

Using Weight Limits to Protect Local Roads

Wisconsin's extensive local road system is a lifeline for our state and local economies. Farms and businesses depend heavily on these roads to move manufactured, forest and agricultural products. Highway and street agencies need them to economically transport road-building materials. The public also relies on truck transportation to receive goods at reasonable prices. However, heavy truck loads can damage local road pavements, especially in spring when they are weakened because they are saturated with water.

Local officials have a responsibility to preserve our investment in roads by protecting them from excess damage caused by trucks carrying heavy loads. They have the authority to restrict truck weights under state statutes. However, local officials must carefully balance the public good in protecting roads against the legitimate need for efficient transportation.

We can't do anything to control the weather, but we can regulate how much weight is carried on certain roads, especially during spring thaw. According to a national study by the Federal Highway Administration (FHWA), reducing truck weights by just 20% between late February and early May can increase the life of vulnerable pavements by 62%. Cutting weights in half increases pavement life by 95%. To be most effective, truck weight control programs should be coordinated with the Wisconsin Department of Transportation, adjoining local road agencies, the trucking industry, and the public.

This bulletin describes the causes of spring weakness in roads, how heavy loads do damage, and the characteristics of vulnerable roads. Techniques are introduced for determining which roads need protection in spring and when roads are vulnerable, along with guidelines on how to set weight limits. Year round restriction on roads and bridges is also discussed briefly. Another Wisconsin Transportation Information Bulletin, *How Vehicle Loads Affect Pavement Performance, No. 2*, discusses in more detail how heavy trucks damage pavements.



As spring thaw weakens pavements, trucks carrying heavy loads can damage them.

How freezing affects pavements

A road's design is based on a reasonable estimate of the average loads it will carry during its projected life. That is why Interstate highways carrying thousands of trucks a day have thick concrete pavements while rural roads, built for local traffic and a few trucks, are often a few inches of compacted gravel or asphalt laid on a shallow base. Soil types and local drainage characteristics also affect design and load capacity.

To build roads, designers use calculations based on strength and moisture tests of the natural soil or subgrade. The road base and surface depth are then designed for the average condition. Roads can be designed for the worst soil conditions but the cost is usually not justified by the expected use.

When the weather gets cold, pavements and the water trapped within them freeze near the surface. As cold temperatures persist and go lower, the frost line moves deeper into the soil. Frost depth may range from relatively minor—one or two feet during mild winters in southern Wisconsin—to extremes of five to eight feet during severe winters in the northern part of the state.

Frost action and frost heaves

Pavements can be severely damaged in winter by frost heaves from water freezing in the soil. Damage can be particularly bad when the heaving is greater in one pavement section than another or when it occurs next to structures that don't move, like bridges or manholes.

There are three critical factors in frost heave: freezing temperatures, a source of water, and susceptible soils. Frost heave results not just from the natural expansion of water as it freezes, but from the buildup of a series of ice layers, called lenses, that form at the freezing front as it penetrates downward. This can cause heaves of a few inches to several feet.

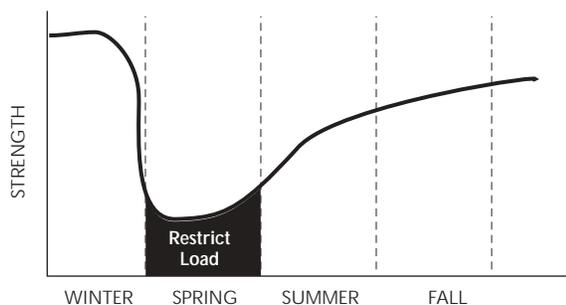
Water comes from the normal water table. Problems are more severe when the water table is near the pavement surface, but significant frost heaving can occur even when it is many feet below the actual frost depth.

Frost-susceptible soils are fine-grained like silt and clay. These permit water to move from the water table to the freezing front through capillary action. Silt is usually the worst because it has enough capillary action to move water and its pore spaces are big enough to transmit large amounts of water. Granular soils like sand have relatively large pore spaces which generally do not have sufficient capillary action to be frost susceptible.

Spring thaw

In spring, roads begin to thaw from both the top and bottom. As ice in the pavement melts, water saturates the road's base and subgrade. These layers lose strength, like a handful of mud compared to dry soil. As thawing continues, melt water becomes trapped in the upper subgrade, unable to drain away through the frozen soils below. Pavements weaken considerably in a very short time under these conditions.

