CHAPTER 15

Bridges

Bridges

The National Bridge Inspection Program and the Highway Bridge Replacement and Rehabilitation Program

Bridges are critical elements within the highway transportation network supporting commerce, economic vitality, and personal mobility. Every day, close to 4 billion vehicles cross bridges in the United States. The public expects these structures to be safe and to have the capability to support their transportation. The safety of the bridge network came into question in the late 1960s when, on December 15, 1967, the Silver Bridge spanning the Ohio River between West Virginia and Ohio collapsed during rush-hour traffic. This catastrophic event resulted in 46 fatalities and numerous injuries, prompting national concern about bridge conditions and safety. Following this disastrous event, programs were established to ensure periodic safety inspection of bridges and provide mechanisms for funding of bridge replacement and rehabilitation needs. The primary bridge programs include the National Bridge Inspection Program (NBIP) and the associated Highway Bridge Replacement and Rehabilitation Program (HBRRP).

General information on the composition and conditions of bridges has been presented in Chapter 2 and Chapter 3. These chapters provide an overview of bridge composition and performance with a focus on ownership and functional classification. As bridges are vital elements within the system, additional detail is provided on the conditions, composition, and performance of the U.S. highway bridge network in this chapter. Additional information concerning bridges on the National Highway System (NHS) can be found in Chapter 17.

As shown in the tables and discussions that follow, the Nation's highway bridges have remained safe as a result of the bridge programs, and progress has been made toward the Federal Highway Administration (FHWA) strategic goals of reducing deficiencies. However, with an ever-aging population of highway structures, increasing traffic demands, and limited budgets, it is important to examine transportation system preservation strategies, such as preventative maintenance, and improved bridge inspection and management techniques to continue to ensure the safety of the motoring public and effective stewardship of the public trust.

Overview and Evolution of the Bridge Programs

For the last 30 years, bridges in excess of 6.1 meters in total length located on public roads have received periodic inspections to ensure safety to the traveling public. Inspections are guided by Federally defined minimum data collection requirements. Every year, bridge information collected for that year is submitted from the States and Federal Agencies to FHWA. Information collected and maintained by FHWA forms the basis for determining the condition of the Nation's bridges and for the apportionment of bridge replacement and rehabilitation funds to the States. Since initiation of the legislation guiding the development of the National Bridge Inspection Standards (NBIS) and associated funding programs, over $60 billion in HBRRP funding alone has been allocated and utilized to improve the condition of the Nation's bridges. Other sources of funding from Federal and State programs are also utilized for bridge activities.

Bridges are critical elements within the highway transportation network. Deterioration of structures must be periodically mitigated through proactive interventions to ensure safety of the traveling public, ensure connectivity of the network, and retain the significant intrinsic asset value of the bridge stock. These preservative actions cost significantly more than highway pavement activity on a unit cost basis. In addition, bridges may become functionally obsolete due to changing traffic demands. Actions must be taken to avoid adverse economic impacts to the traveling public, which may result from this functional obsolescence of the structures.

Programs have been developed and legislated to ensure bridge safety and provide funding for rehabilitation, improvement, and replacement of the structures. These programs are summarized in this section. The information collected through the bridge inspection process, which represents the most comprehensive source of bridge condition and composition data at the national level, is summarized to give a background for the in-depth examination presented later in this chapter.

On December 15, 1967, the Silver Bridge carrying U.S. 35 between Point Pleasant, West Virginia, and Gallipolis (Kanauga), Ohio, collapsed during rush-hour traffic. Thirty-one vehicles fell into the Ohio River or onto the Ohio shore, killing 46 people and injuring nine. The collapse, which was the first major failure of a structure since the wind-induced failure of the Tacoma Narrows Bridge in 1940, prompted national concern about bridge conditions and safety.

Congressional hearings on the failure resulted in mandates requiring the U.S. Secretary of Transportation to develop and implement the NBIS. The NBIS, developed by FHWA in cooperation with the American Association of State Highway and Transportation Officials, was enacted as part of the Federal-Aid Highway Act of 1970. This landmark legislation was enacted on December 31, 1970, and established, for the first time in U.S. history, uniform, national-level standards for bridge inspection and safety evaluation. The Act also designated funding for the replacement of deficient bridges on the Federal-aid highway system. Through the legislation:

- All States were required to perform periodic inspection of bridges in excess of 6.1 meters (20 feet) located on Federal-aid highway systems.
- Bridge inspection data collection requirements were established.
- Qualifications for key bridge inspection personnel were defined.
- Training programs for bridge inspectors were developed and implemented.
- The Special Bridge Replacement Program (SBRP) was established to provide funding for the replacement of bridges located on the Federal-aid system.

Over time, the NBIS has been fine-tuned, additional inspection requirements have been added, and funding programs have been updated. It quickly became evident that safety assurance was required for all structures located on public roadways. The requirement to inventory and inspect bridges on Federal-aid highways was extended to all bridges in excess of 6.1 meters (20 feet) located on public roads. Data collection requirements were enhanced, and training programs continued to be developed and expanded as more knowledge became available through research and experience. Funding programs were expanded to permit the use of Federal funds for replacement of both Federal-aid and non-Federal-aid bridges.

Despite efforts to continually enhance the process of bridge inspection, unforeseen events periodically necessitated expansion. The scene was Interstate 95, the primary highway on the Atlantic seaboard that connects Florida and Maine, approximately 30 miles east of New York City, near Greenwich, Connecticut. On June 28, 1983, a section of the Mianus River Bridge catastrophically failed because of instantaneous fracture of a pin and hanger detail. This failure resulted in several fatalities and disrupted commerce in the northeastern United States for several months. Following this event, significant research into fatigue of steel connections was performed, and tremendous insight into the behavior of steel connections was obtained. The program was enhanced to incorporate more rigorous inspection procedures for fracture critical structures. Training programs were developed, putting the research results and accumulated experience and understanding of fatigue and fracture into practice.

On April 5, 1987, disaster struck again with the collapse of a bridge carrying the New York State Thruway (Interstate 90) across the Schoharie Creek. With rising water levels from localized flooding, the soil around the pier was simply washed or scoured away. The loss of soil around the pier resulted in the subsequent loss of bearing capacity for the foundation of the center pier, which collapsed. Several fatalities resulted from this collapse. A failure due to the washing or scouring of supporting soil from a major pier or abutment of a structure is termed a scour-induced failure. Other notable scour-induced failures occurred throughout the country, including the collapse of the Hatchie River Bridge in Tennessee on April 1, 1989. These bridges indicated the potential problem, given that more than 80 percent of the bridges on public roads cross over waterways. With approximately 475,000 structures crossing waterways, program enhancement was required. The FHWA acted quickly, providing guidance for scour assessment and requiring periodic underwater inspection of all structures at risk and susceptible to scour damage.

The combination of research, experience, and technology transfer of knowledge acquired has been used to train professionals performing inspections of fatigue- and scour-susceptible structures. Catastrophic failures due to scour and fatigue, such as the Mianus River and the Schoharie Creek bridges, have been avoided. Additional knowledge is required on these and other extreme events, such as earthquakes and collisions, to avoid such calamities in the future. Research efforts performed by FHWA and transfer of results to experienced engineers practicing in the field continue to proactively mitigate potential failures.

Catastrophic events highlighted the need to replace bridges before they collapse. The SBRP, created by the Federal-Aid Highway Act that provided funds to help States replace bridges, required expansion to permit rehabilitative activities. Again, action was taken and, in 1978, the Surface Transportation Assistance Act replaced the SBRP with the HBRRP.

The program initiated through the Federal-Aid Highway Act has been incrementally enhanced so that, today, all structures in excess of 6.1 meters on public roads receive, in general, biennial safety inspections. Notable changes in legislation can be seen in *Exhibit 15-1*. "Best practices" for routine, fracture-critical, and underwater inspections have been defined and published. Qualifications of inspection personnel have been established and training programs implemented to ensure completeness of engineering reviews and consistency of inspection condition assessments.

Exhibit 15-1 *Summary of Major Bridge Inspection and Bridge Program Funding Legislation and Noteworthy Changes*

Act and Date	Requirements
Federal-Aid Highway Act of 1970: (P.L. 91-605)	Inventory requirement for all bridges on the Federal-aid system Established minimum data collection requirements Established minimum qualifications and inspector training programs Established Special Bridge Replacement Program
Surface Transportation Assistance Act of 1978 (P.L. 95-599)	Provided $4.2 billion for the HBRRP over 4 years Extended inventory requirement to all bridges on public roads in excess of 6.1 meters Established Highway Bridge Rehabilitation and Replacement Program (extending funding to Rehab) to replace Special Bridge Replacement Program
Highway Improvement Act of 1982	Provided $7.1 billion for the HBRRP over 4 years
Surface Transportation and Uniform Relocation Assistance Act of 1987	Provided $8.2 billion for the HBRRP over 5 years Added requirements for underwater inspections and fracture-critical inspections Allowed increased inspection intervals for certain types of bridges
Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA)	Provided $16.1 billion for the HBRRP over 6 years Mandated State implementation of bridge management systems Increased funding in HBRRP
National Highway System Designation Act of 1995	Repealed mandate for management system implementation
Transportation Equity Act for the 21st Century (TEA-21, 1998)	Provided $20.4 billion in HBRRP funding over 6 years

Information Collected Through the Bridge Inspection Program

As part of the NBIS, qualifications of key personnel have been identified, training programs developed and offered to bridge owning agencies, assistance with bridge program development provided, and minimum data collection requirements defined. The information that is obtained through the process defined by the NBIS is discussed below. This information forms the basis for the subsequent examinations of the conditions and performance later in this chapter.

