NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 108

BRIDGE WEIGHT-LIMIT POSTING PRACTICE

TRANSPORTATION RESEARCH BOARD
National Research Council

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TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to the National Research Council is an assurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NOTE: The Transportation Research Board, the National Research Council, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the individual states participating in the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire highway community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation
Research Board

This synthesis will be useful to bridge engineers and others concerned with bridge rating and posting practices. Detailed information is presented on various approaches currently used to deal with the engineering and administrative considerations.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

Highway agencies use posted weight-limits to allow continued, limited use of bridges for which the maximum legal load produces stresses in excess of specified levels. This report of the Transportation Research Board contains background information on load-limit posting practices and includes a review of administrative and engineering factors considered in current practice.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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Special appreciation is expressed to Roy A. Imbsen, Vice President, Engineering Computer Corporation, who was responsible for the collection of the data and the preparation of the report.

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Adrian G. Clary, Engineer of Maintenance, Transportation Research Board, assisted the NCHRP Project 20-5 Staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

BRIDGE WEIGHT-LIMIT POSTING PRACTICE

SUMMARY

Bridge weight limits allow the continued, limited use of a facility that would otherwise present a significant safety hazard. It is a mechanism for minimizing the impact on users while still protecting the legal and economic interests of the bridge owner. Bridge weight limits are effective only when bridges are posted for the proper weight limit, the motoring public observes the weight limits, and the weight limits are properly monitored and enforced.

The federal government became involved in 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 be structurally inadequate. These standards were eventually extended to virtually all highway bridges when Congress passed the Surface Transportation Assistance Act of 1978.

Through these two acts, the NBIS requires each state to develop inventories for all bridges within its borders, including locally owned bridges. This effort requires a close working relationship between state and local agencies. Not unexpectedly, many administrative problems have been encountered, including conflicts with existing state law, local governments with insufficient resources to provide for necessary engineering, and a large number of structurally inadequate local bridges for which very few records were available. In addition to these problems, there are several other administrative problems related to bridge weight limits. If a structurally inadequate bridge is not posted or posted for too high a weight limit, the bridge owner may be risking possible legal action in the event of a failure. Conversely, if the posted weight limit is too low, it will have detrimental economic effects. In addition, a low weight limit will tend to undermine confidence in posted weight limits, which could result in an increase in posting violations.

The administrative practices related to implementing a bridge weight-limit posting and operating and monitoring a bridge with weight limits also vary. There are variations in the way states relate to the public, inspect posted bridges, enforce bridge weight limits, and, in some cases, issue permits for bridges with weight limits.

The NBIS provides limited guidance in inspecting, evaluating, and posting weight limits on highway bridges, and considerable engineering judgment is required to fill the gaps. As a result, engineering practices vary among the states. This variation in practice leads to differences in posting criteria that reflect different philosophies, different jurisdictional needs, and different traffic conditions. Because they might prove difficult to reconcile, it is conceivable that these differences could lead to a lack of credibility of engineering results. Simple, uniform weight-limit posting criteria that will rationally consider the legitimate differences that exist among states need to be developed.

CHAPTER ONE

BRIDGE WEIGHT-LIMIT POSTING WITHIN THE UNITED STATES

INTRODUCTION

The United States is currently faced with a massive bridge replacement and rehabilitation problem. Many bridges on the highway system were designed several decades ago for vehicle loadings that do not represent the larger trucks using the highways today. In addition, deterioration has weakened many bridges, resulting in reduced live-load capacity. The Federal Highway Administration has estimated that the United States currently has more than 150,000 bridges that are or should be load posted (*1*). Many of these bridges should be rehabilitated or replaced, but they must compete for funding with an equally large number of bridges that are functionally obsolete because of narrow widths and poor alignments. Because the total cost of modernizing all bridges on the nation's highway system is estimated to be nearly $49 billion (*1*), it is necessary to delay improvements on a large number of these bridges for many years. Until a structurally inadequate bridge can be replaced, rehabilitated, or removed from the highway system, it will be necessary in most cases to regulate the traffic using it. This is normally done through the posting of weight limits for vehicles using the bridge.

The maximum weight of vehicles legally allowed to use the highways without special overload permits is governed by statutory law. The posting of weight limits on a structurally inadequate bridge, referred to in this synthesis simply as "posting," is done to further regulate legally allowed vehicle weights to protect the public from death or injury and to ensure the continuous operation of the bridge. Even if these bridges do not collapse, they may become damaged, necessitating costly repairs and unwarranted inconvenience to users.

When establishing weight limits, the need to protect public safety and both public and private property must be weighed against the need to maintain an unrestricted highway system that is conducive to healthy economic activity. If weight restrictions are too severe, trucks may be forced to take unnecessarily long detours, or, in some cases, be denied access to certain areas.

Bridge posting involves a consideration of safety, economy, and the public interest. Because consideration of these factors requires considerable judgment, bridge posting practices are not always uniform. This synthesis is intended to be a comprehensive analysis of both the administrative and engineering aspects of current bridge posting practices in the United States. It summarizes the differences and similarities in the practices of the various states as determined from a survey of the states. It is intended as a resource document for anyone interested in this aspect of bridge engineering.

THE POSTING PROCESS

Bridge inspection and structural strength evaluation are prerequisites for bridge posting. Before a bridge can be permanently posted, it must be evaluated to determine its strength to carry live loads; and before it can be accurately evaluated, it must be inspected to determine its physical condition.

When a bridge is found to be structurally inadequate, weight-limit posting is only one of several alternatives that might be available. The speed and volume of traffic can be regulated through the use of speed limits or lane restrictions. In many cases, where standard evaluation methods indicate the need for traffic regulation, alternatives should be considered. For example, it may be possible to demonstrate the structural load capacity of a bridge through the use of a more detailed analysis or the use of physical testing. Minor repairs or reinforcement of weak components can often be made quickly and at a relatively minor cost. In these cases, a weight-limit posting may be only temporary. Because the severe restrictions often imposed by weight-limit posting can have a significant impact on commerce, each of these alternatives should be given serious consideration.

When a decision is made to post a bridge, there are usually standard procedures that must be followed. However, these procedures vary from jurisdiction to jurisdiction. Signs must be placed at the bridge site that clearly indicate to motorists the nature of the weight limits. Standard signing is included in the Manual of Uniform Traffic Control Devices (MUTCD) (*2*), but many jurisdictions have found it necessary to deviate from these standards to eliminate ambiguity that could lead to misinterpretation under the provisions of the weight-limit laws in their particular state. Because a weight-limit posting has an impact on the public, it is important that the public be notified of a bridge posting. This may be accomplished in several ways, and these vary among the states.

Continued inspection of a posted bridge will be necessary to detect any distress or deterioration that could affect structural strength. In most cases, this inspection should be more thorough and/or frequent for these posted bridges than for bridges that are not posted.

Enforcement of bridge postings will help ensure that posted weight limits are observed. This is important because a significant number of bridge failures have resulted from overweight vehicles using a posted bridge. 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. One obvious example would be emergency response vehicles such as fire

trucks. This is often done through the overweight permit process, but may also be mandated by state law.

A summary of the posting process is shown in Figure 1.

THE NATIONAL BRIDGE INSPECTION STANDARDS

In 1967, the collapse of the Silver Bridge over the Ohio River at Point Pleasant, West Virginia resulted in the deaths of 46 people. Subsequent investigations indicated that the failure was caused, in part, by stress-corrosion cracking in the steel eye-bar members of the suspension chain (*3*). This cracking had not been detected during the maintenance inspections of this structure. This failure focused public attention on the structural safety of the nation's highway bridges and, as a result, Congress passed the Federal-Aid Highway Act of 1968 that called for the development of National Bridge Inspection Standards.

The National Bridge Inspection Standards (NBIS) (*4*) were developed by the U.S. Department of Transportation, in consultation with state highway departments and other interested and knowledgeable parties. The NBIS requires states to inventory all bridges located on all public roads and to inspect them at least once every two years.

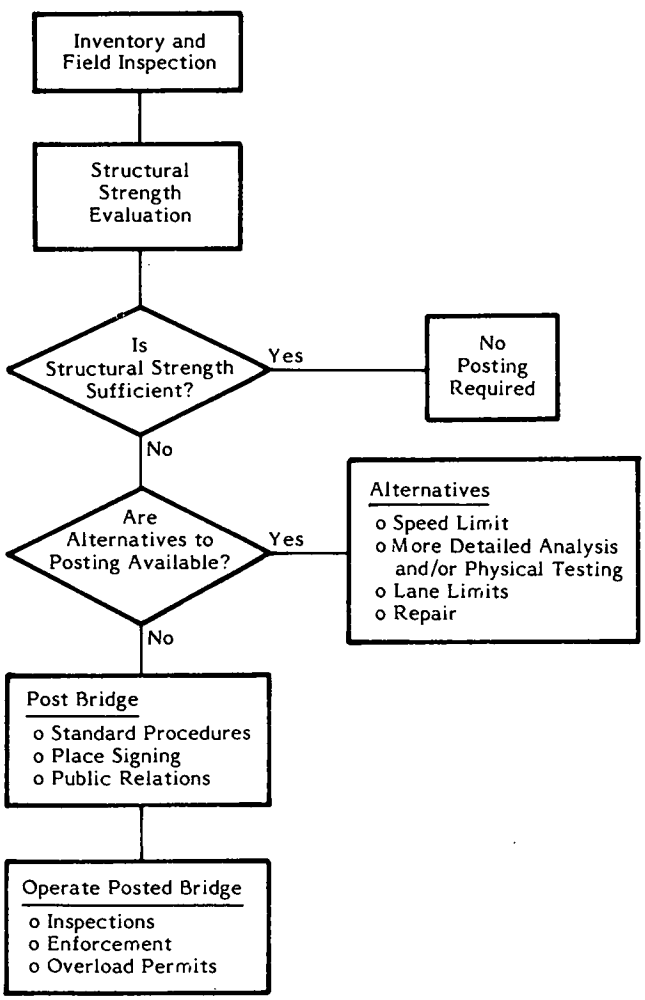

FIGURE 1 Bridge-posting procedure.

The American Association of State Highway and Transportation Officials' Manual for Maintenance Inspection of Bridges (AASHTO manual) (*5*) prescribes inspection procedures, 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 weight-limit rating are described. One, the inventory rating, results in a load level that can safely utilize an existing structure for an indefinite period of time. The other rating, which predicts the absolute maximum permissible load level to which the structure may be subjected, is known as the operating rating.

The NBIS requires that every bridge be rated for its safe load-carrying capacity in accordance with Section 4 of the AASHTO manual. According to the NBIS (*4*):

> If it is determined under this rating procedure that the maximum legal load under State law exceeds the load permitted under the Operating Rating, the bridge must be posted in conformity with the AASHTO Manual or in accordance with State Law.

The AASHTO manual (*5*) provides that the posting be at the load level used for the inventory rating unless an agency has an inspection program that greatly exceeds the minimum requirements and will closely monitor the load history of the bridge. In no case should be posted load exceed that permitted by the operating rating.

CURRENT STATUS OF BRIDGE POSTING

Even though the NBIS requires posting when the legal highway loads exceed the operating rating, a 1981 spot check conducted for Congress by the United States Comptroller General (*6*) indicated that several states were not in compliance with these requirements. This lack of compliance occurred mainly at the local government level.

It should be noted that the federal government does not have the jurisdictional authority to require compliance with the NBIS. The primary incentive for compliance is the ability of the federal government to withhold funding for highway and bridge construction. At the state level, this funding is considerable because most state highways are on the federal-aid system. Therefore, because of the large funding incentive, compliance by the states is not generally a problem. At the local government level the situation is much different. Most local agency bridges are not on the federal-aid system. The fact that 1978 federal legislation made funding available for repair and rehabilitation of off-system bridges may, in some cases, not be enough to induce local agencies to comply with posting requirements. Because local officials are usually closer to the political interests that tend to oppose bridge posting, they may be more likely to yield to political pressure not to post structurally inadequate bridges.

The problem at the local level is compounded by the fact that most of the nation's highway bridges in need of posting are on local, off-system roads. In addition, many local governments have insufficient resources to hire a full-time professional engineer or retain engineering consultants to inspect and rate their bridges. In these cases, the burden of inspecting and rating local bridges is often borne by the states, although many states are

prevented by state law from giving this type of aid to local governments. In most cases, the states do not have the jurisdictional authority to require local governments to comply with the NBIS, and even if the states inspect and evaluate the bridges, they usually cannot force the local government to post their bridges.

Table 1 summarizes the bridge-posting statistics for the United States, as reported in a survey conducted for this synthesis.

Only 17 bridges on the entire Interstate highway system were reported as being posted, and none of these was on main-line freeway. Sixteen were in one state but all were on frontage roads. Therefore, it would appear that permanent bridge posting is not a problem on Interstate highways. There are at least two reasons for this. One reason is that the Interstate system is relatively new and constructed to high design standards. The other reason is that the Interstate system is so important to the economic and security interests of the nation that deficiencies are corrected

TABLE 1

BRIDGE POSTING STATISTICS (1983)

Agency	Interstate		Other Federal Aid		Off-System		Total	
	No.	Posted	No.	Posted	No.	Posted	No.	Posted
Alabama	1,058	0	6,387	221	7,897	964	15,324	1,185
Alaska	120	1	420	18	310	27	850	46
Arizona					692	55	5,032	72
Arkansas	622	0	5,206	439	8,880	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		
Hawaii	103	0	599	53	402	63	1,104	116
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
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	3,989
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 Dakota	405	0	1,511	77	3,839	870	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
Pennsylvania	b	0	10,782	395	10,706	3,080[c]	21,488	3,475
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	45,820	2,520
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				2,079	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
District of Columbia	70	0	156	20	16	4	242	24

[a]State highway statistics only.

