THE IMPACT OF WOOD TRANSPORT WITH OVERLOADED VEHICLES ON THE DIMENSIONS AND THE DURATION OF ROAD PAVEMENTS[1]

by

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1. INTRODUCTION

The main factor which affects the design of pavements thickness is the traffic flow of road,with particular interest to the type and the loading of vehicles.In the forest roads, where trucks constitue the main volume of this load, a percentage 60-90% - in proportion of the road function - referrs exclusively to wood transportation.This means that pavement thickness depending on the quantity of wood transported and on the number **n** which implies how many equivalent standard axlles (E.S.A.L.) carry 1m^3 of wood.

During wood transportation the overloaded vehicles are remarkable because of transportation needs and benefits by the transporter.

The duration of road pavements ranges at about 20-30 years, but in the case of overloaded vehicles we have the increasing of axle loads and the total number of equivalent standard axle loads (E.S.A.L.), which leads to the rapid appearance of surface damages and the decreasing of their lifes.

This paper examines the impact of wood transport with overloaded vehicles on the design of thickness and duration of road pavement, through the determination of the number and weight of axle loads under normal and overloaded conditions.

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2. RESEARCH AREA AND MATERIALS

For the purpose of this research work we have selected the eastern forest complex of Forest District Office of Drama (NE-Greece) -the largest one in Greece- with an area of 76000Ha, woodstock volume at 5.000.000 m^3 and an annual increment(timber cut) at 180.000 -200.000m^3

The forest road studied is the road Kentrika-Filakio Tholou- Paranesti, which is crossing the central area of Eastern Rodopi and has a geological support of calcareous sandstone and estimate subgrade resistance CBR =7.

This road, as the central of three other feeding roads, receives the wood transportation of 65.000m^3 annualy.Because of wood blue-stain, the local Forest Service has set a high priority for the asphaltic overlay of this road , and there is a need for a rapid and safe wood transportation after felling in autumn and / or winter.

For the examination of the impact of wood transport with overloaded vehicles we have studied the composition of circulation,vehicles types,the number and the weight of axle load under the present and normal circulation conditions on the basis of transportation and technical specifications of manufacturing companies.

The methodological priorities of this paper are focused on:

a) The estimation of circulative equivalent axle load with respect to the percentage of overloaded vehicles, b) The estimation of dimensions and the duration of road pavements.

2.1 Research method

Based on measurement which have been carried out in 1987 (August), 1992 and 1993 (July),as well as from transportation reports, we have found that the annual duration of truck transportation is about 150-160 days, with an average wood load per day about 400- 420m^3.

2.1.1 Estimation of equivalent standard axle load (ESAL)

Table 1 presents the vehicles which circulated in the forest road with their technical and transportation specifications under normal and overloaded conditions.

- In column 1 we can see the distribution of the vehicles axle load when they move empty or with full load.

-In column 2 the equivalent standard axle load of vehicles is presented for the same cases of traffic.

-In column 3 the equivalent standard axle load of vehicles is presented for a full course.

TABLE I
Technical and transportation specification of vehicles under normal(N) and overloaded (OL) conditions

Vehicles Type		Axle load distribution with empty and(full) load TN	Equivalent axle load distribution empty and (full) load	Equivalent axle load for a full course	Quantity of wood transported m^3	Coefficient n of equivalent axle load which transport 1m wood
Mercedes 1632	N	6 / 2.5 (8 / 11)	0.8 / 0.02 (2.5 / 3.26	**6.56**	**14.89**	**0.44**
	OL	6 / 2.5 (9 / 13)	0.8 / 0.02 (4 / 6.31	**11.1**	**19.15**	**0.58**
Mercedes 1932	N	5.3 /3.8 (7 / 20)	0.5 / 0.03 (1,5 / 3.6)	**5.6**	**25.4**	**0.22**
	OL	5.3 /3.8 (8.5 /23.6)	0.5 / 0.03 (3.2 / 7)	**10.73**	**32.51**	**0.33**
Mercedes 2628 VOLVO F 89	N	6 / 6.65 (6.5 / 20)	0.8 / 0.04 (1 / 3.6)	**5.4**	**19.6**	**0.27**
	OL	6 / 6.65 (7 / 22.8)	0.8 / 0.04 (1.5 / 6.15	**8.4**	**25.8**	**0.334**
Magirus 23 STEYER DAF 2600	N	5.8 /6.2 (7 / 20)	0.77/0.03 (1.5 /3.6)	**5.85**	**21.3**	**0.28**
	OL	5.8 /6.2 (8.2 /22.8)	0.77 /0.03 (2.8 / 6.14)	**9.71**	**27.26**	**0.354**
DAF VOLVO MAN	K	5.5 / 5 (6.5 /20)	0.75 /0.03 (1.1 / 3.6)	**5.6**	**22.72**	**0.246**
	YΠ	5.5 / 5 (7.5 /23)	0.75 /0.03 (1.95 /6.3)	**9.25**	**29.08**	**0.318**

-In column 4 we have the quantity of wood transported (for each vehicle) and in the last column the coefficient **n** which expresses the number of equivalent standard axle load of vehicles which transport 1m^3 of wood.This is derived from the division of the ESAL for full course (column 3) through the quantity of wood volume transported (column 4).