For most structures, the NBIS requires visual inspection once every 2 years. For structures with safety concerns, inspections may be performed more frequently. Likewise, for structures with special favorable characteristics, the period of observation may be increased. The bridge owners (States, cities, municipalities, etc.) are responsible for these inspections with oversight by the State department of transportation. Information is collected on the bridge composition and conditions and reported to FHWA where the data are maintained in the National Bridge Inventory (NBI) database. This information forms the basis of the bridge safety assurance efforts and provides the mechanism for the determination of fund requirements and fund apportionments.

The NBI database maintains inventory information characterizing the structure, condition ratings, appraisal ratings, and calculated fields. This information has been collected and maintained in the NBI database for over two decades. The NBI database represents the most comprehensive source of information available on the national level.

Inventory information includes location and description fields, geometric data (lengths, clearances, lane widths), functional descriptions (classification, NHS designation, service carried and crossed, etc.), and design characteristics (superstructure designs and materials, deck types, design load, etc.). This information permits classification of structures according to serviceability and essentiality for public use. The composition of structures in the network can be ascertained through examination of the inventory data.

Through periodic safety inspections, data are collected on the condition of primary components of a structure. Condition ratings are collected for the following components of a bridge:

- The bridge deck, including the wearing surface
- The superstructure, including all primary load-carrying members and connections
- The substructure, considering the abutments and all piers
- Culverts, recorded only for culvert designs
- Channel/channel protective systems, for all structures crossing waterways.

In general, each traditional bridge design has distinct deck, superstructure, and substructure components that are each rated independently. Culvert designs are also included in the bridge inventory, if they are located on a public road and have a total length in excess of 6.1 meters. As culverts are considered as "bridges" under the NBIS for funding purposes, they are inspected biennially. Culverts have different design properties, behave differently under subject loads, and have different considerations than traditional bridge designs. Culvert designs are typically used for short-span, low-volume channel flow situations. Since culverts do not have distinct deck, superstructure, and substructure components, an individual culvert condition rating is assigned during the inspection process. These culvert ratings are used to guide deficiency status determination and eligibility of the structure for Federal fund participation.

Condition ratings are also developed for the channel and the channel protection system during the bridge inspection process. The channel/channel protective system rating describes the physical conditions of slopes and the channel for water flow through a bridge. Condition evaluation of these elements is increasingly important for structures susceptible to scour, which can occur and increase in situations due to channel degradation or failed channel protection.

Condition ratings are assigned by bridge inspectors utilizing a 10-point rating system, as described in Chapter 3 [*see Exhibit 3-22*]. Code 9 indicates excellent, as-new condition, and code 0 indicates a failed condition. Codes 7 through 9 indicate satisfactory to excellent conditions. Codes 5 and 6 indicate either fair or satisfactory conditions of the components. Codes 4 through 0 indicate poor, serious, critical conditions, and conditions representing imminent failure of the component or failed conditions. Inspectors assess the ratings in a visual fashion based on engineering expertise and experience. Extensive training for inspectors is provided, and references are available to guide assignment of the ratings. These ratings form the basis for assessing the structural condition of a bridge.

Functional adequacy is also a concern in the bridge population. Following collection of the inventory information and condition ratings, appraisal ratings are calculated to assess the adequacy of a structure to provide the required service. Appraisal ratings are quantified for

- Structural evaluations (load-carrying capacities);
- Deck geometry (indicating constrictions that affect safety);
- Underclearances (which, if insufficient, result in detours); and
- Waterway adequacy (the ability of the opening to handle the flow rates).

A bridge may be structurally deficient and/or functionally obsolete. These determinations are assessed based on the condition and appraisal ratings. Structural deficiencies result from poor condition ratings or from low load ratings. Functional obsolescence results from low appraisal ratings or from low design-load capacities. Inadequate waterway adequacy can be a contributing factor for either structural deficiencies or functional obsolescence.

Composition of the Bridge Network

An overview of the composition and conditions of the bridge system was presented in Chapter 2. This chapter presents additional detail for the system of bridges as a whole and according to traffic volumes, functional classifications, age, and superstructure materials and designs.

The NBI contains nearly 700,000 records, which describe either the features carried by a bridge, termed as "on" records, or the features crossed by the structure, termed as "under" records. Separating the on records from the under records reveals that there are 591,707 bridges over 6.1 meters (20 feet) in total length located on public roads in the United States. These bridges, on average, carry nearly 4 billion vehicles per day and comprise a total deck area in excess of 300 million square meters.

Q. How do the bridge ownership percentages compare with road ownership percentages?

A. The majority of bridges (98 percent) and roadways (97 percent) are owned by State and local agencies. The vast majority of roadways, however, are owned by local agencies (77 percent). Bridge ownership is nearly equally divided between State (47 percent) and local agencies (51 percent).

The discussion of bridges in Chapters 2 and 3 primarily considered the number of bridges in different classifications. Using this approach, every bridge in the inventory is counted equally. Thus, large suspension bridges, such as the Golden Gate or the George Washington Bridges, are considered equivalent to small, two-lane bridges carrying low volumes of traffic. In some cases, better insights into the condition or the composition of bridges can be obtained by considering the size of the structure and/or the traffic carried. Considerations of size of the structure can be incorporated through presentation of information using the deck area of the bridge. Considerations of the volume of traffic served by the structure can be incorporated through presentation of information using average daily traffic (ADT).

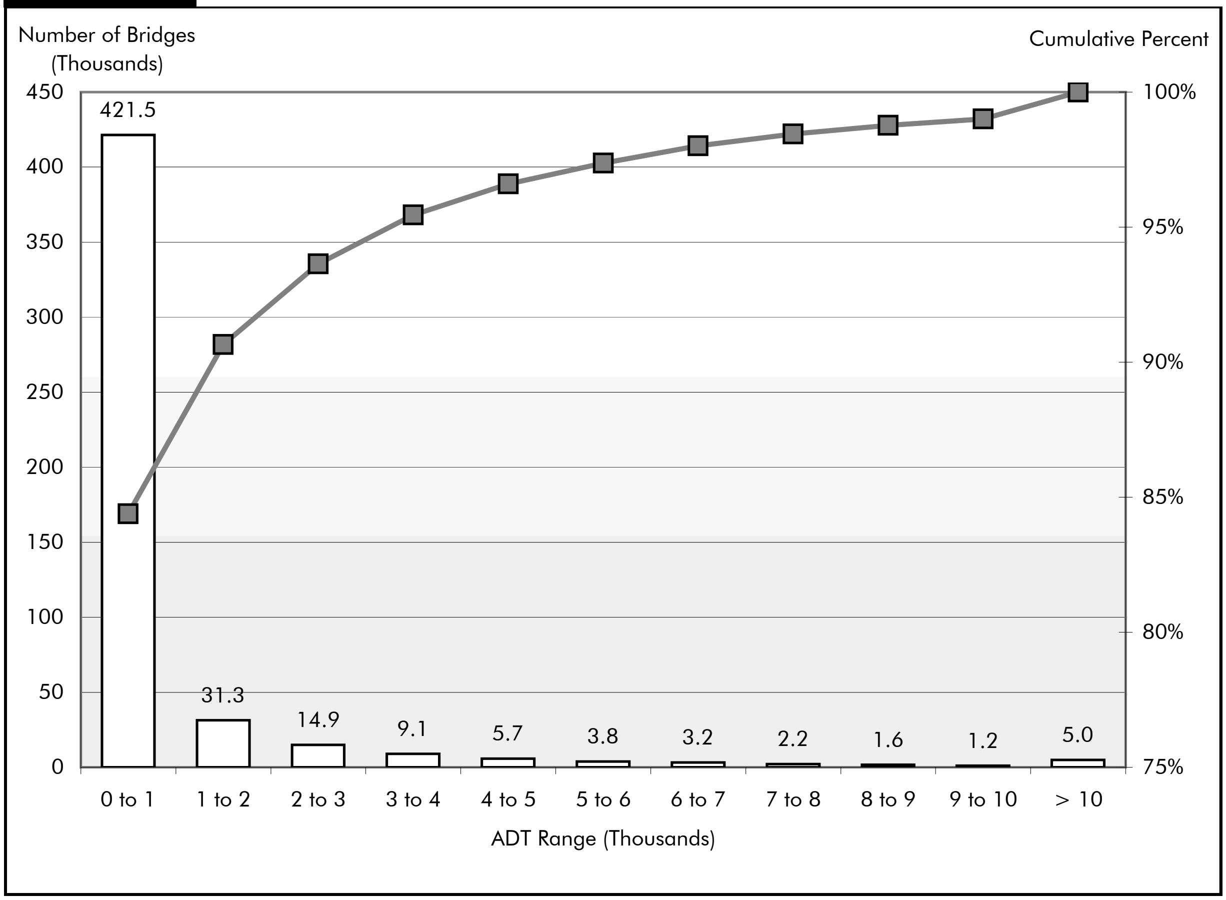
Bridges by ADT

Approximately 27 percent of structures in terms of numbers have an ADT of 100 or less. In excess of 50 percent of these structures have an ADT lower than 700. 96.5 percent of structures have an ADT of 40,000 or below and 97.5 percent have an ADT of 50,000 or below.

