In this case R would be equal to 1.59 and the permitted vehicle weight would be equal to 78.84 tons.

CONCLUSIONS

It has been shown that the modification factors for multilane loading can be obtained statistically and that these factors depend on the life of the bridge, the number of vehicles per day, the length of the span, and the speed of the vehicles. Expressions are developed for calculating this factor for two- and three-lane loadings. The corresponding AASHTO (4) factors are found to be quite conservative, whereas those of the Ontario code (1), although calculated by a different procedure, were found to be more realistic. A method is developed by which safe maximum weights for special-permit vehicles can be obtained without analytically evaluating the bridges on the route.

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Bridge Weight-Limit Posting Practice in the United States

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ABSTRACT

Bridge weight limits allow the continued, limited use of a weak bridge that would otherwise present a significant safety hazard while protecting the legal and economic interests of the bridge owner. For weight limits to be effective, however, bridges must be posted for the proper weight limit, and the posting must be observed and enforced. The federal government became involved in bridge weight-limit posting in 1968 with the creation of National Bridge Inspection Standards (NBIS), which required states to inspect, inventory, and evaluate bridges on federal-aid routes. Weight-limit posting was required for bridges found to have insufficient structural capacity. The results of a survey of state posting practices are presented and the findings of a study on weight-limit posting in the United States are summarized. NBIS provides some engineering guidance for inspecting, evaluating, and posting highway bridges, but considerable engineering judgment is still required to fill the gaps. As a result, even within the limits set by NBIS, engineering practices vary among the states, which leads to differences in posting methods. This is evident from the results of the survey of the states. Development of a simple, uniform posting criterion by which the legitimate differences that exist between states can be rationally considered is recommended.

The United States is currently faced with a massive bridge replacement and rehabilitation problem. FHWA has estimated that there are currently more than 126,600 structurally deficient bridges within the United States (1). Many of these bridges should be rehabilitated or replaced, but they must compete for funding with an equally large number of bridges that have become functionally obsolete because of narrow widths and poor alignments. Because of the cost of modernizing all bridges on the U.S. highway system, it is necessary to delay improvements on many of these bridges for several years. In the meantime, it will be necessary to regulate the traffic on these bridges. This is normally done by establishing weight limits for vehicles using the bridge.

The weight and axle configuration of vehicles allowed to use the highways without special permits is governed by statutory law. In most states, this

legal weight limit is 80,000 lb or less, but several states allow higher weights. Michigan, which has the highest, allows nonpermit vehicle weights of 154,000 lb. Weight limits on deficient bridges are used to further restrict nonpermit vehicle weights. Failure to establish weight limits on a bridge with insufficient strength to carry the legal vehicle weight may subject the bridge owner to liability claims for injuries or damage resulting from a bridge failure. Weak bridges without weight limits may also become damaged, necessitating excessively costly repairs and unwarranted inconvenience to motorists.

In establishing bridge weight limits, the need to protect safety and property must be weighed against the need for an unrestricted highway system that enhances economic activity. Because some of the parameters are not clearly defined, it requires considerable judgment to achieve a balance. Thus, bridge weight-limit posting practices are not always uniform. Some of the administrative and engineering aspects of current bridge-posting practices in the United States are summarized in this paper, including the differences and similarities in the practices of the various states. This information was obtained from a survey of the states conducted by Engineering Computer Corporation as part of a study by NCHRP.

WEIGHT-LIMIT POSTING PROCESS

Bridge weight-limit posting, hereafter referred to as posting, is closely related to bridge maintenance inspection and structural strength evaluation. When a bridge is found to have insufficient structural capacity, weight-limit posting is only one of several available alternatives. The speed and volume of traffic can also be regulated. In many cases, standard evaluation methods may be overly conservative. When such an evaluation is questioned, a more detailed analysis or physical testing can often demonstrate the true strength of the bridge. A careful monitoring of the physical condition and load history of a marginally deficient bridge through frequent inspections could eliminate the need for posting. Minor repairs or reinforcement of weak components that can be made quickly and at a relatively minor cost are also alternatives to posting. Because of the severe restrictions imposed by posting, each of these alternatives should be given serious consideration.

