Original Scientific paper
UDK 551.781:622.012]:553.548
http://dx.doi.org/10.7251/afts.2022.1427.019G
COBISS.RS-ID 137252609

CORRELATION AND REGRESSION RELATIONSHIPS OF PARAMETERS OF RAINWATER DRAINAGE FROM ROADS

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SUMMARY

In order to find the optimal solution for the drainage of rainwater from roads in urban areas, as well as for the evaluation and ranking of conceptual solutions, appropriate mathematical models and software packages were used in this research.

For relevant rain episodes, i.e. rainfall of appropriate duration and intensity, runoff coefficients and flows were taken into account and analyzed according to the rational method, all for the purpose of obtaining data on the amount of rainwater entering the sewage system.

Through this research, very good correlations and regressions were established between the cross slope of the road and the parameters of rainwater drainage from the road, as well as the correlation and regression relationships of the cross slope of the road and the efficiency of the drain. Likewise, the dependences of the drainage parameters, the efficiency of the drains and the cross slope of the road were determined, expressed through mathematical functions.

Keywords: *runoff, cross slope, efficiency, drainage, correlations, regressions*

INTRODUCTION

Effective road drainage is very important for ensuring the stability of the lower and upper road machinery, as well as for comfort and safety in working conditions. [1] The basic task for fulfilling these conditions is that all forms of water are kept under constant control and drained by the shortest route into permanent or occasional natural watercourses. Correct selection of the geometric relationships of the upper machine and the drainage system results in faster drainage, and in this sense the level of traffic safety increases.

In order to review the results of the research on the drainage of surface water from the road with regard to the efficiency of the drains, the paper processed the variants with the longitudinal slope of the roads of 2% and 5%, while the transverse slopes were changed in an interval of 1.5%, up to the final 3.5% . For the purposes of the research in this paper, the area of the pavement construction basin was determined, and the concentration time of the basin was calculated for each transverse slope separately. [2,3]

CORRELATION AND REGRESSION ANALYSIS OF SETS OF HYDROTECHNICAL PARAMETERS

This chapter of the dissertation will deal with the correlation and regression analysis of the results of the hydrotechnical parameters obtained in the hydraulic calculation of drainage from the road, (results shown in table 1. Results of the hydraulic calculation of drainage for the longitudinal fall of the road 2% and table 2. Results of the hydraulic calculation drainage for the longitudinal fall of the road 5%).

Table 1. Correlation and regression analysis of the results of the hydrotechnical parameters

value of cross slope	intensity of the rain	the flow coming into the drain	inflow directly in front of the drain	the part passing over the drain	travel time of storm runoff to the roadside	the initial width of flooding	the extreme width of flooding	the average width of flooding	average speed of the flow	the travel time of rainwater runoff along the roadside between two drains	the time of concentration of the watershed	the parameter	the part of the flow that encounters the drain head-on	part of the flow that flows laterally into the drain	the efficiency of the drain system in accepting the frontal inflow	the efficiency of the drain in accepting the lateral inflow	efficiency of the drain
	ik (mm/min)	Qi (l/s)	Q (l/s)	Qb (l/s)	t01 (min)	b1 (m)	b2 (m)	bs (m)	va (m/s)	t02 (min)	t0 (min)	E0	Qw (l/s)	Qs (l/s)	Rw	Rs	E
1,50%	3,405045	7,405972	11,05369	3,647718	0,721582	1,028216	1,558266	1,30934	0,540468	0,770937	1,49	0,643651	7,114721	3,938969	1,115946	0,082876	0,747812
1,75%	3,431313	7,463107	11,13897	3,675859	0,66795	0,936471	1,419226	1,192511	0,562783	0,740368	1,40	0,685957	7,640857	3,498109	1,108553	0,08927	0,788455
2,00%	3,449071	7,501729	11,19661	3,694881	0,626862	0,863157	1,308119	1,099152	0,582639	0,715137	1,34	0,723173	8,09709	3,09952	1,101975	0,095224	0,823279
2,25%	3,467027	7,540785	11,2549	3,714118	0,593885	0,803462	1,21765	1,023136	0,60083	0,693485	1,28	0,755822	8,506699	2,748204	1,095948	0,100741	0,85294
2,50%	3,479111	7,567067	11,29413	3,727063	0,567107	0,75324	1,141539	0,959183	0,617403	0,67487	1,24	0,78491	8,864881	2,429249	1,090458	0,105965	0,878704
3,50%	3,51902	7,653869	11,42369	3,769816	0,49434	0,613001	0,929005	0,780601	0,673502	0,618657	1,11	0,872595	9,968255	1,455431	1,071872	0,124259	0,951142