The weakness can continue for weeks or months after the pavement is completely thawed. It takes a long time for water to leave the pavement because frost-susceptible silt and clay soils are relatively slow to drain.



Variation in pavement strength throughout the year.

How heavy vehicles damage roads

Without adequate support, a pavement or gravel surface deflects too much under trucks carrying heavy loads, developing cracks or ruts. These then let more moisture penetrate, worsening the cycle until the road fails completely. The amount of damage a road sustains is directly related to the weight of the load and how often it is applied, according to tests by AASHTO (the American Association of State Highway and Transportation Officials). Passenger autos and light duty vehicles are not a problem. It is trucks carrying legal weight loads of up to 80,000 GVW over weakened surfaces which do the damage. When trucks carry loads that are heavier than the statutory weight limit, the potential for damage is much higher.



Another factor is the amount of weight and number of tires on each axle. Damage increases rapidly with higher axle loads and actually worsens at a faster rate than the load increases. A nine-ton axle load, for example, causes about ten times more damage than a five-ton axle load. Distributing a vehicle's weight and its payload over more axles and tires makes the load lighter at each point of contact, reducing damage to the road.

However, low-inflation tires do not protect roads from damage. It has been commonly assumed that large loads carried by off road equipment would have little adverse affect because they have flotation tires or treads that allow them to work in soft soils. In actual field tests, the South Dakota DOT showed that off road equipment with axle loads that exceeded legal limits caused damage to asphalt, sealcoat, and gravel roads and shortened pavement life.

Imposing restrictions on truck weight limits is a reasonable and practical way to protect vulnerable local roads when they are at their weakest. Spring weight limits should begin with the first thawing and continue until the pavement is again strong enough to carry normal loads.

Choosing roads for spring weight restrictions

Consider the following factors in deciding which roads or segments should have restrictions.

- *Pavement thickness* Asphalt surfaces of two inches or less, or total pavement less than 12 inches thick.
- *Type of subgrade* Fine-grained subgrade soils, like silts and clays, and areas with a high water table and poor drainage.
- *Past experience* Areas with alligator cracking or rutting that break up every year and need frequent patching and repair.
- *Amount and type of truck traffic* Consider all truck traffic and especially seasonally higher volumes of trucks carrying heavy loads.
- *Surface deflection* Pavement sections where the surface deflects or bends 50% more during spring thaw than in summer. Also, increased deflection lower than 50% on weaker pavements where summer deflections are relatively high.
- *Pavement age/condition* Weight restrictions can protect your investment in new pavements and prolong the life of weak or aging pavements.

Year round restrictions — Class II and Class B roads

All public roads are considered to be Class A unless designated otherwise. Vehicle weight restrictions established in Chapter 348 are intended for travel on Class A highways. Some roads, designated Class II or Class B, have permanent weight restrictions, with some exceptions.

The state may designate certain highways as Class II. These are limited to legal loads. No overloads are allowed, even when the hauler has an overload permit. About 1600 miles of state highway, mostly in the north and west, are Class II.

State, county and local authorities may designate all or a portion of their systems as Class B highways under Sections 349.15 and 349.16, Wisconsin Statutes. This designation reduces the permitted weight, year round, not to exceed 60% of the legal load limits. It takes effect when signs are posted and remains in effect until the signs are removed.

Two types of loads are exempted under Class B designation. The rules now allow local pick-up and delivery of full legal loads. Also, waste haulers can haul their full legal load if, because of health concerns, the material must be removed from a septic or holding tank within 24 hours and if they minimize their travel on the weight-restricted roads.



Class B highway designation, which in general is permanent, not seasonal, is intended for situations where the pavement cannot withstand normal, legal truck weights. Such roads may not have been constructed to adequately handle these loads, or they may be roads through low areas with poor supporting soils. The Class B designation is well understood by industry. It is a reasonable option for local authorities when they believe it is necessary to protect pavement. WisDOT recognizes this local authority through administrative code. For example TRANS 255.12(6) requires explicit written permission for movement on Class B local roads even if a state permit has been issued.

Posting reduced load limits, such as a 24-ton limit, is an alternative for protecting roads in weak condition. Local officials may choose this option if the exemptions which were added in 2002 to Class B for local pickup and delivery are unacceptable.