[b]Included in Other Federal Aid.

[c]Includes 2,432 local bridges.

relatively quickly so that only a temporary emergency posting may be needed.

National bridge inventory data from December 31, 1982 indicates that there are 564,499 highway bridges in the United States and that 88,000 of these are posted with a weight limit (*1*). The inventory also indicates that there are nearly 65,000 bridges that should be posted with a weight limit but are not.

The survey for this synthesis also asked for the number of bridges closed during the last 10 years. Bridges that are closed are usually too deficient to rely on weight-limit posting. A summary of the results from this survey are shown in Table 2.

TABLE 2

BRIDGES REPORTED CLOSED DURING THE LAST 10 YEARS[a]

Type	Number
Interstate	33
Other Federal-Aid	336
Off-System	5481
Total	5950[b]

[a]Some states only reported bridges currently closed.

[b]Numbers for Interstate, other federal-aid, and off-system bridges will not total this amount because some states were unable to give a breakdown by system.

TABLE 3

ESTIMATED BRIDGE COLLAPSES CAUSED BY LIVE LOAD DURING THE PAST YEARS

	Steel	Timber	Reinforced Concrete	Prestressed Concrete	Total
Interstate	0	0	0	0	0
Other Federal-Aid	38	43	1	0	82
Off-System	169	344	1	0	514
Total	207	387	2	0	596
Bridges that were posted	127	144	2	0	273

The failure to post a bridge will increase the chances of a structure collapse under live load. The survey asked state bridge engineers to estimate the number of these types of failures over the past ten years for four different bridge types and for different types of highway systems. Although the numbers are only estimates, the results reported in Table 3 show some definite trends. Bridge failures are far more frequent with off-system bridges. As the numbers indicate, many of these bridges were not posted with a weight limit. It is interesting to note that steel or timber bridges were more likely to fail than reinforced concrete bridges, which will show signs of distress before collapse. Of the two reported to have collapsed, only one actually involved the failure of the superstructure, and this occurred in a very old, deteriorated local bridge that had not been maintained. Prestressed concrete bridges, which are relatively modern in construction and design, were not reported to have collapsed.

CHAPTER TWO

ADMINISTRATIVE ISSUES

STATE AND LOCAL RESPONSIBILITIES

The NBIS requires states to inventory all bridges, including local bridges. Although states may be able to collect the required inventory data from local agencies for bridges not under state jurisdiction, it is often impossible to do so because many counties do not possess the resources to conduct inspections and ratings in a timely manner. If states are to carry out their obligations under the NBIS, they must take an active cooperative role in supporting the inspection and rating of local bridges.

The NBIS requirements have created a conflict with state law in many cases. Frequently, there are restrictions on the amount of state money available for local bridge inspection and rating. In addition, the states frequently do not have the right to inspect or rate bridges without the expressed consent of local officials. In some states it was necessary to modify state law before the state could comply with the NBIS requirements. Although only four of the states surveyed indicated that state laws were changed, several others indicated some difficulties were encountered.

Almost all bridges have now been inventoried, inspected, and rated for a weight limit. There are still some bridges, however, that must be inventoried, particularly those not on federal-aid highway systems. In some cases, bridges have been inventoried and/or inspected, but have not yet been rated.

Inspection and rating of bridges do not have a direct impact on bridge users. Therefore, it is easier for the states to carry out these tasks than it is to convince local agencies to post a structurally inadequate bridge. To force a bridge posting on a local agency would raise serious questions of local control. Because of this, most state highway officials believe that they do not have the authority to post a bridge over the objections of local officials. The survey of states showed that in only seven did state highway officials believe they had this authority. In almost all states the authority to post a bridge belongs to the bridge owner, although in a few states there is combined authority.

Despite the difficulties inherent in the NBIS requirements, more bridges are currently posted than before the federal legislation mandated these standards. Table 4 shows the effect of the NBIS requirements on the number of bridges posted in the states surveyed.

LEGAL CONSIDERATIONS

There are several legal implications to consider when deciding whether or not to post a bridge. First, a bridge posting is done to regulate traffic and may be enforced under the law. Consequently, legally prescribed procedures must be followed when posting a bridge, and posting may be subject to legal challenge.

Second, posting is a method that owners can use to encourage safe operation of the highway system. Because owners are expected to make every reasonable effort to ensure safe highways, it follows that the owners may be legally liable for any damages or injuries that can be shown to have resulted from compromised highway safety caused by improper use of the posting process.

Another consideration is the link between compliance with the National Bridge Inspection Standards and the availability of federal matching funds for bridge replacement or rehabilitation.

Liability

Although there have been some exceptions, states have generally been immune from liability resulting from their approval of plans or designs (*7*). However, states have frequently been held liable for failing to properly construct or maintain safe bridges (*8*). Although not required to guarantee absolute safety, the states are required to ensure a reasonable level of safety, as expressed in the following language from a 1979 court decision:

> [I]f the State were required to anticipate and protect against all imaginable acts of negligent drivers, it would become an insurer against all such acts. Rather its duty is to maintain its roads in such a condition that they are reasonably safe for persons using them in a proper manner and exercising ordinary care for their own safety. (Stewart v. State, 92 Wash. 2d 285, 597 P.2d 101.)

The courts have also ruled that a given state's duty to correct an unsafe condition arises only after the state has received an actual or constructive notice of the condition and has therefore previously had the opportunity to act.

With respect to bridge posting, several situations might arise that can potentially involve the bridge owner in litigation. Courts have held that highway agencies are not required to remove potential hazards, such as structurally inadequate bridges, provided adequate warning of the danger is posted. The adequacy of the posted warning is a question that is decided by the courts on an individual, case-by-case basis.

TABLE 4

EFFECT OF FEDERAL LEGISLATION ON POSTED BRIDGES

Change in Number of Posted Bridges	Number of States
More than 100% increase	19
25 to 100% increase	7
Less than 25% increase	8
No increase	7
Reduction	1

The most obvious situation that can result in liability is the case in which an owner has failed to post a structurally inadequate bridge for a reduced live loading. The single most common and successful claim by plaintiffs who are injured on highway bridges is that the state was negligent by failing to provide adequate warning of a hazardous condition on the bridge (*8*). Courts have often ruled that states are liable because bridge posting is an inexpensive method that states can and should use to warn motorists of the potential hazard. Improper posting may also result in legal action. In 1981, a county in Nebraska was found liable (Hansmann v. Gosper County, 207 Neb. 659, 300 N.W. 2d 807) when it was shown that a 10-ton-limit sign was removed from a bridge after the county highway superintendent concluded that the posting was invalid because 23- to 24-ton trucks frequently used the bridge without incident. The county was sued when a 24-ton truck collapsed the bridge, injuring the driver (*8*).

It should be noted that a bridge collapse directly resulting from a single, heavy vehicle is not the only concern. The passage of such vehicles could cause significant damage to the structure. Such damage could result in an unsafe condition, which in turn might cause a subsequent light vehicle to lose control and become involved in an accident or to sustain physical damage. For example, in a 1955 case in Louisiana (Hogg v. Department of Highways of the State, 80 So. 2d 182), a motorcyclist was injured when he lost control of his vehicle as a result of striking a hole in the bridge deck. The hole had been caused by the passage of heavy trucks. The courts ruled in favor of the injured party when it was shown that the highway department knew about and failed to repair the hole (*8*).

Another aspect of liability concerns inspection and replacement of signs. In one case [Department of Highways v. Fogleman, 210 La. 375, 27 So. 2d 155 (1946)] where a state sued a truck driver to recover damages to a bridge caused by his heavy truck, the state's claim was rejected because the state had failed to replace a load-limit sign that had been removed by unknown individuals (*8*). Although issues relating to posting signs may vary on a case-by-case basis, an excerpt from the ruling on another case may shed some light on the opinion of the courts:

> [I]t would not automatically follow that the State would be liable even if a third person, without its knowledge or consent, removed the sign from the bridge. In such event, responsibility would depend upon whether the Department of Highways had actual or constructive notice that the sign was missing and failed, within a reasonable length of time, to remedy the situation. [Norman v. State, 227 La. 904, 80 So. 2d 858 (1955)]

There is no action that guarantees immunity from litigation. Therefore, all posting decisions should be made as if they will have to be defended in court. This will generally include following accepted procedures and documenting each evaluation. In addition, every reasonable effort should be made to conduct frequent inspections, maintain the posted signs, and vigorously enforce the posted weight limits. These actions will help keep the owner's legal problems to a minimum.

NBIS Compliance

Although the federal government cannot require state and local compliance with the NBIS, Title 23, Section 1.36 of the Code of Federal Regulations allows the Federal Highway Administrator to take appropriate action against any state not complying with federal-aid highway laws or regulations. Conceivably this could include the withholding of matching funds for replacement and rehabilitation of bridges to encourage agencies to comply. Some local agencies have willingly foregone matching funds. In a report to Congress in 1981, the United States Comptroller General (*6*) cited several instances where local agencies were reluctant to participate in the Federal Bridge Program. Reasons given by the local officials included government "red tape," government requirements that were perceived to be unreasonable, lack of interest and knowledge, and inability to match federal funding.

Even when local agencies fail to comply with posting requirements, they do not always lose their eligibility for matching funds. In one state where some local agencies failed to post deficient bridges, a state official stated that he knew of no instance where federal matching funds were withheld as a result of a local agency's failure to post bridges.

ECONOMIC CONSIDERATIONS

Bridge posting will undoubtedly have some economic impact. Restricting the traffic that can use a bridge will result in a redistribution of traffic patterns. This usually means that heavy vehicles will be required to use a longer route. This can result in higher vehicle operating costs, lost time, and greater maintenance expenses for the detour route. In some instances, it may mean excessive traffic on the detour route or increased response time for emergency vehicles. These situations may have safety as well as economic implications. Although individual truckers will often have to bear the direct costs related to detouring around a posted bridge, these costs will eventually be borne by the general public in the form of higher prices or loss of economic activity.

Posting is an alternative to bridge replacement or rehabilitation. Associated with posting are certain costs that must be weighed against the costs of other economic alternatives. In addition to the economic impact, discussed in the previous paragraph, there are certain direct costs associated with posting and operating a posted bridge. These direct costs include the administrative costs of obtaining a posting order, the cost of installing and maintaining signs, increased bridge inspection costs to monitor the load capacity of the bridge, the costs associated with enforcing the posting, and the costs of maintaining what is usually an old and deteriorating bridge.

The initial costs associated with implementing a posting are generally small. Among the states surveyed, these costs averaged slightly over $500. However, other costs, especially those associated with maintaining the posted bridge, can be substantial. When combined with the costs to users of detouring traffic, it is possible that the least expensive alternative will be bridge replacement or rehabilitation.

Another economic consideration is the level of the posted load. To help minimize user costs, it is desirable to keep the posted load level as high as possible, provided the level of posting will not cause the bridge to deteriorate at an increased rate, resulting in higher maintenance costs and potential safety problems. Because knowledge of the relationship between load and rate of deterioration is, at best, only approximate, resolution of this problem requires engineering judgment based on the past performance of bridges.

IMPLEMENTING A BRIDGE POSTING

State-Owned Bridges

The procedures for posting state-owned bridges with weight limits vary from state to state. Once an engineering investigation has shown a bridge to be structurally inadequate to the point that posting should be considered, most states require that some sort of authorization be obtained before posting can take place. Many times this authorization will come from some individual within the state department of transportation, such as a chief bridge engineer. In other instances, this authorization comes from an appointed or elected body or official, such as the State Highway Commission or the Director or Secretary of Transportation. All states, however, have some legal procedure for posting their own bridges.

The time required to carry out the official posting procedure also varies among the states. In some states this procedure may be carried out in a day, while in other states the procedure takes as long as three months. The differences are largely a function of the legal procedures for obtaining a posting order in each of the states. Because permanent posting takes so long, engineering personnel in most states are given the legal authority to erect temporary signs indicating the load capacity of the bridge. Engineering personnel in eleven of the states surveyed indicated that they lacked the authority to temporarily post a bridge while permanent posting was being sought. In some states temporary posting is advisory only and cannot be enforced.

Very few states have established procedures for obtaining public input before posting a bridge. One state official indicated that allowing public input would only compound the difficulties he was already having in posting bridges. In at least three states, however, a public hearing is required before a bridge can be posted. The purpose of this hearing is to consider the engineering report on the bridge and hear any other evidence that may be offered. An official from one of these states indicated that the engineering report has always been the basis for posting, regardless of public input at these hearings. The only instance where posting recommendations would be changed would be when state engineers had made an obvious error.

The final step in the posting process is the erection of permanent signs at either end of the bridge. These signs constitute prima facie evidence of the load capacity of the bridge. Without signs, even if official authority has been obtained, a weight-limit posting cannot be enforced.

Where posting is accomplished by an official, legally prescribed process, it is also necessary to follow a legal process to remove or change a posting. When a bridge is repaired, removed, or replaced, or when the posted load is changed for any reason, an official order to rescind the existing posting is usually required.

