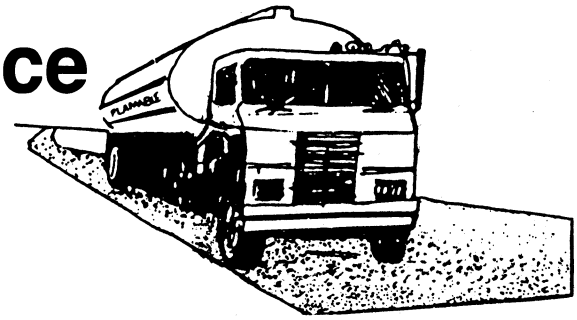
Baystate Roads Program
Tech Notes

How Vehicle Loads Affect Pavement Performance



Why keep roads in good condition? The economy of any area depends on shipping and receiving products and materials: trucks are the most common form of transport. The condition of area roads directly affects the speed, efficiency, and ultimately, the costs of transportation.

What is Pavement Fatigue?

Fatigue is progressive damage from many applications of a load. Pavement usually breaks up from fatigue failure. Here's an example which explains the mechanics of fatigue. Bend a metal rod once, it won't break. Bend it many times and eventually it will break. How far the rod is bent is also important. It will take many more slight bends before it breaks than large ones.

Roads also bend under vehicle loads. As the pavement bends, its various layers are affected differently (see Figure 1). Like the metal rod, the upper portion is compressed while the lower portion stretches. As bending causes fatigue, the pavement surface cracks, which allows moisture into the pavement base and subgrade. This results in greater bending, further cracking and finally failure.

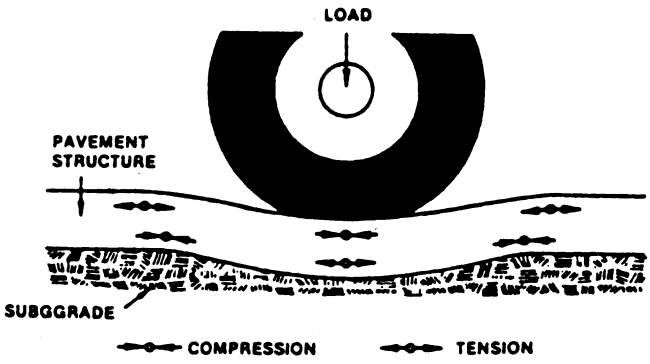


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Figure 1: Repeated tension in the surface layer causes cracking.

Fatigue damage depends on the weight and arrangement of axle loads, the thickness of the pavement, and the strength of the soil below (the subgrade).

Effects of Wheel Loads

There are several basic vehicle wheel arrangements: single wheel, dual wheel, single axle, and tandem axle. Loads per wheel equal the axle load divided by the number of wheels.

Pavement fatigue is measured by the number and weight of axle loads needed to make the pavement unusable. As each axle load is increased, the road can withstand fewer trips before it breaks up. If axle loads are decreased, the pavement will carry more vehicles before failing. The lower the wheel load, the less a pavement bends and consequently, the longer it lasts. Trucks are the primary concern because of their great weight.

Pavement damage increases rapidly with higher axle loads, and actually increases faster than the loads increase. One nine-ton axle load, for example, causes about ten times more damage than a five-ton axle load.

Information on the relative effects of axle loads and wheel arrangements on different pavements comes from the AASHTO road tests in Ottawa, Illinois. These tests developed the *damage unit*, a simple method for measuring pavement damage