Some bridges may also need protection. Although their strength is not affected by freezing, bridges may be weakened by age. Load limits should be determined by a competent bridge inspector or consulting engineer. As with roads, local agencies have authority to post weight limits for bridges under Chapter 349 of the Wisconsin Statutes. In addition to a sign at the bridge, there must be an advance warning sign at the nearest intersection.

Determining weight limit reductions

A weight reduction of just 20% during critical weeks in March and April can make a major difference in pavement life according to a study by the Federal Highway Administration. As weights are reduced further, potential pavement life increases even more.

Local agencies have the authority to determine seasonal weight limits on their road systems. About 50% of the normal limit is typical, but establishing limits that are consistent with those set by the state DOT and adjoining agencies on nearby roads is strongly recommended. For state highways WisDOT normally uses a

Load reduction	Increase in pavement life
20%	62%
30%	78%
40%	88%
50%	90%

spring weight limit of six tons per single axle and 10 tons per tandem axle.

To be effective, loads should be reduced at least 20%, while reduction over 60% may have little added benefit. Nationally, the average reduction is 44% which would lengthen

pavement life by about 88%, according to study results. Consider other factors also, however. Thin or weak pavements may need significant reductions during spring thaw; small or even modest load reductions will not prevent damage.

Since limits will be ineffective if local haulers do not cooperate with them, the most effective restrictions are reasonable and directly related to pavement damage.

Other remedial actions

Along with restricting load limits, consider other ways of protecting pavements. When haulers seek exemptions, consider including special requirements. For example, a load could be made in two smaller loads. The route could be modified so that pick-up or delivery is made at the start or end, or so that the route is traveled in a different direction. The goal is to minimize the length of travel and number of truck loads on weak road sections.

Another common approach to exceptions is to require that deliveries be made at night or in the early morning when roads may be stronger due to overnight freezing. Be careful not to overuse this approach. If substantial subgrade thawing has started, a light frost in the pavement surface offers limited value.

Physical changes can also help. For example, where pavements are shaded, you can increase exposure to sunlight by removing trees, billboards or other obstacles. Eliminate standing water in roadside ditches and fill pavement surface cracks to reduce the amount of water getting to the freezing zone.

Improve drainage in the roadbed by removing frost susceptible soils. A three foot combined depth of pavement and replacement base will prevent substantial subgrade freezing in the coldest winter in 10, according to the 1993 AASHTO Design Guide.

Install geosynthetics between the free water layer and the freezing zone. Optimal placement depth and whether multiple layers are needed remains to be determined, however. Geosynthetic

reinforcements may also limit damage during spring thaw by helping bridge weak areas and limiting pavement spread.