Sometimes a posted bridge will deteriorate to the point where its posted weight limit is no longer valid and the posting limit will have to be lowered or the bridge closed. Almost every state surveyed indicated that they had been faced with this problem. However, at least half said this was a rare situation.

Locally or Privately Owned Bridges

Because the responsibility for posting locally or privately owned bridges is usually different for state bridges, it follows that the procedure for posting is also different. In only a few cases are the states able to post local bridges with a load limit. This presents a problem for many local jurisdictions that cannot afford to conduct engineering investigations. To remedy this, many states have become involved to some degree in posting local bridges. For example, the state of California is involved in the posting of local bridges. However, under state law, the state cannot post a locally owned bridge unless requested to do so by the local government officials.

According to California state law, when local government officials suspect that a bridge is structurally inadequate, they may request an engineering investigation of the bridge from the California Department of Transportation (Caltrans). In practice, this investigation is conducted regardless of local requests, because the state currently inspects and inventories all local bridges under the provisions of the Surface Transportation Assistance Act of 1978. To comply with this act, the state performs engineering calculations to determine the safe load capacity of any given bridge and sends a bridge report detailing the findings of the engineering investigation to the local agency. If the local agency officials did not formally request the investigation, they are under no legal obligation to post the bridge although the potential for tort liability may encourage them to post.

If posting is recommended by Caltrans and the local agency concurs, a posting hearing is set up by the state to be held within the local jurisdiction. The local officials are responsible for placing notices of the hearings at the bridge site. Following the hearing, the State Director of Transportation issues a posting order. It is the responsibility of the local officials to implement the posting order by placing signs, etc.

Currently there are problems in some states with state and local cooperation. These problems stem primarily from the unwillingness of local governments to relinquish control of their bridges and of hesitation by state governments to become involved in local matters. A great deal of this reluctance is apparently due to questions of liability in the event of an accident. In California, the state would be responsible for the accuracy of its engineering investigation, but local government would be responsible for initiating the posting process and implementing the posting order. When a bridge investigation that is not requested is conducted by the state because of the 1978 legislation, California state officials believe that their obligation has been fulfilled when they send the bridge report to the local agencies.

In some states, privately owned bridges, such as those owned by toll authorities or railroads, carry traffic on public highways. Over 80 percent of the states surveyed said they did not have statutory authority to inspect and/or post these bridges. Although this probably represents a small number of bridges, it seems that most state officials must rely on their powers of persuasion with private bridge owners to ensure proper bridge inspection and posting.

Public Relations

In many cases, there is considerable public resistance to bridge posting. This may come from trucking companies, local residents, industry, or other individuals or groups who would be inconvenienced. It is often difficult for non-engineers to understand why vehicle weights should be limited when they have observed heavier vehicles use the bridge with no apparent dif-

ficulty. The public pressure in some jurisdictions, especially on local agencies, is so intense that some officials are reluctant to post bridges.

A 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. Figures 2 and 3 summarize the responses to two questions asked in the survey. Figure 2 reflects the opinions of state officials regarding the amount of public pressure against bridge posting. Figure 3 is a summary of the opinions of state officials regarding public confidence in posted weight limits. Cases have occurred in which angry motorists have removed barricades from a closed bridge and continued to use the bridge despite repeated attempts by officials to close it. Such actions indicate the low confidence level many people have regarding weight limits.

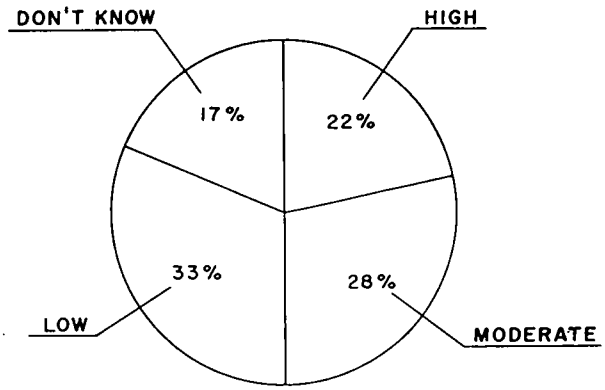

FIGURE 3 Variation in perception of public confidence in posted load limits by states.

Signing Practices

Standard highway signs minimize driver confusion when crossing different governmental jurisdictions. Because of this, uniform signing practices have been established on all streets and roads in the United States. The AASHTO manual requires that the standards contained in the Manual on Uniform Traffic Control Devices (MUTCD) (*2*) be followed when placing regulatory signing on posted bridges.

The MUTCD states, "Regulatory Signs inform highway users of traffic laws and regulations and indicate the applicability of legal requirements that would not otherwise be apparent." It further states: "Regulatory signs normally shall be erected at those locations where regulations apply. The sign message shall clearly indicate the requirements imposed by the regulation and shall be easily visible and legible to the vehicle operator." Because weight-limit signs by definition are regulatory signs, they are legally enforceable only if the regulations they express are clearly stated and recorded in the legal records of the responsible jurisdiction.

The current issue of the MUTCD recommends five standard signs that can be used for bridge posting, 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. This has led to many variations of the standard signs plus the development of many new nonstandard signs (*9*). Some of these are shown in Figure 5.

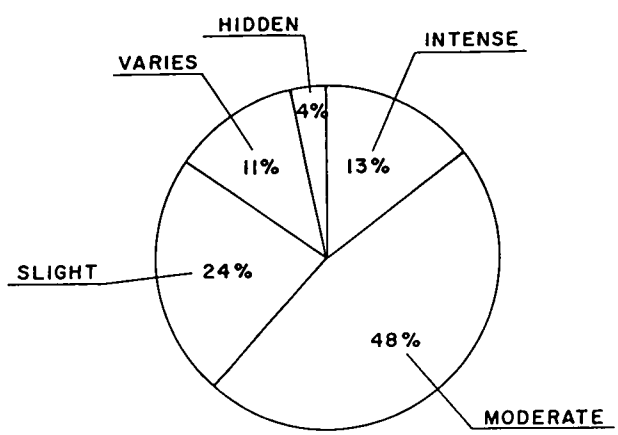

FIGURE 2 Variation in perception of public pressure against posting by state.

The weight-limit sign (R12-1) limits the gross weight of vehicles and vehicle combinations. Some jurisdictions interpret this same sign as limiting the gross weight of vehicles only. Because the definition of a vehicle includes trailers, this interpretation would allow each vehicle in a vehicle combination to have a gross weight up to the specified limit. Therefore, by this interpretation, a three-vehicle combination could have a legal gross weight three times the specified weight limit. Some jurisdictions have used the R12-5 weight-limit sign, but in lieu of the single-axle symbols on the standard sign, in one case they have modified the vehicle symbols to show tandem axles and in another case they have removed axle symbols from the sign altogether. One jurisdiction initiated the use of the R12-5 weight-limit sign but discontinued its use when the enforcement agency complained that it could not be legally interpreted. The conditions described here are prevalent throughout the United States, and such conditions are specifically intended to be avoided by the use of the MUTCD.

A recent survey by Halstad (*10*) 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 (12m) and by 11 states for bridges with span lengths greater than 40 ft. Type R12-4 is preferred in only 3 states for any type bridge and type R12-2 and R12-3 are not preferred by any states. Nine states preferred nonstandard signs of their own design.

OPERATION OF A POSTED BRIDGE

Enforcement

Even when bridges are posted or closed, the postings are sometimes disregarded. Individuals and businesses often continue to use a bridge even though they are aware that they are exceeding the posted weight limit. Frequently this is because the penalties for violating a posted load limit are low and en-

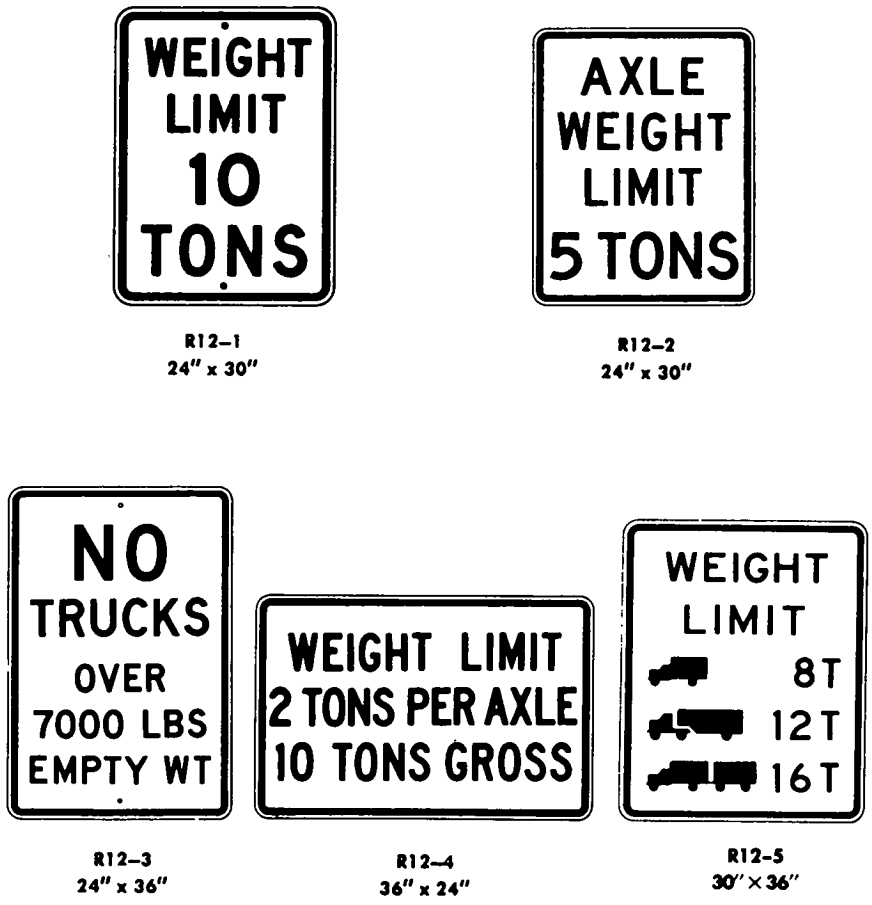

FIGURE 4 Standard bridge posting signs (after MUTCD).

forcement is limited. Public confidence in posted weight limits also appears to be low.

Enforcement of posted weight limits is often more difficult than enforcement of normal legal weight limits because of the likelihood that permanent scales will not be near the posted bridge. This requires the use of portable scales to check the weights of individual trucks. This is more time-consuming and therefore fewer vehicles can be weighed. Because of their other duties, law enforcement agencies are unable to devote much time to bridge-posting enforcement.

When someone is caught exceeding the posted weight limit of a bridge, the legal consequences are often relatively minor. In addition, some courts have tended to be very lenient toward offenders. Because of the low probability of being caught and the small fines often involved for violators who are caught, many truckers knowingly exceed bridge weight limits and take their chances on having to pay a small fine.

The survey of state posting practices revealed that there were considerable differences among the states in the legal consequences for exceeding a posted weight limit. Most states can assess a fine 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, while in others the fine is based on the amount of overweight. Many states require that offenders pay for any damage done to the bridge. Other penalties are also used in various states, including the revocation of vehicle registration. Table 5 summarizes the possible legal consequences for violating a posted weight limit as reported by each of the states that responded to the questionnaire.

The responsibility for enforcing a posted weight limit usually lies with law enforcement agencies such as the state highway patrol or local police departments. On state-owned routes the state highway patrol usually has exclusive jurisdiction, while on local roads the primary responsibility for enforcement belongs to the local police; however, the local police often share enforcement responsibilities with the state highway patrol. Since the special equipment necessary for effective enforcement, such as portable scales, is often not available to local police agencies, the burden of local enforcement is often borne by the state highway patrol. A few states have special agencies responsible for the enforcement of posted weight limits. In at least two states surveyed, local agencies are not allowed to enforce bridge postings and the state has exclusive enforcement authority.

