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THE STUDY OF PLANNING AND DESIGNING SOME ELEMENTS OF AGRICULTURAL ROADS LOCATED WITHIN UPLAND PROTECTED AREAS

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ABSTRACT

The paper presents the principles of planning and designing selected elements of agricultural roads to be built on uplands located within protected areas. Special attention is paid the problem of localization of a road and choice of size of geometric elements. Various surface technologies, both presently applied and suggested to be used on local and internal roads are also discussed.

Key words: agricultural road, protected area.

INTRODUCTION

The economic development of rural terrains contributes to considerable growth of motorization, which extorts building of new agricultural roads as well as modernization of existing ones. It concerns particularly upland areas, where networks of agricultural roads should make up an aesthetical component of the surrounding landscape and, simultaneously, fully satisfy communication needs as well as create one of the elements of anti-erosion meliorations. Agricultural roads on those areas often pass gullies and ravines. Transportation on such roads is difficult due to the lack of hardened surfaces, ornate paths on adjoining fields limiting the size of transported cargo, small width of roads and steep slopes, often ambushed and afforested which restricts

visibility. They are also periodically closed as a result of being covered by snow or strong erosion in period of superficial flows.

The principles of planning and geometrical designing of agricultural roads described by different authors [1-7] are hardly sketched, and they require further research, which will allow elaboration of exact guidelines.

The work presents the results of many-years research on the extension of fundamentals for the spatial planning and geometrical designing of agricultural roads in country areas, including protected areas.

METHOD OF INVESTIGATIONS

The investigations were conducted in 1995-2002 on chosen objects on Nałęczow Plateau on ten segments of roads of the total length 14.5 km in small towns Kazimierz Dolny and Wąwolnica. For the selected road segments conceptions of road belt development were worked out, followed by systematic investigations concerning:

- analysis of route of studied roads on topographical maps in scale 1:10 000, with special regard to the terrain relief - the planes, slopes, river valleys, gullies;
- elaboration of conceptions of chosen geometrical elements of the roads - route composition, establishing road straight lines and curvilinear segments in a situational plan, formation line and vertical curves in the longitudinal profile of a road and its cross-section including the road together with its shoulder-spaces, crown of the road, road belt and gauge as well as transverse slopes;
- analysis of behavior of agricultural vehicles moving on chosen elements of agricultural roads;
- recognition of the accessibility of roads to adjacent fields and built-up terrains.

RESULTS OF INVESTIGATIONS ON AGRICULTURAL ROADS ON PROTECTED AREAS

From the carried out investigations it resulted that on slopes with the inclination up to 6% the existing and newly designed agricultural roads with the longitudinal formation line slope up to 4% may be strengthened by corrections of the ground texture covering the road to the so-called optimum mixture or leave the road in the profiled shape. However the roads with the slope exceeding 4% require surface hardening and implementation of specially reinforced devices for piping away superficial runoff waters. Such roads, if they have only land surfaces, transform in to road gullies, deepening fairly by 4.5 cm/year, and maximally up to 9.0 cm/year.

The examined roads were located on slopes with the inclination up to 14% in dorsal slope parts, on local watershed borders with smallest concentration of superficial waters, to limit erosion (Fig. 1a, 1b). On the roads this way situated there were no destructions caused by erosive processes. However on the slopes with the inclination exceeding 14% the roads were designed obliquely to the slope, along a curvilinear course in order to decrease the longitudinal slope, (down to 6%) and to achieve an aesthetical composition with the landscape (Fig. 1c). The thus situated roads, however, have large drainage areas, so flowing periodical waters erode them considerably. During the investigations, the observed rills in roadways reached even 1.8 m. Therefore, it is better to locate roads in inter-slope valleys, on the condition that the road belt lies apart from the range of concentrated flow of superficial waters (Fig. 1d). Besides, one should avoid crossing valleys, because it requires constructing road roll passes and special draining devices which increase the final cost considerably.