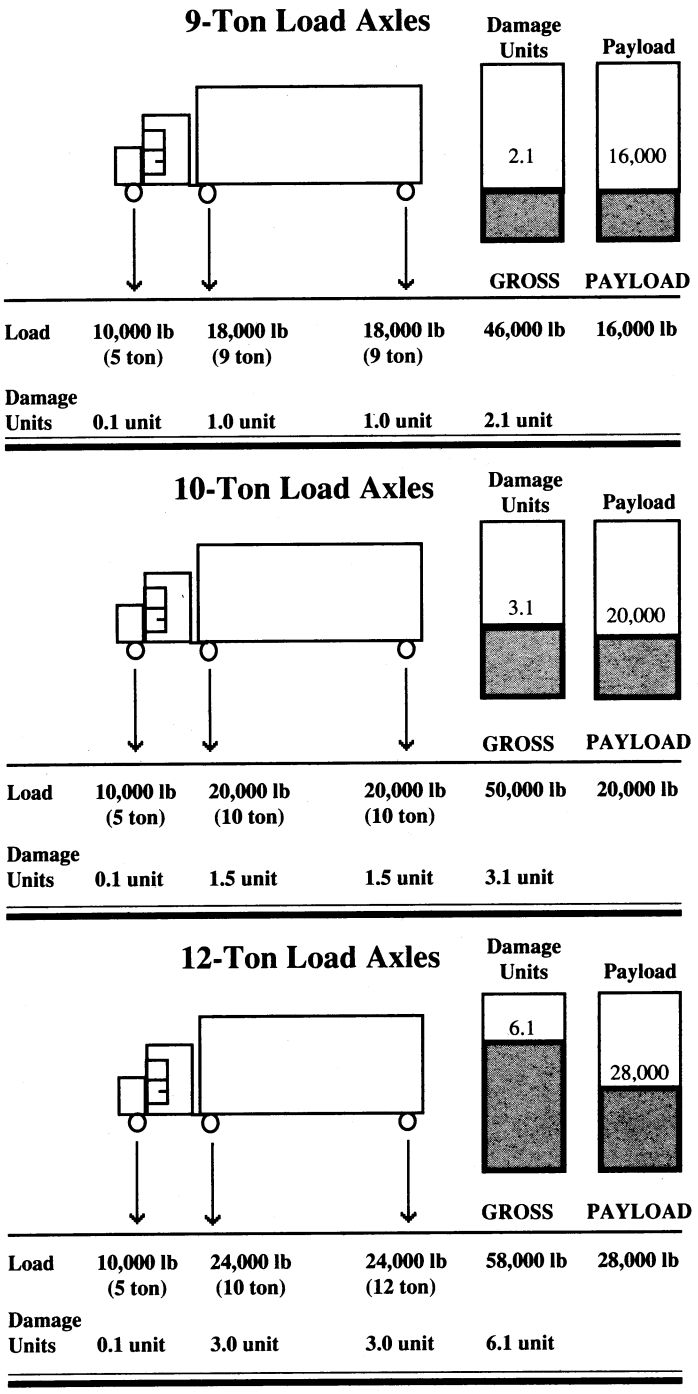

Figure 2: Total truck effects for trucks with single load axles.