In terms of numbers of bridges, low-volume roadways are predominant. However, the high-volume structures have a significant impact on the user population. There are approximately 21,000 structures with ADT values in excess of 40,000 vehicle crossings daily. These structures are predominantly in urban environments (approximately 90 percent in terms of numbers, nearly 95 percent in terms of deck area). Over 95 percent of such bridges are located on Interstates or other principal arterials.

Weighting the number of bridges by ADT values provides a mechanism for evaluating the impacts of the composition and conditions of bridges in terms of their impact on the highway user. *Exhibit 15-2* shows that the distribution is significantly skewed to lower values of ADT.

Exhibit 15-2 *Bridges by ADT Values, Distribution, and Cumulative Percentages*



Bridges by Functional Classification

Exhibit 15-3 shows the percentage of bridges by functional classification with bridges equally weighted by numbers, weighted by ADT, and weighted by deck area. Rural bridges are predominant when the percentages are determined by numbers, as 77.1 percent of all structures are located in a rural environment. Urban bridges, which comprise 22.9 percent of the inventory, carry over 73 percent of all daily traffic. Not surprisingly, urban structures are generally larger in terms of deck area as additional lanes are required to carry larger volumes of traffic. Urban structures constitute 52.6 percent of all total deck area on bridges in the inventory.

The disparity between urban and rural structures in terms of traffic carried and size is readily evident on the national level by comparing the percentages. Further examination of Exhibit 15-3 reveals similar trends across functional classification. Whereas bridges on Interstate and other arterial routes comprise

Exhibit 15-3 *Bridges by Functional Class Weighted by Numbers, ADT, and Deck Area*

Functional Class	Total	% by Nos. (% of All)	% of ADT	% of Deck Area
Rural				
Interstate	27,316	4.6%	10.2%	8.0%
Other Principal Arterials	35,227	6.0%	6.5%	9.0%
Minor Arterial	39,587	6.7%	3.7%	6.6%
Major Collector	94,781	16.0%	3.8%	10.0%
Minor Collector	49,320	8.3%	0.9%	3.6%
Local	209,722	35.4%	1.6%	10.2%
Rural Total	**455,953**	**77.1%**	**26.6%**	**47.3%**
Urban				
Interstate	27,929	4.7%	35.2%	19.2%
Other Expressways	16,844	2.8%	14.3%	9.2%
Other Principal Arterials	24,307	4.1%	12.1%	10.7%
Minor Arterial	24,516	4.1%	7.1%	7.0%
Collectors	15,171	2.6%	2.3%	2.8%
Local	26,609	4.5%	2.3%	3.5%
Urban Total	**135,376**	**22.9%**	**73.3%**	**52.6%**
Unclassified	378	0.1%	0.0%	0.1%
Total	**591,707**			

Source: National Bridge Inventory.

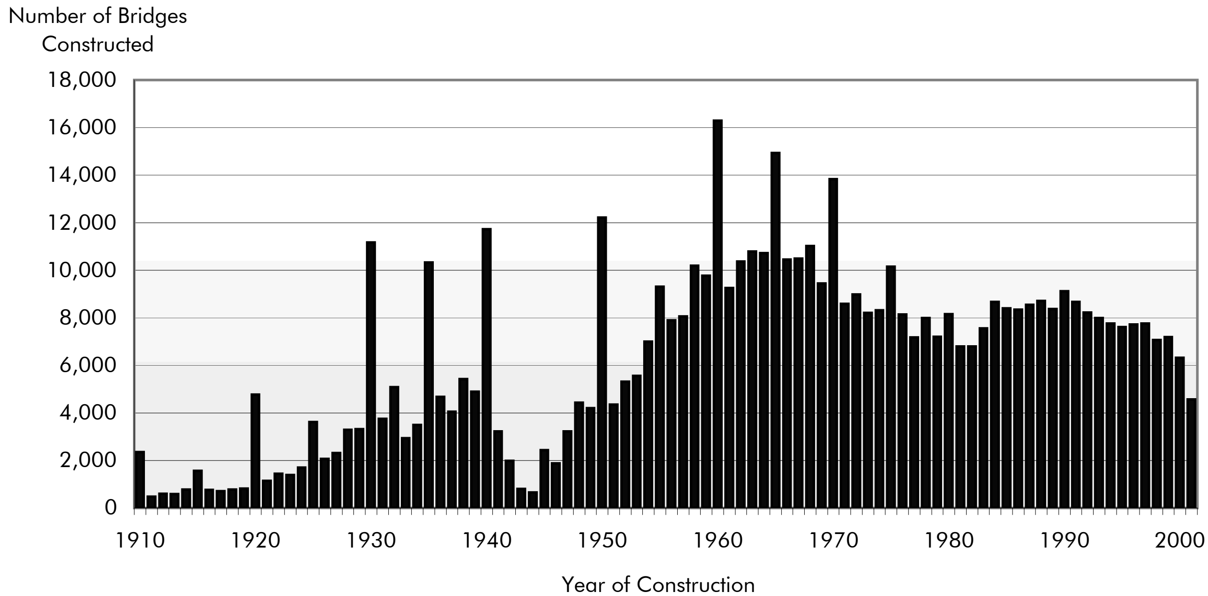
approximately one-third of the inventory by numbers, they carry close to 90 percent of all daily traffic and approximately 70 percent of the deck area. Likewise, the local and collector roads constitute two-thirds of the inventory by numbers, but carry only 10 percent of total daily traffic volume.

Bridges by Age of Construction

For each bridge in the NBI, the year of construction is recorded and a year of construction distribution may be generated. This is shown in *Exhibit 15-4* where the number of bridges constructed by year is presented for all owners and for all functional classifications. Note that some of the annual "spikes" seen in the number of bridges constructed before 1970 are artificial, as some localities have recorded year of construction information using 5-year increments for older bridges. Peak periods of construction are seen mainly before World War II and during the Interstate construction era.

Exhibit 15-5 shows the average year of bridge construction by functional classification and owner. Standard deviations are provided with the mean values in order to give additional information on the distributions. Bridges in the inventory are, on average, 40 years old with an average year of construction of 1964. Urban structures are slightly younger than rural structures, with an average year of construction of 1968. Comparing rural bridges across ownership classifications shows that State, local, and Federal owners have values within a few years of the mean for all rural bridges. Rural bridges owned by other owners, which are primarily private owners and railroads, are on average 10 years older than the general population. With urban bridges, State and locally owned bridges are slightly younger or slightly older than average, respectively. Federally owned urban bridges and urban structures owned by others are 5 to 10 years older than State and local counterparts on average. It is important to note, however, that the number of bridges owned by Federal and other agencies is much smaller.

Exhibit 15-4 *Bridges: Year of Construction Distribution*



Source: National Bridge Inventory.