Signs must be placed near bridges to clearly indicate to motorists the weight limits. Although standard signing is included in the Manual of Uniform Traffic Control Devices (MUTCD) (2), many jurisdictions have found it necessary to deviate from these standards to avoid ambiguities that could lead to misinterpretation under the provisions of their own weight-limit laws. The method of notifying the public of bridge weight limits also varies among the states.

Posted bridges remain an integral part of the highway system and must be operated accordingly. Continued inspection, usually at more frequent intervals and in greater detail than routine bridge inspections, will be necessary to detect any distress or deterioration that could affect structural strength.

Enforcement of bridge postings is important because a significant number of bridge failures have resulted from the use of a posted bridge by overweight vehicles. Proper maintenance of posting signs is necessary to make a posting enforceable.

Finally, it may be in the public interest to allow overweight vehicles to use posted bridges under strictly controlled conditions. This special allowance is often made through the overweight-permit process, but it may also be mandated by state law for certain types of vehicles.

The bridge-posting procedure, including its relationship to other aspects of bridge maintenance engineering, is summarized in the flowchart shown in Figure 1.

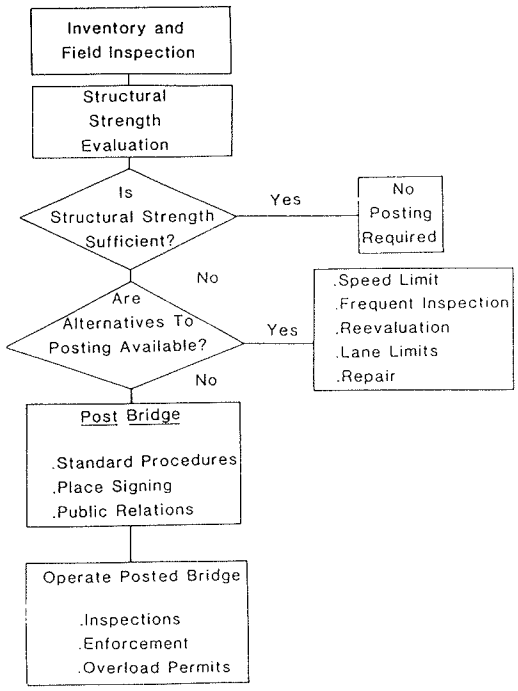

FIGURE 1 Bridge-posting procedure.

NATIONAL BRIDGE INSPECTION STANDARDS

In 1968, in the wake of the collapse of the Silver Bridge over the Ohio River at Point Pleasant, West Virginia, Congress passed the Federal-Aid Highway Act, which called for the development of National Bridge Inspection Standards (NBIS) (23 CFR, Section 650, 1968).

NBIS was developed by the U.S. Department of Transportation in consultation with state highway departments and other interested and knowledgeable parties. NBIS currently requires states to inventory their bridges and to inspect them at least once every 2 years. Specific items have been established that must be included in the inventory data. Those in charge of bridge inspection organizational units must be registered engineers or have 5 years of bridge inspection experience and must complete a comprehensive training course based on the bridge inspector's training manual, which was developed by a joint federal-state task force.

NBIS also requires that every bridge be rated for its safe live-load-carrying capacity according to guidelines in the manual published by AASHTO entitled Manual for Maintenance Inspection of Bridges (3), hereafter referred to as the AASHTO manual. When these ratings indicate that a bridge has insufficient strength to carry legal-weight vehicles, NBIS requires that the bridge be posted for reduced live loads.

Subsequent federal legislation made matching funds available for bridge rehabilitation and replacement. The Surface Transportation Assistance Act of 1978 extended the federal program to include bridges not on the federal highway system. This

legislation included the requirement that the inventory and inspection of these off-system bridges comply with the requirements of NBIS. As a result of this legislation, virtually every highway bridge in the country was made subject to NBIS requirements.

The AASHTO manual, in addition to prescribing inspection procedures, also discusses the rating of bridges and provides specifications for checking the capacities of existing bridges. The specifications are written to allow for variations in practice. Specific reference is made in many instances to the use of engineering judgment in determining loadings, resistance, and structural response. In addition, two levels of load-limit rating are described. One level, the inventory rating, is the load level that can safely use an existing structure for an indefinite period of time. The other level, the operating rating, is the maximum load level permissible under any circumstances. Because the AASHTO manual requires bridge weight limits to be set between the inventory and the operating ratings, there is considerable variation in posting practices among the various state and local jurisdictions.

