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MAXIMIZING THE PAYLOAD ON CHIP VANS

J. Michaelsen, B.Sc.F.* and D. MacGregor**

Abstract

In 1994, FERIC surveyed open-topped chip vans in Nova Scotia, Quebec and Ontario to assess their payloads and the characteristics of the chips being loaded. Based on these observations, recommendations are presented on payload optimization strategies as related to trailer configuration, loading method, and chip characteristics.

Figure 1. Loading a chip van at a sawmill.

Introduction

During the past decade, wood chip transportation has become increasingly important in the Canadian forest industry as more pulp mills are relying on in-woods chipping or sawmills for all or part of their fiber supply (Figure 1). For example, the volume of chips delivered to pulpmills increased from 36.1 to 66.1 million solid m³ between 1984 and 1994 (Statistics Canada 1985, 1995). Based on the 1994 figure, every 1% increase in the average payload would decrease the total number of chip loads across Canada by around 12 600, representing a saving of $3.8 million in transportation costs. Minimizing chip transportation costs is therefore an important step in reducing overall fiber costs. Because of the relatively low bulk density of chips, chip trailers are designed to maximize volume, but even so, often fill up before reaching legal weight limits.

Depending on whether volume or weight is the limiting factor, payload can be optimized by increasing the

* Jan Michaelsen is a researcher, Transportation and Roads, Eastern Division.
** Douglas MacGregor is a senior technician, Transportation and Roads, Eastern Division.
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available volume in the van, compacting the chips so that more chips fit in the available space, or reducing the tare weight. To determine the potential for these alternatives to improve chip payload, FERIC conducted a project in 1994 to survey the existing equipment and to determine the current levels of payloads being achieved by the various tractor-trailer configurations.

The survey was conducted at four locations: one in northern Ontario, two in Quebec and one in Nova Scotia. These locations were selected to represent different maximum legal weights, loading methods, tree species, and trailer configurations.

Methodology

The data collected in the project included the source of the chips, distance hauled, loading method, chip species, net volume of each van (the actual volume available), volume of the unfilled space at the top of the loaded van (measured at the delivery point), gross and net weights of each load, and (whenever possible) any chip data furnished by the mills involved. To calculate the amount of unfilled space at the top of the van, the difference in height between the top of the chips and the top of the trailer was measured at 45 locations arranged in a 9×5 grid (Figure 2). The total volume of each van was either measured by FERIC or supplied by the manufacturer. All other data were supplied by the scale houses of the four mills.

Figure 2. The method used to calculate the volume of unfilled space.

Two measures were used to describe a vehicle's payload performance: the fill percent and the chip bulking factor. The fill percent was defined, using the relationships in the glossary, as the extent to which the volume available in a given chip van configuration was completely utilized. This proportion provides a useful measure for comparing different vehicle configurations and loading methods. The bulking factor measures the degree of "looseness" of the chips in the van; a high bulking factor indicates a low degree of compaction, which indicates the potential for compressing more chips into the available space. The bulking factor determines, in large part, the bulk density of the chips (i.e., the weight per cubic metre of loose chips), which determines the tradeoff between maximizing volume and minimizing the risk of overloads.

FERIC assumed that each truck in the study was configured to meet its maximum permissible gross weight for that province. No analysis was done on axle weights, since data on these weights were unavailable.

Results

In all, 211 top-loaded chip van loads were sampled. All units were open-topped vans that used tarpaulins to secure the load. No closed vans were included since the amount of unfilled space could not be easily measured and, therefore, the net chip payload volume could not be determined.

Weights and Volumes

Table 1 summarizes trailer and payload weights for each province, by type of trailer and legal weight limit. There are two different legal limits in Nova Scotia, one for the trans-Canada class (schedule "C") highways and another for secondary highways. The loads included in the 41.5-tonne limit were from sawmills located on secondary highways. Table 1 indicates that the legal limits for semi-trailers in Nova Scotia are much lower than those in Quebec. The B-trains from Ontario have an even higher legal weight limit than semi-trailers. It is clear that the current provincial laws permit a much greater payload of chips to be transported in Ontario than in either Quebec or Nova Scotia. Chip haulers operating on secondary highways in Nova Scotia are particularly limited in the amount of chips they can haul.