Methods for Notifying the Public

When a bridge is posted, it is desirable to give the public advance notice of the posting so that motorists can make arrangements to use detours or to limit their loads to the maximum weight allowed. When motorists are not informed of a scheduled posting, overweight trucks are more likely to arrive at the bridge

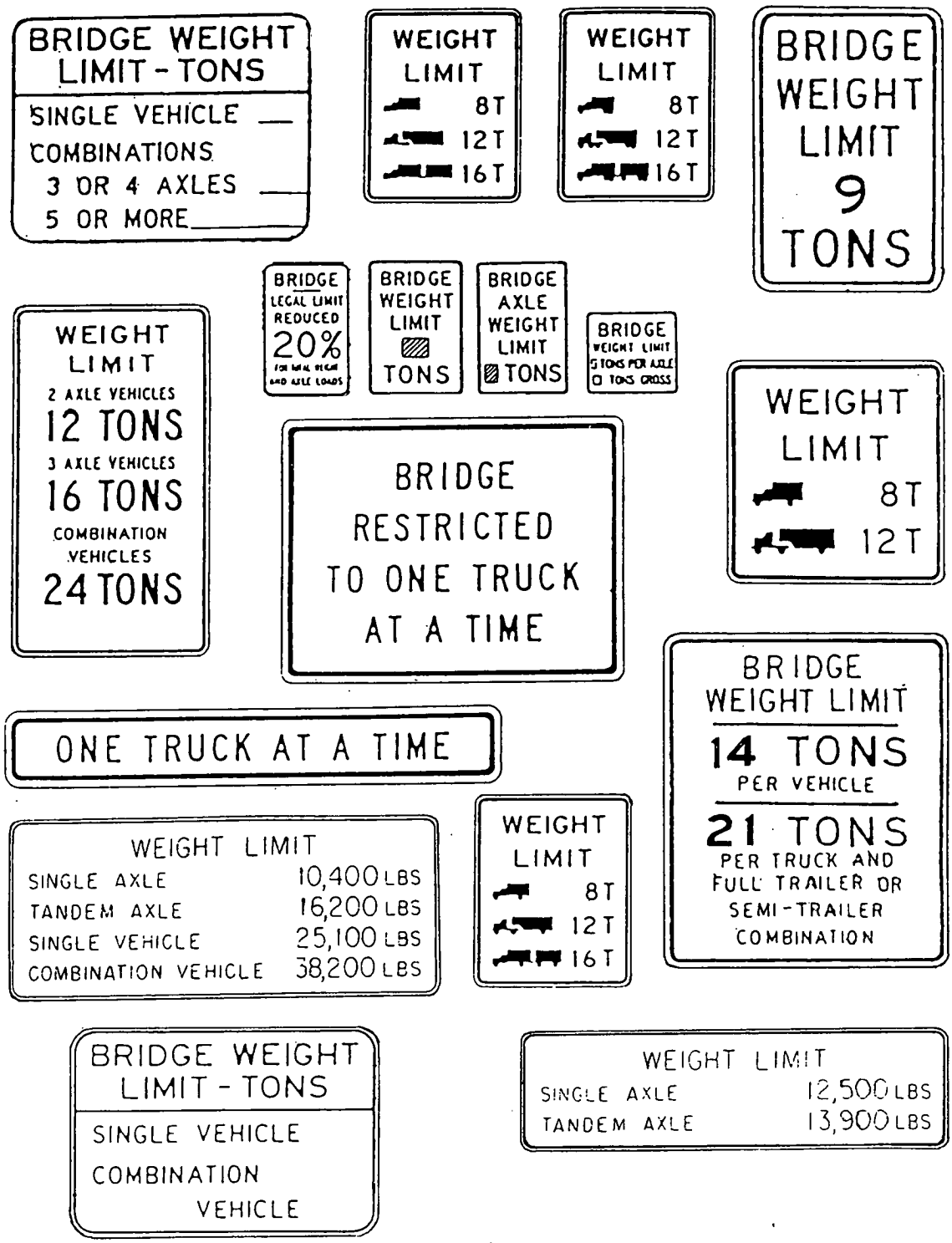

FIGURE 5 Bridge posting signs in current use (*9*).

site, and drivers will be more likely to take their chances crossing rather than obeying the sign and turning back. Various methods are used by the states to notify the motoring public of a posted bridge. These methods include news releases, special notification given to trucking associations, legal notices, public hearings, published lists of restricted bridges, and advisory signs on routes with posted bridges. While some states make no special effort to notify motorists other than by placing regulatory signs at the bridge, other states use a combination of methods for notifying the public. Table 6 summarizes the methods used to notify the public and shows the number of states surveyed that use each of these methods.

Monitoring a Posted Bridge

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 because of live load. The live-load capacity of such a bridge can potentially be affected to a greater degree by the passage of time than a bridge in relatively good condition. Although bridge posting is often considered a temporary solution until funding for replacement or rehabilitation becomes available, in many cases the old bridge will continue in service as is for many years. In other cases, bridge posting may be acceptable as a permanent solution, with no immediate plans made for improving the bridge. In both of these cases, it is necessary to monitor the condition of the posted bridge periodically to verify that the posted weight limit is appropriate.

Many local agencies lack the personnel or financial resources to conduct the inspections of their own bridges. When the National Bridge Inspection Standards were extended to locally owned bridges, it became necessary in some cases for the states to assume responsibility for local bridge inspections. More than half the states surveyed are involved in inspecting local bridges. Although these inspections include bridges on and off the federal-aid system, the majority of these states only inspect on-system bridges. A summary of bridge inspection practice is shown in Table 7.

TABLE 5

CONSEQUENCES OF BRIDGE-POSTING VIOLATIONS

Agency	Fine	Maximum Fine	Jail	Maximum Jail Time	Other
Alabama	Y	$500	Y	60 days	
Alaska	Y		N		
Arizona					a
Arkansas	Y	b	N		
California	Y	$1000	N		
Colorado	Y		N		
Connecticut	Y		Y		
Delaware	Y				
Florida	Y	$2500[b]	N		
Georgia	Y	$2500[b]	Y	365 days	c
Hawaii	Y	$500[b]	N		
Illinois	Y	$6000[b]	N		
Indiana	Y	$10,000	N		
Iowa	Y	b	N		
Kansas	Y	$2500	Y	365 days	
Louisiana	Y	$100	N		
Maine	Y	$1000	N		
Maryland	Y	$5650[b]	N		
Massachusetts	Y	$200	N		
Michigan	Y	$100	N		
Minnesota	Y	b	N		
Mississippi	Y	$5500[b]	N		
Missouri	Y	$500	Y	365 days	
Montana	Y				
Nevada	Y	$4000[b]	N		
New Hampshire	Y	$100	N		
New Jersey	Y		N		
New Mexico	Y	$500	N		
New York	Y	$500	Y	30 days	e
North Dakota	Y		N		
Ohio	Y	$200	Y	30 days	
Oklahoma	Y	$500[b]	Y	180 days	
Pennsylvania	Y	$14,258[b,f]	N		d
Rhode Island	Y		N		
South Carolina	Y	$100	Y	30 days	
South Dakota	Y	$100[b]	Y	30 days	
Tennessee	Y	$2470[b]	Y	180 days	
Texas	Y		N		
Vermont	Y	$300	N		
Washington	Y		N		
West Virginia	Y	$1600[b]	Y	10 days	
Wisconsin	Y	b	N		
Wyoming	Y	$500[b]	N		
District of Columbia	Y	$2800[b]	N		
Alberta	Y	b	N		
Ontario	Y	$2265[b]	N		

[a]No specific law on exceeding a posted limit; penalties specified for legal sizes and weights only.

[b]Fine based on the amount of overload. Amount, if shown, is based on 50,000-lb overload.

[c]Any posting by county ordinance can be cited as a misdemeanor and fined up to $1000 and up to 1 year in jail.

[d]Liable for cost of repair.

[e]Revocation of vehicle registration from 10 days to 6 months. Driver of overloaded vehicle must pay cost of damage caused to bridge.

[f]Because of very high fine structure, some judges are imposing lower fines.

TABLE 6

METHODS FOR NOTIFYING PUBLIC OF BRIDGE POSTING

Method	Number of States
News release	23
Special notices to trucking associations	20
Legal notice	4
Advance advisory signs	3
Notice posted at weigh stations	1
Notify other agencies	6
Weight limit maps or lists issued	5
Public hearings before posting	3
Regulatory signing only	9

Permits for Posted Bridges

Bridge posting often results in hardships that are critical and even life threatening. It is therefore sometimes in the public interest to allow certain overweight vehicles to use a posted bridge. This is usually done through the use of special overweight permits. This is often possible for bridges that are posted at the inventory rating, which is the load level that a bridge can safely sustain for an indefinite period of time. The operating rating, which is the maximum load to which a bridge can be subjected, is often significantly higher than the inventory rating. For bridges posted at the operating rating, stresses can be reduced by restricting the number of vehicles on the bridge at any one time, by reduced vehicle speeds (which will result in lower live-load impact), or by temporarily reinforcing the structure by shoring or some other method.

Most states surveyed indicated that they do issue overload permits for posted bridges, but many of these states said such permits were rare. Figure 6 illustrates the degree to which the states surveyed utilize special overweight permits for posted bridges.

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, providing that the fire-fighting agency pays for any bridge damage.

TABLE 7

RESPONSIBILITY FOR CONDUCTING THE LOCAL BRIDGE INSPECTION

Agency	Federal-Aid Bridges	Off-System Bridges
Alabama[a]	Local	Local
Alaska	State[b]	State[c]
Arizona	Varies[b]	Varies[c]
Arkansas	State	State
California	Shared	Shared
Colorado	Local	Local
Connecticut	State	State
Delaware	Sate	Local
Florida	Local	Local
Georgia	State	State
Hawaii	State	Local
Illinois	Local	Local
Indiana	Local	Local
Iowa	Local	Local
Kansas	Shared	Shared
Louisiana	State	State
Maine	State	State
Maryland[d]	Varies	Varies
Massachusetts	State	State
Michigan	Local	Local
Minnesota	Local	Local
Mississippi	Local	Local
Missouri	State	Local
Montana	State	State
Nebraska	Local	Local
Nevada	State	State
New Hampshire	State	State
New Jersey	Local	Local
New Mexico	State	State
New York[e]	State	State
North Dakota	State	Local
Ohio	Local	Local
Oklahoma	State	State
Pennsylvania[f]	Local	-
Rhode Island	State	State
South Carolina	State	State
South Dakota	State	State
Tennessee	State	State
Texas	State	Local
Vermont	State	State
Virginia	Local	Local
Washington	Local	Local
West Virginia	Local	Local
Wisconsin	Local	Local
Wyoming	State	State
District of Columbia	DPW	DPW

[a]County or state inspects city-owned bridges where city does not have engineering personnel.

[b]45% state/55% local.

[c]41% state/59% local.

[d]State Highway Administration is responsible for inspecting county-owned bridges in 6 of 23 counties. Others are inspected by counties or consultants.

[e]State is empowered to inspect local bridges if owner does not do so. Owners have deferred to the state, and the state does all bridges.

[f]Restricted by law.

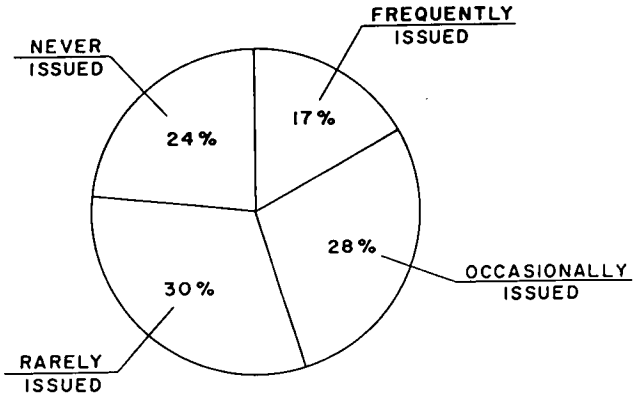

FIGURE 6 Variations in state practice of issuing overload permits on posted bridges.

ALTERNATIVES TO BRIDGE LOAD-LIMIT POSTING

Bridge weight-limit posting is only one method to ensure that public safety is protected when a bridge is structurally inadequate. There are some alternative measures for protecting public safety that are usually available. These are often considered in lieu of weight-limit posting.

Rehabilitation

Bridge rehabilitation is always an alternative to posting, but it is often not feasible because of the location, time, and expense required. Although rehabilitation may eventually be performed and the weight-limit posting subsequently removed, it will probably be necessary to post the bridge in the interim. In some cases, however, bridge rehabilitation may be relatively inexpensive and within the capabilities of maintenance crews. In such cases, it may be possible to shore or repair the bridge immediately and avoid the need for posting. When conditions permit, live-load capacity has been increased by removing excess dead load caused by several layers of nonstructural pavement overlay on the bridge deck.

Many state agencies have the authority to temporarily post a bridge in an emergency. This is often done while a more formal, permanent posting is being sought. In general, there is a limit to the amount of time that a bridge can be temporarily posted. If, however, this time is sufficient to allow the bridge to be rehabilitated and funding is available to perform the rehabilitation, then it may not be necessary to seek a permanent posting.

Bridge Closure

Bridge closure is usually considered when the weight-limit rating of a bridge is too low to make enforcement feasible or when the bridge has deteriorated to an extent that there is a real danger of collapse. The AASHTO manual requires that a bridge be closed if it is incapable of carrying 3 tons (2.7 Mg). It is usually necessary to permanently barricade or remove the bridge if closure is to be effectively enforced.

Frequent Inspections

Load-limit ratings are established at a level that will result in a small probability of structural failure. Failure may result because of overestimation of the in-situ strength of the structure or an underestimation of the effect of loadings. Implicitly considered in the AASHTO inventory rating are factors of safety to account for uncertainties resulting from structural deterioration, fatigue, and increased live-load patterns over the life of the structure. If the bridge is inspected frequently, deterioration and indication of overstress can be detected before they can seriously affect the strength of the bridge. In such a case, each inspection can be considered a reevaluation of the structural condition and may affect the load rating. Each reevaluation will be valid only for the period between inspections, and when monitored on this basis a structure may safely carry loads greater than indicated by the inventory rating. The AASHTO manual allows frequently inspected bridges to be posted for weight limits higher than the inventory rating. However, the posted weight should never exceed the operating rating.

States that post at weight limits above the inventory rating are in effect acknowledging that their scheduled inspections are sufficient to allow posting at the higher level. Several states surveyed indicated that they consider more frequent inspections an alternative to bridge weight limits.

Other Restrictions on Bridge Use

Load-limit posting is only one method of controlling traffic to ensure the safe operation of a bridge. Several other methods can also be used that might greatly reduce the hardship to the public. Most of these methods would be most desirable on roads with relatively low traffic volumes.