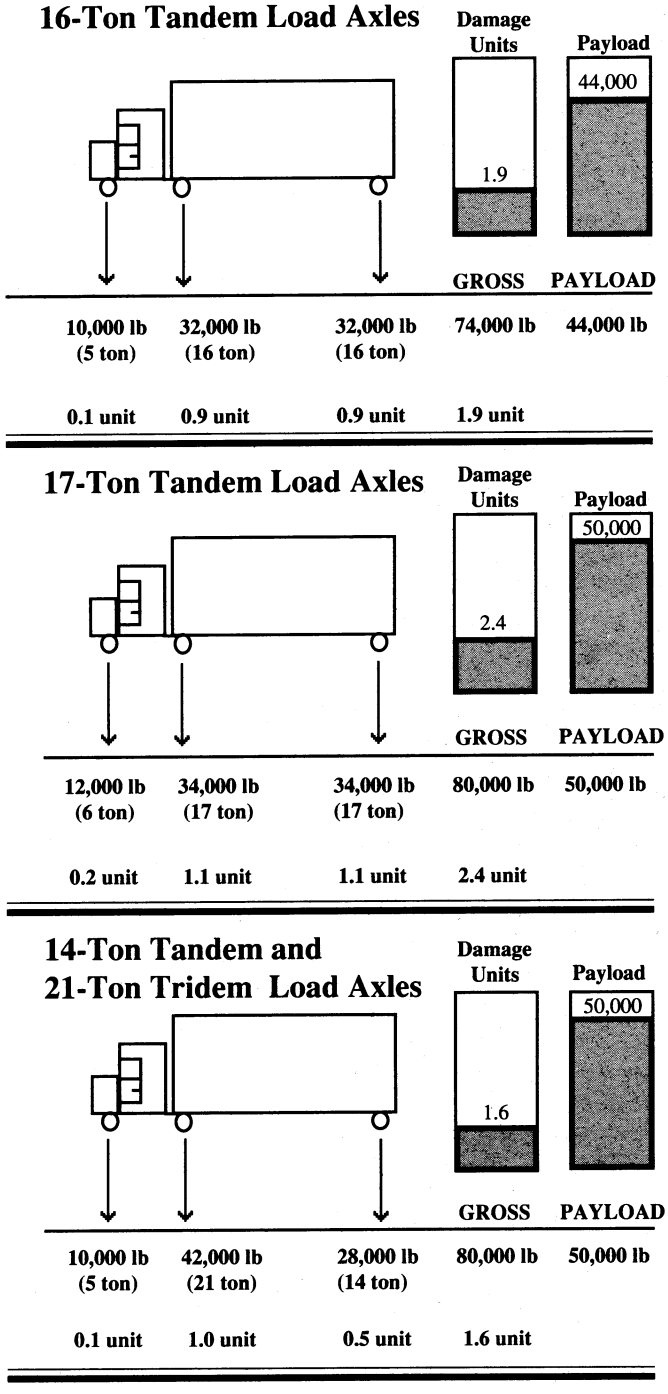

Figure 3: Total load effects for trucks with tandem and tridem load axles.

based on the relationship between axle load and road damage. Eighteen thousand pounds (nine tons) yields one unit of damage in one pass. If a truck with a standard axle weight of 18,000 lbs. makes 100 passes over a pavement, 100 units of pavement life are used up per axle. However, as figure 2 shows, pavement damage increases faster than axle loads. A semi-trailer with a five-ton front steering axle and two single nine-ton load axles carrying a 16,000 lb. payload would use up 2.1 damage units. If a similar truck with two single ten-ton axles carries a 20,000 lb. payload, the payload increases by 25%, but pavement damage would increase by almost 50%. Also, if the same truck was illegally overloaded by 24,000 lbs. per axle, pavement damage would increase by 100% over the ten-ton load (and 300% over the nine-ton load), but the 28,000 lb. payload is only 40% larger.

Number of Axles

Tandem axles can carry much greater payloads with little increase in pavement damage.

A tandem load of 32,000 lbs. will cause only 1.9 damage units (figure 3). Compared to the original example in figure 2, the payload has been increased about 175% to 44,000 lbs., while the resulting pavement damage has actually decreased by 10%. Tridem (three) axles are even better for reducing road damage. Tridem axles have 12 wheels on three axles arranged trailing one another under the truck. A truck with an 80,000 lb. gross load on a tridem would cause only two-thirds the damage of a tandem carrying the same load. In fact, it is possible to do less damage to the pavement with tridems and carry even more payload. Because different truck configurations can carry greater loads without necessarily causing more road damage, it makes sense to post several load limits on roads which regularly carry different truck configurations.

Number of Tires

The number of tires (or wheels) is also important. Changing from dual tires to single tires, on a single axle load truck, will increase the pavement stress by 10-20% because the load is now concentrated in one spot rather than in two. The effect of dual wheels depends in part on pavement thickness. As depth increases, the stress caused by dual wheel loads becomes equivalent to single wheel loads.

Tire pressure is also important. Tire pressure increases with truck weight, and the higher the pressure the greater the stress on the pavement. Also, the effects of tire pressure are more pronounced in upper pavement layers.

Pavement Base

Because the majority of local roads are constructed with relatively thin (2"-4") asphalt surfacing, the strength of the aggregate base becomes very important in the road's ability to support loads. A good base increases the overall strength of the road by distributing load effects to the soil beneath it and provides drainage to help protect against frost heave (see Figure 4). Any weakening of the underlying soil by moisture or freeze-thaw action will greatly diminish the road's strength. Because underlying soils, field conditions, and pavement materials vary, a deflection (strength) test can be very helpful in evaluating a pavement for future maintenance and improvement.