It is interesting to note the effect of legislated weight limits on trailer design. In Nova Scotia, the legal weight limit is such that the tare weight of the van

Table 1. Average weights by province, type of trailer and legal limit

Province	Trailer type	Trailer length (m)	Legal limit (t)	No. of loads	Weights (t) Gross	Tare	Net	Gross minus legal[a]
Nova Scotia	Semi	12.2 - 13.4	41.5	5	45.0	16.7	28.3	3.5
	Semi	12.2 - 13.4	51.5	26	47.7	17.7	30.0	-3.8
	Semi	13.7 - 14.6	51.5	26	49.7	18.9	30.8	-1.8
Quebec	Semi	13.7 - 14.6	55.5	8	52.0	21.8	30.1	-3.5
		15.2	55.5	118	52.9	21.5	31.4	-2.6
Ontario	B-train	7.6 & 10.9	63.5	5	61.8	22.5	39.3	-1.7
	B-train	9.2 & 10.3	63.5	22	65.3	21.8	43.5	1.8

[a] A negative value indicates a gross weight below the legal limit.

becomes a significant factor in limiting payload. To address this, vans used in Nova Scotia had an average tare weight that was more than 3 tonnes lighter than those in Quebec, even though the trailers were about the same size and the payloads hauled were similar. This suggests that tare weights will only be reduced when this is required to meet legislated weight limits. Based on their current volumetric capacity, there is no payload incentive to lighten the Quebec vans since these are already below the legal weight at their full capacity and could not carry any more payload. However, if volumes *could be* increased or the chips compacted more, tare weights would have to be reduced so as not to increase the risk of overloading.

The B-train configurations in Ontario had sufficient volumetric capacity to achieve the full legal weight. As is the case for Nova Scotia semi-trailers, Ontario B-trains appear to employ lightweight trailer design, as their tare weights were only slightly heavier than those of the Quebec semi-trailers, which have fewer axles and a shorter overall trailer length. The longer B-trains performed better than the shorter B-trains, with an increase in average payload of around 3.5 tonnes. It is obvious that design improvements had been made in the longer version, as its tare weight was less than that of the shorter B-train. However, the longer units exceeded the legal weight limit by an average of 1.8 tonnes. Since a 10% increase (about 6 tonnes) in legal weights is permitted in Ontario during the winter months, this overloading is only a concern during part of the year. With their lower payload capacity, the shorter B-trains cannot take advantage of the increased winter limit. If equipped with onboard scales, the longer B-trains could then potentially load their maximum legal payload on nearly every trip without exceeding the legal axle-weight limits. There may also be potential for further improving payload with the longer B-trains by reducing their tare weights.

Table 2 shows the fill percent for each trailer configuration, grouped by trailer length. As expected, longer units had higher gross volumes available for chips, and the unfilled volume increased with increasing trailer length since it was difficult to load right to the top of the sidewall. The higher fill rates found with the Nova Scotia trailers are noteworthy; these apparently resulted from the practice of crowning the chips higher than the tops of the chip trailer's walls. This is possible in Nova Scotia because "overheight permits" are available that permit loads of up to 15 cm above the normal legal height limit of 4.15 m. By using these overheight

Table 2. Average van volumes, by province and type of trailer

Province	Trailer type	Trailer length (m)	No. of loads	Volume (m^3) Van	Unfilled	Payload	% filled
Nova Scotia	Semi	12.2 - 13.4[a]	31	89.9	-1.5[b]	91.4	101.7
	Semi	13.7 - 14.6	26	96.3	1.0	95.3	99.0
Quebec	Semi	13.7 - 14.6	8	103.1	4.5	98.6	95.6
	Semi	15.2	118	111.1	4.9	106.2	95.6
Ontario	B-train	7.6 & 10.9	5	143.2	5.5	137.7	96.2
	B-train	9.2 & 10.3	22	152.1	7.1	145.0	95.3

[a] This class combines the first two trailer categories from Table 1, whose volumes were not significantly different.
[b] A negative unfilled volume indicates that the load was crowned above the chip trailer's walls.

permits, haulers are essentially increasing the effective volume of their chip vans. Without such permits, loads can still be crowned, but the loads must settle sufficiently to be within legal height limits before traveling on a public road.