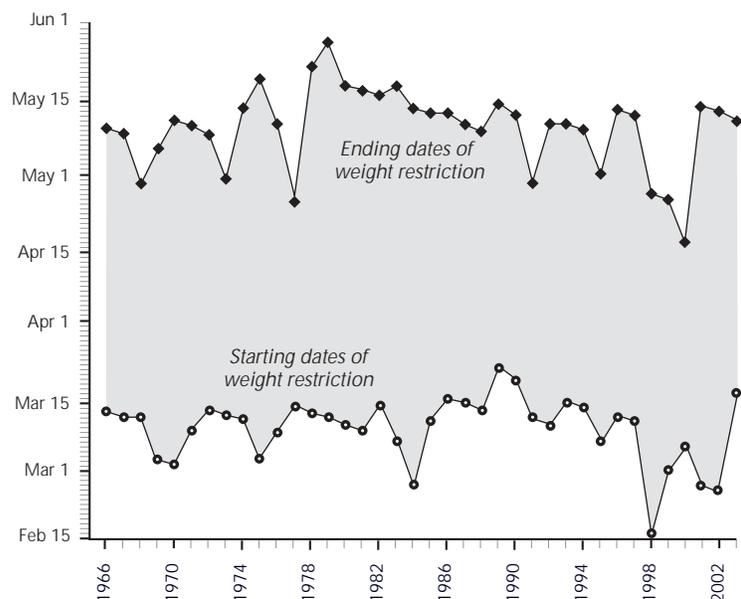
When to begin restrictions

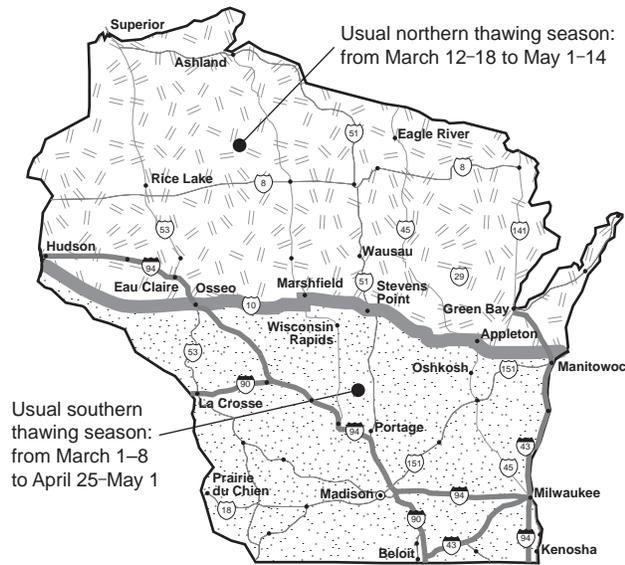
It can be difficult to determine when the thaw begins. In Wisconsin, it generally starts in early March and is complete by early May. According to 38 years of data from the Wisconsin Department of Transportation (WisDOT), the average date for legal load restrictions on some state highways is March 10. Posting usually begins between March 1–8 in the southern half of the state and March 12–18 in the north. The posted road period generally ends between April 25–May 1 in the south and May 1–14 in the north. However conditions in the state can vary considerably from north to south, and even from road to road in the same county. Unusually warm winters also affect road posting dates. Local knowledge of typical thaw periods is extremely helpful.

Since a uniform system of spring weight restrictions is more understandable and enforceable, it is vital to coordinate with the Wisconsin DOT, the county, and adjoining road agencies. Also, when weight limits are not uniform or when some communities post limits and others don't, vulnerable unposted roads may be damaged by truck traffic taking alternate routes.

Local officials should time their road postings to coincide with the spring weight restrictions that WisDOT posts on the state highway system. The county highway department, WisDOT district maintenance office, and the WisDOT central maintenance office can tell you when they will begin.

Wisconsin Spring Weight Limits Season on Class II Road Sections





Thawing conditions can vary considerably from north to south.

To decide on a posting date, WisDOT uses information from frost tubes buried in pavements around the state. A liquid in the tubes changes color when it freezes. District maintenance staff check the tubes periodically to determine frost depth and location.

There are also about 60 automatic pavement and weather monitoring stations in place around the state. By watching reports from these stations on pavement surface temperatures and at 18 inches below the surface, county and state highway staffs can better predict when spring thawing is underway.

For local roads, you generally must use judgment and experience. However, a Thawing Index (TI)—calculated like heating degree days used by winter fuel suppliers—can help you predict when to begin restrictions. Figuring thawing degree days involves recording daily high and low air temperatures in your community and making a

simple calculation. For weaker or problem pavements you may want to record daily highs and lows at the site. Studies also show that the Thawing Index is more reliable for fine-grained soils than coarse-grained ones.

Begin using the Thawing Index when the average daily temperature rises above 29° F—chosen as a reference temperature because tests show that an asphalt pavement surface is 32° F when air temperature is about 29° F. For midwinter thaws, use 31° F as the reference temperature for the Thawing Index because of lower sun angle and increased cloud cover in midwinter.

You can use high and low temperature predictions from a five-day advance weather forecast to project when load restrictions must take effect. This will allow you to prepare the public and alert local heavy haulers.

Pavement thickness determines how many thawing degree days are needed for applying spring load restrictions. The FHWA study *Guidelines for Spring Highway Use Restrictions* has established “should” and “must” Thawing Index levels for thick and thin pavements (see below). The “should” level estimates thaw to the bottom of the base course. The “must” level estimates thaw to about four inches below the bottom of the base course.

When to remove restrictions

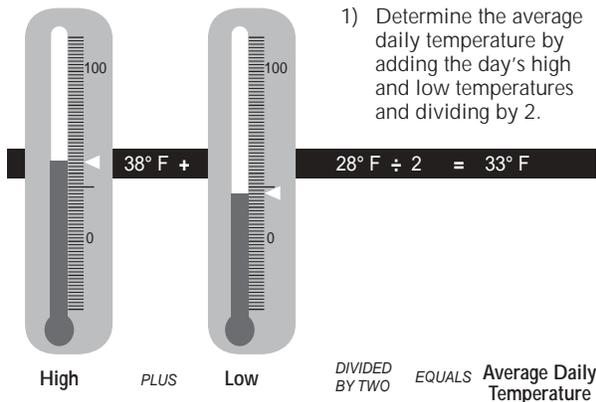
In general, keep weight restrictions in place until soils are completely thawed and drained to normal moisture levels. The most accurate way to tell is by testing for