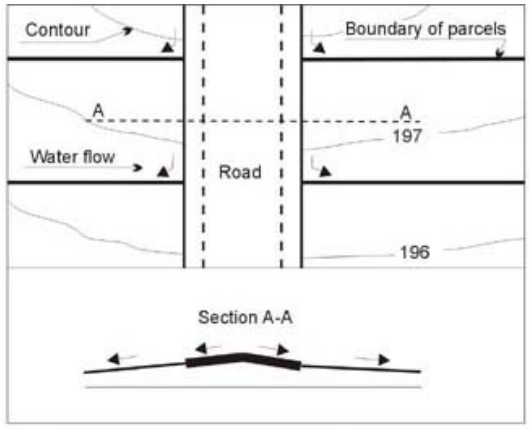
The investigations showed also that agricultural roads in river valleys should be located, if possible, on the edge of a valley - at the foot of the slope. Then they have smaller longitudinal formation line slopes (to 4%), and are slightly threatened with erosion. Such roads are correctly put into a composition with the surrounding landscape and are characterized in the situational plan by large quantity of curvatures as well as many draining objects (ditches, roll passes and bridges).

The studied roads were characterized by gentle curvatures and small longitudinal formation line slopes (to 4%) as well as small road drainage areas. The water concentration in the road belt did not threaten the land surface. It occurred that natural sod protected the surface of these roads perfectly, therefore one should conclude that durable sodding strengthens the surface of such roads well.

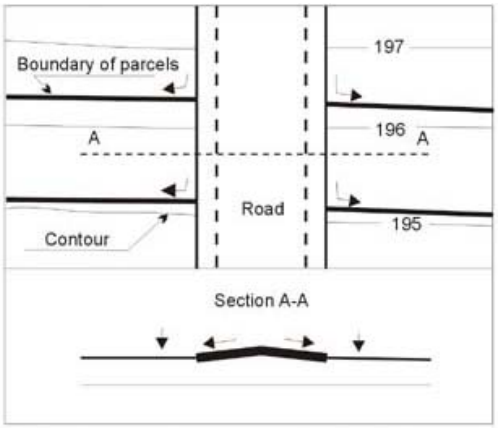
The examined roads near gullies were characterized by a high longitudinal formation line slopes (above 6%) and large road drainage areas. The water concentrating in the road belt caused large erosive damages to the ground surface. Therefore, one should harden roads located near gullies, and reinforce their draining devices. Road gullies, with their special natural values, should be intended for foot and bicycle paths, preserving the natural

ground surface, whereas vehicular traffic should be reduced to the indispensable minimum. For piping away superficial waters from the drainage area of such a gully one should apply efficient draining devices, designed exclusively for the protected gully.

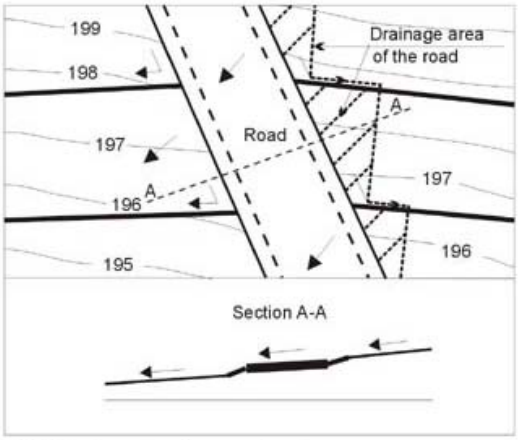
Figure 1. Localization of roads in the relief