It may be difficult to improve on these fill levels, since a certain amount of settling inevitably occurs during the trip. Uusvaara (1969) found that settling reaches 4 to 8% over transportation distances of 100 km (Figure 3) and that the majority of settling occurs within the first 50 km. Similarly, Okstad et al. (1990) found settling rates of 4% for transport distances below 50 km, of 6.4% from 50 to 150 km and of 7.6% for distances greater than 150 km in Norway. FERIC found an overall fill level of 96.9% over an average transportation distance of 154 km (ranging from 48 to 576 km). Since vans from Ontario and Quebec are arriving at the mill with an average of only 4 to 5% unfilled space, FERIC assumes that the chip vans are either being overfilled or that certain compac- tion methods, such as tamping with the loader or using a roller (Figure 4), are already being used to compress the chips.

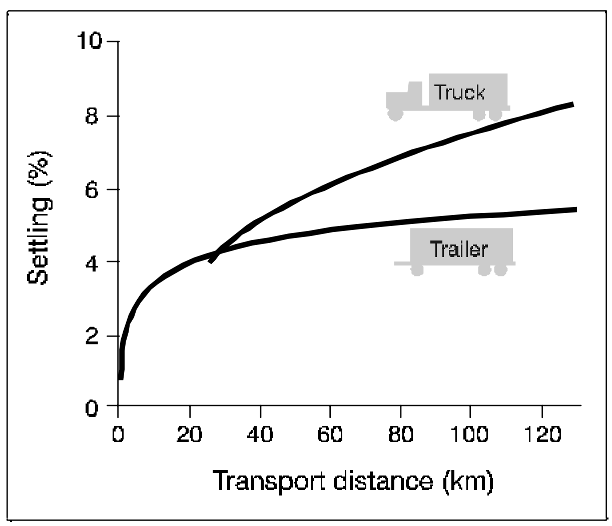

Figure 3. Settling of chips during transport in European-style trucks and trailers as a function of transportation distance (based on data from Uusvaara 1969).

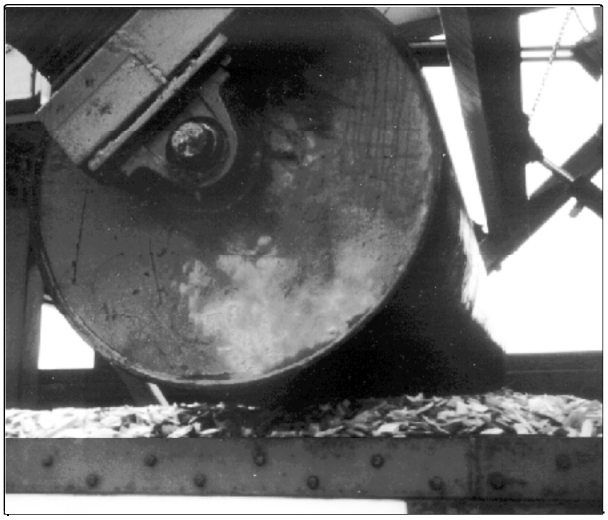

Figure 4. Tamping chips with a roller to increase compaction.

Chip and Wood Properties

From the point of view of trailer design, the bulk density of the chips is the most important characteristic of the chip load in determining the potential payload: the desired payload, divided by the bulk density of the chips, determines the total required volumetric capacity of the van. Table 3 summarizes the bulk density values and moisture contents observed during this study.

The average bulk density was just below 300 kg/m³; a 60% black spruce plus 40% balsam fir chip mix had the lowest average bulk density (267 kg/m³), and a red pine/white pine mixture had the highest (334 kg/m³). This variation among species indicates that it is important to know the species mix to be able to predict potential payloads. There is also a wide range in bulk density within a species. Therefore, it is important to note that a trailer whose volume will give the maximum legal payload with an *average* bulk density may typically be overloaded for 50% of the loads, and many of these by a significant amount.

