FORMEC 2010
Forest Engineering: Meeting the Needs of the Society and the Environment
July 11 – 14, 2010, Padova – Italy

EXPOSITION OF FOREST ROAD SLOPES AND THEIR NATURAL REVEGETATION ON HARD SURFACE

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Keywords: cut slope, fill slope, hard ground surface, forest road, Alps.

Abstract: *The revegetation of forest road slopes depends on many factors. For this research work we studied 170 transverse profiles of forest road in Menina planina (Alpine region, northern Slovenia) on hard, mainly limy ground surface. Unvegetated slopes present a threat for traffic safety, spoil the aesthetic image of landscape, and are regarded as potential erosion focal points. The inclination of slope, width of clearance, and ground surface all contribute to successful natural revegetation of slopes. Causeway side slopes revegetate better than excavated side slopes, because they are flatter and constructed in a way that enables faster revegetation. Slopes on warm positions (S, W) revegetate better than slopes on cold sites (N, E). Slopes with sufficient sunlight are also revegetating faster. The established key factors of revegetation of forest road slopes are exposition (position) of forest road, sunlight, and the inclination of slope. The amount of organic matter on the slope depends on these factors.*

1. Introduction

Primarily, the forest roads are designed for wood transportation with various silviculture trucks. Constructive and technical elements of forest roads are adjusted to the dimensions (length, width, height) of these vehicles. To build a forest road, an appropriate forest belt has to be cut down in order to provide for easy road structure construction. The construction of forest road represents the interference with natural environment, and for this reason all the damage done needs to be promptly repaired. The most delicate parts of road structure are excavated and causeway side slopes which are susceptible to temperature changes, erosion due to insufficient growth substratum, and water.

In view of the construction of the forest road network (technological choice, utility of material for the construction, dimension and type of drainage system) and the environment's potential fragility it is important to know the geological conditions. As a rule, on less stable and softer geological grounds there are problems with ground and rain water; if these influences are not considered, this may create a centre of erosion. Moreover, the geological ground has an impact on the incline chosen for the cut slopes. On soft ground, the cut slopes are more gentle (1/1 to 1.5/1). However, this increases the width of the roadway, and, in turn, the width of the belt of felled trees (Table 1). Likewise, humid locations and unstable slopes above the embankment necessitate a larger width of the belt of felled trees for the forest road.

Table 1. Average width of felled forest belt

Incline of ground (in %)	20	30	40	50	60	> 60
Soft ground	8 m	9 m	10 m	11 m	13 m	-
Hard ground	-	7 m	7 m	8 m	9 m	11 m

In stands of conifers (spruces, firs), a 5 m - wide cut through the forest may be considered as not having a marked impact on the stand. In stands of deciduous trees (beech trees), such a cut may have a width of 8 m. In beech tree forests, a period of 20 years after the construction of a forest road is usually sufficient for the border trees to totally cover the road profile with their crowns (Potočnik 1998).

For this reason, we plan a roadway width of 2.8 to 3.0 m for the most problematic ground, which is sufficient for normal lorry traffic. Lengthways, the road incline must not be in excess of 8 % on soft surfaces. Special attention should be paid to the length- and crosswise drainage, as well as the thickness and structure of the upper roadway layer (thick supporting and wear layer, and extra impervious layer).

This research work deals with the problem of revegetation of forest road slopes according to its age and cardinal point on hard geological surfaces, which are, from the aspect of revegetation, especially problematic due to steeper excavated side slopes. This research work tries to determine the successfulness of excavated and causeway side slopes revegetation according to their age and tries to find out the significance of position (the influence of forest road exposition on successful revegetation of slopes). Thus, several hypotheses were constructed, i.e. that causeway side slopes revegetate more successfully than excavated side slopes, that the slopes on warm positions revegetate more successfully, and that slopes with more light (greater width of clearance) revegetate more successfully than profiles with dense tree crowns.

The reasons for revegetating bare ground when constructing forest roads (Potočnik 1999):

- On bare excavated surface the erosion processes are present caused by rain fall and damage of drainage devices,
- Rolling of rocks from excavated slopes on the road surface endangers traffic safety and hinders the traffic,
- Bare slopes are unproductive, whereas the revegetated ones have direct and indirect advantages,
- Bare surfaces are not considered natural in otherwise green environment, therefore they interfere and spoil aesthetically harmonized landscape image.