Thawing Index levels for posting load restrictions on asphalt

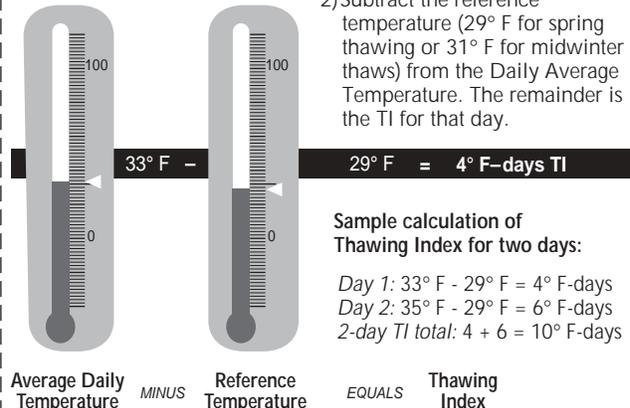
Pavement structure	Thawing Index	
	“Should” Level	“Must” Level
THIN Asphalt 2” or less Base course 6” or less	10° F-days	40° F-days
THICK Asphalt more than 2” Base course more than 6”	25° F-days	50° F-days

Calculating the Thawing Index

Compute average daily temperature



Compute Thawing Index (TI)



2) Subtract the reference temperature (29° F for spring thawing or 31° F for midwinter thaws) from the Daily Average Temperature. The remainder is the TI for that day.

Sample calculation of Thawing Index for two days:

Day 1: 33° F - 29° F = 4° F-days
Day 2: 35° F - 29° F = 6° F-days
2-day TI total: 4 + 6 = 10° F-days



deflection. However, combining judgement and experience with an estimate based on the Thawing Index is very economical and will suffice in many cases.

To make this estimate you must know the Winter Freezing Index. The Freezing Index is calculated the same way as the Thawing Index, using 32° F as the reference temperature. Beginning when the average daily temperature has been below 32° F for several days, calculate daily average temperatures. (Add the high and the low for the day and divide by 2.) Subtract the average daily temperature from 32° F and record the result. Keep a running total until spring thawing begins. This total is the winter's freezing index in your area. High and low temperatures reported in the local media may also work well enough for this purpose.

To calculate the total number of thawing degree days until the thaw is complete, multiply the Winter Freezing Index by 0.3. For example, for a Winter Freezing Index of 1375° F-days, the Thawing Index would be 412° F-days: $0.3 \times 1375 = 412$

Implementing local weight limits

Authority

To institute a permanent weight limit on a road, the local elected board or council should pass an appropriate ordinance and post the necessary signs. For a temporary restriction like spring load limits, the "authority in charge of maintenance" can impose the limits under Section 349.16 of the *Wisconsin Statutes*.

It may not be clear who is the "authority in charge of maintenance." It is best for the local board or council, at a regularly scheduled meeting, to specifically identify a person or position to have that authority. For county trunk highways, the highway commissioner is commonly chosen. Towns, villages or cities should designate their highway superintendent, road foreman, street superintendent, or similarly titled officer. The board or council should also give this person or position authority to issue special weight permits.

The local authority can impose weight limits on a highway or bridge that they believe will be damaged because of roadbed weakness or other special conditions. Signs must be posted to give notice of the restrictions, and these signs must conform to the current *Manual on Uniform Traffic Control Devices* and the *Wisconsin Supplement* to that manual. For bridges there must be an advance warning sign at the nearest intersection. Limits become enforceable as soon as signs are in place.



It can be complicated to analyze the capacities of individual pavements and bridges. Local authorities may use their judgement and knowledge of existing pavement conditions or may hire a consultant to conduct engineering analyses. Limits based on actual testing will stand up to potential litigation better than those based on experience alone.

Legal authority for establishing weight limits is found in Chapters 348 and 349 of the Wisconsin State Statutes. Chapter 348 establishes restrictions on the size, weight and loading of vehicles. Section 348.15 establishes specific truck weight limitations and exemptions.