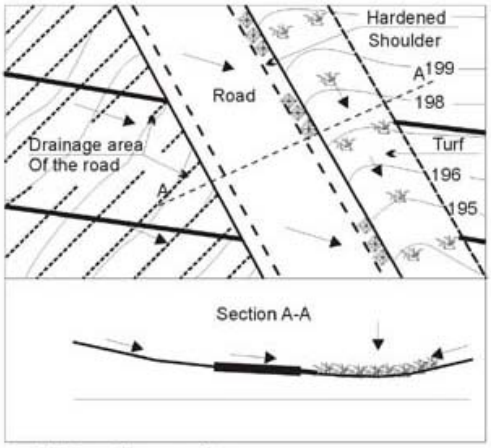
A) The road on watershed border



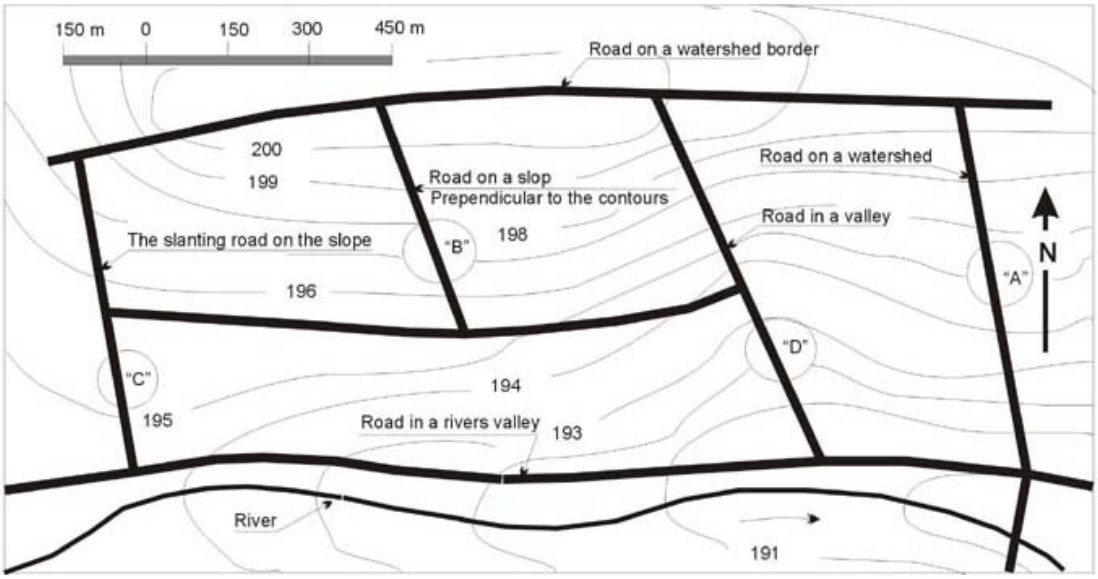
B) Road on a slope preprndicular to the contours



C) Slanting road on a slope



D) Road in a valley



GEOMETRICAL ASPECTS OF THE DESIGN OF AGRICULTURAL ROADS ON PROTECTED AREAS

The basis for dimensioning of geometrical elements of a agricultural road is the assumed velocity - Vp (km/h) as well as atypical gauge for agricultural vehicles and combined harvesters. In the investigations, the assumed velocity serves first of all to determine curvatures along the route, transverse and longitudinal cross-sections as well as longitudinal and transverse slopes. Numerical values of assumed velocities depend on the terrain, foreseen traffic intensity and its character as well as economical issues (Tab. 1).

Table 1. Elements geometric design of rural roads on terrains with a diverse

Technical data	Unit of measure	Agricultural road category		
		main road	common road	field road
		A	B	C
Design speed (V_p)	km/h	40	30	30
Minimum radius of horizontal curve	m	60	30	30(15)
Width of roadway	m	5.0–6.0	3.5–4.0	3.0–3.5
Width of road crown (road and shoulder)	m	6.5–8.0	5.0–6.0	5.0–6.0
Width of road line	m	10.0–15.0	8.0–10.0	6.0–8.0
Minimum visibility distance on horizontal curves ($2S_H$)	m	50	40	40
Recommended length of transient lines	m	20	20	15
Maximum gradient of formation line	%	7	8	10
Minimum rays of vertical convex curves	m	300	200	180
Minimum rays of vertical concave curves	m	200	120	100
Maximum cross slope on horizontal curves	%	7	6	6

The basic geometrical elements of the studied agricultural roads in a situational plan are straight lines, transitory straight lines, horizontal circular arcs as well as, in several cases, horizontal basket arcs. The length of the straight line segments of the studied roads in the protected area is dependent on the composition of the surrounding landscape and relief of the terrains. The transitory straight lines are designed between the straight line segments and circular arcs in situations of making use of an extension or one-sided superelevation on a circular arc. The applied lengths of transitory straight lines (from 15 to 20 m) put themselves correctly together into a composition of the straight line and circular arc. The radius of circular arcs for every curvature in a situational plan can be found with the help of the formula, [1]:

$$R_{\min} = V_p 2(127(\mu + i)) - 1$$

To calculate the minimum radii, the maximum superelevation of $i = 7\%$ on a horizontal arc was assumed, and the coefficient of the transverse adhesiveness $R = \mu$, in the numerical range from 0.27 to 0.34 for V_p correspondingly 40-20 km/h was incorporated as well radii of horizontal arcs recommended for roads in upland areas are given in Tab. 1.