The axial loads W are converted in to **f** equivalent axles, from the relation :

$$f = \left(\frac{W}{W_t}\right)^4 \quad \text{where}$$

Wt= 8.2 tn ,when converting single axles with twin wheels

Wt= 6.34 tn ,when converting single axles with single wheels

Wt= 14.5 tn, in twin axles with twin wheels

-From measurements carried out in various periods of time we found the percentage of vehicles which are presented in Table 2.

TABLE 2: Traffic percentage in the area of research.

TYPE OF VEHICLE	TRAFFIC PERCENTAGE %
Mercedes 1632	5
Mercedes 1932	35
Mercedes 2628	20
VOLVO F 89	5
Magirus - Steyer - DAF 2600	15
DAF - VOLVO - MAN	20

-Based on statistical analysis of the transported loads from each vehicle,we have found that one half of vehicles are overloaded at 15- 20% above the load allowed. From the same analysis we have realized that a 20% are small private cars, without any influence on the dimensions of road pavement. About 80% are trucks and heavy machinery and about 26% of them refer to non-forestry needs.The rest 54% refers to wood and other forest products transportation.

-The columns 1 and 2 of Table 3 depict the number of trucks with annual wood transportation according to the valid regulations as well as those with overloaded conditions.

-In columns 3 and 5, the annual wood transported for every type of truck are given with normal and overloaded conditions(todays conditions); and in columns 4 and 6 we have the annual number of equivalent standard axles load.(E.S.A.L) for the above quantity of wood.

-In columns 7 and 8 the total annual quantity of wood transported and the total annual number of equivalent standard axles are presented.

TABLE 3: Number of vehicles, wood quantity and equivalent standard axles (annual) under todays conditions(with overloaded vehicles)

Vehicle Type	Annual frequency of vehicles transporting timber	
	Normal (N)	Overloaded (OL)
	1	2
Mercedes 1632	80	54
Mercedes 1932	483	456
Merc. 2628, Volvo F 89	349	322
Magirus-Steyer DAF 2600	188	215
DAF-Volvo-MAN	269	268
TOTAL	**1369**	**1315**

If the same wood- quantity of 65000m^3 would have not been transported with overloaded vehicles, then we should have been needed more trucks and various axle numbers. The table 4 depict these data in this case.

TABLE 4: Vehicles capacity for heavy goods and the annual equivalent axles under normal conditions

Vehicle Type	Annual frequency of vehicles transporting timber	Total annual quantity of wood transported m^3	Total annual number equivalent standard axles E.S.A.L
Mercedes 1632	153	2279.7	1003.7
Mercedes 1932	1071	23990.4	5997.6
Mercedes 2628 VOLVO F 89	765	14994.0	4131.0
Magirus - Steyer DAF 2600	459	9776.7	2685.0
DAF -VOLVO -MAN	612	13904.6	3427.2
TOTAL	**3060**	**64945.4**	**17244.5**

2.1.2 Estimation of dimensions and the duration of road pavement

For the estimation of dimensioning of this road pavement we have applied the methods of the Asphalt Institute and that of AASHTO.

A. ASPHALT INSTITUTE

For the estimation of dimensioning with this method we need to know the total equivalent standard axle load (E.S.A.L.) for pavement duration 20 years and the resilient modulus M_r .From the nomograph of Fig. 1, for E.S.A.L.=20X 17244 =3,45.10^5 axles by normal(N) traffic and 20X20494=4,099.10^5 axles with overloaded (OL) vehicles, and resilient modulus M_r=10,3XCBR =10,3X 7= 72MPa, we have :

1. Road pavement for normal circulation consist of 30 cm gravel and 7,5 cm bitumen (asphaltic layer).

2. Road pavement with overloaded vehicles consist of 30 cm gravel and 10 cm bitumen (asphaltic layer).

B. AASHTO METHOD

Applying this method, taking into account the same E.S.A.L., and for R(Reliability)=95%, So(combined standard error)=0,35 and ΔPSI =1.9 , we have found SN (structural number)=2.9 for normal axles and SN=3.38 for overloaded axles.