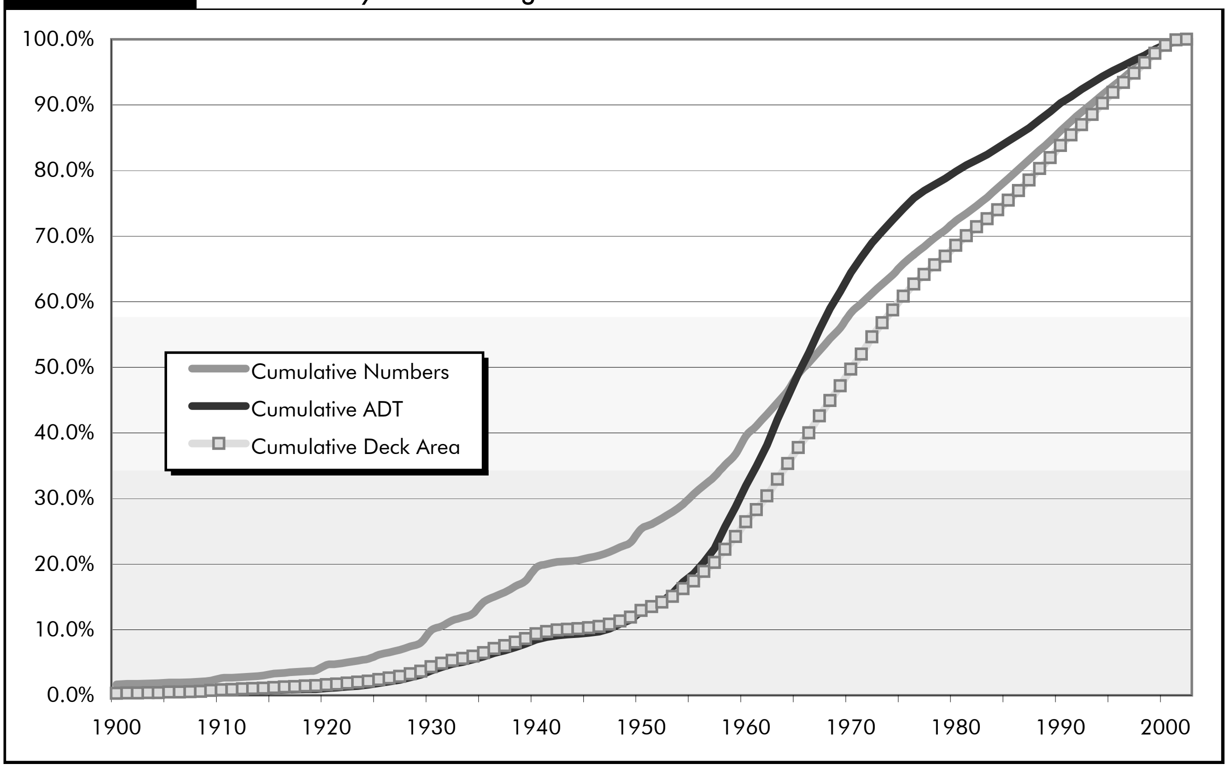
Exhibit 15-5 *Average Year of Bridge Construction by Owner and Functional Classification*

	Average Year of Construction and Standard Deviation									
Functional Class	**State**		**Local**		**Federal**		**Other**		**All Owners**	
Rural										
Interstate	1968	(11)	1959	(28)	1963	(6)	1965	(11)	1968	(11)
Other Principal Arterial	1965	(22)	1968	(24)	1967	(18)	1973	(19)	1966	(22)
Minor Arterial	1958	(23)	1972	(28)	1968	(21)	1966	(27)	1959	(23)
Major Collector	1960	(21)	1963	(22)	1968	(18)	1949	(32)	1962	(22)
Minor Collector	1962	(20)	1964	(24)	1962	(19)	1950	(32)	1963	(23)
Local	1966	(22)	1963	(28)	1965	(20)	1946	(33)	1963	(27)
All Rural Bridges	**1963**	**(21)**	**1963**	**(26)**	**1965**	**(20)**	**1952**	**(32)**	**1963**	**(24)**
Urban										
Interstate	1970	(12)	1963	(17)	1956	(8)	1975	(19)	1970	(12)
Other Freeways and Expressways	1973	(16)	1971	(20)	1945	(37)	1980	(15)	1973	(16)
Other Principal Arterial	1964	(22)	1962	(25)	1961	(30)	1960	(32)	1964	(23)
Minor Arterial	1964	(22)	1964	(25)	1965	(21)	1946	(33)	1964	(24)
Collector	1966	(22)	1965	(25)	1959	(18)	1953	(34)	1965	(24)
Local	1969	(20)	1966	(25)	1958	(21)	1949	(36)	1966	(25)
All Urban Bridges	**1968**	**(18)**	**1965**	**(25)**	**1959**	**(22)**	**1960**	**(33)**	**1967**	**(21)**
Rural and Urban										
Interstate	1969	(11)	1963	(17)	1962	(6)	1973	(18)	1969	(11)
Other Principal Arterials	1967	(21)	1964	(24)	1965	(22)	1974	(22)	1967	(21)
Minor Arterials	1960	(23)	1965	(26)	1968	(21)	1951	(32)	1961	(24)
Collectors	1961	(21)	1964	(23)	1963	(19)	1951	(33)	1963	(22)
Local	1966	(22)	1963	(28)	1965	(20)	1947	(34)	1964	(27)
All: Rural and Urban	**1964**	**(20)**	**1964**	**(26)**	**1965**	**(20)**	**1957**	**(33)**	**1964**	**(24)**

Source: National Bridge Inventory.

The cumulative distributions shown in *Exhibit 15-6* depict the increased rate of construction during the Interstate era. Cumulative distribution curves are presented for the numbers, ADT, and deck area. The mean year of construction occurs where the curves pass through the 50 percent value and is roughly equivalent when bridges are weighted equally (numbers) or when bridges are weighted by traffic carried (ADT). Half of all the bridges in the country were built before 1964, and 50 percent of all daily traffic carried by the system travels over these structures. The mean year of construction is approximately 1971 where structures are weighted by deck area. This indicates that recent structures tend to be larger than their older counterparts. This conforms with conventional wisdom as standards have changed over time.

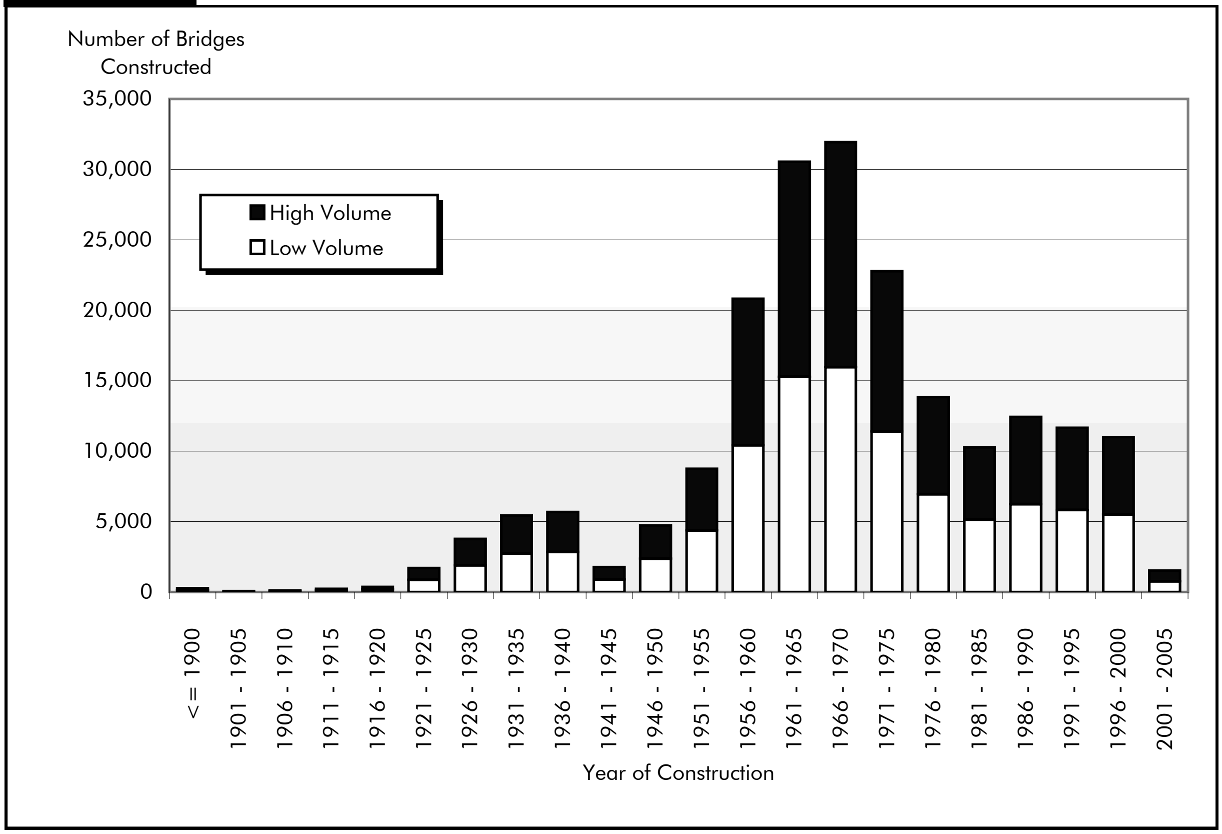
Exhibit 15-6 *Cumulative Percentage of Numbers, ADT, and Deck Area by Year of Bridge Construction*



Source: National Bridge Inventory.