Several methods have been used to limit the number of trucks on a bridge at any one time. If this can be done successfully, the need for weight-limit posting can often be avoided. One method of limiting the number of trucks is to post the bridge with a sign reading "one truck at a time," "one lane bridge," etc. Several states use this method when low traffic volume, sufficient sight distance, and bridge length permit. A more positive method for restricting all bridge traffic to one lane is to construct curbs limiting the usable bridge width to one lane. This method has the additional advantage of restricting truck wheel lines to the most desirable location. An example of this would be a truss bridge where the wheels were located in such a way as to load each truss equally.

Another method of limiting the number of trucks in a given lane would be to utilize traffic control signals, allowing only one vehicle at a time to pass. If the signal were placed near the end of the bridge, this method could also be used to restrict speed by requiring vehicles to stop before proceeding.

The dynamic effect of live loads, known as impact loading, has been shown to be a function of vehicle speed and the dynamic properties of the bridge superstructure as well as the surface roughness of the bridge and approaches. If vehicle speed can be reduced to a crawl [approximately 5 mph (8 km/h)], then the impact loading can often be reduced or, in some cases, effectively eliminated. In many cases, such a reduction in impact loading can eliminate the need for posting. The survey of state practices revealed that only a few states use a posted speed limit as an alternative to posting. Many states indicated they did not use this method because such speed limits were very difficult to enforce and thus ineffective in reducing impact loading. In cases where high impact loading can be attributed to rough bridge approaches, the need for posting may be eliminated by smoothing these approaches.

CHAPTER THREE

ENGINEERING PRACTICES

INSPECTION

Bridge maintenance inspection is an art combining the application of scientific principles and the type of engineering judgment that is usually acquired through years of experience in the field. A discussion of inspection as it relates to bridge posting practice is conveniently divided into two categories: inspections required before weight-limit posting and inspections required after weight-limit posting.

Inspection before Posting

The primary purpose of the bridge inspection conducted before rating a bridge is to obtain the information necessary for properly evaluating the strength of the bridge and its action under load. This may only require measurements sufficient to verify that a structure was constructed according to plans or it may involve detailed measurements of a bridge for which construction plans are not available. Often a bridge will be in a deteriorated condition and portions of the structure will be less than totally effective in resisting load. It will be the responsibility of the inspector and/or bridge engineer to determine the structural effectiveness of each deteriorated member. The judgment will usually be quantified in terms of a reduced allowable stress, a loss of cross section, or both.

The judgments of the inspector and/or engineer about the effectiveness of deteriorated members, or the actions of these members under load, must be properly incorporated into the rating calculations. For this reason, it is often desirable that those persons become involved, at least to a certain degree, in the rating of structurally inadequate bridges. Of the states surveyed, only eight reported that their inspectors were not directly involved in bridge rating. A few states indicated that their inspectors occasionally performed or checked the rating calculations. Most states indicated a close liaison between inspectors and rating engineers in that inspectors would provide special information and judgment to be used in the rating. Table 8 summarizes the degree to which bridge inspectors are involved in the rating process in each of the states surveyed.

It is sometimes difficult for bridge inspectors to become directly involved in weight-limit rating because many are technicians who lack the engineering background to perform the necessary structural calculations. Therefore, bridge rating is often performed by a separate group of engineers. Many states prefer inspectors who are registered civil or structural engineers because of the engineering judgment required for inspection.

Inspection after Posting

Bridge maintenance inspection must be carried out periodically after posting. Although the National Bridge Inspection Standards require that bridges be inspected at least once every two years, more frequent inspections are recommended for bridges subjected to corrosive environments, scour, or high frequency of operating stresses, or that have questionable assembly details, decaying timber, or poor maintenance records. Often, posted bridges will fall into one or more of these categories.

In addition, certain bridges may warrant more thorough inspections than others. For example, when no observed distress or deterioration is apparent, there is little need to take detailed measurements to monitor the rate of loss caused by deterioration. Badly deteriorated bridges that are also structurally inadequate may require frequent and thorough inspections.

The majority of states surveyed indicated that they inspect their posted bridges more thoroughly and/or frequently than other structures. Although the frequency of inspection varies, a typical frequency often quoted for this type of bridge was once every year. Many states will alert road maintenance personnel to a problem bridge. Because these individuals drive the roads on almost a daily basis, they can monitor structures for obvious signs of distress.

BRIDGE STRUCTURAL EVALUATION

Bridge postings are usually based on the results of an analytical evaluation of the structural strength of the bridge. Some guidance for performing this type of evaluation is given in the AASHTO Manual for Maintenance Inspection of Bridges (*5*). However, the AASHTO manual allows considerable leeway for the use of engineering judgment in evaluating or posting a bridge. This leeway has resulted in considerable variation in the ways different states evaluate and post bridges.

Safety and Reliability

To perform an evaluation it is necessary to know something about the available capacity, the applied loading, and the response of the structure to that loading. Knowledge and information with respect to each of these items is never complete; and therefore, safety factors are used to ensure that failure does not occur.

The AASHTO manual states: "In the determination of proper safety factors, the absolute safety to all types of vehicle loads shall be kept in mind, but the adoption of unreasonably large safety factors, causing unnecessary hardship on economic hauling, is to be avoided" (*5*, Art. 5.1.1).

This statement is applicable to the load level that would be used in weight-limit posting. The NBIS requires posting if the weight of vehicles legally allowed on the highways is greater than the load permitted under the operating rating. The AASHTO manual indicates that the posting should be at the

TABLE 8

BRIDGE INSPECTOR'S INVOLVEMENT IN CONDUCTING THE RATING

Agency	Performs Calculations	Reviews Calculations	Provides Information and Judgment	Not Directly Involved	Other
Alabama			X		
Alaska	X				
Arizona			X		X[a]
Arkansas			X		
California[b]	X	X	X		
Colorado			X		
Connecticut			X		
Delaware	X		X		
Florida			X		
Georgia	X				
Hawaii			X		
Illinois			X		
Indiana[c]	X	X	X		
Iowa				X	
Kansas			X		
Louisiana[d]			X[d]		
Maine	X[e]		X[f]		
Maryland					X[g]
Massachusetts				X	
Michigan				X[h]	
Minnesota			X		
Mississippi			X		
Missouri			X		
Montana				X	
Nebraska				X	
Nevada	X	X	X		
New Hampshire[i]			X		
New Jersey[j]	X	X			
New Mexico			X		
New York			X		
North Dakota				X	
Ohio				X[k]	
Oklahoma			X		
Pennsylvania			X[k,l,m,n]		
Rhode Island			X[o]		
South Carolina					X[l]
South Dakota			X		
Tennessee			X[m]		
Texas			X		
Vermont			X		
Virginia			X		
Washington[p]	X	X			X
West Virginia			X[n]		
Wisconsin			X		
Wyoming			X		
District of Columbia			X		
Alberta			X		
Ontario			X		

[a] Ratings for state-owned bridges are calculated by bridge design staff. Bridge inspectors perform calculations on some local government bridges.

[b] Inspection engineers can be involved in any combination of those marked.

[c] Inspectors performing the routine biannual inspections are not involved in rating calculations or review.

[d] Field inspection reports are used as part of the department's weight policy. Inspectors provide all data for structural analysis of timber bridges.

[e] 30% local bridges only.

[f] 30% state bridges.

[g] Inspectors provide data to engineers.

[h] Rating is done by special design groups. Field measurements and data are provided by inspectors.

[i] All weight limits are determined by registered professional engineers.

[j] If the inspection is done in-house, bridge inspectors perform the calculations. If the inspection is done by a consultant, bridge inspectors review their calculations.

[k] Generally, inspectors are skilled technicians supervised by a professional engineer and are not involved in the bridge load-capacity rating process.

[l] Inspectors are capable of making calculations in some circumstances.

[m] Bridge inspectors complete forms and provide pictures and descriptions of problems. These reports are reviewed and the bridge elements are rated by engineers and technicians before the work is finally reviewed by a registered professional engineer (P.E.).

[n] Bridge inspectors provide a report showing all detail and condition data necessary for engineers to make a structural analysis.

[o] Special information is provided through the chief of the section if requested by the inspection engineer.

[p] Answers pertain to state. Involvement of local agency inspectors varies with the capability of the inspectors.

load level used for the inventory rating (unless an agency has a strict inspection program). These two requirements present an anomaly in that a bridge need not be posted where legal loads are above those permitted by the inventory rating as long as they are below those permitted by the operating rating.

A survey of the states showed considerable variation in the load level used for posting. Some states' posting policies are dependent on the bridge type. In general, approximately 40 percent of the states post at the operating level, 30 percent at inventory, and 30 percent somewhere in between.

With respect to the question of safety and reliability in bridge posting, there are several recent efforts that are worth mentioning. NCHRP Project 10-15, "Structural Strength Evaluation of Existing Reinforced Concrete Bridges," is directed toward improving the methodology for evaluating the structural capacity of reinforced concrete bridges and developing a new approach to safety in bridge rating. This approach is directed toward eliminating much of the current lack of uniformity and, although specifically developed for reinforced concrete bridges, may also be applicable to other types of bridge structures.

When completed, this methodology for evaluating structural strength will be presented in guideline form. It will utilize a limit-states format with both load and resistance factors. This format provides a basis on which probability theory and engineering judgment can be rationally combined to allow for independent consideration of each of the major variables that can affect the determination of the live-load capacity of a bridge. The proposed methodology includes consideration of the level of effort in maintenance and inspection, the degree of weight-limit enforcement, the quality of the original construction, the refinement used in simulating the bridge, the effects of deterioration on the load-carrying capacity, the effects of deterioration on the response, and the degree of refinement in determining the load distribution factors. For the most part, these factors are currently considered intuitively when selecting the load level at which to post. This new methodology would allow for a more formal consideration of these factors and therefore encourage uniform posting practices.

The Ontario Ministry of Transportation and Communication has recently conducted a landmark effort by rewriting their bridge design code (*11*). The code was written through the efforts of seventeen subcommittees, each composed of approximately five people representing government, industry, private practice, and the universities. The new code, which is written in the limit-states format with load and resistance factors, explicitly states that ultimate load capacity and serviceability must be considered as the limit states and that both limit states must be included in design. The values of the load and resistance factors for the ultimate load capacity were selected to yield a probability of exceeding a limit state over a 50-year period of approximately 1 in 10,000.

The code also discusses the structural strength evaluation of existing bridges. When evaluating existing bridges, only the ultimate limit states are considered. The load and resistance factors specified for design may differ from those allowed for rating existing bridges. This is justified on the assumption that the resistance and action under load of an existing bridge are often known or can be measured with greater reliability than for a bridge that has yet to be constructed and that may be subjected to unknown deterioration, distress, and/or loadings. Therefore, the probability of failure can often be predicted with equal reliability by using different load and resistance factors.

The Canadian Standards Association (CSA) has also rewritten its bridge-design code based on a limit-states approach in a load-and-resistance factor format (*12*). The CSA has written a supplement to its code, covering the structural evaluation of existing bridges (*13*). This supplement on bridge evaluation takes a novel approach to code development in that it allows the engineer to select the target probability of failure. Guidelines for doing this are included in the code. Load and resistance factors for evaluation will depend in part on the selected probability of failure. When selecting the load and resistance factors the code provides for direct consideration of many sources of variation, including both load effects and resistance.

Load Configurations

The types of loads considered when determining a weight-limit rating are usually limited to gravity loads, such as the dead load of the bridge superstructure rails, overlays, major utilities, and any other significant nonstructural features, plus the vehicle live load and its corresponding dynamic effect (impact). Loadings such as earthquakes, wind, or other environmental loads may be included under special conditions, but in general these loads do not have a major effect on the members most affected by gravity loads. In addition, some engineers believe that the probability of environmental loads occurring when the structure is subjected to maximum gravity loading is extremely small. Only a few of the states surveyed indicated that they ever consider environmental loads when evaluating the vehicular weight limit for a bridge.

The traffic live load for determining the live-load capacity should be representative of the actual vehicles using the bridge. Highway vehicles come in a wide variety of sizes and configurations, and no single vehicle can accurately reflect the effects of all of these vehicles. Because it is necessary to limit the number of vehicle configurations considered to a manageable level so that the evaluation process will not become too cumbersome, only a few live-load configurations are used; but these envelop the effect of actual vehicles.

Of equal importance is the number of vehicles to be considered on the bridge at any one time. This number should be limited to the maximum number of vehicles likely to be on the bridge under normal traffic situations.

Judgment must also be exercised with regard to sidewalk loadings. The likelihood of the maximum truck loading occurring at the same time as the maximum sidewalk loading is small. The sidewalk loading used to evaluate the vehicular weight limit will generally be less than the design sidewalk loading.

The AASHTO manual states that the live load to be used for rating may be AASHTO "H" or "HS" design trucks, legal trucks defined in the manual, or trucks conforming to the size and configuration of actual legal trucks in the state where the bridge is located. The manual states that only one truck need be considered per lane, except in the case of bridges with span lengths in excess of 200 ft (60 m) or when the maximum allowable truck weight is less than 12 tons (7 Mg). Each lane shall be loaded in accordance with the AASHTO design specifications, with the following exceptions: (a) the minimum roadway width for two lanes of traffic will be 18 feet, (b) fewer lanes may be considered if warranted by traffic conditions, and (c) truck trains shall be considered to be in only one lane with no more than one unit in any adjacent lane. The maximum assumed

sidewalk loading should also be included in the calculations of capacity.