In table 1. the results of the hydraulic calculation of drainage from roads are presented for the longitudinal fall of roads of 2%, where the transverse fall of the road was changed through variants in the interval from 1.5% to 3.5%. [4]

Table 2. Hydraulic calculation of drainage from roads

value of cross slope	intensity of the rain	the flow coming into the drain	inflow directly in front of the drain	the part passing over the drain	travel time of storm runoff to the roadside	the initial width of flooding	the extreme width of flooding	the average width of flooding	average speed of the flow	the travel time of rainwater runoff along the roadside between two drains	the time of concentration of the watershed	the parameter	the part of the flow that encounters the drain head-on	part of the flow that flows laterally into the drain	the efficiency of the drain system in accepting the frontal inflow	the efficiency of the drain in accepting the lateral inflow	efficiency of the drain
poprečni pad	ik (mm/min)	Qi (l/s)	Q (l/s)	Qb (l/s)	t01 (min)	b1 (m)	b2 (m)	bs (m)	va (m/s)	t02 (min)	t0 (min)	E0	Qw (l/s)	Qs (l/s)	Rw	Rs	E
1,50%	3,419585	7,437596	11,10089	3,663294	0,898397	0,86729	1,314383	1,104416	0,762887	0,546171	1,44	0,720991	8,003645	3,097245	1,042259	0,046339	0,764389
1,75%	3,449071	7,501729	11,19661	3,694881	0,819828	0,790171	1,197508	1,006211	0,794564	0,524396	1,34	0,763378	8,547245	2,649364	1,031765	0,05005	0,799469
2,00%	3,473058	7,553901	11,27448	3,720578	0,758341	0,728794	1,104491	0,928053	0,822962	0,506301	1,26	0,79958	9,014853	2,259627	1,022357	0,053501	0,828179
2,25%	3,491287	7,593548	11,33365	3,740106	0,708937	0,678402	1,028121	0,863883	0,848665	0,490967	1,2	0,830759	9,415539	1,918115	1,013842	0,056752	0,851863
2,50%	3,509723	7,633648	11,3935	3,759856	0,667977	0,636424	0,964503	0,810428	0,872464	0,477575	1,14	0,857496	9,769886	1,623618	1,005957	0,059801	0,871126
3,50%	3,556748	7,735927	11,54616	3,810233	0,557461	0,518303	0,785491	0,660012	0,952192	0,437587	0,99	0,932723	10,76936	0,776797	0,979544	0,070699	0,918399

In table 2. the results of the hydraulic calculation of the drainage from the roads are presented for the longitudinal slope of the roads of 5%, where the transverse fall of the road was changed through variants in the interval from 1.5% to 3.5%. The data on the cross slopes of the road, the speed of the flow, the concentration time of the watershed, the width of flooding and the efficiency of the watershed were examined for mutual connection, that is, correlation and regression. At the same time, connection means that the value of one variable can be predicted with a certain probability on the basis of knowledge about the value of another variable. In order to examine the correlation and regression between individual measured parameters, the 3Bstat software package was used. Pearson's coefficient of simple linear correlation, r, shows the degree and direction of linear (straight-line) quantitative agreement of variations between two numerical variables (characteristics), [4,5]

CORRELATION AND REGRESSION OF THE SETS "CROSS SLOPE" AND "DRAINAGE EFFICIENCY" FOR THE LONGITUDINAL SLOPE OF THE ROAD 2%

In table 3. in the software package 3Bstat, the Pearson coefficient of simple correlation was calculated and displayed for two sets, cross-fall and drainage efficiency.