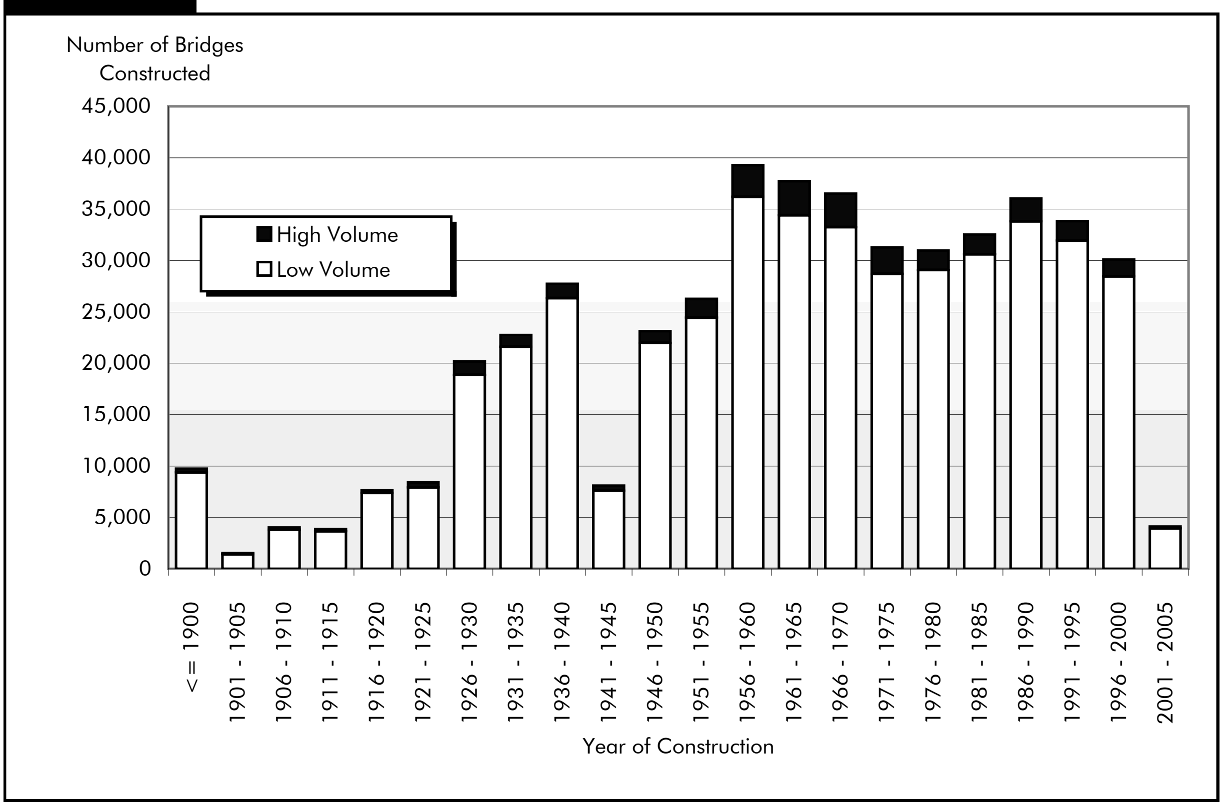
Chapter 17 provides information on the composition and conditions of high- and low-volume bridges on and off the NHS. The majority of traffic is carried on NHS structures, which include the Interstate System. High- and low-volume NHS structures are defined using a threshold of 50,000 vehicle crossings daily. NHS structures include the majority of higher functional classifications and are typically owned by State agencies. The threshold value for distinguishing between high- and low-volume NHS structures is 10,000. Local ownership tends to focus on low-volume non-NHS structures. *Exhibits 15-7* and *15-8* show the year of construction distributions for high- and low-volume NHS and non-NHS bridges.

Exhibit 15-7 *Year of Construction Distribution for High- and Low-Volume NHS Bridges*



Source: National Bridge Inventory.

Exhibit 15-8 *Year of Construction Distribution for High- and Low-Volume Non-NHS Bridges*

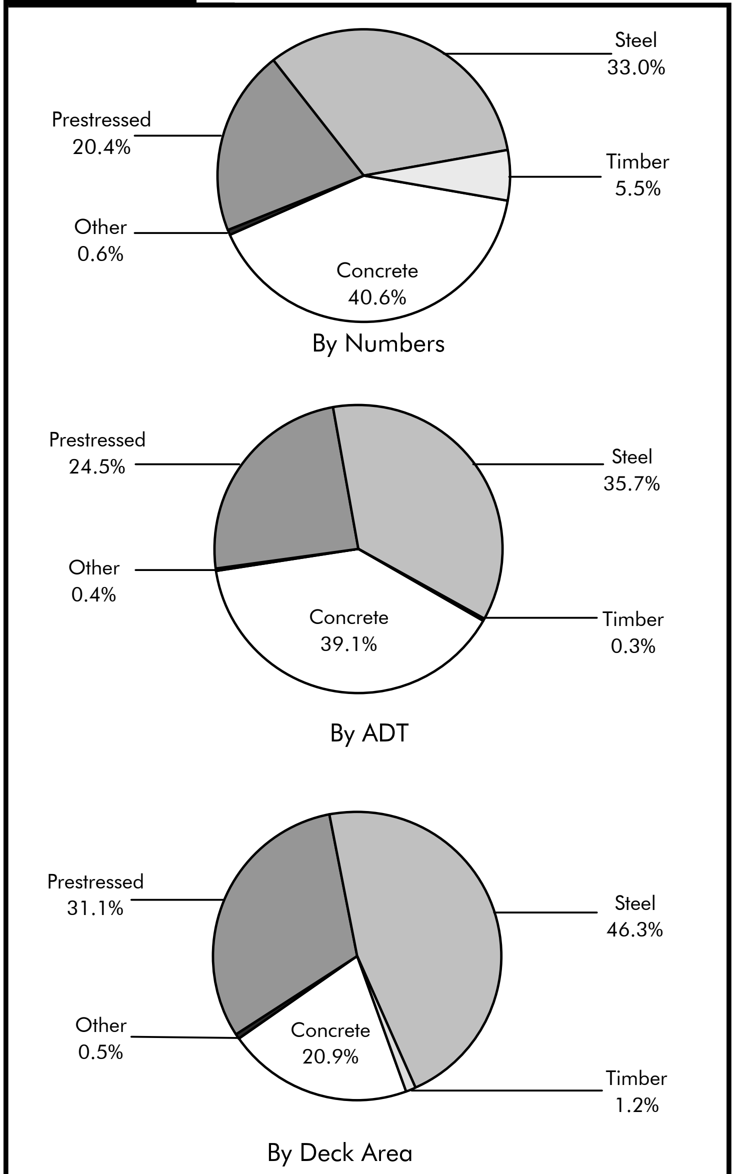


Source: National Bridge Inventory.

Bridges by Type of Superstructure Material

Superstructure material types are maintained in the database for the main span and for the approach spans. Predominant materials used for bridge superstructures are steel, concrete, prestressed concrete, and timber. Other materials, such as aluminum, iron, and composite materials, are utilized on less than 1 percent of the structures. The percentage of superstructure materials utilized is shown in *Exhibit 15-9* weighting bridges equally by numbers, weighting by ADT, and weighting by deck area. While only 33.0 percent of bridges have steel superstructures, these bridges carry 35.7 percent of bridge traffic, and represent 46.3 percent of total deck area on all bridges. From these percentages, it may be inferred that steel bridges tend to be utilized for longer-than-average structures carrying higher-than-average volumes of traffic. Timber bridges, which constitute 5.5 percent of the inventory by numbers, carry small volumes of traffic and are smaller than average in terms of deck area.

Exhibit 15-9 *Percentage of Superstructure Material Types: Bridges Weighted by Numbers, ADT, and Deck Area*



Source: National Bridge Inventory.

The number of bridges by type, superstructure material, functional classification, and ownership are shown in *Exhibit 15-10.* The average year of construction and the standard deviation are shown for these combinations in *Exhibit 15-11.* Bridges carrying Interstate, other principal arterial, and minor arterial routes are predominantly constructed of reinforced concrete, steel and prestressed concrete. Timber superstructures and other materials become more significant within the population of bridges carrying collectors and local roadways.

Concrete and steel superstructure bridges on the Interstate are, on average, 35 to 40 years old. Prestressed designs were introduced more recently and have become the predominant superstructure material employed today, with over 50 percent of new structures employing prestressed concrete. Today, there are over 45,000 prestressed superstructure bridges carrying Interstates, other principal arterials, and minor arterials in the United States. There are also sizable numbers of prestressed concrete bridges carrying collector and local roadways. Bridges constructed of this material are, on average, 25 years old. The average age of timber superstructure bridges is approximately 45 years, while the average age of other materials is in excess of 65 years. Other materials are used on many older designs that used iron and masonry or on newer structures employing composites or other new materials.