By analyzing these values to distributive layers we have found the bitumen thickness D_1= 9,5cm and D'_1=11,1 cm, the base thickness D_2=12,7cm and D'_2=16cm and the subbase with gravel-sand D_3=17cm and D'_3=18cm. In this case the pavements would appear as follows:

3.RESULTS

From Table 1 we can realize that 50% of trucks are overloaded in a percentage 15-20% up to the permitted gross weight, with 27% more wood transported.

This result leads to the need of increasing the equivalent axle loads of full course at 55-90%, during normal and overloaded circulation .In this case we have an annual increase of equivalent axle loads at 18% compared to the axles number of vehicles which would not be overloaded.

The influence of this increase of circulative axle plays a defitive role on the estimate of dimension of road pavement.

From the nomograph of Figure 1 we can see an increasing of 2,5cm in bitumen, while from the nomograph of AASHTO (Fig.2), we can see an increasing of all layers,e.g. 1,6cm in bitumen, 3,5 cm in base with gravels and 1cm in subbase with gravel-sand and a total increase of pavement about 15% when we have overloaded vehicles.

This difference of pavement thickness is indicative of influence of overloaded vehicles.

The difference of pavement thickness will be greater if we could estimate the additional load of vehicles which circulate for non-forestry needs, and if we could estimate the additional coefficient of annual in increase of traffic flow.

Finally, a pavement designed and constructed for normal axles, but it has to be used for overloaded axle , shows an appearance of surface damages much faster and the reduction of duration of road pavement , is derived from the relation :

$$T_{OL} = T \cdot \frac{(ESAL)_N}{(ESAL)_{OL}}$$

Where:

T_{OL} = The duration of road pavement with overloaded vehicles

T = The duration of road pavement with normal conditions

$(ESAL)_N$ = The total equivalent axles with normal conditions $=3{,}45.10^5$

$(ESAL)_{OL}$= The total equivalent axles with overloaded conditions $=4{,}1.10^5$

By replacing the values we may calculate the duration of road pavement, which will be 16,8 years and we will have a reduction at 3,2 years or 16%.

The reduction of duration of road pavement and the construction of strengthened pavement will automatically increase the construction cost and the cost of wood transportation.

If we take into consideration the increasing danger of accidents due to the overloaded vehicles, we realizethat we must change the policy of traffic control on forest rods, in order to achieve higher safety and performance standards of forest operations.

4. CONCLUSIONS

The traffic of overloaded vehicles in forest roads is a usual phenomenon due to the transportation needs but mainly for the benefit by transporter.We measured that 50% of traffic on forest roads are overloaded at 15-20%.

The concequence of this load increase implies the increase of equivalent standard axle load and the appearance of surface damages as well as the reduction of duration of road pavement .

We have studied in this paper ,based on the Asphalt Institute method and AASHTO method, the necessary pavement thickness needed at normal and overloaded conditions.This difference of pavement thickness is indicative of influence of overloaded vehicles.

The reduction of duration of road pavement and the construction of strengthened pavement will automatically increase the construction cost and the cost of wood transportation.

If we take into consideration the increasing danger of accident because of the overloaded vehicles, we realize that we must change the policy of traffic control on forest rods, in order to achieve higher safety and performance standards of forest operations.

Finally , the dimensioning and the construction of forest roads should be based on a multi dimensional optimization approach, taking into account not only the wood harvesting needs and specifications, but also the increasing demand by the public for multiple sustained use of the forests and especially the non- wood products, functions and services of the forest resources.

ABSTRACT

The number and the weight of the axle load of a vehicle transporting wood products are directly related to the methodology for determining the depth of a new pavement or of an overlay . This number expressed in equivalent standard axle load (E.S.A.L.) and in the factor **n** , which implies how many (E.S.A.L.) carry 1m^3 of wood .

This factor ranges between 0.24-0.44, but when the vehicles are overloaded the value rises up to 0.31-0.6. This increase is related to excessive loading for the same amount of wood transported.

This paper examines the impact of the overloaded vehicles on the life duration of the road pavement which accelerates the appearance of surface damages.

TABLE 1: Technical and transportation of vehicles under normal (N) and overloaded (OL) conditions.

Wood quantity and annual (E.S.A.L)				Total annual quantity of wood transported and total annual E.S.A.L	
Normal (N)		Overloaded (OL)			
m^3	ESAL	m^3	ESAL	Q (m^3)	E.S.A.L.
3	4	5	6	7	8
1191	525	1034	599	2225	1124
10819	2705	13001	4893	23820	7598

6840	1885	8308	2705	15148	4589
4005	1100	5861	2088	9865	31 88
6112	1506	7793	2488	13905	3995
28967	**7721**	**35997**	**12773**	**64963**	**20494**

Resilient modulus M_r (MPa) .

S.E.A.L.(20 years)

Fig. 1. The design of pavement thickness based on the Asph. Institute method.- Pavement with thickness 30cm of gravel base course.

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