The maximum allowable vehicle weight is most significantly affected by the number of axles, their spacing, and the portion of the gross weight carried by each axle. Larger gross vehicle weights will almost always be acceptable if the number of axles and/or their spacing are increased. Therefore, use of the AASHTO "H" and "HS" design vehicle configurations for rating will result in conservative gross weight limits because their wheelbases are much shorter, their number of axles are fewer, and their differences in axle weights are greater than typical legal vehicles that most frequently use the highways. Establishing weight limits with AASHTO "H" and "HS" vehicle configurations will therefore likely result in a very low probability of the occurrence of reaching the allowable stress in the structure when a passing vehicle's weight is near the weight limit.

TABLE 9

VEHICLE CONFIGURATION USED FOR RATING A BRIDGE FOR POSTING

Agency	Rating Vehicle(s)
Alabama	AASHTO legal vehicles[a]
Alaska	AASHTO legal vehicles
Arizona	AASHTO legal vehicles
Arkansas	Modified legal vehicles (Type 3 & 3-S2)
California	AASHTO legal vehicles
Colorado	Modified legal vehicles (Type 3, 3-S2, & 3-2)
Connecticut	AASHTO legal vehicles
Florida	Eight typical legal truck configurations (Type SU2, SU3, SU4, C3, C4, C5, H, & HS)[b]
Georgia	AASHTO legal vehicles
Hawaii	Modified legal vehicles
Illinois	Modified legal vehicles (Type 3, 3-S1, & 3-S2)
Indiana	AASHTO legal vehicles and AASHTO H vehicles
Iowa	Modified legal vehicles (Type 4, 3-S3, 3-3)
Kansas	AASHTO legal vehicles and AASHTO H & HS vehicles
Louisiana	Modified legal vehicles (Type 3 & 3-S2)
Maine	AASHTO legal vehicles
Massachusetts	AASHTO legal vehicles and AASHTO H vehicle
Michigan	Modified legal vehicles (Type 3, 3-S2, and Michigan 11-axle truck)[b]
Minnesota	Modified legal vehicles (Type 3, 3-S2, & 3-S3)
Mississippi	Modified legal vehicles
Missouri	Four typical legal truck configurations (H20, 3-S2, MO5, 3-S3P) and typical school bus[b]
Montana	AASHTO legal vehicles
Nebraska	AASHTO legal vehicles
Nevada	AASHTO legal vehicles
New Hampshire	AASHTO H & HS vehicles
New Jersey	AASHTO legal vehicles
New Mexico	AASHTO legal vehicles
New York	AASHTO H & HS vehicles; in some cases AASHTO legal vehicles are used
North Dakota	AASHTO H vehicles
Ohio	Modified legal vehicles (Type 4S1, 5C3, & 6T1)[b]
Oklahoma	AASHTO H & HS vehicles
Pennsylvania	Modified legal vehicles
Rhode Island	AASHTO H vehicles
South Carolina	AASHTO legal vehicles
South Dakota	Modified legal vehicles (Type 3, 3-S2, & 3-2)
Tennessee	AASHTO legal vehicles
Texas	Modified legal vehicles (Type 2, 3, & 4)
Vermont	AASHTO H, HS, & 3-S2 vehicles plus 4 special vehicles (3, 4, 5, & 6 axles)
Virginia	AASHTO H & HS vehicles
Washington	Modified legal vehicles (Local agencies use AASHTO legal configurations)
West Virginia	AASHTO legal vehicles
Wisconsin	AASHTO legal vehicles
Wyoming	Modified legal vehicles (Type 3, 3-S2, & 3-3)
District of Columbia	AASHTO legal vehicles
Ontario	Modified legal vehicles (single truck unit, truck-trailer, and truck-semitrailer-trailer)

[a]From AASHTO manual.

[b]See Appendix.

The vehicle configurations used for rating bridges vary among the states. The survey of practice indicated that of the 45 agencies responding, approximately half use the typical AASHTO legal trucks. The remaining states use special legal truck configurations developed for their states, or AASHTO "H" or "HS" design trucks. The type of rating vehicles used are summarized in Table 9, and the rating vehicles used in some of the nontypical states are described in the Appendix.

Another factor that has a significant impact on structural strength evaluation is the number of vehicles assumed to be on the bridge during maximum loading. The probability of having more than one legal weight truck on the bridge in a position that would result in the maximum stress condition is small. The probability is smallest when the traffic volume is low and loaded vehicles travel predominantly in one direction. The AASHTO manual specifies that all lanes be loaded when determining the rating except when, in the judgment of the engineer, traffic movement and volume warrants the consideration of fewer lanes. Most states follow the AASHTO recommendations fairly closely and make only occasional use of the lane-reduction clause. Five states responding to the survey consider only a single vehicle at a time on the bridge.

Because the dynamic effects of moving vehicles are related to vehicle weight, it is customary to increase the live-load effects by an impact factor. This approach is particularly useful when the allowable weight of the vehicle is unknown.

As part of the development effort for the Ontario Bridge Code, comprehensive studies were conducted on the dynamic effects of moving vehicles. The findings of these studies led to the development of impact factors that are dependent on the dynamic frequency of the bridge deck.

It is assumed that impact loading is related to the roughness of the bridge deck and the speed of the vehicle. The AASHTO manual allows the vehicle impact factor to be reduced when roadway alignment or an enforced speed limit requires a reduction in speed. AASHTO does not specify a relationship between speed and impact, but the Ontario Bridge Code recommends speed factors that are multiplied by impact factors to account for the effect of reduced maximum vehicle speed. These values are shown in Table 10.

Most states surveyed indicated that a speed limit was difficult to enforce and therefore did not rely on reduced impact except in special cases.

Structural Resistance

Structural resistance is a function of the allowable stresses or strains in the bridge structure. The establishment of allowable values depends on the consequences that are expected to occur when these allowable values are achieved. As an absolute maximum, stress and/or strain values should not result in a condition that could lead to the collapse of the bridge. For the purposes of evaluating the structural strength of bridges, however, it is necessary to define resistance at a level below the absolute maximum value. This is true both because serious structural damage will often result long before the bridge collapses

TABLE 10

SPEED FACTORS FOR REDUCING IMPACT (BASED ON THE ONTARIO BRIDGE CODE)

Maximum Vehicle Speed	Speed Factor
25 km/h (15.5 mph)	0.50
10 km/h (6.2 mph)	0.30

and because it is very difficult to define the maximum resistance at the threshold of collapse. Even the ultimate strengths used with the load factor approach are taken as the assumed ultimate strength of a single structural element. Most bridge structures have built-in redundancies to allow for a redistribution of load that will provide significantly larger resistance to collapse than predicted by the ultimate strength method.

The AASHTO manual provides for two resistance levels. One level, which is used to establish the inventory rating, is determined by using allowable stresses and strains and/or load and resistance factors similar to those used in the design of the structure. Therefore, if the design criteria for a bridge can be established, the inventory rating is often taken to be the design live load. The second resistance level is used to determine the operating rating. The operating rating is defined as the absolute maximum load to which a structure can be subjected on an occasional basis. Although this load is nowhere near the collapse load, it is significantly higher than the inventory load. As was mentioned earlier, there is a considerable difference among the ratings used by the various states in posting their bridges.

Regardless of the resistance level used, it is necessary that a reliable evaluation of the in-place condition of the structure be made. This is usually done during bridge inspection and requires considerable engineering judgment. One of the most troublesome evaluation tasks is determining the allowable stresses and/or the effective cross-section of a member when a bridge is in a deteriorated condition. In addition to the condition of the structure at the time of inspection, it is necessary to project the likely future condition of the bridge over the effective life of the weight-limit rating or until the next inspection.

The AASHTO manual lists nominal allowable stresses that can be used when the bridge is in good condition. These stresses must be adjusted, however, when the condition of the material is poor or when the quality or age of the material does not conform to the listed allowable stresses. Many states have prepared guidelines that can be used to estimate allowable stresses and loss of material in a more uniform manner.

Evaluating completely the load capacity of every structural component in a bridge would be extremely time-consuming. 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. Several computer programs evaluate only the main structural members in the superstructure. Many of the states responding to the survey indicated they do not evaluate several structural components or failure modes unless an unusual condition exists. Table 11 lists some of these components and failure modes and summarizes the number of states that usually do not include these components and failure modes in bridge evaluations.

Some special problems exist for certain types of structures. In steel bridges, fatigue caused by repeated loading may result in a failure. It is often difficult to consider fatigue when posting a bridge, because both the number and size of loadings are important. Although most bridges are usually only subjected to the maximum loading on a few occasions, they are frequently subjected to lesser loading. Because the lesser, repeated loading plays a major role in the fatigue of steel bridges, most states do not make allowances for member or weldment fatigue when determining weight limits, although the survey indicated that at least 11 states do take fatigue into consideration when posting their bridges.

When plans are not available, it is often difficult to determine the resistance of reinforced concrete bridges. Special equipment has been used to locate reinforcing steel, but such procedures are expensive and may be unreliable. The AASHTO manual recognizes the difficulties with these reinforced concrete bridges and allows bridge owners to defer posting of such bridges if they have been carrying normal traffic for some time without signs of distress. Most states surveyed take advantage of this clause in the AASHTO manual. However, this clause is interpreted to require posting for a similar reinforced concrete bridge in the same condition if plans are available.

If distress is present in a reinforced concrete bridge without plans, then posting may be required. The determination of the posting load in such a case may be based on engineering judgment. In some cases, engineers have physically removed concrete cover to count reinforcing bars.

Rating Method

The AASHTO manual allows the use of either the allowable-stress or load-factor methods in bridge weight-limit rating. In the allowable-stress method, stresses are not permitted to exceed maximum specified values. For example, tension in steel is specified as 55 and 75 percent of the yield stress for the inventory and operating loads, respectively. Elastic analysis methods are used to determine the state of stress in a bridge. The load-factor method provides that the ultimate strength of a structural member (factored for reinforced concrete and unfactored for steel) shall not be exceeded when subjected to factored loadings. Ul-

TABLE 11

SUMMARY OF THE NUMBER OF STATES THAT USUALLY DO NOT CONSIDER CERTAIN COMPONENTS OR FAILURE MODES IN RATING

Component or Failure Mode	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 components or failure modes	3	3	3	3

timate strengths are determined by assuming inelastic behavior, but analysis is by elastic methods.

Most agencies surveyed use the allowable-stress method for rating all of their structures. Others use the load-factor method for some structures and allowable-stress for others. For example, a few states use load factor for rating reinforced concrete bridges and allowable stress for steel bridges. Only two agencies surveyed used the load-factor method for all of their bridges.

Because load-factor methods are relatively new, they have not had an opportunity to become fully implemented. Several states are considering using the load-factor approach. One reason why implementation of load-factor rating methods has been slow is that many states make use of computer programs for their ratings; these programs originally utilized allowable-stress methods, although they now have load-factor capability.

Load Tests

Load testing is a potential method for verifying the necessity for posting. Behavior of a structure under load may be different than assumed in the standard methods used for bridge evaluation. Load testing is one way of determining the true structural response of a bridge. Nearly a third of the states surveyed indicated that they had on certain special occasions made use of physical load tests when rating a bridge.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

SUGGESTED ADMINISTRATIVE IMPROVEMENTS

It is difficult to suggest specific administrative improvements to bridge posting because of the considerable variations in the administrative environments of the states. As long as a method within a state is working well, there is no need to alter it. Standardization of administrative practices should not be a goal. In reviewing state practices, however, several observations were made that are worthy of comment.

State-Local Relations

The majority of structurally inadequate bridges are locally owned. Because of the requirements of the NBIS, the state is often involved in inspecting and evaluating these bridges. In most states, however, bridge posting is primarily the responsibility of the local agency. To ensure that potentially unsafe bridges are posted, the states and the local agencies must vigorously pursue a close working relationship. The key elements in such a relationship are respect and trust.

Local control is a long-standing tradition of American government and should be respected. The relationship between state and local governments with respect to bridge posting should be as equal partners striving toward the same goal of protecting the public safety. The state should respect the local agencies' rights to post their own bridges and be able to trust that local agencies will act in the best interests of the general public. Conversely, local agencies should be able to respect and trust the engineering judgment of the state.

State agencies should not force local agencies to accept their engineering judgments, but should be willing to supply these judgments to local agencies if asked. If state law prevents such state and local cooperation, and this has resulted in structurally inadequate bridges going unposted in the past, then state legislators have a responsibility to amend the laws to allow for better state-local cooperation.

Respect and trust must be built on understanding. It is sometimes difficult for non-engineers to understand the structural problems of bridge maintenance engineering and the need and purpose of bridge weight-limit posting. Many local agencies do not have a bridge engineering staff and therefore may be mystified by the bridge-posting process. These agencies often encounter considerable public pressure and may find it very difficult to defend bridge posting. A large part of the public does not understand the bridge-posting process either, which is one reason why there is sometimes such strong opposition to bridge posting.

A program to inform the public about the bridge-posting process and the need for and purpose of bridge posting would help to alleviate these problems. Such a program should be the primary responsibility of the states, with the federal government participating. If properly informed, local agencies and the public would be less likely to believe that postings were being forced on them. This would encourage trust between engineers and non-engineers. Local agencies would tend to be more cooperative in posting structurally inadequate bridges, and the public would be more likely to direct their frustrations in a more positive direction, such as campaigning for the rehabilitation of public highways.