Table 3. Pearson's simple correlation coefficient r (excerpt from 3Bstat software)

14. 03. 2022 09:37 Analysis Number: 1		
Pearson's simple correlation coefficient r		
Varijables		
X :	Cross slope %	
Y :	Drain efficiency	
r :	0,9819	
TESTING		
Standard error Simple correlation coefficient	**T-test statistics**	***P***
0,0946	10,3828	0,0004858
$\mathbf{H_0}$:	There is NO linear correlation in the base set	
$\mathbf{H_1}$:	There is a linear correlation in the basic set	
Conclusion:		
When testing the null hypothesis that there is no linear correlation in the basic set, the obtained p-value of 0.0005 indicates that		
in the basic set there is a linear relationship at the significance level of 0.01 because the p-value is < 0.01.		
We conclude that the simple correlation coefficient r IS statistically significant		

In table 3. it is visible that the Pearson coefficient is r =0.9819, has a positive value and is very close to the value r =1.0. Further, from table 3. the conclusion is also visible; When testing the null hypothesis that there is no linear correlation in the basic set, the obtained p-value 0 indicates that there is a linear relationship in the basic set at a significance level of 0.01 because the p-value is < 0.01 and that the simple correlation coefficient r IS statistically significant. Pearson's coefficient with its value r =0.9819 indicates a strong correlation between the examined sets. [5,6]

In table 4. in the software package 3Bstat, the results of simple regression were calculated and displayed for two sets of cross-fall and efficiency of the drain. As the explanatory variable X, the total cross-fall was taken, and as the dependent variable Y, the set of results was the efficiency of the drain.

Table 4. Simple regression (excerpt from 3Bstat software)

14. 03. 2022 09:37 Analysis Number: 2				
Simple regression				
Explanatory variable X = cross slope %			Dependent variable Y = Drain efficiency	
Drain efficiency = 0,6175 + 0,0991 * cross slope %				
Parameter	Rating	Stand. Estimation error	t-value	*p*-value
Section	0,6175	0,02230	27,6432	0
Slope	0,0991	0,00951	10,3828	0,0005
Determination coefficient r^2 = 0,9642 (96,4223 %)				
Standard regression error s = (0,0151)				
Comment:				
The grade of the section is significant at the level of 0.05				
The slope estimate is significant at the 0.05 level. Variable cross slope % affects the variable Drain efficiency				

From table 4. the implementation of the regression analysis with all its elements is visible (intercept score, slope score, coefficient of determination r2, standard error of the regression).

The value of the coefficient of determination is r2 =0.9642 or 96.42%, indicating that the variations of variable Y are almost entirely explained by the regression line, which indicates a strong regressive relationship of the studied sets, Figure 1 and 2.

Likewise, in the comment of the table, it is shown that: the section grade is significant at the 0.05 level, and that the slope grade is also significant at the 0.05 level, and that the variable cross fall % affects the variable drain efficiency. [7]

The mathematical formula is also shown:

$$E\ (d) = 0.6175 + 0.0991\ x\ cross\ slope\ \%, \quad (1)$$

taking into account the standard error with respect to the sample size (in this case, a small sample).

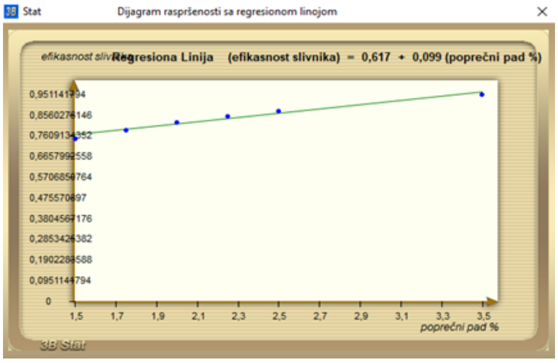

Figure 1. Scatter plot with regression line (excerpt from 3Bstat software)

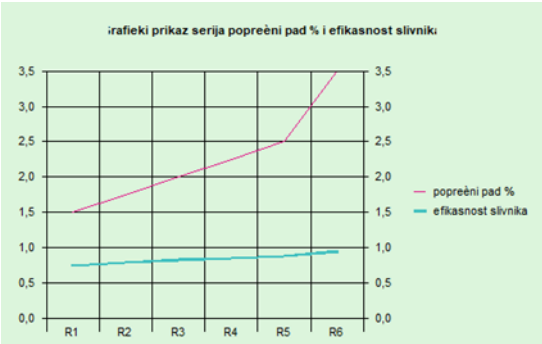

Figure 2. Graphic representation of series transverse fall – drain efficiency (excerpt from 3Bstat software)

CORRELATION AND REGRESSION OF THE SETS "CROSS SLOPE" AND "DRAINAGE EFFICIENCY" FOR THE LONGITUDINAL SLOPE OF THE ROAD 5%

In table 5. in the software package 3Bstat, the Pearson coefficient of simple correlation was calculatedand displayed for two sets, cross-fall and drainage efficiency, [7,8,9]

