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DEGRADATION FORMS OF FOREST GRAVEL ROAD ROADWAYS UNDER HEAVY VEHICLES USED IN TIMBER TRANSPORT

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Abstract: *The conducted research followed the establishment of degradation forms of forest roadways and their extending on the forest road Pravăţ, as secondary gravel road. The obtained results, both, on recorded degradations types and their dimensions demonstrate that degradation, even in conditions of reduced traffic, can affect approximately 0.2% from the roadway surface. The obtained data is useful for annual planning and time distribution for repairing-rehabilitation operations.*

Key words: *secondary road, roadway, gravel, degradation.*

1. Introduction

The transportation of harvested timber from forest to the final beneficiary is realized by specialized vehicles which use forest roads as transport infrastructure. The used vehicles are in great majority forest train-truck vehicles, of autochthon or imported provenance. The tonnage increment constitutes one of the actual trends in transport activity.

As known, during vehicle movement on the road, the former act on the roadway by tangential and vertical loads, which, corroborated with climatic factors, provoke in time specific degradations of the roadway. The shapes and dimensions of the occurring degradations depend, in a great measure, on the cover layer type applied to the road.

Presently, the forest roads network is represented by more than 32.500 km, and consists almost entirely of gritted or graveled roads. Gritted roads (usually simple gritted) can be realized of one single layer (having bearing and crust functions) or of two layers (one for bearing purposes and another for hard covering purposes); also, in problematic zones (clayey or increased humidity terrains), a third layer, having the role of a foundation sub-layer can be realized [3].

The reinforcement modality depends, generally, on forest traffic intensity, which presently is situated under 5.000 tones/year corresponding in this way to secondary forest roads [1]. The road systems recommended by the currently applied normative, which were elaborated in conditions of realization of a concordance between the traffic intensity and bearing capacity of the roadway for secondary forest roads, are presented in Figure 1.

As it results from Figure 1, the mentioned roads present 1-2 layers, being made of rocky

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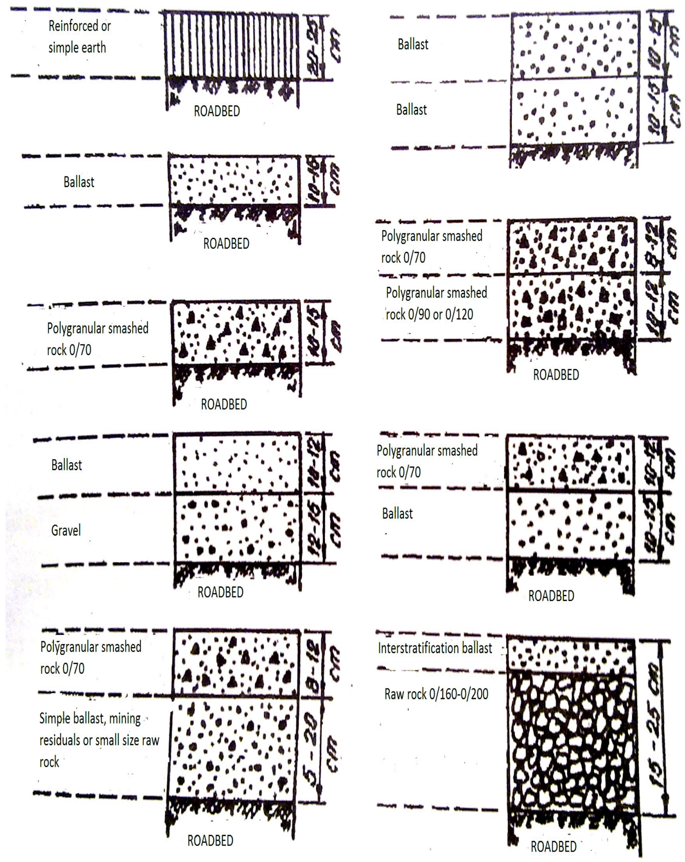

Fig. 1. *Road systems for secondary forest roads*

materials, belonging in this way to secondary roads.

When the road system contains only one layer (ballast or smashed poly-granular rock) it presents a thickness of 10…15 cm, having both, bearing and crust functions; in case of two layer systems (foundation with bearing function and cover - crust function), the first one is realized of local materials (ballast or gravel) and has a thickness of 15…20 cm; in some cases a raw rock foundation can be used (sort 0/150…0/200) having a thickness of 15…20 cm. The cover layer is executed similarly to one layer systems, respectively from ballast or poly-granular smashed rock, having a thickness of 10…12 cm in one layer construction and 25…30 cm in two-layer construction.

The research conducted up to now regarding the behavior of forest roads under traffic [5] underlined that during their exploitation, forest roads are permanently influenced by traffic action, as well as by the climatic factors' activity. Due to these factors, they produce, slowly or rapidly, according to amplitude, intensity and duration of stresses, moderated or extended degradations of the road structure.