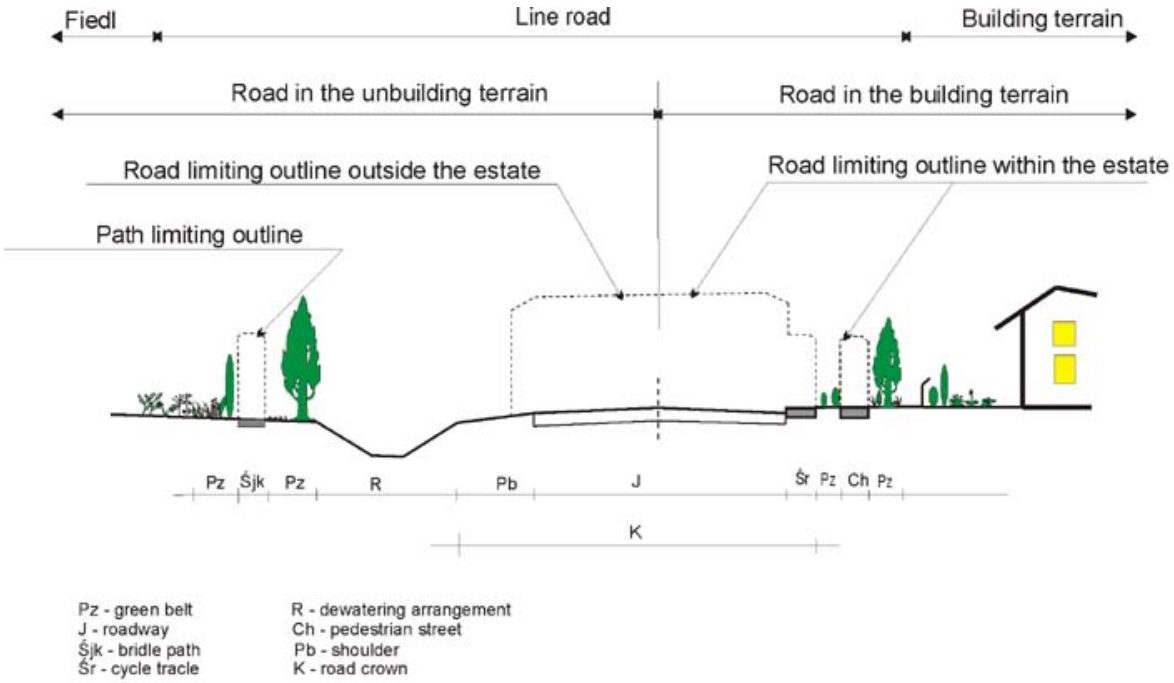
The basic units of the formation line of the studied roads were straight linear segments with a uniform inclination as well as perpendicular concave and convex arcs. It was observed that on the examined terrain, the vehicles being operated overcame considerable longitudinal slopes of the roads.

To maintain fluency of traffic on roads, longitudinal slopes with the interval 1%, were tested which made it possible to establish the maximum inclinations of the road formation line (Tab. 1). In the elaborated conceptions, the formation line refractions were softened by convex and concave perpendicular arcs, and the values of the curvature radius were assigned on the basis of geodesic measurements realized by the method of longitudinal intersections. The recommended minimum values of the radius obtained in the investigations that ensure the required softening of the formation line refraction and put the road into a composition with the terrain are given in Tab. 1.

The conducted investigations show that the correct management of the road belt of agricultural roads on protected areas should include a hardened or improved surface of the road, ground or hardened shoulders, bicycle and foot paths (sidewalks), paths for horsemanship, draining devices as well as safety side belts (Fig. 2).

The mentioned elements establish an integral area called the road belt. The widths of a road with shoulders have a close relationship with the function of the road, operational (assumed) velocity, intensity of traffic as well as with the width of combine harvesters and agricultural vehicles. On the basis of the field and cartographical investigations one can establish the dimensions of a road with shoulders, the crown of road and road belt (Tab. 1). The road gauge of the transverse cross-section, i.e. the part of space occupied by moving vehicles, should not be covered by any buildings, signs, devices as well as not be afforested or ambushed either. The analysis of possibility of passage of on agricultural machine 3.5 – 6.5 m wide in the working state resulted in the gauge of the studied roads to ensure a safe width, about 1 m larger than the largest width of the machine itself.