Table 5. Pearson's simple correlation coefficient r (excerpt from 3Bstat software)

10. 04. 2022 23:35 Analysis Number: 1			
Pearson's simple correlation coefficient r			
Varijables			
X :	Cross slope %		
Y :	Drain efficiency		
r :	0,9671		
TESTING			
Standard error Simple correlation coefficient		**T-test statistics**	***P***
0,1271		7,6088	0,0016012
H_0 :	There is NO linear correlation in the base set		
H_1 :	There is a linear correlation in the basic set		
Conclusion:			
When testing the null hypothesis that there is no linear correlation in the basic set, the obtained p-value of 0.0016 indicates that			
in the basic set there is a linear relationship at the significance level of 0.01 because the p-value is < 0.01.			
We conclude that the simple correlation coefficient r IS statistically significant			

In table 5. it is visible that the Pearson coefficient is r =0.9671, has a positive value and is very close to the value r =1.0. Further, from table 5. the conclusion is also visible; When testing the null hypothesis that there is no linear correlation in the basic set, the obtained p-value 0 indicates that there is a linear relationship in the basic set at a significance level of 0.01 because the p-value is < 0.01 and that the simple correlation coefficient r IS statistically significant. Pearson's coefficient with its value r =0.9671 indicates a strong correlation between the examined sets.

In table 6. in the software package 3Bstat, the results of simple regression were calculated and displayed for two sets of cross-fall and efficiency of the drain. As the explanatory variable X, the total cross-fall was taken, and as the dependent variable Y, the set of results was the efficiency of the drain.

Table 6. Simple regression (excerpt from 3Bstat software)

10. 04. 2022 23:35 Analysis Number: 2				
Simple regression				
Explanatory variable X = cross slope %			Dependent variable Y = Drain efficiency	
Drain efficiency = 0,6718 + 0,0743 * cross slope %				
Parameter	Rating	Stand. Estimation error	t-value	*p*-value
Section	0,6718	0,02290	29,3959	0
Slope	0,0743	0,00981	7,6088	0,0016
Determination coefficient r^2 = 0,9354 (93,5374 %)				
Standard regression error s = (0,0154)				
Comment:				
The grade of the section is significant at the level of 0.05				
The slope estimate is significant at the 0.05 level. Variable cross slope % affects the variable Drain efficiency				

From table 6. the implementation of the regression analysis with all its elements is visible (intercept score, slope score, coefficient of determination r^2, standard error of the regression). The value of the coefficient of determination is r^2 =0.9354 or 93.53%, indicating that the variations of the variable Y are almost entirely explained by the regression line, which indicates a strong regressive relationship of the examined sets, Figure 3 and 4.

Likewise, in the table's commentary, it is shown that: the section grade is significant at the 0.05 level, and that the slope grade is also significant at the 0.05 level, and that the variable cross fall % influences the variable flow velocity va (m/s).

The mathematical formula is also shown:

$$E_{(d)} = 0.6718 + 0.0743 \text{ x cross slope } (\%), \qquad (2)$$

taking into account the standard error with respect to the sample size (in this case, a small sample).

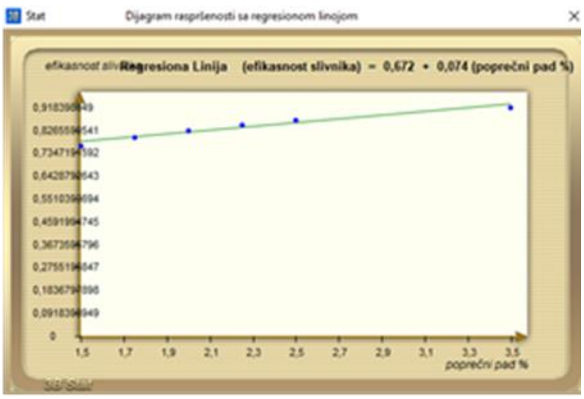

Figure 3. Scatter plot with regression line (excerpt from 3Bstat software)