CURRENT STATUS OF BRIDGE POSTING

A 1981 spot check conducted for Congress by the United States Comptroller General (4) indicated that several states were not in total compliance with the NBIS posting requirements. This lack of compliance occurred mainly at the local government level. The problem at the local level is compounded by the location of most of the nation's highway bridges in need of posting on local, off-system roads.

Engineering Computer Corporation (ECC) surveyed the state highway departments to determine bridge-posting practices in the United States. The statistics on the number and types of posted bridges for each of the states responding to the survey are summarized in Table 1. Although a few states did not respond, these statistics bring out some important features of current U.S. bridge-posting problems.

Few bridges on the Interstate highway system were reported as being posted. There are at least two reasons for this lack of posting. One is that the Interstate system is relatively new and constructed to high design standards. The other is that the

TABLE 1 Bridge Posting Statistics, 1983

State	Interstate		Other Federal Aid		Off-System		Total	
	No. of Bridges	No. Posted	No. of Bridges	No. Posted	No. of Bridges	No. Posted	No. of Bridges	No. Posted
Alabama	1,058	0	6,387	221	7,897	964	15,342	1,185
Alaska	120	1	420	18	310	27	850	46
Arizona	–	–	–	–	692	55	5,032	72
Arkansas	622	0	5,206	439	8,860	1,495	14,708	1,934
California	–	–	–	–	–	–	24,116	676
Colorado	959	0	2,615	100	3,895	1,908	7,469	2,008
Connecticut	754	0	2,314	102	1,662	149	4,730	251
Delaware	–	–	–	–	244	70	686	96
Florida	1,416	0	4,055	120	3,555	555	9,026	675
Georgia	–	–	–	–	6,738	797	6,738	797
Hawaii	103	0	599	53	402	63	1,104	116
Idaho	–	–	–	–	–	–	–	–
Illinois	1,861	0	5,939	99	17,272	2,159	25,072	2,258
Indiana[a]	1,809	0	3,350	78	10	2	5,169	80
Iowa	644	0	6,715	–	20,127	–	27,486	–
Kansas	1,301	0	9,071	2,202	14,543	6,087	24,915	8,289
Kentucky	–	–	–	–	–	–	–	–
Louisiana	1,201	0	4,644	222	8,787	1,119	14,632	1,341
Maine	225	0	1,044	15	1,406	115	2,675	130
Maryland	487	0	1,420	27	268	18	2,175	45
Massachusetts	915	0	2,457	450	1,165	418	4,537	868
Michigan	1,054	0	4,598	484	4,517	1,948	10,169	2,432
Minnesota	1,158	0	4,429	279	7,828	1,842	13,415	2,121
Mississippi	937	16	6,620	2,234	9,951	0	17,508	2,250
Missouri	1,107	0	7,317	1,493	15,383	2,496	23,807	3,869
Montana	779	0	1,593	50	2,912	453	5,284	503
Nebraska	330	0	4,806	1,137	11,270	4,704	16,406	5,841
Nevada	465	0	498	3	212	11	1,175	14
New Hampshire	372	0	1,159	24	1,926	556	3,458	580
New Jersey	626	0	2,672	320	1,754	488	5,090	808
New Mexico	1,087	0	1,825	39	638	28	3,550	67
New York	1,690	0	7,177	169	8,381	1,675	17,248	1,844
North Carolina	–	–	–	–	–	–	–	–
North Dakota	405	0	1,511	77	3,839	670	5,755	947
Ohio	2,176	0	9,912	619	16,787	6,004	28,875	6,623
Oklahoma	1,541	0	6,476	201	14,551	2,376	22,568	2,577
Oregon	–	–	–	–	–	–	–	–
Pennsylvania	–	–	–	–	–	–	21,300	3,466
Rhode Island	144	0	425	27	124	26	693	53
South Carolina	519	0	3,622	111	4,979	1,056	9,120	1,167
South Dakota	480	0	2,326	326	4,230	2,334	7,036	2,660
Tennessee	1,286	0	6,887	576	9,381	5,539	17,554	6,115
Texas	6,898	0	19,471	4	19,493	2,516[b]	45,820	2,520[b]
Utah	–	–	–	–	–	–	–	–
Vermont	385	0	841	43	1,357	186	2,583	229
Virginia	–	–	–	–	–	–	13,170	3,736
Washington	1,100	0	3,191	88	2,995	365	7,286	453
West Virginia	–	–	–	–	193	27	6,835	2,106
Wisconsin	849	0	5,336	72	6,579	1,242	12,764	1,314
Wyoming	995	0	984	30	892	165	2,871	195
Washington, D.C.	70	0	156	20	16	4	242	24