Pavement Thickness

Pavement thickness is a major factor in load capacity. Pavements are designed using the predicted number and weight of axle loads over

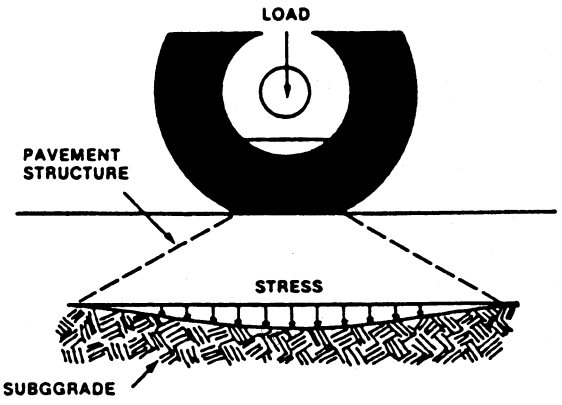

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Figure 4: Wheel load transmitted to subgrade soil.

the expected life. Pavement must be thick enough or strong enough to withstand stress for this period before it begins to break up from fatigue damage. The major component of fatigue is deflection or bending. Thicker pavements suffer less stress and deflection, and therefore, will last longer under heavy loads. Weakened roads are commonly strengthened by adding thickness through overlays or complete rebuilding.

Changing Seasons

Regardless of traffic, environmental effects will cause roads to need maintenance after about 15 years. Spring is the critical time of the year for a road. It is at its weakest during spring thaw. As frost leaves the ground, the moisture softens the soil causing it to lose its strength and ability to support loads. The amount soil weakens is related to its composition. Granular soil (sand) doesn't lose as much strength as a soil containing a lot of silt or clay. Figure 5 shows that later in the year the soil gets stronger reaching its greatest strength in the winter. If the amount of deflection (bending) it endures during this time can be reduced, its life will be increased.

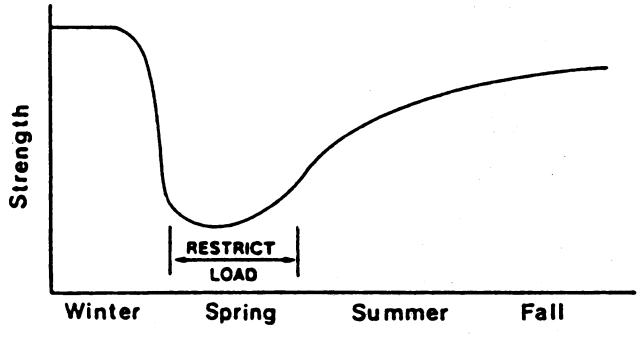

Figure 5: Variation in pavement strength throughout the year.

Summary

- Pavement fatigue damage increases as payload increases.
- Fatigue damage increases more rapidly with increased axle load than does the payload.
- Pavement fatigue damage is reduced by using axle arrangements which spread the load out. Tandem is better than single, and tridem is better yet.
- Dual wheels also spread out the load.
- The ability of a road to carry loads depends on its strength, which in turn depends on the type of pavement materials and the strength of the soil beneath it.
- Deflection (fatigue damage) can be reduced by increasing the strength of the pavement — usually by increasing its thickness.
- Pavement strength varies throughout the year, and is lowest during the spring.

Posting Roads

Because road strength varies throughout the year, roads may be posted for different load limits depending on the season. It is most important to change load limits in spring when the subgrade is the weakest. Coordinate your spring posting with your neighboring governments and the state. If you do not coordinate your posting with your neighbors, overweight trucks may tend to use your roads, increasing your maintenance costs.

Maintenance

To develop and carry out an effective maintenance program, it is helpful to know traffic volumes, truck types, average road damage per vehicle, and future volume increases. Even slight loading limit increases may shorten the time until a road needs significant maintenance.

Road posting and the use of truck routes are good management techniques to preserve pavements. Improvements to pavements should be made only after considering the existing strength and anticipated traffic loads. These decisions are only as good as the information on which they are based. Learning more about your traffic patterns and existing pavement strength can pay dividends through better management decisions.

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