Table 3. Chip densities and moisture contents, by species or species mix[a]

Species or species mix	No. of loads	Basic density[b] (kg/m³)	Moisture content (%)		Bulk density (kg/m³)	
			Average	Range[c]	Average	Range[c]
60% black spruce/40% fir	15	382	41	36 - 46	267	250 - 283
25% black spruce/75% fir	10	360	44	42 - 46	280	228 - 332
Trembling aspen	3	370	46	42 - 50	291	288 - 293
Jack pine/black spruce	12	394	36	31 - 41	295	262 - 329
95% black spruce/5% fir	72	428	41	34 - 48	295	264 - 326
Jack pine	15	409	37	26 - 46	298	275 - 321
Dense hardwoods	21	546	37	23 - 52	327	266 - 388
Red pine/white pine	5	372	47	18 - 73	334	272 - 396
Combined average (unweighted)	---	408	41	---	298	---
Range (extremes)	---	---	---	18 - 73	---	228 - 396

[a] Data from Nova Scotia were not included because moisture contents were unavailable.
[b] Basic densities were only provided by one of the mills in the study. Other average basic densities were compiled from the literature (e.g., Besley 1966; Alemdag 1984; USDA 1987; Gonzalez 1990).
[c] Ranges are based on a 95% confidence interval.

For species other than those included in Table 3, a bulking factor can be used to estimate bulk density. Dividing the green density by this bulking factor will provide the bulk density. The green density is available from many sources (e.g., Alemdag 1984) or can be calculated from the basic density and the moisture content using the equation in the glossary. Table 4 provides bulking factors for three loading methods. Bulking factors averaged 2.3 for all methods, and ranged from 1.6 to 3.3. The chips loaded with either a bin or a front-end loader had similar bulking factors (2.5 and 2.4, respectively). Loading with a blower provided significantly better compaction, with an average bulking factor of 2.1.

Table 4. Chip bulking factor for three loading methods

Loading method	No. of loads	Average bulking factor	Range[a]
Blower	19	2.1	2.0 - 2.3
Front-end loader	42	2.4	1.6 - 3.3
Bin	85	2.5	2.1 - 2.9
Combined average (unweighted)	---	2.3	1.6 - 3.3

[a] Based on the 95% confidence interval.

These bulking factor values are slightly lower than those reported in previous studies, but fall in the same range. Flann (1962) reported bulking ("expansion") factors of 2.4 for wood chips blown into boxcars or scows using a pneumatic system, 3.1 for chips gravity-fed from a height of 1.2 m (4 ft) into a shallow pile, and 2.7 when gravity-fed from a height of 3.7 m (12 ft) and built up to a depth of 3 m (10 ft). These factors are probably higher than those in the current study because chip densities were measured before transport, and no settling of the chips had occurred. Okstad et al. (1990) presented results that translated into an average bulking factor of 2.7 after transport, but they did not specify the loading method.

The results also permit an estimate of the maximum amount of chip compression that is likely to be possible, and suggest a potential bulking factor target of 1.6 (the low end of the range, representing the densest load). Loading with a blower is one way to achieve lower bulking factors, but changing loading methods might not be logistically or economically viable. Therefore, the incorporation of some form of compaction that does not cause undue chip damage could be investigated to optimize payload for systems that load chips from a bin or with a front-end loader.

Conclusions and Recommendations

Chip payloads can be maximized in three ways: increasing the volumetric capacity of the trailer, packing more chips into the existing space, and minimizing the trailer's tare weight.

The first way to maximize chip payload is to maximize the volume of the chip van. In Ontario, using B-trains has increased payload volumes significantly, allowing operators to take better advantage of the higher legal weights. The B-trains, with a legal limit of 63.5 tonnes, have more than enough volumetric capacity for a full legal load; in fact, these larger B-trains risk overloads during the summer period. This could be overcome by using onboard weigh scales to ensure the maximum legal payload on every trip. In Nova Scotia, overheight permits provide an easy and inexpensive way to increase the effective van volume.