[a] State highway statistics only.
[b] Approximate number.

Interstate system is so important to U.S. economic and security interests that deficiencies are usually corrected relatively quickly.

More than 80 percent of the posted bridges are on local, off-system roads. The survey indicated that 21 percent of all local, off-system bridges are posted. In addition, many of the reported federal-aid bridges are probably owned by local jurisdictions. Many local bridges are not reported as being posted because some local agencies fail to comply with the NBIS posting requirements. Therefore, it follows that bridges with insufficient structural capacities are usually under the jurisdiction of local governments.

State bridge engineers were asked to estimate the number of bridge collapses over the past 10 years for four different bridge types on three different types of highway systems. Although their answers are only estimates, the results reported in Table 2 from the 45 states responding show some definite trends. Bridge failures are far more frequent with off-system bridges than with bridges on the federal-aid system. Many of the bridges that collapsed were not posted with a weight limit. Most failures occurred on steel or timber bridges, whereas reinforced-concrete bridges, which will show signs of distress before collapse, were not nearly so vulnerable. No collapses were reported for prestressed-concrete bridges, which are relatively modern in construction and design.

TABLE 2 Estimated Bridge Collapses During Past 10 Years

Route Type	No. of Collapses by Bridge Type			
	Steel	Timber	Reinforced Concrete	Prestressed Concrete
Interstate	0	0	0	0
Other federal aid	38	43	1	0
Off-system	169	344	1	0
Total	207	387	2	0

Note: 45 states responded to survey; number of bridges posted by type is as follows: steel, 127; timber, 144; reinforced concrete, 2; prestressed concrete, 0.

ADMINISTRATIVE ISSUES OF BRIDGE POSTING

Compliance with NBIS requires a close working relationship between state and local agencies. Not unexpectedly, many administrative problems have been encountered, including conflicts with existing state laws, local governments with insufficient resources to provide for necessary engineering, and a large number of weak local bridges for which few records are available. Despite the administrative difficulties, 28 of the 45 states responding to the ECC survey reported that they have completed the inventory of their off-system bridges. A report published for Congress on the status of the bridge replacement and rehabilitation program estimates that 98 percent of all off-system bridges had been inventoried as of December 31, 1981. The inventory of bridges on the federal-aid system is essentially complete.

In spite of the difficulties inherent in the NBIS requirements, more bridges are currently posted as a result of these standards. Table 3 shows the effect of the NBIS requirements on the number of bridges posted in the states surveyed by ECC.

The administrative practices related to implementing bridge postings and to operating and monitoring posted bridges also vary. There are variations in the ways states relate to the public, inspect posted bridges, enforce bridge postings, and issue permits for posted bridges.

TABLE 3 Effect of Federal Legislation on Number of Posted Bridges

Effect	No. of States
More than doubled	19
Increased 25-100 percent	7
Increased <25 percent	8
No increase	7
Reduced	1

Public Relations

In many cases there is considerable resistance to bridge posting from trucking companies, local residents, industry, or other individuals or groups who would be inconvenienced. The ECC survey of the states showed that state officials had different perceptions about the amount of public pressure and the degree of public confidence toward the posted weight limits within their states. In Figure 2 the opinions of state officials regarding the amount of public pressure against bridge posting are summarized. Figure 3 is a summary of the opinions of state officials about the level of public confidence in posted weight limits.

