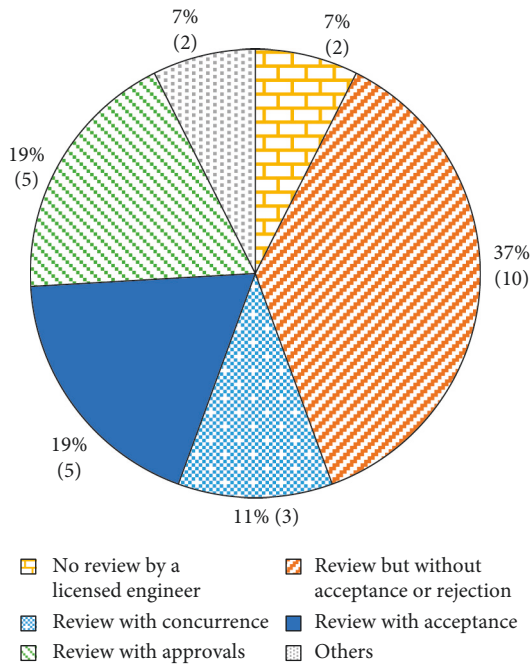

Figure 4: Number of states conducting various degrees of oversight to accept bridge demolition plans [13].

heavily dependent on the specific equipment being used, which is contractor dependent, and many of the loads are largely unknown.

Inspection and field oversight during the demolition is as important as the development of an effective demolition plan. The majority of responding states (59 percent) assign the contractor as the party responsible for ensuring demolition plans are executed as planned. Others either assign the responsibility to the bridge owner (7 percent), engineer of record (4 percent), field engineer (7 percent), or they do not specify a responsible party (7 percent), as shown in Figure 5.

Demolitions oftentimes do not go as planned, which stresses the importance of having processes in place for stopping bridge demolitions, making field changes, and having contingency plans developed before demolition begins. The majority of responding states (68 percent) do have a mechanism in place for stopping bridge demolitions. Field changes normally require the approval of the bridge owner (31 percent), the engineer of record (26 percent), or the contractor (14 percent). Of the states that require a demolition plan be submitted, only three require a contingency plan be developed before the start of the project.

5. Summary of Results: Needed Documents

According to the results of this survey, most states believe the following documents would be beneficial, as shown in Figure 6.

(1) Best Practices for Bridge Demolition Execution (48 percent).

(2) Best Practices for Bridge Demolition Administration (52 percent).

(3) Guide Specification for Bridge Demolition (69 percent).

The development of these documents is recommended for future research.

6. Overview of Current Policies

As was mentioned, six states provided their demolition guidelines or specifications [14–19]. Most of these guidelines focused on construction, construction requirements, removal of structures, methods of measurements, and basis of payments. A summary of the details included in each specification is provided in Table 1.

All of the specifications had some type of requirements for the demolition plans. In general, the plans are prepared by the contractor, submitted to the bridge owner, and include some of the following components:

(i) Removal sequence, including staging of removal activities and equipment locations

(ii) Temporary support shoring or bracing

(iii) Locations where work is performed over traffic, utilities, or railroad property

(iv) Locations and types of protective covers

(v) Protection of people, property, utilities, and improvements

(vi) Methods for preventing material, equipment, and debris from falling onto traffic or railroad property

(vii) Contingency plan indicating procedures to be carried out if the demolition stage completed does not comply with the submitted plan

(viii) Calculations necessary to show that the structure has sufficient strength and stability for each stage of demolition

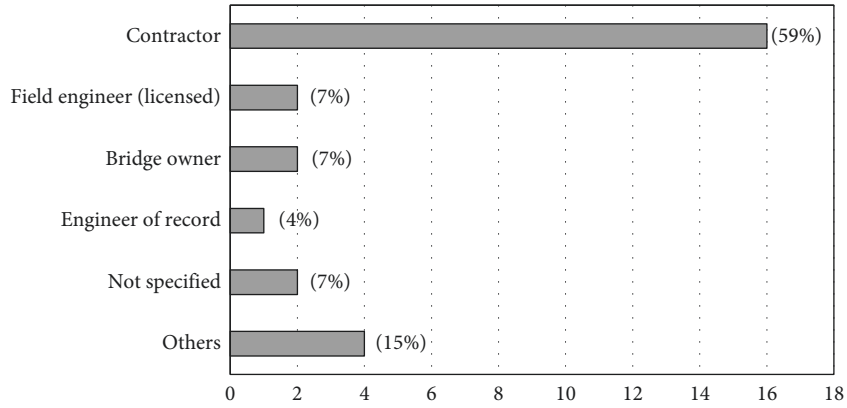

Figure 5: Party responsible for ensuring demolition plans executed as planned.