Sections 348.25, 348.26 and 348.27 outline the provisions for permits for vehicles of excessive size and weight. Such permits are generally issued by the state Department of Transportation for state highways. Local officials also have authority to issue credentials for their road systems under Section 348.26(2).

Chapter 349 gives state and local agencies authority to regulate movement of heavy vehicles. Section 349.15 provides the authority to establish Class B highways on local roads. Section 349.16 gives the authority for local officials to impose special or seasonal weight limitations. Section 349.17 is the authority for cities, villages, and towns to establish designated truck routes.

Exemptions and enforcement

State statutes have many provisions permitting overloads for specific commodities such as milk and logs. As a result, some people believe that this special treatment applies to local roads with load restrictions. This is not the case. In fact, local weight limits override *all* special permits in the statutes. Local officials *may* make exceptions, but are not required to.

Once load limits are posted, numerous requests for exceptions are likely. Local agencies may make exceptions, but it is important to be consistent and reasonable. Overusing exceptions weakens the effectiveness of load limit programs.

Public agency vehicles are not exempt from weight and size restrictions. All statutory restrictions and locally adopted weight restrictions apply uniformly to public vehicles as well as private trucks.

To implement your authority to issue exemptions under Section 349.16(3) it is best to put the exemptions in writing. For commodities that will be exempted either seasonally or permanently, make a good faith effort to publish these rules. If, as a local official, you intend to exempt some commodities, you can still restrict their movement by specifying how often each day they may travel on a road. You may also require that they travel at specific times during the day, such as before 7:30 am when overnight temperatures may have temporarily strengthened the road. Like the basic exemptions, these restrictions should be in writing and publicized.

Before posting roads, local agencies should plan how to enforce the limits. Law enforcement officers can order an apparent violator off the highway and issue citations. Repeat violators must pay higher amounts, and the amount to be paid increases with the amount of weight over the limit.

State Patrol officers and county deputies are authorized to enforce weight limits. The State Patrol offers annual training sessions on enforcing truck sizes and weights for local law enforcement officials. Scales used to enforce weight laws must be certified accurate.

Haulers have another considerable incentive to comply. Under Section 86.02 of the Statutes, a party which has caused damage to the highway is liable for triple the cost to repair the damages. These are collected through civil court.

Speed enforcement is also important because damage is increased at high speed.

Permits

Haulers with loads over the weight and size limitations can request permits for travel on state trunk highways from the Wisconsin DOT. Permits can be for a single trip or multiple trips and are issued at the WisDOT central office in Madison.

Except for vehicles authorized in the Statutes to have excess axle weights (Sections 348.15(3) (bg, br, & bv), trucks which intend to also use local road systems must obtain permission from the local maintenance authority.

Local agencies should establish permit procedures and designate a person with authority to issue them. Assigning this to the same person who establishes weight limits is reasonable and convenient. However, if a different person is issuing permits—the town clerk, for example—it is a good idea to coordinate with the local authority which establishes the limits. Local permit forms may be individualized, but many local officials have found it useful to copy WisDOT forms.

Single trip permits authorize an overweight or oversized vehicle to make one trip over a designated route. The local authority should carefully select roads and bridges that can adequately handle the excess load. Determining these permitted routes can be complex and may require help from an engineering consultant.

When the state puts roads into “thaw status,” it reduces maximum weights for single trip permits. It also suspends the authority for moving overweight loads that are divisible (like garbage, logs, agricultural products), and declares certain vulnerable state highways as Class II roadways which limits the maximum weight during spring thaw to a GVW of 80,000. Class II roadways may also be temporarily posted for even lower weight limits.

Signing for weight restrictions

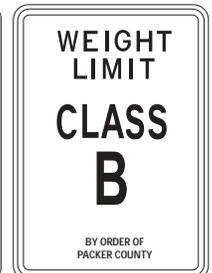
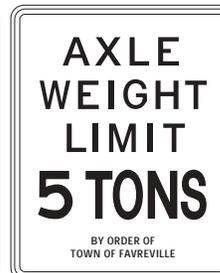
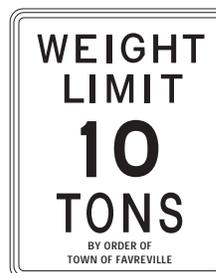
Weight restriction signs are regulatory and should be white with black lettering to conform with the federal *Manual on Uniform Traffic Control Devices (MUTCD)* and the *Wisconsin Supplement*. Uniform signing improves cooperation and makes enforcement easier.