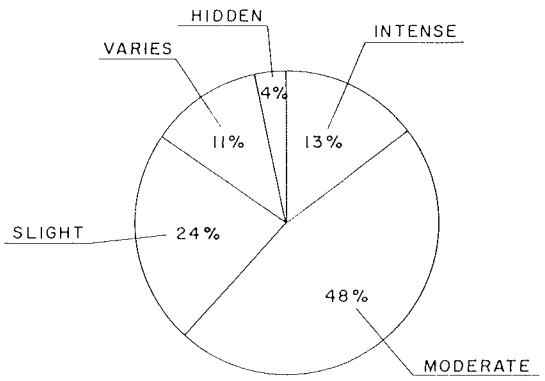

FIGURE 2 Perception of public pressure against posting by states.

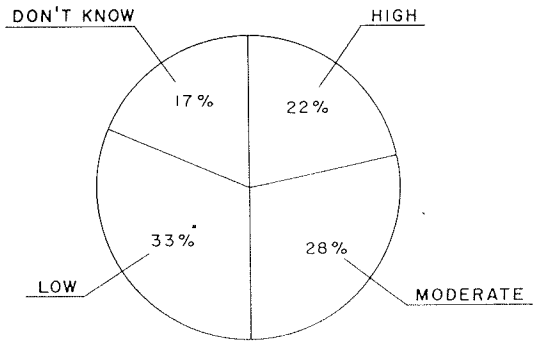

FIGURE 3 Perception of public confidence in posted load limits by states.

It is desirable to give advance notice of the posting so truckers can make arrangements to use detours or to limit their loads to the maximum weight allowed. When truckers are not informed of a scheduled posting, they are more likely to violate the weight limit. Various methods used by the

states to notify truckers of a posted bridge include news releases, special notification given to trucking associations, legal notices, published lists of restricted bridges, and advisory signs on routes with posted bridges. In Table 4 the methods used to notify the public are summarized and the number of states surveyed that use these methods is shown.

TABLE 4 Methods for Notifying Public of Bridge Posting

Method Used	No. of States
News release	23
Special notice to trucking association	20
Legal notice	4
Advance advisory signs	3
Notice posted at weigh stations	1
Notification of other agencies	6
Weight-limit maps or lists	5
Public hearings before posting	3
Regulatory signing only	9

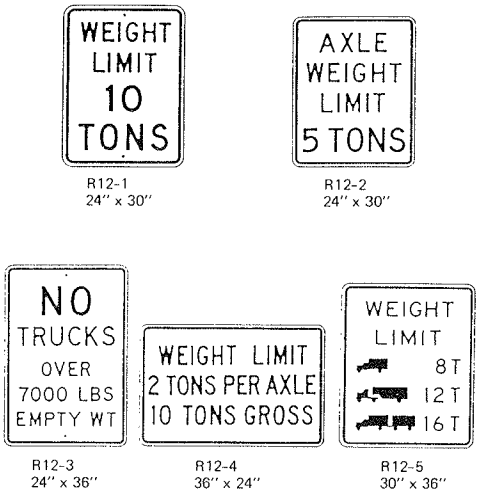

FIGURE 4 MUTCD standard bridge-posting signs.

Inspection

A posted bridge is typically an older structure that has not been designed to carry modern traffic. Often the structure is in a deteriorated condition and may have experienced some distress due to live load. It is necessary to monitor the condition of such bridges continually by frequent inspections to verify that the posted weight limits are appropriate.

Although local agencies have primary responsibility for their own bridges, many of them lack the qualified personnel or resources to perform bridge inspections in conformance with NBIS. In many states the state agency has taken over responsibility for bridge inspection, yet in others this practice is prohibited by state law. Many local agencies without qualified staff have retained consultants for bridge inspection. The responsibilities for local bridge inspection for the states responding to the ECC survey are summarized as follows:

	No. of Bridges by Type of Highway	
Inspector	Federal-Aid	Off-System
State agency	23	18
Local agency	16	20
Combination of state and local agencies	4	4
Consultant	3	3

Signing Practices

The AASHTO manual requires that the standards contained in the MUTCD (2) be followed when regulatory signing is placed on posted bridges. The current edition of the MUTCD recommends five standard bridge-posting signs, as shown in Figure 4. These signs do not always give precise definitions of axle loads and spacings and may have to be modified slightly to conform with local regulatory statutes. In addition to many variations of the standard signs, these modifications have also led to the development of many new nonstandard signs (J.C. Porter, unpublished data, February 1981).