None of the semi-trailers in the study had sufficient volumetric capacity to regularly achieve a full legal load for a 51.5- or 55.5-tonne gross combination weight allowance. There may be some potential to increase the available volume, as some 14.6-m semi-trailers on the market have a 110-m^3 volumetric capacity, compared with average values of 96.3 and 103.1 m^3 for the trailers in this study. However, given that there is a large variation in the bulk densities of chips, even the current volumes can produce occasional overloads. If the volumes of the semi-trailers were increased to the point at which the average payload would be at the maximum legal weight, as many as 50% of the vans might be overloaded. As with the B-trains, semi-trailer payloads could be optimized by increasing trailer volumes and using scales to prevent overloads.

The second way to increase chip payloads is to pack more chips into the available space. In general, trailers are only filled to about 96% capacity by the end of the haul. Using the extra 4% capacity would represent an increase of about 1.3 tonnes for the Quebec semi-trailers and 1.7 tonnes for the Ontario B-trains, provided that this does not result in overloading. One way to improve the fill percent is to use load crowning. During the first 50 km or so, the chips are expected to settle by between 4 and 5%. For operations where the haul begins on private roads, this could be an option so long as the chips settle enough to prevent an over-height violation by the time the trailer reaches a public road.

Higher levels of compaction can also be achieved by increasing the bulk density. Blowing the chips into the van instead of dropping them from a bin or loader could decrease the bulking factor by more than 10%, resulting in denser loads. It may also be possible to increase the density by using compaction methods such as a roller or by vibrating the vehicle during loading to mimic the 4 to 8% compaction that occurs due to settling during travel. Further research is required to determine the viability of these methods.

The third approach is to minimize the vehicle's tare weight to ensure that the vehicle will not be overweight once the available volume is completely filled. In Ontario, replacing shorter B-trains with a longer, lighter model minimized tare weight while maximizing volume. The longer B-trains, however, were overloaded by an average of almost 2 tonnes. This suggests the potential for up to two additional tonnes of payload through further tare-weight reductions. Nova Scotia is a good example of tare-weight optimization. Although the Nova Scotia legal weight limit is 4 tonnes lighter than that in Quebec for the same semi-trailer, the Nova Scotia operation used lighter trailers than those in Quebec and was able to achieve a payload within 0.7 tonnes of the Quebec payloads for trailers of similar size.

FERIC's ongoing program in trailer design will continue to investigate potential methods for optimizing chip payloads.

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Glossary

Van volume: The net volume (m^3) available for chips.

Unfilled space: The volume (m^3) of unfilled space at the top of the van.

Payload volume: The actual loose volume of chips (m^3) in a load.

$$Payload\ volume = Van\ volume - Unfilled\ space$$

Fill percent: The percentage of the van volume occupied by chips.

$$Fill\ \% = \frac{Payload\ volume}{Van\ volume} \times 100\%$$

Bulk density: The ratio of the net weight of a load of chips to its loose volume (kg/m^3).

Basic density: The oven-dry weight per unit of green volume of solid wood (kg/m^3).

$$Basic\ density = \frac{Oven\text{-}dry\ weight}{Green\ volume}$$

Moisture content: The percentage of water by weight in wood or chips. The moisture content based on green weight is used in this report.

$$M.C.\ (\%) = \frac{Green\ weight - Oven\text{-}dry\ weight}{Green\ weight} \times 100\%$$

Green density: The green weight per unit of green volume of solid wood (kg/m^3).

$$Green\ density = \frac{Green\ weight}{Green\ volume}$$

or:

$$Green\ density = \frac{Basic\ density}{1 - (Moisture\ content/100)}$$

Bulking factor: The ratio of the loose volume of wood chips to the solid volume of wood from which they were produced.

$$Bulking\ factor = \frac{Green\ density}{Bulk\ density} = \frac{kg/m^3\ solid}{kg/m^3\ loose} = \frac{m^3\ loose}{m^3\ solid}$$