Figure 2. Design of a suggested cross-section of a rural road placed on a protected



The literature and own investigations indicate that transverse inclinations of agricultural roads can be two or one-sided. Bilateral inclinations appear on two-roadway roads, whereas one-sided ones on single-roadway roads. Numerical values of the inclinations determined from the worked out criteria, taking into account the kind of a surface and inclination of the road formation line, are given in Tab. 2.

Table 2. Inclinations of agricultural roads

Kind of road structure	Gradient of formation line (%)		
	0-2	2-4	>4
	Cross slope (%)		
Improved and hardened (to be improved before winter)	2.0-1.5	2.0-1.0	1.0
Hardened	3.5-3.0	3.0-2.5	2.5-1.5

REMARKS ON THE SURFACE OF AGRICULTURAL ROADS ON PROTECTED AREAS

On upland terrains, where roads become periodically impassable, there occurs a tendency that aims to make surfaces of the road from local materials stabilized with binding hydraulic agents (cement, lime, ashes from lignite) or from natural and crumbled aggregates, stabilized mechanically. Carriageway layers (if they appear) are most often built from thin bituminous layers or superficial bituminous consolidations. These solutions are applied so far to agricultural roads fulfilling simultaneously the function of local roads. It seems that, at present, it is possible to make use of prefabricated concrete bricks to carriageway layers in protected areas (and others). Such surfaces may be applied in areas of antique town-planning of cities, settlements, colonies and agrotouristic villages. One may use them to harden roadways, representative municipal squares, crossings, bus lanes, bicycle paths, pavements, park avenues, sidewalks and foot paths, footbridges, car parks, sport fields as well as car and pedestrian drawbridges over protected gullies. An apt adaptation of the colour of the road surface to the surroundings can increase aesthetical values. Admittedly, especially important remains the durability of the road, resistance to the influence of atmospheric conditions and convenient maintenance.

On non-developed areas, one may give up the coating of carriageway layers in order to lower the cost of building of the road. Hardened surfaces deprived of the carriageway are especially susceptible to excessive dusting during times of immoderate dry weather. On the other hand excessive moisture may create local deformations and gaps on the road surface which would unfavorably affect their technical and aesthetical condition.

In the technical process of road belt organization one must not omit road drainage measures, which lie in the proper shaping of road geometrical parameters, including suitable longitudinal and transverse slopes, elevation over the adjacent terrain, realization of wayside ditches, sewages as well as storm sewage systems. The draining measures have to be particularly protected via different methods against the destructive impact of superficial waters [1,6]. From among existing methods, the fixing with turf on an artificial subsoil [6] deserves special attention.

CONCLUSIONS

1. The conducted investigations have broadened the data base of spatial and technical conditions on the network of agricultural roads in upland terrains of protected areas menaced with erosion. The obtained qualitative and quantitative data can be used particularly in order to optimize the principles of the locating and geometrical designing of agricultural roads on steep terrains.
2. The investigation results show that the best locations of agricultural roads in terrains with a diverse relief are watershed borders or dorsal parts of slopes, in other words the places without any inflow of superficial waters. Mid-slope valleys out of the range of flowing superficial waters are good locations as well.
3. The investigations results show that agricultural roads with the longitudinal slope of the formation line up to 4% do not require hardening. They may be improved by correcting the ground texture beneath the road to the so-called optimum mixture or by soding. However in the case when the slope of the longitudinal formation line exceeds 6%, the hardening of roadways and application of draining devices becomes inevitable.
4. The geometrical elements of agricultural roads (straight line segments, transitory straight lines, horizontal and vertical circular arcs, inclination of the formation line) should be designed according to the function of the road as well as of the assumed traffic velocity - from 20 up to 40 km/h.
5. The correctly developed road belt of on agricultural road on protected areas should consist of a road with a hardened or improved surface, ground or hardened side space (gauge), bicycle path, pavement, path for horsemanship, draining devices as well as safety two-sided ground belts separating the road from the adjacent terrain.

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