A recent survey by Halstad revealed that there is considerable variation among the states with respect to the type of signs preferred for posting bridges. About half the states prefer the standard R12-5 sign or some similar, modified version. The next most popular sign is type R12-1, which is preferred by 17 states for bridges with span lengths less than 40 ft and by 11 states for bridges with span lengths more than 40 ft. Type R12-4 is preferred by only three states, whereas types R12-2 and R12-3 are not preferred by any state. Nine states preferred nonstandard signs of their own design.

Posting Enforcement

Truckers often disregard bridge weight limits because the penalties for exceeding the posted weight limits are low and enforcement is limited. One of the difficulties in enforcing bridge weight limits is that portable scales to check the weights of individual trucks are often necessary.

Most of the states responding to the ECC survey can assess fines against offenders and a few have the power, at least in theory, to sentence violators to jail. Fine structures vary considerably among the states. In some states maximum fines may be based on the number of previous offenses, whereas in others the fine is based on the amount of overweight. At least two states require that offenders pay for any damage done to the bridge, whereas one state reported that it can revoke the offender's vehicle registration. The possible legal consequences for violating a posted weight limit as reported by each of the states that responded to the ECC questionnaire are summarized in Table 5.

Permits for Posted Bridges

Because the hardship caused by bridge weight limits can be critical and even life-threatening (as in the case of fire-fighting equipment), it is sometimes in

TABLE 5 Consequences of Violation of Posted Weight Limit

Consequence	No. of States
Fine	
Maximum < $500	8
Maximum between $500 and $1,000	9
Maximum > $1,000	2
Maximum based on overweight	13
Jail	
Maximum < 30 days	1
Maximum between 30 and 180 days	7
Maximum > 180 days	3
Other	
Liability for cost of repair	2
Revocation of vehicle registration	1

the public interest to allow certain overweight vehicles on a posted bridge. This is usually done through the use of special permits.

Most of the states surveyed by ECC indicated that they have issued overload permits for posted bridges, but many of these states said that such permits were rare. Figure 5 shows the degree to which the states surveyed use such permits.

In certain states overload permits for posted bridges are never issued. In California, for example, permits are not issued for posted bridges, but state law allows fire-fighting equipment to use a bridge, provided the fire-fighting agency pays for any bridge damage.

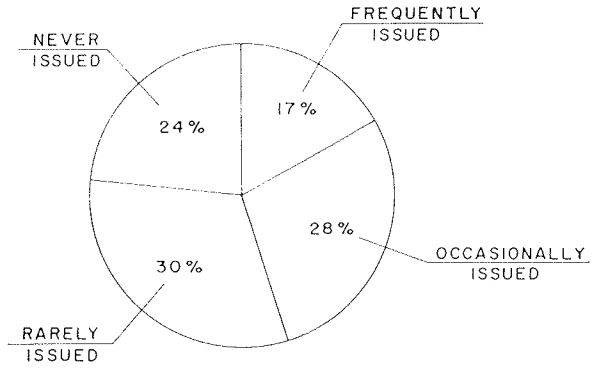

FIGURE 5 State practice of issuing overload permits on posted bridges.

ENGINEERING ASPECTS OF BRIDGE POSTING

NBIS provides some limited engineering guidance for inspecting, evaluating, and posting highway bridges, but considerable engineering judgment is still required to fill the gaps. As a result, even within the limits set by the NBIS, engineering practices vary among the states. This variation in practice leads to a difference in posting criteria that reflects different philosophies, different jurisdictional needs, and different traffic conditions.

INSPECTION

Bridge maintenance inspection is an art involving the application of both scientific principles and considerable engineering judgment gained from years of experience. Inspection relating to bridge-posting practice is most conveniently divided into inspections that are required before and those required after load-limit posting. Before a bridge can be posted, a thorough field inspection must be conducted. This is required so that a reliable structural-strength evaluation can be made. Subsequent to bridge posting, continued field inspection is required to monitor the condition of the posted bridge.