Public Relations

One of the major problems with respect to bridge weight-limit posting is the continued use of posted bridges by overweight vehicles. A large part of this continued use is caused by a lack of confidence and trust on the part of the trucking industry and the public. In most cases, there is a need to improve the current relationship between bridge engineers and the general public. The information program discussed earlier would help alleviate some of this distrust.

Although only three states indicated they had public hearings as part of the posting process, it seems that such hearings can serve very important public relations purposes. An open hearing dispels the notion that officials are trying to post a bridge by "going behind the back" of the public. The hearing can serve the function of informing the public regarding the need for posting and give them an opportunity to air their concerns. Although public pressure should not be allowed to affect engineering decisions, the public will have an opportunity to influence future highway planning by expressing their needs for improved transportation facilities. Another advantage of the public hearing is that it notifies the public of a bridge posting. Inadequate notification is often a problem that can tend to encourage motorists to ignore posted weight limits.

Signing

Currently, many states are not using the standard weight-limit signing recommended by the MUTCD. Some of the standard signs are not used at all, while other signs have ambiguities that require modification to be in compliance with state laws. It has been suggested that one reason for this is that bridge inspection engineers have not been sufficiently involved in the development of signing standards. A review of all current signing practices with the goal of developing standard weight limit signs should be initiated, and bridge inspection engineers should be heavily involved in the process.

Enforcement

Although improved public relations may reduce the incidence of bridge load-limit violations, there will always be those who continue to utilize the bridge illegally. A vigorous enforcement effort is needed to discourage these few individuals. At the present time, bridge weight-limit enforcement is not given sufficient priority. There is a need for increased patrolling and weighing of overweight trucks, higher fines, and stricter courts.

SUGGESTED ENGINEERING IMPROVEMENTS

Opportunities for Future Research

At the present time, there is too much variation in posting criteria among the states. Differences are often justified, but the current AASHTO manual and NBIS, while allowing for variation, do not provide guidance in rationally selecting the most appropriate criteria. Improved criteria should be developed that will allow states and local jurisdictions to account for factors that could legitimately affect the posted weight.

It is proposed that these criteria be formulated as a limit-states approach with load and resistance factors. They should be specifically developed for the evaluation of existing bridge structures and would therefore be different from design criteria. Selection of load and resistance factors for a particular case would depend on the level of effort in performing the evaluation, the level of structure maintenance, the type of materials, the nature and amount of deterioration, the frequency and degree of inspection, the control of live loads, and the type of response analysis used. Each of these factors would affect the reliability of nominal resistance and load effects obtained during an evaluation. Thus, load and resistance factors would be adjusted to reflect the difference in reliability, with the objective being to obtain weight limits that would result in an equal probability of structural failure.

When implemented, these criteria would lead to a more consistent determination of weight limits. In certain types of bridges that have traditionally been underevaluated, specifically those with a high dead-to-live-load ratio, this approach would result in more realistic weight limits.

This approach would also provide a framework on which future improvements could be made. Because the basis of the criteria would be clearly stated in probabilistic terms, new knowledge could be rationally and systematically incorporated into the procedures.

Research is needed to develop these criteria. A pilot effort to do this for reinforced concrete bridges is currently under way in NCHRP Project 10-15. This project, if successful, should be followed by a more comprehensive project that would involve a number of qualified individuals from throughout the bridge engineering community. The model criteria, developed in this manner, should be refined through a process of trial application. The resulting criteria should then be presented to AASHTO for adoption as a guide specification.

To be truly accepted by bridge engineers on a large scale, computer programs must be developed to assist engineers in applying the procedures. When the benefits of newly developed criteria have been demonstrated, public agencies responsible for funding highway research should consider funding an effort to develop such a program.

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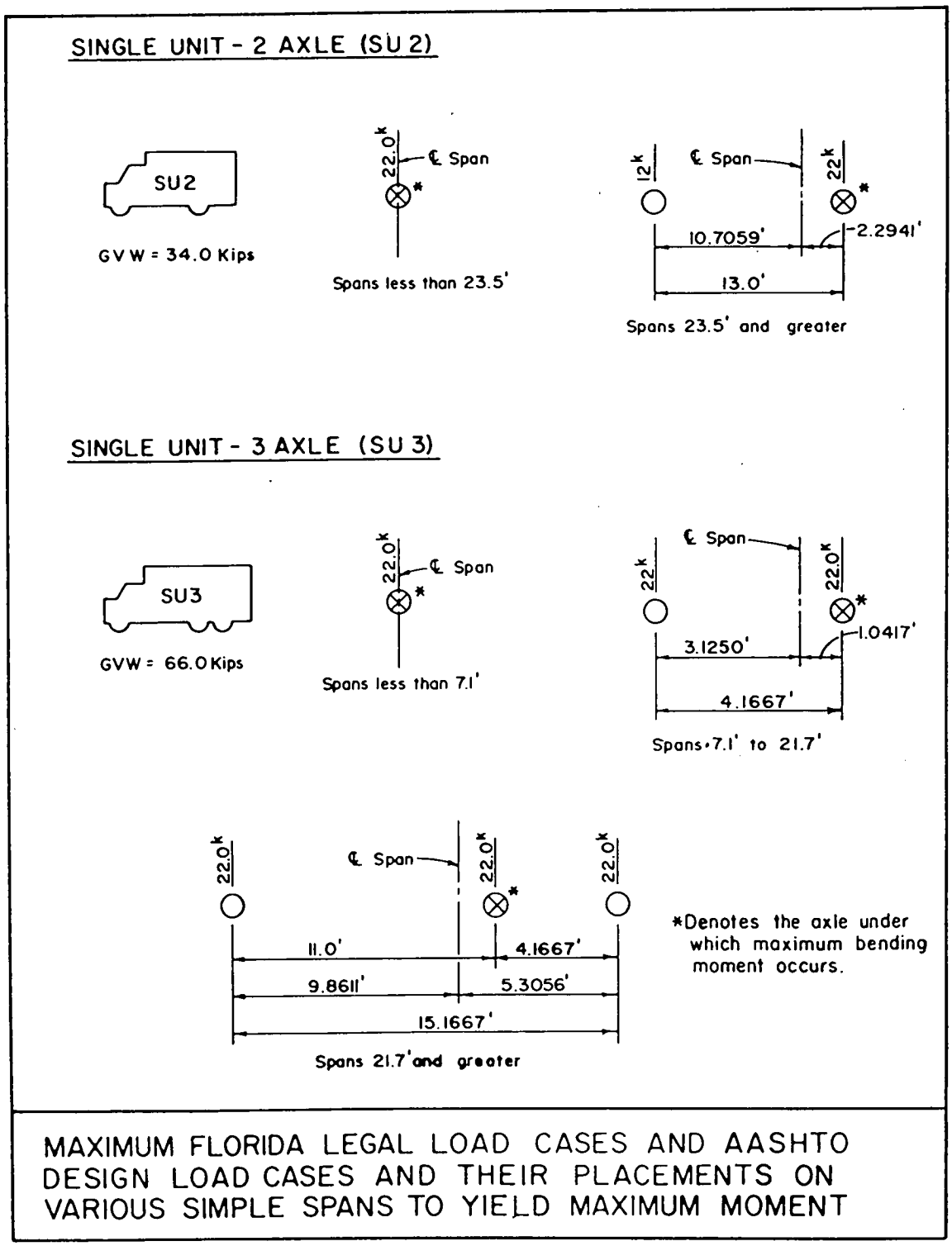
11. Ontario Ministry of Transportation and Communications, *Ontario Highway Bridge Design Code Supplements* (1979).
12. Canadian Standards Association, "Design of Highway Bridges." *CSA Standard CAN3-S6-M78* (August, 1978).
13. Canadian Standards Association, "Design of Highway Bridges Supplement No. 1-1980." *CSA Standard CAN3-S6-M78* (April, 1980).

APPENDIX

VEHICLE CONFIGURATIONS USED FOR BRIDGE RATING

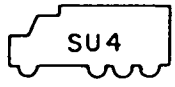
FLORIDA LEGAL LOAD



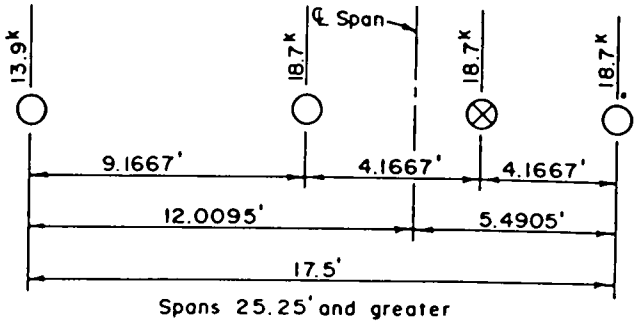
MAXIMUM FLORIDA LEGAL LOAD CASES AND AASHTO DESIGN LOAD CASES AND THEIR PLACEMENTS ON VARIOUS SIMPLE SPANS TO YIELD MAXIMUM MOMENT

MICHIGAN LEGAL LOAD

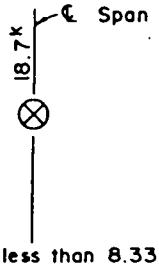
SINGLE UNIT - 4 AXLE (SU4)



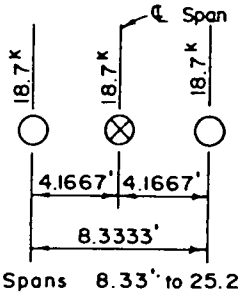
GVW = 70.0 Kips



Spans 25.25' and greater

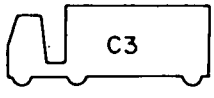


Spans less than 8.33'

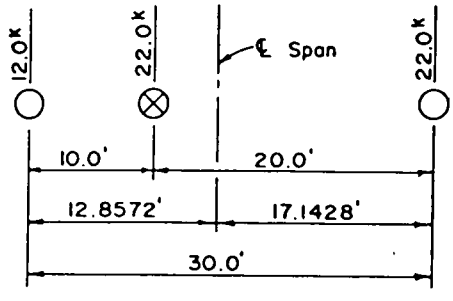


Spans 8.33' to 25.25'

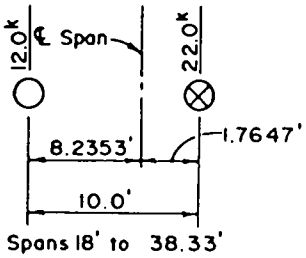
COMBINATION - 3 AXLE (C3)



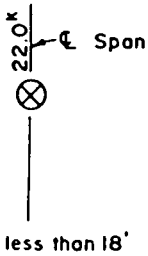
GVW = 56.0 Kips



Spans 38.33' and greater

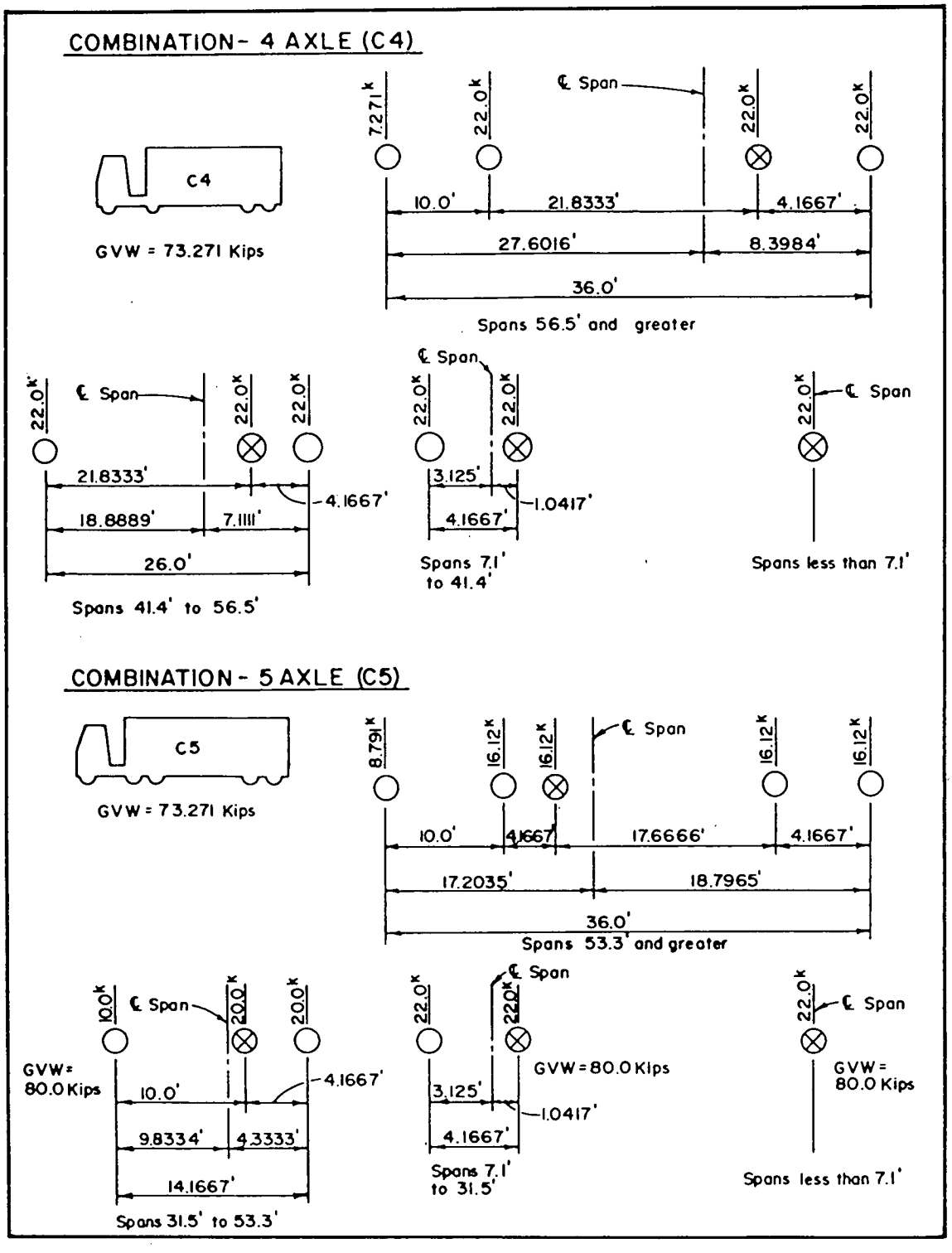


Spans 18' to 38.33'

