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SIDE DRAINAGE DESIGN FOR ROADS USING SDDRoads®

Julián Andrés Pulecio Díaz[1], Oscar Camilo Valderrama Riveros[1] and Myriam Rocío Pallares Muñoz[2]
[1]Civil Engineering Program, Faculty of Civil Engineering, Universidad Cooperativa de Colombia, Colombia
[2]Faculty of Engineering, Universidad Surcolombiana, Colombia
E-Mail: myriam.pallares@usco.edu.co

ABSTRACT

In this paper SDDRoads® software is introduced for the side drain design for roads using the rational empirical methods and the Continuity and Manning equations. The Hypertext Preprocessor (Php) programming language applied to develop SDDRoads® allows multiplatform running and since this is a Web application it works on all operating systems. SDDRoads® software helps to estimate the length of ditch for four triangular cross-sections, one of these built on ground and three ones built with concrete. SDDRoads® software proves to be an interesting calculation application to use from anywhere in the world for its versatility since being a Web application it could be installed in computer, tablet or smartphone (multiplatform). The results obtained using SDDRoads® were satisfactorily verificated with a study case proposed by the INVIAS (2007) proving that SDDRoads® is able to solve designs adapted to the constructive reality of ditches from runoff coefficient (C), longitudinal slope of ditch (S), rainfall intensity (I), impluvium width (B) and velocity of water (v) data.

Keywords: software, ditch, lateral drainage, hydraulic design, SDDRoads®.

1. INTRODUCTION

This work has been done to facilitate the side drain design because in roads of over the world the design and construction of ditches are mandatory assignments. Side drains are hydraulic structures required to control the runoff water on the surface of road (unpaved or paved).
SDDRoads® try to solve effectively in short time the design of ditches for roads because when engineers are designing roads, priority is not given to control of runoff water so ditches absence accelerates deterioration of roads [1][2][3][4][5].

The absence of ditches in many roads around the world has had repercussions on different road structures. For example, when roads are pavemented and they lack of side drainage, erosion of shoulder [5] and deformation and cracking of the edges are presented in flexible pavements [6]. When roads are unpaved, transverse furrows, mud, hard heads, and advanced erosion are presented [3].

For this reason, the software SDDRoads® was developed. The meaning of program come from Side Drain Design for Roads and it is a Web application (multiplatform) to be executed in a computer, tablet or smartphone as long as you have internet access.

2. METHODS

2.1 Empirical Method

The empirical methods are the referent in the hydrology and hydraulic, because numerous formulations have been developed to help determine the flow rate (hydrology) and the dimensions of a structure (hydraulics). For this purpose, the rational method is highlighted, which is useful for estimating surface runoff in the absence of direct flow measurements, see Equation (1). In addition, Continuity and Manning equations -see Equations (3, 4)-, let calculate the dimensions of a ditch.

The rational method from hydrology is a rainfall-runoff model [7][8][9][10][11][12], which is applied to determine the flow in small basins ($\leq 2.5\ km^2$), assuming a uniform intensity of precipitation for the total duration of an event [13][14][15].

Continuity equation is applicable to any flow, whether permanent or non-permanent. Its applicability is focused on a channel section [16][17][18].

Manning equation is for uniform flow and from the technical literature, it is considered that the uniform flow is permanent, therefore, its union with the Continuity equation has allowed to obtain satisfactory results at a practical level [16][19][20][21][22][23].

$$\mathrm{Q_{hydrologic}} = 2.78 * 10^{-7} * C * I * \mathrm{A_{affluent}} \rightarrow \text{rational method} \qquad (1)$$

$$\mathrm{A_{affluent}} = \mathrm{B} * \mathrm{L} \qquad (2)$$

$$\mathrm{Q_{hydraulics}} = \mathrm{v} * \mathrm{A_{ditch}} \rightarrow \text{(Continuity)} \qquad (3)$$

$$\mathrm{v} = \frac{1}{\mathrm{n}} * \left(\mathrm{R}^{2/3}\right) * \left(\mathrm{S}^{1/2}\right) \rightarrow \text{(Manning)} \qquad (4)$$

Equation (2) represents the tributary area, also called the basin area, as a function of the length of the ditch (*L*) and the width of the impluvium (*B*). Figures 1 to 2 are some examples to interpret the width of the impluvium (*B*) and Figure 3 to understand the length of ditch (*L*).

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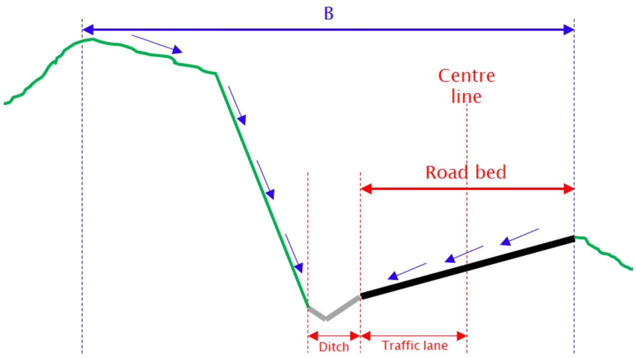

Figure-1. Example one: cross section of a road with impluvium width (B).

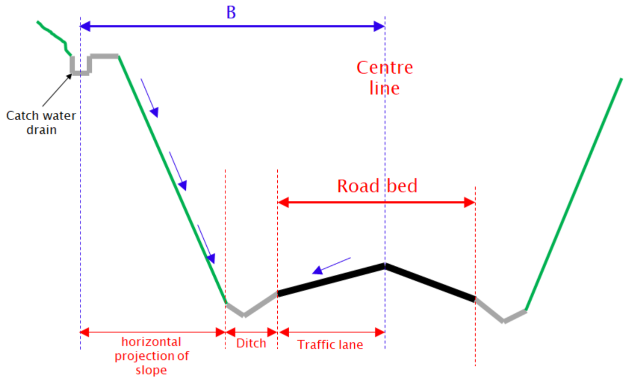

Figure-2. Example two: cross section of road with impluvium width (B).