The revegetating of slopes could be achieved in two ways: natural and artificial. The natural revegetating is appropriate because the severe consequences are not to be expected on temporarily bare surfaces, when the basic ecological conditions for growth are given, and when the period (time) of revegetation is not important. The natural revegetation means that the vegetation is adjusted to the specific environment, vegetation renews itself, and revegetation itself does not represent any costs. However, the natural revegetation lasts for relatively longer period and offers us no choice regarding the selection of vegetation species.

When there are no basic conditions for natural revegetation, the artificial revegetation is applied. It has to be fast, efficient, vegetation has to be adjusted to the environment, and the execution inexpensive. In case of steep slopes (hard surface) the biotechnical measures for stabilization of slopes are applied.

2. Working methods

The objects of research were chosen on the area of Menina planina (Alpine region, northern Slovenia), on mainly hard surface – dolomite limestone or limestone. The first transverse profile on the forest road was chosen at random, whereas all the following profiles succeeded at the distance of 10 steps, starting from the first transverse profile.

The network of forest roads on the selected locations enabled us to organize forest roads into three age classes:

- constructed in the period 1980 – 1989,
- constructed in the period 1970 – 1979,
- constructed in the period 1960 – 1969,

For each age class we found 15 – 20 transverse profiles. We measured the width of roadway, oblique length of excavated and causeways side slopes, the inclination of cut and fill slopes, azimuth of transverse profile and width of clearance. The measurement accuracy was 10 cm or 1 degree. Positions (azimuths) of profiles were combined into four cardinal points, so that the north direction was represented by azimuth from 316 to 46 degrees, south from 136 to 225 degrees, east from 46 to 135 degrees, and west from 226 to 315 degrees. Northern and eastern expositions were considered cold positions, whereas the southern and western ones were considered warm. With extra precision we tried to establish the level of revegetation of excavated and causeway side slopes, where we evaluated the revegetation with levels from 1 to 10; level 1 meaning the revegetation up to 10 %, level 2 from 11 % to 20 %, etc.

3. Results

The average inclination of cut slopes was 90 %, whereas with fill slopes the inclination was 58 %. Excavated side slopes were shorter than causeway side slopes, 3.3 m or 7 m respectively. The average width of the roadway was 4.9 m, whereas the average width of forest road clearance equalled 3.6 m. The revegetation of excavated and causeway side slopes is given in Tables 2 and 3. Only in the first age class (the youngest road) the statistically significant differences in revegetation of excavated and causeway side slopes were established. Results are shown in the Table 4.

Table 2. Average revegetation of cut slopes according to age classes of forest road and exposition

Exposition	Age class			
	1	2	3	Total
South	6.7	4.5	2.0	4.4
North	/	3.3	/	3.3
East	3.7	6.0	1.0	4.7
West	2.7	3.4	1.9	2.7
Total	4.3	4.4	1.9	3.8

Table 3. Average revegetation of fill slopes according to age classes of forest road and exposition

Exposition	Age class			
	1	2	3	Total
South	7.8	3.6	2.0	4.5
North	/	1.2	/	1.2
East	2.2	6.7	1.0	4.3
West	9.0	3.0	2.4	4.7
Total	6.3	4.0	2.2	4.4

Table 4. Calculation of t-test (p = 0.05) between the revegetation of cut and fill slopes according to age classes of forest road

	Cut slope 1-Fill slope 1	Cut slope 2-Fill slope 2	Cut slope 3-Fill slope 3
Arithmetic mean	4.3 – 6.3	4.4 – 4.0	1.9 – 2.2
Variance	9.20904 – 12.68814	9.99511 – 13.37950	1.94310 – 2.94737
Num. of measurements	60 – 60	72 – 72	38 - 38
Degrees of freedom	115	139	71
t-calculated	- 3.25546	0.70690	-0.58684
t-criterion	1.98081	1.97718	1.99394

We conclude that the proven differences in revegetation of cut and fill slopes are evident only on the youngest road, however these differences disappear with age. Furthermore, it is also interesting that the level of revegetation regarding cut and fill slopes of older forest roads is smaller than it is the case with younger roads. This could be ascribed to insufficient sunlight due to more shady clearance and construction technology – older roads have been built with bulldozers leading to lesser slope stability in comparison to excavator technique applied in construction of younger roads.