Exhibit 15-10 *Number of Bridges by Superstructure Material, Functional Classification, and Ownership*

Material & Functional Class	Ownership				
	State	Local	Federal	Other	All Owners
Interstate					
Concrete	19,843	61	10	3	19,917
Steel	21,532	222	7	16	21,777
Prestressed	13,429	30	3	5	13,467
Timber	4	3			7
Other	54	1			55
Total	**54,862**	**317**	**20**	**24**	**55,223**
Other Principal Arterial					
Concrete	30,243	3,003	15	151	33,412
Steel	20,102	1,889	37	165	22,193
Prestressed	18,082	1,595	21	497	20,195
Timber	275	28			303
Other	**176**	**72**	**1**	**4**	**253**
Total	**68,878**	**6,587**	**74**	**817**	**76,356**
Minor Arterial					
Concrete	26,040	7,424	160	101	33,725
Steel	13,197	3,299	133	153	16,782
Prestressed	8,681	3,456	112	64	12,313
Timber	519	300	30	14	863
Other	181	199	9	3	392
Total	**48,618**	**14,678**	**444**	**335**	**64,075**
Collector					
Concrete	40,392	37,684	849	84	79,009
Steel	19,933	23,392	199	208	43,732
Prestressed	12,117	17,108	278	110	29,613
Timber	1,670	4,306	31	45	6,052
Other	313	522	20	7	862
Total	**74,425**	**83,012**	**1,377**	**454**	**159,268**
Local					
Concrete	8,507	63,212	2,002	211	73,932
Steel	16,222	71,976	1,677	469	90,344
Prestressed	6,923	36,542	1,165	147	44,777
Timber	1,215	21,337	2,400	237	25,189
Other	263	1,546	50	9	1,868
Total	**33,130**	**194,613**	**7,294**	**1,073**	**236,110**
All Bridges					
Concrete	125,025	111,384	3,036	550	239,995
Steel	90,986	100,778	2,053	1,011	194,828
Prestressed	59,232	58,731	1,579	823	120,365
Timber	3,683	25,974	2,461	296	32,414
Other	987	2,340	80	23	3,430
Total	**279,913**	**299,207**	**9,209**	**2,703**	**591,032**

* Note: Records with unknown or incorrectly coded materials, functional classifications, or ownership codes were not included.

Source: National Bridge Inventory.

Exhibit 15-11 *Average Year of Construction and Standard Deviation for Superstructure, Functional Classification, and Ownership Combinations*

Material & Functional Class	Ownership									
	State		Local		Federal		Other		All Owners	
Interstate										
Concrete	1966	(10)	1969	(23)	1963	(2)	1974	(19)	1966	(10)
Steel	1968	(11)	1958	(11)	1958	(9)	1966	(17)	1968	(11)
Prestressed	1975	(11)	1989	(12)	1968	(5)	1993	(5)	1975	(12)
Timber	1971	(13)	1969	(15)	0	(0)	0	(0)	1970	(13)
Other	1987	(16)	1979	(0)	0	(0)	0	(0)	1986	(16)
All Materials	1969	(11)	1963	(17)	1962	(6)	1973	(18)	1969	(11)
Other Principal Arterial										
Concrete	1959	(21)	1960	(23)	1965	(17)	1963	(24)	1960	(21)
Steel	1965	(19)	1959	(24)	1954	(20)	1964	(30)	1965	(19)
Prestressed	1981	(15)	1979	(18)	1985	(9)	1981	(14)	1981	(15)
Timber	1942	(12)	1957	(22)	0	(0)	0	(0)	1944	(14)
Other	1943	(51)	1913	(36)	1918	(0)	1910	(19)	1933	(49)
All Materials	1967	(21)	1964	(24)	1965	(22)	1974	(22)	1967	(21)
Minor Arterial										
Concrete	1954	(22)	1965	(24)	1961	(23)	1953	(33)	1957	(23)
Steel	1959	(20)	1956	(27)	1968	(20)	1943	(30)	1958	(22)
Prestressed	1979	(18)	1977	(19)	1978	(12)	1970	(29)	1978	(18)
Timber	1945	(14)	1968	(29)	1958	(14)	1947	(29)	1953	(23)
Other	1916	(41)	1910	(41)	1983	(13)	1909	(9)	1914	(42)
All Materials	1960	(23)	1965	(26)	1968	(21)	1951	(32)	1961	(24)
Collector										
Concrete	1957	(20)	1963	(22)	1959	(17)	1951	(33)	1960	(21)
Steel	1959	(20)	1956	(24)	1962	(20)	1943	(31)	1958	(22)
Prestressed	1979	(17)	1978	(17)	1977	(12)	1977	(25)	1978	(17)
Timber	1952	(16)	1959	(22)	1955	(15)	1931	(23)	1957	(21)
Other	1933	(41)	1938	(40)	1954	(43)	1925	(24)	1936	(41)
All Materials	1961	(21)	1964	(23)	1963	(19)	1951	(33)	1963	(22)
Local										
Concrete	1961	(22)	1966	(26)	1960	(19)	1957	(36)	1965	(26)
Steel	1964	(20)	1954	(29)	1963	(22)	1940	(32)	1956	(28)
Prestressed	1979	(15)	1980	(18)	1977	(14)	1974	(26)	1980	(17)
Timber	1959	(22)	1960	(23)	1964	(19)	1937	(26)	1960	(23)
Other	1953	(52)	1936	(43)	1951	(35)	1906	(27)	1939	(44)
All Materials	1966	(22)	1963	(28)	1965	(20)	1947	(34)	1964	(27)
All Classes										
Concrete	1959	(20)	1965	(25)	1960	(18)	1957	(32)	1962	(22)
Steel	1964	(18)	1955	(28)	1963	(22)	1945	(32)	1959	(24)
Prestressed	1978	(15)	1980	(18)	1977	(13)	1978	(20)	1979	(16)
Timber	1953	(19)	1960	(23)	1964	(19)	1937	(26)	1959	(23)
Other	1940	(48)	1934	(43)	1954	(37)	1913	(23)	1936	(44)
All Materials	1964	(20)	1964	(26)	1965	(20)	1957	(33)	1964	(24)

Source: National Bridge Inventory.

Considering functional classifications, only small variations are seen in the average age of construction between the owners. For all functional classifications and for all material types, the average year of construction (1964/1965) are effectively equivalent for State, local, and Federal owners. There is also minimal variation between the functional classifications with average ages for all functional classifications for State, local, and Federal owners in the 1960s.

Conditions of Bridges

In Chapter 3, an overview of the condition of the highway bridge network was presented. Chapter 17 presented information on structural deficiencies and functional obsolescence for high- and low-volume NHS and non-NHS mobility measure categories.

Structural deficiencies and functional obsolescence are not mutually exclusive, and a bridge may have both types of deficiencies. When deficiency percentages are presented, however, bridges are indicated as being structurally deficient, functionally obsolete, or nondeficient. As structural deficiencies may imply safety problems, they are considered more critical; thus, a bridge that is both structurally deficient and functionally obsolete is identified only as structurally deficient. Approximately 50 percent of the structurally deficient population also will have functional issues that must be addressed. Bridges that are indicated as functionally obsolete do not have structural deficiencies.

Q. What makes a bridge structurally deficient, and are structural deficient bridges unsafe?

A. Bridges are considered structurally deficient if significant load carrying elements are found to be in poor or worse condition due to deterioration and/or damage or, the adequacy of the waterway opening provided by the bridge is determined to be extremely insufficient to point of causing intolerable traffic interruptions. The fact that a bridge is "deficient" does not immediately imply that it is likely to collapse or that it is unsafe. With hands-on inspection, unsafe conditions may be identified and, if the bridge is determined to be unsafe, the structure must be closed. A "deficient" bridge, when left open to traffic, typically requires significant maintenance and repair to remain in service and eventual rehabilitation or replacement to address deficiencies. In order to remain in service, structurally deficient bridges are often posted with weight limits to restrict the gross weight of vehicles using the bridges to less than the maximum weight typically allowed by statute.

Overall, there are 162,869 bridges that are deficient within the highway bridge network. This represents 27.5 percent of the total inventory of highway bridges when bridges are weighted equally. The overall percentage of deficiencies is roughly the same when considering traffic carried (27 percent deficient) and deck area (27.5 percent deficient). Over 1 billion vehicles cross deficient bridges daily, and close to 90 million square meters of deck area are on deficient bridges.

Exhibit 15-12 shows the percentage of structurally deficient (SD) and functionally obsolete (FO) bridges by functional classification and owner. The overall percentage of structurally deficient bridges is approximately equal to the percentage of functionally obsolete bridges. There are nearly twice as many functionally obsolete bridges across all functional classifications for State and Federal owners. For bridges owned by local agencies, private entities, and others, the number of structural deficiencies outweigh the number of functionally obsolete bridges.