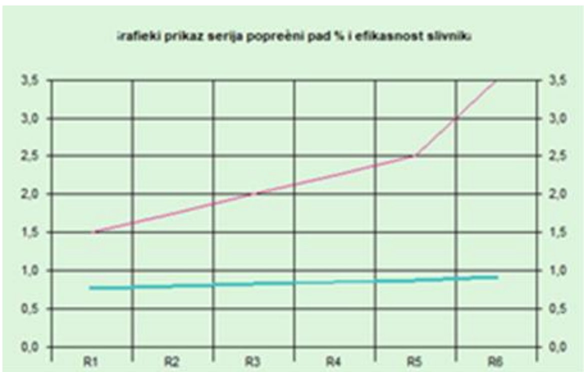

Figure 4. Graphic representation of series cross slope – drain efficiency (excerpt from 3Bstat software)

The scatter diagram is constructed in a rectangular coordinate system. At the same time, the units of the phenomenon, which we marked as the independent (explanatory in the regression analysis) variable X (transverse decline %), were applied to the abscissa axis, and the units of the dependent variable Y (watershed efficiency) to the ordinate axis.

By plotting all empirical pairs of data, an important picture can be obtained at a glance about the possible existence, shape, direction and strength of the connection between the observed phenomena. In the specific case in Figure 3. it is visible that there is a quantitative agreement. All empirical data pairs are on the regression line, which indicates a strong quantitative agreement between the observed phenomena. The stacking form is linear, with a direct stacking direction (an increase in one phenomenon leads to an increase in another phenomenon, which is also visible from the graphic representation in Figure 4. [4,10]

CONCLUSIONS

Correlation and regression relationship was established between the cross slope (%) and the efficiency of the drain for the analyzed longitudinal slopes of the road. The analyzes show that when testing the null hypothesis that there is no linear correlation in the basic set, the obtained p-value 0 indicates that there is a linear relationship in the basic set at a significance level of 0.01 because the p-value is < 0.01 and that the simple correlation coefficient r IS statistically significant. Pearson's coefficient with its value $r = 0.9819$ indicates a strong correlation between the examined sets. The analysis table shows that the value of the coefficient of determination is $r^2 = 0.9642$ or 96.42%, indicating that the variations of the variable Y are almost entirely explained by the regression line, which indicates a strong regressive relationship of the examined sets.

Likewise, in the comment of the table, it is shown that: the section grade is significant at the 0.05 level, and that the slope grade is also significant at the 0.05 level, and that the variable cross fall % affects the variable drain efficiency. The direct dependence of the sets was also determined, i.e. when the value of one set increases, the value of the other set also increases. In this case, when the value in the cross-fall set increases, so does the value in the sump efficiency set. For the analysis and modeling of sets of cross-fall and drainage efficiency in the 3Bstat package, a mathematical expression is given that describes their connection.

(Received October 2022, accepted October 2022)

REFERENCES

[1] Stanić, M. (2018). Rainwater drainage, University of Belgrade, Faculty of Civil Engineering, Serbia. *[Serbian language]*

[2] Bašić, Z. (2014). Roads, publishing house OFF-SET Tuzla, Bosnia and Herzegovina. *[Bosnian language]*

[3] Hrelja, H. (2007). Engineering Hydrology, University of Sarajevo, Bosnia and Herzegovina. *[Bosnian language]*

[4] Galamić, A. (2022). Drainage of rainwater from roads with analysis of pollution burden calculation methods, Doctoral dissertation, University of Tuzla, Bosnia and Herzegovina. *[Bosnian language]*

[5] Manual for road design in the Republic of Serbia, drainage system, (2011). Belgrade, Serbia. *[Serbian language]*

[6] Nurkanović, Z., Demirović- Garić, M. (2016). Selected Chapters in Mathematics, PrintCom Tuzla Publishing House, Tuzla, Bosnia and Herzegovina. *[Bosnian language]*

[7] Galamić A., Tokić M., Hrnjadović J, (2019). The influence of cross slope on hydraulic calculation of drainage pavements , Modern achievements in construction, Subotica 23-24. April 2019. Serbia. *[Serbian language]*

[8] Suljić, N. (2018). Hidrotehnika- solved tasks and theoretical bases, publishing house OFF-SET Tuzla, Bosnia and Herzegovina. *[Bosnian language]*

[9] Hvitved-Jacobsen T., Vollertsen J., Nielsen A. 2010. Urban and Highway Stormwater Pollution-concepts and Engineering. CRC Press. Taylor&Francis Group, Boca Raton, FL, USA.

[10] U.S. Department of Transportation, Federal Highway Administration, 2001. Hydraulic Engineering Circular No. 22, Second Edition, Urban Drainage Design Manual