Before Posting

The primary purpose of inspecting a bridge before rating it is to determine information that is necessary to properly evaluate the strength of the bridge and its action under load. For this reason, it is desirable that inspectors become involved, at least to a certain degree, in the rating of bridges. The degree to which bridge maintenance inspectors are involved in the rating process in each of the states surveyed by ECC is shown in the following:

Involvement	No. of States
Performs calculations	9
Reviews calculations	5
Provides information and judgment	36
Not directly involved	7
Varies	2

After Posting

The majority of the states surveyed by ECC indicated that they reinspect their posted bridges more thoroughly or frequently than other structures. Many states also reported that they have the road maintenance personnel who drive the roads on almost a daily basis monitor posted structures for obvious signs of distress.

RATING

Bridge postings are usually based on the results of an analytical evaluation of the structural strength of the given bridge. Although the AASHTO manual (3) provides some guidance for evaluating or posting bridges, it also allows for a considerable amount of engineering judgment.

Posting Level

NBIS specifically states that posting is required if the AASHTO operating rating is less than the maximum legal weight of vehicles allowed to use the highways. Bridges need not be posted for loads below the AASHTO inventory load. Therefore, posted loads vary between the operating and the inventory levels. Although the AASHTO manual implies that frequency of inspection may be considered when a proper posting level is selected, it offers almost no additional guidance.

The ECC survey of the states showed considerable variation in the posted load level. There was also variation within some states in how they posted different bridge types. The posting levels of all states responding to the questionnaire are summarized in Table 6.

TABLE 6 Posting Levels Used by States

	No. of States by Bridge Type			
Posting Level	Steel	Timber	Reinforced Concrete	Prestressed Concrete
Operating	19	18	20	19
Inventory	14	15	12	13
Intermediate	8	8	7	8
Variable	5	5	5	5
Deferred	—	—	2	—

Loading

The traffic live load used for rating a bridge should be representative of the actual vehicles using the bridge. Only a few hypothetical rating-vehicle configurations are necessary to envelop the moments and shears caused by actual vehicles.

The vehicle configurations used for rating bridges vary among the states. Approximately 40 percent of the 45 states responding to the ECC survey use the typical AASHTO legal trucks. The remaining states use specially developed legal truck configurations, AASHTO H or HS design trucks, or some combination of truck types. The types of rating vehicles used by the states are summarized as follows:

Vehicle Configuration	No. of States
AASHTO legal vehicle	17
Modified legal vehicle	16
AASHTO design vehicle	5
Combination of AASHTO legal and design vehicles	4
Combination of AASHTO and modified vehicles	3

Of equal importance to the vehicle types is the number of vehicles assumed to be on the bridge at any one time. The AASHTO manual specifies that all lanes should be loaded when the rating is determined unless, in the judgment of the engineer, traffic movement and volume warrants the consideration of fewer lanes. Most of the states surveyed make only occasional use of the lane-reduction clause; however, five states consider only one vehicle at a time on the bridge.

Analysis Methods

Experience has shown that only a few structural components or failure modes control the maximum allowable live load for a bridge. These structural components or failure modes vary, depending on the type of bridge. Some of the less critical components and failure modes and the number of states surveyed by ECC that usually do not include these components or failure modes in bridge evaluations are listed in Table 7.

TABLE 7 Components or Failure Modes Not Considered in Rating

Component or Failure Mode	No. of States by Bridge Type			
	Steel	Timber	Reinforced Concrete	Prestressed Concrete
Concrete deck slab	19	15	16	–
Girder shear	19	7	14	16
Negative girder moment	3	3	3	3
Bent cap	23	15	25	23
Substructure	29	23	31	29
Other	3	3	3	3

The AASHTO manual allows the rater to use either working-stress or load-factor methods when a bridge is rated for its weight limit. Most of the states surveyed by ECC use working-stress methods exclusively for rating their structures. However, some states use load-factor methods for some structures and working-stress methods for others. Only one of the states surveyed used load-factor methods exclusively. The analysis methods used by each of the states surveyed (46 responded to the survey) are summarized as follows:

Method	No. of States
Working stress	26
Load factor	1
Combination	19

RECOMMENDATIONS

At this time there is too much variation in the posting criteria used by the different states. These differences are often justified; however, the current AASHTO manual and NBIS, although allowing for some variation, provide almost no guidance for rationally selecting the most appropriate criteria. Improved criteria need to be developed that will allow states and local jurisdictions to take into account those factors that legitimately affect the posted weight limits.

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