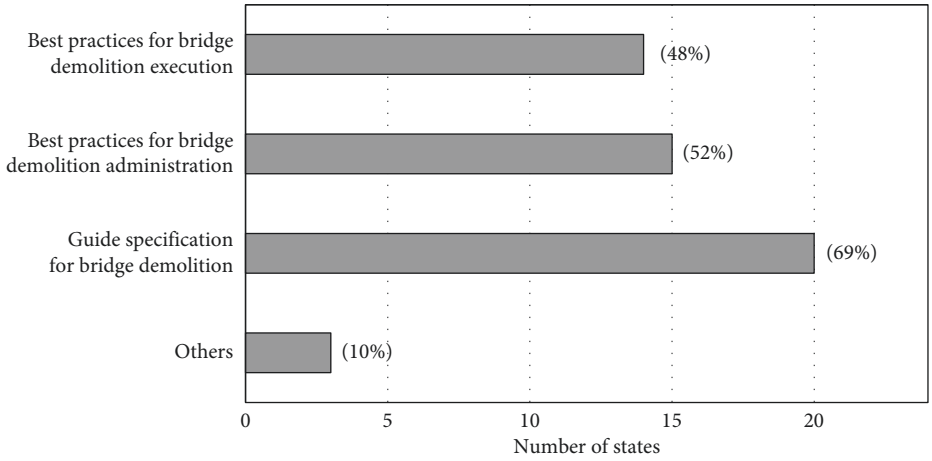

Figure 6: Information or resources beneficial for agency.

Table 1: Contents of guidelines [14–19].

	AL	CA	IL	IA	KS	TX
Demolition plan required	✓	✓	✓	✓	✓	✓
Details for demolition plan		✓	✓		✓	✓
Involved party responsibilities					✓	
Demolition guidance (means and methods)	✓	✓	✓	✓		✓
Protective system requirements		✓	✓			
Measurement and payment	✓	✓	✓	✓	✓	✓

These plans are typically required to be submitted to the owner some set amount of time before demolition begins for the owner's review and approval before demolition can start. In some cases, these plans need to be signed by a licensed engineer, typically if the demolition is near or over traffic.

Two of the specifications provide details related to protective covers or shield systems [15, 16]. These sections include details on timing (before demolition begins), protection requirements (sufficient to prevent debris from falling into traffic, pedestrians, or railway), and loading (200 psf).

Two of the specifications provide details on quality control and demolition oversight [15, 18]. CalTrans requires the registered engineer who signed the plans to be present at all times during the bridge demolition and prepare a daily inspection report. KDOT requires a demolition supervisor be present, who is prequalified for the scope, type, and complexity of the existing structure, and has an Owner's Inspector with specific requirements. The other specifications did not specifically mention oversite requirements.

Several of the specifications contain details on removal of superstructures (of different materials) or substructures either partially or completely [16, 17, 19]. These sections have details on clearance requirements (e.g., remove an additional one foot below the proposed elevation of subgrade or ground surface), dismantling for reuse (e.g., dismantle in a manner that will avoid damage to any members), and specifics on allowable demolition equipment (e.g., 15 lb chipping hammer or hand tools should be used when removing a deck for reuse at a saw cut boundary) to name a few. Finally, several of the specifications contain sections on basis of payment [16–18].

7. Conclusions

As discussed in this paper and observed in the survey results, bridge demolition administration is owner dependent; each state has their own policy with differing levels of detail. While some states view their policy (or lack thereof) as successful, there is a general consensus that some type of

national guidelines or best practices guide is needed. The existing specifications that were submitted as part of this survey can serve as a starting point for the components needed in this document, but should be supplemented by the results of the survey. As shown in the results of this study, contractors play the most important role in the bridge demolition projects.

Data Availability

Data generated or analyzed during the study are available from the corresponding author by request.

Disclosure

The opinions, findings, and conclusions expressed here are those of the author(s) and not necessarily of the sponsor.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This paper is based on a project supported by the US Department of Transportation (Grant no. DTRT13-G-UTC41) through the Accelerated Bridge Construction University Transportation Center (ABC-UTC).

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