3.1 Cut slope

According to the exposition and within the age class, the revegetation of cut slopes was in certain combinations significantly different. Within the first age class (year of construction 1981 – 1990), the differences were established between southern and eastern, and southern and western exposition at the risk level of 5 %. However, the differences in slope revegetation were not proven between warm and cold positions (Table 5).

Table 5. Calculation of t-test (p = 0.05) for excavated side slope in the first age class (1981 – 1990)

	South - East	South - West	East – West	warm – cold
Arithmetic mean	6.7 – 3.65	6.7 – 2.65	3.65 – 2.65	4. 67 – 3.65
Variance	6.96 – 5.92	6.96 – 6.34	5.92 – 6.34	10.69 – 5.92
Num. of measurements	20 – 20	20 - 20	20 – 20	20 - 20
Degrees of freedom	38	38	38	38
t-calculated	3.80041	4.96594	1.27679	1.36564
t-criterion	2.02439	2.02439	2.02439	2.00957

Within the second age class (year of construction 1971 – 1980) the significant differences in revegetation were proven only between eastern and western positions. There were also no proven differences between cold and warm positions (Table 6).

Table 6. Calculation of t-test (p = 0.05) of cut slopes revegetation in second age class (1971 – 1980)

	north – south	north - east	north – west	south - east
Arithmetical mean	3.3 – 4.5	3.3 – 6.0	3.3 – 3.4	4.5 – 6.0
Variance	9.07 – 11.69	9.07 – 10.16	9.07 – 6.33	11.69 – 10.16
Num. of measurements	6 – 22	6 - 20	6 – 24	22 - 209
Degrees of freedom	9	9	7	40
t-calculated	- 0.81633	- 1.84159	- 0.03128	- 1.42242
t-criterion	2.26216	2.26216	2.36462	2.02107

	south - west	east - west	warm – cold
Arithmetical mean	4.5 – 3.4	6.0 – 3.4	3.9 – 5.3
Variance	11.69 – 6.33	10.16 – 6.33	9.01 – 10.79
Num. of measurements	22 - 24	20 - 24	46 – 26
Degrees of freedom	38	36	48
t-calculated	1.26158	2.93149	- 183315
t-criterion	2.02439	2.02809	2.01063

In the third age class there was impossible to do analyses of significant differences of cut slopes revegetation between warm and cold positions, neither it was possible to analyse them according to cardinal points due to insufficient number of data.

Then, we also tested the differences in cut slopes revegetation between different age classes. Between the first and second age classes we did not prove any differences in excavated side slopes revegetation neither in cold nor warm positions.

Table 7. Calculation of t-test (p = 0.05) of cut slopes revegetation between age classes

	warm 1 – warm 2	cold 1 – cold 2
Arithmetical mean	4.68 – 3.91	3.65 - 5.35
Variance	10.69 – 9.01	5.92 – 10.80
Num. of measures	40 – 46	20 – 26
Degrees of freedom	80	44
t-calculated	1.11964	- 2.01099
t-criterion	1.990065	2.015367

3.2 Fill slope

In the first age class we found out the significant differences in fill slopes revegetation between southern and eastern, and eastern and western positions with risk smaller than 5 %. The differences also existed between warm and cold positions, whereas between southern and western positions they were not established. Fill slopes on warm positions had greater level of revegetation as it was the case on cold positions, thus showing the influence of exposition (temperature) on the revegetation intensity.

Table 11. Calculation of t-test (p = 0.05) of causeway side slopes revegetation in the first age class

	south - east	south - west	east – west	warm - cold
Arithmetical mean	7.75 – 2.20	7.75 – 8.95	2.20 – 8.95	8.35 – 2.20
Variance	7.67 – 2.73	7.67 – 2.16	2.27 – 2.16	5.16 – 2.27
Num. of measurements	20 – 20	20 – 20	20 – 20	40 – 20
Degrees of freedom	29	29	38	53
t-calculated	7.970663	-1.71199	-14.3439	12.48633
t-criterion	2.045231	2.045231	2.045231	2.005745

In the second age class we found out that the differences in revegetation of causeway side slopes were significant between northern and southern positions, northern and eastern positions, northern and western, southern and eastern, and eastern and western positions – in each case with risk smaller than 5 %. The slopes on warm positions had also greater level of revegetation as it was the case on cold positions, thus indicating the positive influence of warmth on causeway side slope revegetation.