Exhibit 15-12 *Bridge Deficiency Percentages by Functional Class and Owner*

Description	State # of Bridges %SD / %FO	Local # of Bridges %SD / %FO	Federal # of Bridges %SD / %FO	Other # of Bridges %SD / %FO	Total # of Bridges %SD / %FO
Rural					
Interstate	27283 4.0% / 11.7%	10 10.0% / 30.0%	18 0.0% / 5.6%	5 0.0% / 40.0%	27316 4.0% / 11.8%
Other Principal Arterial	34686 5.4% / 9.5%	300 7.0% / 13.7%	55 5.5% / 25.5%	186 2.2% / 4.3%	35227 5.4% / 9.6%
Minor Arterial	36682 8.5% / 11.1%	2414 9.0% / 12.2%	402 17.2% / 15.2%	89 22.5% / 25.8%	39587 8.6% / 11.2%
Major Collector	52737 11.2% / 13.5%	41742 13.1% / 7.3%	179 13.4% / 10.6%	123 34.2% / 19.5%	94781 12.1% / 10.8%
Minor Collector	16602 12.4% / 13.9%	31423 14.7% / 9.7%	1178 5.7% / 17.4%	117 38.5% / 12.0%	49320 13.8% / 11.3%
Local	28177 14.3% / 16.9%	173578 22.6% / 11.0%	7255 7.5% / 15.0%	712 39.8% / 22.3%	209722 21.1% / 11.9%
All Classes	196167 9.2% / 12.6%	249467 19.9% / 10.2%	9087 7.8% / 15.2%	1232 32.0% / 18.7%	455953 15.1% / 11.4%
Urban					
Interstate	27601 6.0% / 20.0%	307 21.2% / 30.6%	2 50.0% / 0.0%	19 0.0% / 26.3%	27929 6.1% / 20.1%
Other Freeways and Expressways	15429 6.1% / 20.3%	970 8.9% / 26.3%	2 0.0% / 0.0%	443 0.5% / 10.8%	16844 6.1% / 20.4%
Other Principal Arterial	18785 8.9% / 20.9%	5317 10.3% / 27.5%	17 11.8% / 29.4%	188 22.3% / 16.5%	24307 9.4% / 22.3%
Minor Arterial	11939 10.8% / 27.7%	12288 10.0% / 24.6%	42 26.2% / 11.9%	247 28.7% / 27.5%	24516 10.6% / 26.1%
Collector	5086 11.6% / 30.7%	9850 11.1% / 21.9%	20 20.0% / 30.0%	215 23.3% / 27.4%	15171 11.5% / 24.9%
Local	4956 10.4% / 29.6%	21096 11.8% / 16.1%	195 10.8% / 34.4%	362 31.2% / 23.2%	26609 11.8% / 18.8%
All Classes	83796 8.0% / 22.6%	49828 11.1% / 20.8%	278 14.0% / 29.9%	1474 18.9% / 20.0%	135376 9.2% / 21.9%
All: Rural and Urban					
Interstate	54884 5.0% / 15.9%	317 20.8% / 30.6%	20 5.0% / 5.0%	24 0.0% / 29.2%	55245 5.1% / 16.0%
Other Principal Arterials	68900 6.5% / 15.0%	6587 10.0% / 26.7%	74 6.8% / 25.7%	817 5.9% / 10.6%	76378 6.8% / 16.0%
Minor Arterials	48621 9.0% / 15.2%	14702 9.9% / 22.5%	444 18.0% / 14.9%	336 27.1% / 27.1%	64103 9.4% / 16.9%
Collectors	74425 11.5% / 14.8%	83015 13.5% / 9.9%	1377 6.9% / 16.7%	455 30.1% / 21.3%	159272 12.5% / 12.3%
Local	33133 13.7% / 18.8%	194674 21.5% / 11.5%	7450 7.6% / 15.5%	1074 36.9% / 22.6%	236331 20.0% / 12.7%
All Classes	279963 8.8% / 15.6%	299295 18.4% / 12.0%	9365 8.0% / 15.7%	2706 24.8% / 19.4%	591329 13.7% / 13.8%

SD = Structurally Deficient

FO = Functionally Obsolete

Source: National Bridge Inventory.

Deficiencies can be examined by functional classification irrespective of ownership. With bridges carrying higher functional classifications, such as the Interstates and arterials, the percentages of structural deficiencies is significantly lower than the percentages of functionally obsolete bridges. For bridges carrying collector roadways, the percentage of structurally deficient bridges is roughly equal to the percentage of functionally obsolete bridges. For bridges carrying local roadways, 20 percent are structurally deficient, outweighing the 12.7 percent functionally obsolete.

Rural functional classifications and ownership percentages follow the same general trend as the overall population. With bridges carrying higher functional classifications, such as Interstates and principal arterials, functional obsolescence percentages exceed the structural deficiency percentages. The reverse is true for bridges carrying lower functional classification roadways in rural environments where the structural deficiencies outweigh the functional issues. In the urban environment, functional obsolescence percentages were higher than structural deficiency percentages for all functional classifications and for all owners.

Exhibit 15-13 shows the percent of structural deficiencies and functional obsolescence where bridges are weighted using different methods. Percentages determined by equal weighting through counting of the number of bridges are compared with percentages where bridges are weighted by ADT and deck area. In general, if the percent deficiencies by ADT are higher than those determined using number of bridges, it may be inferred that the deficiencies are occurring on bridges with higher-than-average traffic volumes. Likewise, where the deck area percentages exceed the percentages determined by numbers, it may be inferred that the deficiencies are occurring on bridges with higher-than-average deck areas. For both cases, the converse is also true; with lower percentages, it may be inferred that the deficiencies are occurring on bridges with lower-than-average traffic or area.

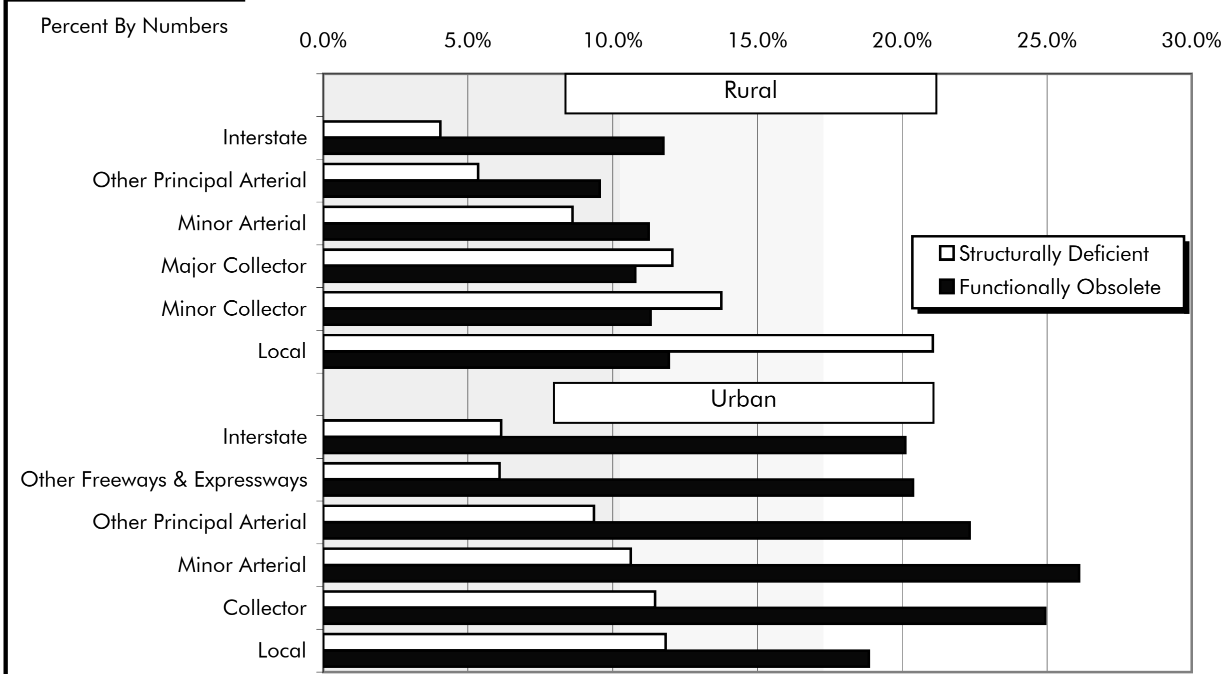
The stacked bars in Exhibit 15-13 allow evaluation and comparison of deficiencies. For both rural and urban structures, percentages of deficiencies increase for the lower functional classifications. Bridges carrying principal arterials clearly have lower deficiency percentages than bridges carrying local roadways. Percentages of functionally obsolete bridges remain relatively constant across the functional classifications, and the increases shown are primarily attributable to structural deficiencies.

Actions Taken to Remove Deficiencies

Over $60 billion in HBRRP funding alone has been allocated and utilized to ensure safety and continuing functionality of the bridge network. Historically, HBRRP funds have been utilized only for repair, rehabilitation, or replacement of deficient bridges. An examination of bridge construction and bridge rehabilitation activity with Federal fund participation, including HBRRP and other funding programs through 1998 reveals the following:

- Over 50 percent of all activity focuses on replacement of deficient bridges.
- Approximately 40 percent of activity is used for major or minor rehabilitation of deficient bridges.
- The remaining 10 percent of activity is used for new bridge construction.