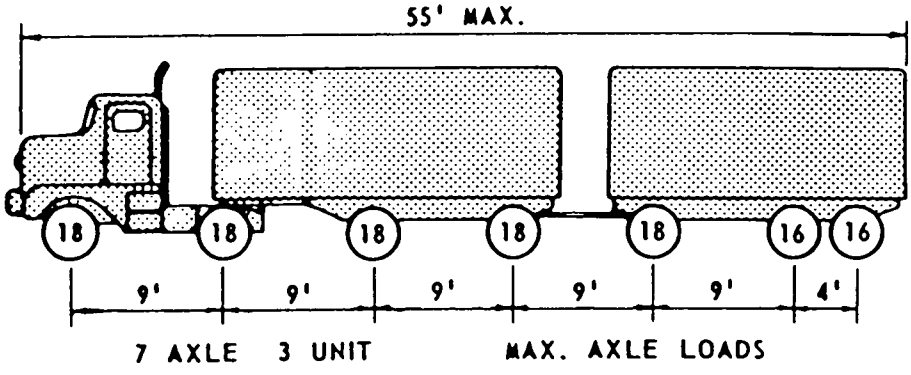


Spans less than 18'

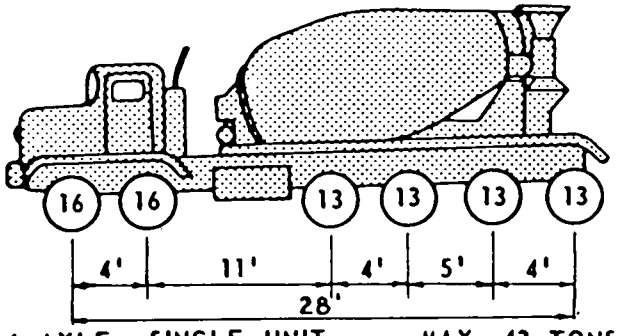
Maximum Legal Loads 1970



Other Maximum Legal Loads



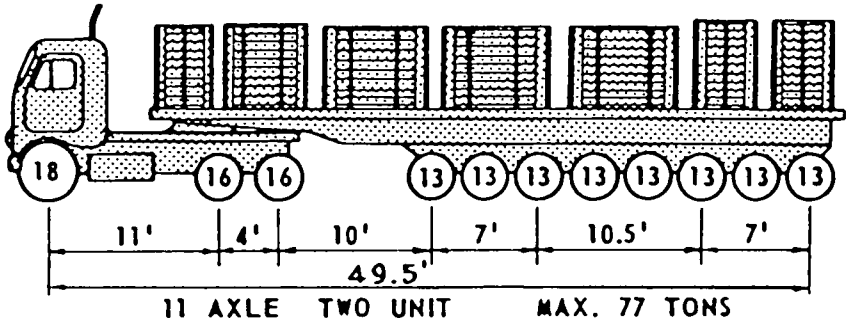
7 AXLE 3 UNIT MAX. AXLE LOADS



6 AXLE SINGLE UNIT MAX. 42 TONS

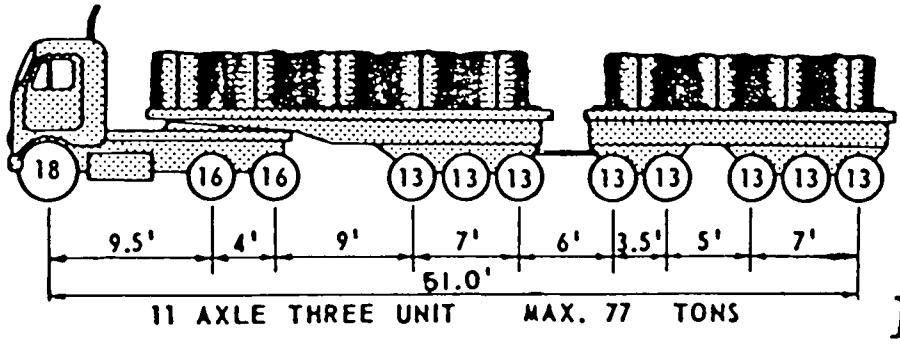
I

NOTE :
NUMBER IN CIRCLE INDICATES 1000 LBS PER AXLE .
AXLE SPACING IS FOR TYPICAL VEHICLES .



11 AXLE TWO UNIT MAX. 77 TONS

II

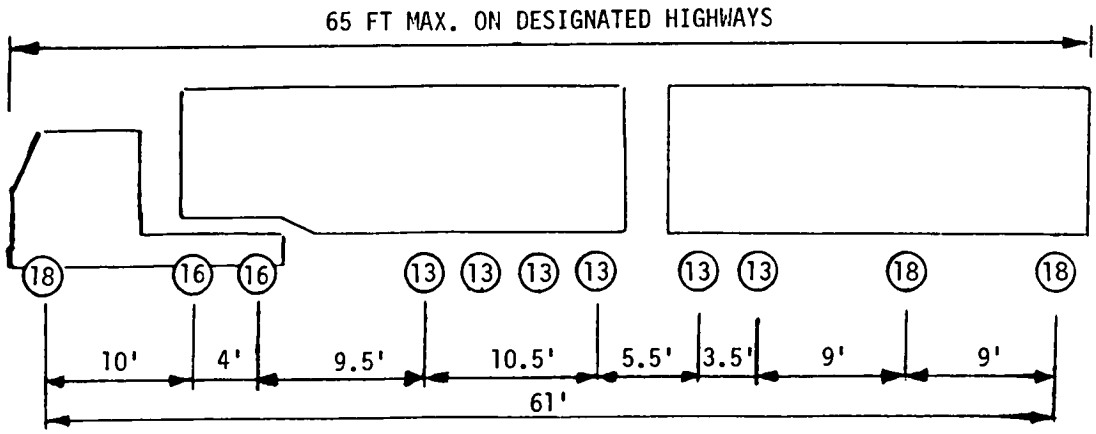


11 AXLE THREE UNIT MAX. 77 TONS

III

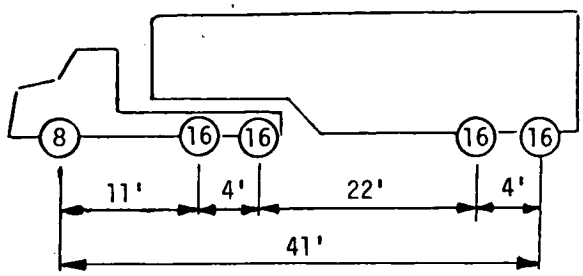
ANY BRIDGE WITH LESS CAPACITY WILL BE POSTED FOR GROSS LOAD LIMIT

MISSOURI LEGAL LOAD



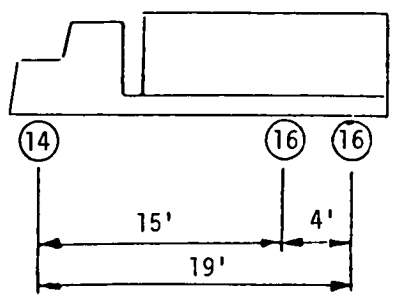
MICHIGAN 11 AXLE THREE UNIT MAX. 82 TON

(MOMENTS ARE LESS THAN THOSE FOR A TWO UNIT 77 TON FOR SPANS LESS THAN 104 FT)



II A

AASHTO TYPE 3-S2 5 AXLE MAX. 36 TON

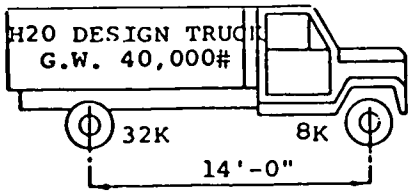


I A

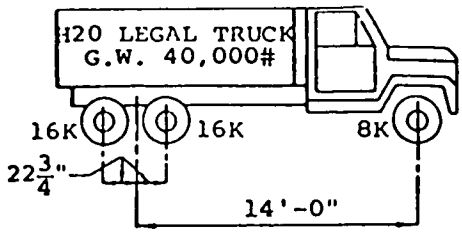
AASHTO TYPE 3 3 AXLE 23 TON

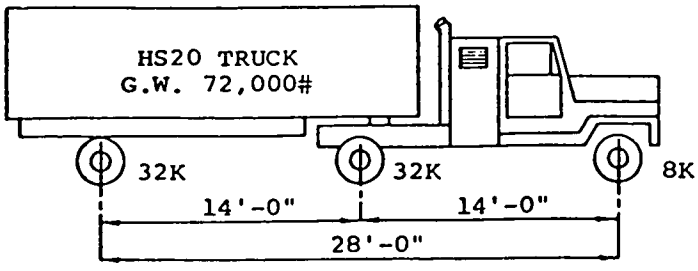
IF ANY BRIDGE DATES BEFORE ABOUT 1920 OR HAS A KNOWN WEAKNESS, THE AASHTO TYPE 3 AND 3-S2 SHOULD BE USED FOR INITIAL ANALYSIS. IF THE RESULTING AXLE LOADS EXCEED LEGAL LOADS THEN USE VEH. I & II.

OHIO LEGAL LOAD

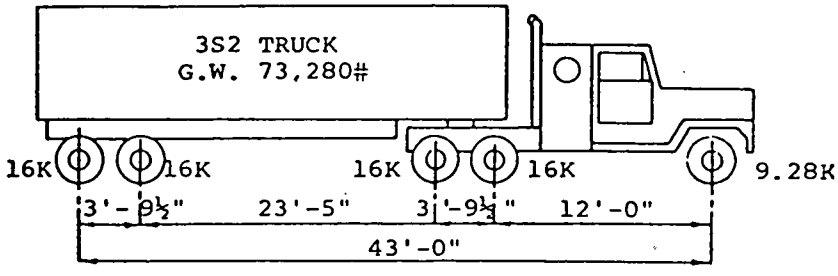


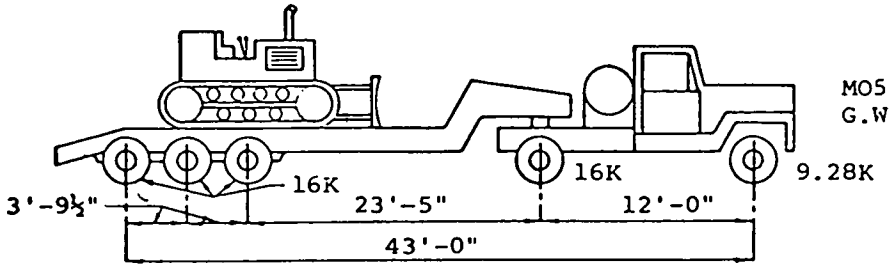
INVENTORY ONLY 55%

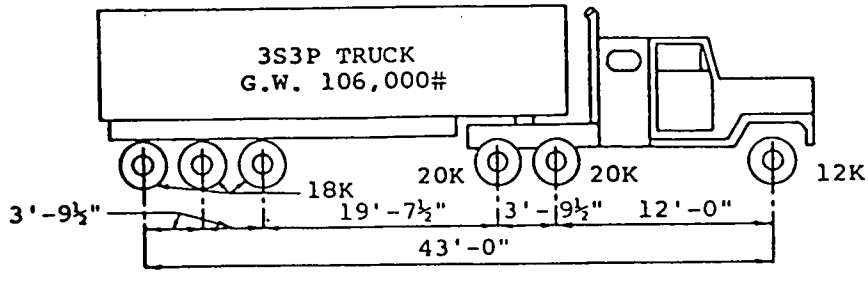


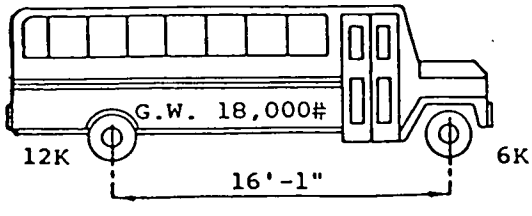


INVENTORY ONLY 55%









Ohio DOT Test Legal Load Descriptions

	Stored Legal Loads					
	Vehicle 1 (4S1)		Vehicle 2 (5C3)		Vehicle 3 (6T1)	
Axle No.	Axle Loads (kips)	Spacing (ft)	Axle Loads (kips)	Spacing (ft)	Axle Loads (kips)	Spacing (ft)
1	10.0	15.0	8.0	12.0	10.0	13.0
2	16.0	4.0	16.0	4.0	16.0	4.0
3	16.0	4.0	16.0	21.0	16.0	4.0
4	16.0		20.0	10.0	16.0	10.0
5			20.0		11.0	16.0
6					11.0	
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
GVW (lbs)	58,000		80,000		80,000	

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