Table 12. Calculation of t-test (p = 0.05) of causeway side slope revegetation in the second age class

	north - south	north - east	north - west	south - east
Arithmetical mean	1.2 – 3.6	1.2 – 6.7	1.2 – 3.0	3.6 – 6.7
Variance	0.17 – 12.73	0.17 – 13.82	0.17 – 8.74	12.73 – 13.82
Num. of measurements	6 - 22	6 – 22	6 – 24	22 – 20
Degrees of freedom	23	20	26	39
T-calculated	-3.11315	-6.46802	-2.86225	-2.71500
T-criterion	2.06866	2.08596	2.05553	2.02269

	south - west	east – west	warm – cold
Arithmetical mean	3.6 – 3.0	6.7 – 3.0	3.3 – 5.4
Variance	12.73 – 8.74	13.82 – 8.74	10.51 – 16.09
Num. of measurements	22 - 24	20 – 24	46 – 26
Degrees of freedom	41	36	44
t-calculated	0.65153	3.59419	-2.30741
t-criterion	2.01954	2.02809	2.01537

In third age class we had insufficient number of measurements at our disposal to do the analysis.

We also tried to establish the significance of differences in cut slope revegetation on warm and cold positions between first two age classes (Table 14). It turned out that the time represented an important factor regarding slope revegetation: regarding younger roads, the causeway side slopes on warm positions were more revegetated, whereas on fill slopes of older roads the case was exactly the opposite - colder positions were more revegetated than warmer ones.

Table 13. Calculation of t-test (p = 0.05) of revegetation differences of fill slope between age classes

	warm 1 – warm 2	cold 1 – cold 2
Arithmetical mean	8.35 – 3.26	2.20 – 5.38
Variance	5.16 – 10.51	2.27 – 16.09
Num. of measurements	40 – 46	20 – 26
Degrees of freedom	81	34
t-calculated	8.51328	-3.72124
t-criterion	1.989688	2.032243

4. Discussion and conclusion

Results of studying the revegetation of slopes could help us making decisions when and in which sections it is reasonable to perform a rehabilitation of slopes with biotechnical measures, or what kind of natural conditions have to prevail in order to leave unvegetated slopes to natural processes. Regarding the area in question, the recreational function of forest is highlighted, therefore the aesthetic effect of revegetating – unrevegetating forest road slopes is important. In the case of this study, it was exclusively a matter of natural slope revegetation.

The main part of study dealt with analysis of slope revegetation significance in relation to age of forest road and cardinal point – exposition. The general finding is that the sides of older forest roads are less vegetated than it is the case with younger roads. Forest reacts to disturbances and tries to neutralize them by gradually closing the forest road clearance with tree crowns. The more the stand is dense, the less light reaches the ground, leading to less intensive revegetation – mostly there prevail mosses instead of shoots, shrubs and tree species. We established that causeway side slopes are greener than the excavated ones. The reason lays in stable inclinations of causeway side slopes and better growth conditions – loosened ground surface and protection of the existing trees. Differences in revegetation between fill and cut slopes are considerable, however they become less evident with time – the differences are proven only on the youngest roads. Furthermore, we found out the differences in revegetation of fill slopes between cold and warm positions: in principle, the fill slopes, as well as warm positions, are more suitable to revegetation. Apart from exposition, the time or age of forest road is also an important factor: regarding cut as well as fill slopes the most revegetated forest roads are the youngest, but the revegetation intensity decreases with age due to lack of light.

When dealing with sustainable forest road management, the slopes with inclinations on lower interval limit of stable inclinations for specific kind of ground surface have to be foreseen already in the process of planning. In principle, artificial revegetation and other biotechnical measures should be avoided due to financial and ecological reasons – it is more appropriate and rational to plan and construct such forest roads which will ensure stability of the whole road structure with their construction and technical elements.

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