Exhibit 15-13 *Percent of Bridge Deficiencies by Numbers, ADT, and Deck Area*



Functional Classification	% by Numbers		% by ADT		% by Area	
	SD	FO	SD	FO	SD	FO
Rural						
Interstate	4.0%	11.8%	4.5%	10.8%	4.9%	9.7%
Other Principal Arterial	5.4%	9.5%	5.4%	10.3%	6.8%	10.4%
Minor Arterial	8.6%	11.2%	8.8%	15.2%	9.8%	12.9%
Major Collector	12.1%	10.8%	10.4%	18.8%	11.4%	11.1%
Minor Collector	13.8%	11.3%	11.7%	20.0%	10.9%	10.6%
Local	21.1%	11.9%	11.8%	26.3%	14.7%	13.0%
Urban						
Interstate	6.1%	20.1%	6.9%	19.3%	9.0%	22.0%
Other Freeways & Expressways	6.1%	20.4%	7.4%	19.6%	8.8%	20.1%
Other Principal Arterial	9.4%	22.3%	9.8%	23.1%	12.1%	23.7%
Minor Arterial	10.6%	26.1%	9.7%	27.9%	11.8%	25.5%
Collector	11.5%	24.9%	10.2%	28.8%	10.8%	25.6%
Local	11.8%	18.8%	8.5%	31.8%	10.1%	26.8%

Source: National Bridge Inventory.

In 1990, 17 percent of activity with Federal fund participation involved new bridge construction. This percentage has decreased from 1990 to 1998, and today approximately 90 percent of all projects receiving Federal fund participation involve reconstruction or rehabilitation.

Exhibit 15-14 shows the number and percent of deficient bridges reconstructed, as indicated in the NBI database. The information is presented by functional classification, rural/urban designation, and owner. The average number of years before the reconstruction was undertaken is also indicated.

Exhibit 15-14 *Rehabilitation Summary by Functional Class and Owner (% Reconstructed/Average Number of Years to Reconstruction)*

Functional Class	State	Local	Federal	Other	All
Rural					
Interstate	6220 23% / 21	2 20% / 49	1 6% / 25	0 0% / 0	6223 23% / 21
Other Principal Arterial	7526 22% / 30	51 17% / 34	16 29% / 33	61 33% / 29	7654 22% / 30
Minor Arterial	8012 22% / 33	287 12% / 36	36 9% / 28	8 9% / 60	8343 21% / 33
Collector	8189 12% / 27	7312 10% / 41	88 6% / 36	40 17% / 49	15629 11% / 34
Local	2335 8% / 27	18576 11% / 40	1646 23% / 17	77 11% / 43	22634 11% / 37
Urban					
Interstate	6782 25% / 23	66 21% / 25	2 100% / 37	2 11% / 28	6852 25% / 23
Other Principal Arterial	7272 21% / 29	1315 21% / 33	5 26% / 38	100 16% / 32	8692 21% / 29
Minor Arterial	2115 18% / 30	2153 18% / 36	4 10% / 39	49 20% / 62	4321 18% / 33
Collector	713 14% / 29	1311 13% / 37	4 20% / 17	49 23% / 65	2077 14% / 35
Local	512 10% / 27	2140 10% / 38	56 29% / 30	65 18% / 48	2773 10% / 36
All: Rural and Urban					
Interstate	13002 24% / 22	68 21% / 26	3 15% / 33	2 8% / 28	13075 24% / 22
Other Principal Arterial	14798 21% / 29	1366 21% / 33	21 28% / 34	161 20% / 31	16346 21% / 29
Minor Arterial	10127 21% / 33	2440 17% / 36	40 9% / 29	57 17% / 61	12664 20% / 33
Collector	8902 12% / 27	8623 10% / 40	92 7% / 35	89 20% / 58	17706 11% / 34
Local	2847 9% / 27	20716 11% / 40	1702 23% / 17	142 13% / 45	25407 11% / 37

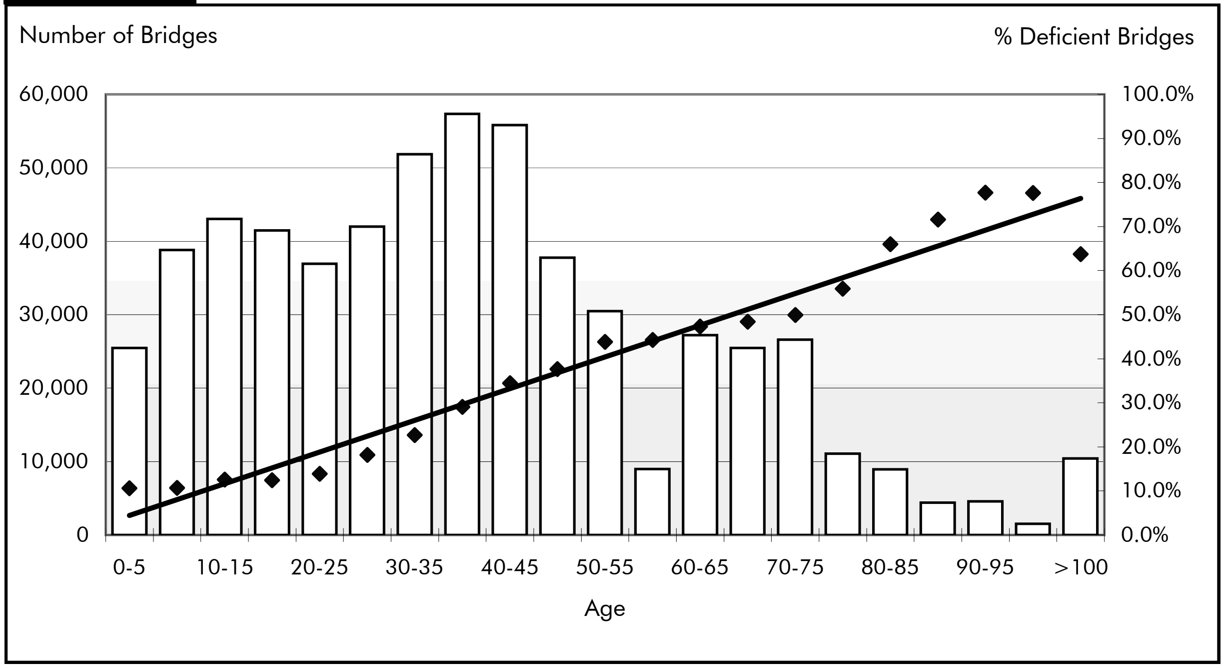
Source: National Bridge Inventory.

Historically, Interstate bridges undergo rehabilitation approximately 22 years after they are placed in service. The time to rehabilitation is longer for other functional classifications. Bridges carrying higher functional classifications, such as Interstates and principal arterials, are rehabilitated sooner than bridges carrying lower functional classifications, such as collectors and local routes. This trend is seen for rural and urban functional classifications for all owners and does not necessarily apply for all owner/functional classification combinations.

Progress has been made in reducing the deficiencies. More than 85,000 structures (15 percent of the inventory) have been reconstructed or rehabilitated and are in service today. These reconstruction and rehabilitation efforts have contributed to the reduction in deficiencies discussed in Chapter 3.

Exhibit 15-15 shows the relationship between bridge age and the percentage of bridges that are classified as deficient. When a structure is placed in service, the deterioration process begins on the components of the bridge. As bridges age, increasing numbers of structures become deficient and increasing funds are required

Exhibit 15-15 *Age and Deficiency Percentages*



Source: National Bridge Inventory.

to address these deficiencies. This is a concern with the increasing age of the large Interstate population and the relatively short period of time for the average reconstruction effort on Interstate bridges. With this ever-aging, continually deteriorating population of highway structures, increasing traffic demands, and limited budgets, the FHWA and the Nation need to take a closer look at transportation system preservation strategies. This includes increased activity in preventative maintenance and improved bridge inspection and management techniques to continue to ensure the safety of the motoring public and effective stewardship of the public trust.

Conclusions

As can be seen from the information presented in this chapter, the Nation's bridges are aging and traffic demands are increasing. Asset management principles through bridge management systems and transportation system preservation techniques are becoming more important as the States, locals, and Federal government struggle to maintain the safe condition of the Nation's bridges, while at the same time providing for increased demands on the highway bridge network. Improved bridge inspection techniques, through the use of new and innovative equipment, are needed to better ensure the safety of the motoring public. Longer design life structures, using the latest material and design technologies, are needed so that the Nation can maintain a safe bridge network that provides the life span needed to avoid congestion and improve safety of the highway bridge network. Such goals can be achieved only through an emphasis on fundamental long-term research.