The road traffic manifests its destructive action by vertical and horizontal stresses. The vertical ones are proportional to the vehicle's mass and are transmitted to road complex through contact surface tire-road; the horizontal stresses also occur at the contact surface level, but are tangentially manifested, being generated by accelerationdeceleration of the vehicle, as well as by centrifugal force effect in curved portions of the road.

Generally, structure deformations are proportional to the heavy use period.

As engineering constructions in open environment, roads are permanently exposed to stresses generated by climatic factors, especially precipitations, winds and temperatures [5]. The action of water precipitations represents the main factor in the roadway degradation process, and it manifests itself through the maintaining of an increased humidity, in temperature variations leading to erosion of roadway and resulted particles washing.

The wind intensifies the pluvial erosion by accelerating rain drops, and by dry-wet frequent states of the roadway leading to its cracking.

Temperature variations have important effects on the roadway, which lead to repercussions on the manifestation of the effect of stress, as well as by micro-cracking due to the dilating-contracting phenomena frequency of the constituent materials.

The scientific literature from our country underlines that the main degradations of graveled-gritted forest roads, especially of those simple graveled are: wavings, holes, wheel-tracks and frost-melting dips [2].

Wavings are the result of a non-corresponding particle distribution of the used material as well as of an insufficient compaction.

Holes, popularly named “chicken nests”, appear as result of great particles dislocation under water and traffic action.

Wheel tracks present themselves in the shape of flutes created by tire tracks, and are the result of decreased bearing capacity of the road system, as well as of the use of some rocky materials which are nonresistant to frost or with increased clay content.

Frost-melting dips are presented as irregular bulges, which affect the entire road complex.

Once appeared, the mentioned degradations require immediate interventions in order to realize the necessary repairing, and presuppose differentiated measures according to the degradation location and type. In situations in which there is not a systematic intervention, degradations are permanently extended and the road becomes unavailable for circulation.

From the documentation appeared in the last period, results show that presently approximately 9000 km from the total of forest roads are not proper for circulation, a fact which affects the forests accessibility.

2. Research Location and Methodology

2.1. Research location

The observations were deployed on Pravăţ forest road, from Cotmeana Forest District, Piteşti Forest Administration.

In this forest district, the forest roads network contains 101.9 km, out of which 91.9 km are main roads and 10 km secondary roads.

Pravăţ forest road (Figure 2), having a length of 2.5 km, is a secondary road and assures the annual transport of 11,000 tones of wood.

By considering that timber transportation period is concentrated in 10 business days, and is realized with forest train vehicles carrying a quantity of 20…25 tones, it results a daily traffic of 4 charges/day, out of which 2 empty and 2 loaded (in the area where 2 economic agents operate).

Fig. 2. *Pravăţ forest road*

The geometrical and constructive characteristics of the road, according to its design project and field measurements are:

- design speed: 15 km/hour;
- average platform width: 5.2 m;
- average roadway width: 3.5…4.1 m;
- shoulder width: 0.375 m;
- minimum radius: 20 m;
- maximum longitudinal rise:
- on loaded transport: 9%;
- on empty transport: 12%;
- visibility distance: 40 m;
- the confidence degree on torrential events: 3%;
- recommended road system: simple gravel with two ballast layers.

As a consequence of the realized traffic there appeared a series of roadway degradations.

2.2. Research methodology

The research methodology was based on field observations and measurements. For this purpose there were established 4 observation points, uniformly distributed on the road length. In these observation points all the existent degradations were inventoried.

For each degradation, the type, as well as its dimensions (length, width, depth) were recorded. The recorded field results were centralized in order to be analyzed. The results centralization is presented in Table 1.

According to the recorded results for degradations, the afferent roadway affected surfaces were calculated. Some direct observations, necessary for conclusion formulation, were presented in the last column of Table 1; in the final part of the mentioned table, the total degraded surface as well as its proportion to the total surface (extracted from the forest management) were established.

In order to better reflect the current situation, in Table 2 is presented the affected roadway is presented by considering the degradation types.

3. Results and Discussions

The obtained data (from direct observations and measurements) has permitted the formulation of some preliminary conclusions regarding the technical state of Pravăţ forest road:

- on Pravăţ forest road, as a result of climatic and traffic stresses, all the known degradations which are specific to a graveled road were recorded (wavings, wheel-tracks, Frost-melting dips holes);
- the encountered degradations affected the roadway surface on an area of 23.03 m^2 (cumulated areas), which represents approx. 0.2% from total roadway area;
- each degradation type affected a greater or a smaller portion of the degraded area, respectively 68.11% in case of wavings, 22.72% in case of frost-melting dips, 8.17% in case of wheel-tracks and 1% in case of holes;
- the depths on which the roadway was affected vary between 4 and 43 cm; the deepest degradations were encountered in case of frost-melting dips, and the most reduced in case of wavings; encountered degradations confirm the fact that, during road exploitation, the most intense stresses are produced under the corroborated action of traffic and climatic factors;
- determinations regarding the depths of degradations showed that sometimes only the cover layer is affected, a fact which is justified by tangential solicitation actions occurring especially on the surface contact level; on the other hand, just like in case of holes, heavy use affects the entire road system, sometimes even the road bed (frost-melting dips);
- wheel-tracks present depths of 4…5 cm, and by being vertical deformations, depend on road bearing capacity and vehicle tonnage;
- supplementary observations realized on field, showed that on the Pravăţ forest road, heavy use has provoked greater degradations (Figure 3) than those encountered on other roads from the studied area, endowed with

Table 1

Inventory of recorded degradations in observation points from PRAVĂȚ forest road

Observation point no. and its localization	Degradation of roadway						Observations
	Degradation type	Dimensions					
		Length, [m]	Width, [cm]	Depth, [cm]	Maximum diameter, [cm]	Area, [m^2]	
1 Km 0+500	*Wavings*						Only the cover layer was affected
	No. 1	10	37	4.5	-	3.70	
	No. 2	14	26	4.0	-	3.64	
	No. 3	8	33	4.0	-	2.64	
	No. 4	15	38	5.0	-	5.70	
	Total wavings					15.68	
2 Km 1+000	*Wheel-tracks*						The tire width was considered for surface determination
	No. 1	12	-	5.0	-	0.6	
	No. 2	10	-	5.0	-	0.5	
	No. 3	8	-	6.0	-	0.48	
	No. 4	5	-	6.0	-	0.30	
	Total wheel-tracks					1.88	
3 Km 1+500	*Frost-melting dips*						Affects either only the cover layer or the entire road system, sometimes roadbed
	No. 1	3	39	25	-	1.17	
	No. 2	4	21	40	-	0.84	
	No. 3	3	44	43	-	1.32	
	No. 4	5	38	39	-	1.90	
	Total frost-melting dips					5.23	
4 Km 2+000	*Holes*						
	No. 1	-	-	15	0.31	0.075	
	No. 2	-	-	24	0.25	0.049	
	No. 3	-	-	30	0.28	0.040	
	No. 4	-	-	22	0.21	0.035	
	No. 5	-	-	6	0.20	0.031	
	Total holes					0.230	
Total degradations [m^2]						**23.02**	
Total roadway surface [m^2]						**12300.00**	
Affected surface A						**0.187**	

2 traffic lanes in the same traffic conditions; the phenomenon is augmented by the fact that in the case of 2 lane roads the traffic is realized on both lanes, and in the case of one lane Pravăț road, the existing lane serves traffic in both directions;

- the most intense stress is produced in small radius curves, where the action of the centrifugal force is more pronounced, as well as in high declivity portions, where the friction coefficient increases, due to slope contribution and/or supplementary deceleration effort [4].

Table 2

Affected surface on degradation types

Nr. crt.	Degradation type	Degrades surface percent, [%]	
		In rapport with total degraded surface	In rapport with total roadway surface
1	Wavings	68.11	0.127
2	Wheel-tracks	8.17	0.015
3	Frost-melting dips	22.72	0.043
4	Holes	1.00	0.002
Total		**100**	**0.187**

Fig. 3. *Holes and wavings on Pravăţ forest road*

4. Conclusions

From the conducted research, the following conclusions can be extracted:

- Forest roads which presently serve for timber transportation, are mostly graveled or gritted roads, meant to support an yearly traffic under 5,000 tones, this way being secondary roads;
- The graveled roads roadway is generally made of 1…2 layers which present in ensemble or separately both bearing and crust functions; in some situations (pronounced humidity, non favorable granulomety), a foundation layer is added to the road system;
- Total thickness of road layers used in secondary roads' realization is between 10…30 cm;
- Forest roads which are opened to circulation are affected by traffic and climatic factors, leading to degradations whose measure and shape has to be known or forecasted, in order to adopt adequate strategies and measures (reparations, rehabilitations) which would assure the functionality of the roads;
- Field studies revealed that the main degradations encountered on forest graveled roads are: wavings, wheel-tracks, frost-melting dips and holes; these degradations present extensions and depths which are directly proportional to vehicles' tonnage, traffic intensity and tire-road contact characteristics;
- In case of a relatively reduced yearly traffic, on Pravăţ forest road (4 passes/day during a 10 business day transport duration), the degradations' location affects 0.2% of roadway surface, if consolidated with ballast or poly-granular smashed rock;
- The degradations' depths vary between 4 and 43 cm, and they can affect, according to the degradation type, only the cover layer or the entire road system, sometimes even the roadbed;
- The obtained results, as the formulated conclusions impose the permanent deployment of a repairing-maintaining action, as well as a periodical rehabilitation of the road.

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