All weight limit signs must say: “by order of” the local agency.

Class B highway signs should be installed at intersections with other highways.

Bridge weight restriction signs must follow instructions from WisDOT. These signs must include the gross weight and maximum limits for axle loads. Signs should be posted at the bridge and also far enough in advance that trucks can detour around the limited structure.

Permanent special weight signs must be permanently installed and designate the maximum gross weight.



Temporary weight limits such as spring load restrictions should also be on standard signs that are reflectorized and that meet the standards of the *MUTCD*. Hand painted and faded signs are not appropriate.

Communication

Effective communication with the public, your own agency, and affected haulers is essential. Alert the local media when weight restrictions are imminent. Remind drivers of public works trucks that weight restrictions apply to them too. Contact industries which make local deliveries or supply local services and tell them what the limits are and when limits will begin.

Consult with local haulers about ways to protect particularly vulnerable roads. For example, milk haulers could alter the order of pick up to lessen the weight at a bad site, or septic pumpers may limit how full their tanks are when traveling problem roads to service customers.

Large construction projects that require hauling heavy construction materials need special coordination in advance. Local officials and contractors should plan together well before the limits are imposed. They can agree on specific hauling routes using roads that are both strong enough and reasonably efficient.

Advance agreements with contractors and other heavy haulers can be very effective. Informal agreements or formal contracts assign responsibility to these haulers for repairing damage along their routes. Some agencies require bonds or escrow accounts in advance to ensure compliance. Inspecting haul routes ahead of time is important in enforcing these agreements. Photographing or video taping is also helpful in documenting existing condition. These techniques establish pavement conditions before spring thaw begins.

The alternative to advance agreements—establishing very restrictive weight limits after bids are in or construction is underway—can be very disruptive and costly, and may result in litigation. Both contractors and local agencies are responsible for this advance coordination.

Summary

Protecting local roads from damage by heavy vehicles is the responsibility of local authorities. *Wisconsin Statutes* provide adequate authority to exercise this control. In establishing weight restrictions, local authorities must use judgment and common sense to balance the need for protecting roads with maintaining commerce and an efficient transportation system. Close coordination with Wisconsin DOT and adjoining local agencies is essential to an effective program. Also, set a good example with your own agency. Be sure that all publicly-owned equipment observes the weight restrictions.

Resources

Guidelines for Spring Highway Use Restrictions, Federal Highway Administration, Report No. FHWA-TS-87-209, Turner-Fairbank Highway Research Center, 6300 Georgetown Pike, McLean, VA 22101-2296. And related videotapes.

State Highway Maintenance Manual, Guideline 30.06, January 1, 1993, Wisconsin Department of Transportation, State Maintenance Engineer for Highways, PO Box 7916, Madison, WI 53707-7916.

How Vehicle Loads Affect Pavement Performance, Wisconsin Transportation Information Bulletin, No. 2, Wisconsin Transportation Information Center-LTAP, 432 N. Lake St., Madison, WI 53706.

Other references

Study Effects of Off-Road Equipment Tires on Flexible and Granular Pavements. An Executive Summary of the South Dakota Department of Transportation describes damage to test pavements. The report is available for download at: http://www.state.sd.us/Applications/HR19ResearchProjects/oneproject_search.asp?projectnbr=SD1999-15 (The 131 page report is a 4.4 MB pdf file.)

Frost Heave: What causes it and how we can interfere with it, Special Bulletin #19, November 1995. Written by Dr. Rich Reid, Asst. Prof. of Civil Engineering, South Dakota State University, for South Dakota Transportation Technology Transfer Service.

A Guide to Spring Highway Use Restrictions: When to Apply, How Long to Apply, and When to Remove. The Bridge Fact Sheet, Spring 1994, Michigan Local Technical Assistance Program, Houghton, Michigan.

Posting and Bonding Local Roads: A Solution to Damages Caused by Heavy Haulers, LTAP Technical Information Sheet #57, January 1994, by Alan L. Gesford, LTAP Engineer, Pennsylvania Local Roads Program, Penn State Harrisburg, 777 West Harrisburg Pike, Middletown, PA 17057-4898.

Walsh County's Load Limit Enforcement Program, by Harvey Melstad, in *The Center Line*, Fall 1990, North Dakota State University.

Legal Opinions by Attorney J.R. Habeck, in the newsletter of the Wisconsin Towns Association.

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