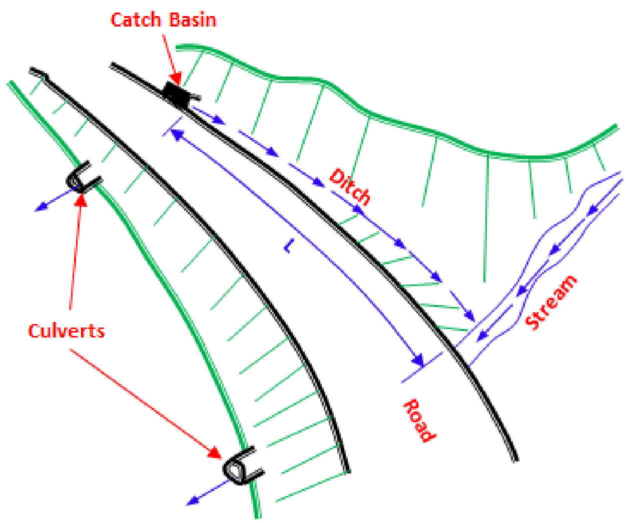

Figure-3. Example of 3D view of a road with ditch length (L).

Therefore, the hydraulic design of a roadside ditch consists of verifying the capacity of the ditch with the flow of runoff. Then, Equations (1), (2) and (4) are replaced in Equation (3) to present the new Equation (5).

$$2.78 * 10^{-7} * C * I * (B * L) = \frac{1}{n} * R^{2/3} * S^{1/2} * A_{ditch} \quad (5)$$

Finally, Equation (5) has been solved to establish *L*, the solution is shown in Equation (6).

$$L = \frac{R^{2/3} * S^{1/2} * A_{ditch}}{2.78 * 10^{-7} * C * I * B * n} \quad (6)$$

Where *L* is the length of the ditch, which depends on the runoff coefficient (*C*), the longitudinal slope of the ditch *(S)*, the rainfall intensity *(I)*, the width of the impluvium (*B*) and the Manning's roughness coefficient *(n)* representing the friction applied to the flow through the ditch.

The length of ditch indicates where the ditch is overflowing and where it is necessary to divert the water by means of a spillway or culvert [24][25].

The runoff ratio (*C*) is selected to reflect basin characteristics such as topography, soil type, vegetation and land use [9][15][7].

The longitudinal slope of the ditch (*S*) is determined for the local range of the ditch being analyzed by dividing the elevation or change in elevation of that range by the distance of that range. This slope is typically measured in the actual ditch of the stream, on the ascending and descending slope of the site, and ideally also checked on a topographic map [9][15][14]. Also, it can be the same as the slope of a road.

The rainfall intensity (*I*) is the average rain intensity for the selected frequency and for a duration equal to the concentration time, in millimeters per hour [9][15][13].

The Manning Roughness Coefficient (*n*) represents the roughness of the ditches and its value varies according to the characteristics of the ditch [16][26].

Equation (6) is used for the development of the SDDRoads® software. Therefore, Equation (6) is applied in concrete ditches with non-symmetrical and symmetrical triangular sections. Furthermore, Equation (6) is applied in ground ditches with symmetric triangular cross section. Soils are a function of water speed. The cross section shown in Figures 4 to 7.

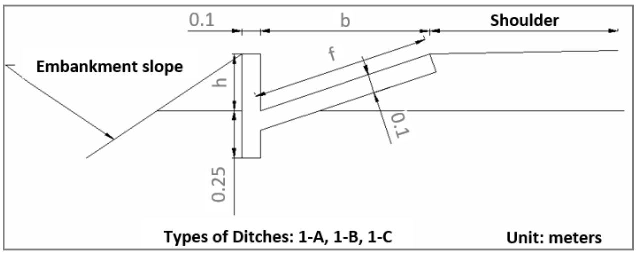

Figure-4. Concrete ditch with triangular cross-section (not symmetrical): 1-A or 1-B or 1-C.

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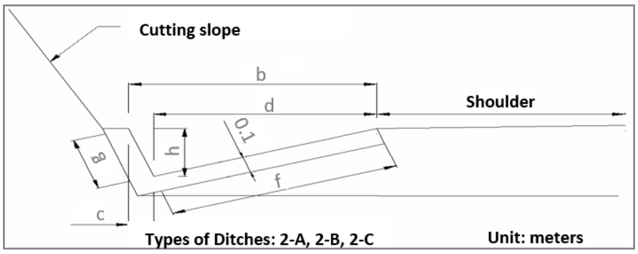

Figure-5. Concrete ditch with triangular cross-section (not symmetrical): 2-A or 2-B or 2-C.

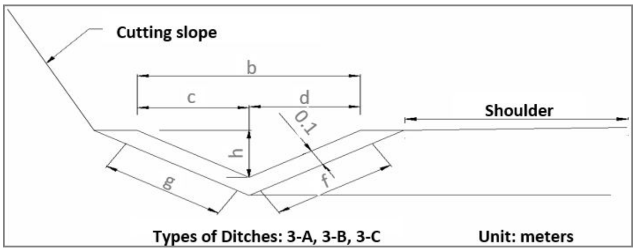

Figure-6. Concrete ditch with triangular cross-section (not symmetrical): 3-A or 3-B or 3-C.

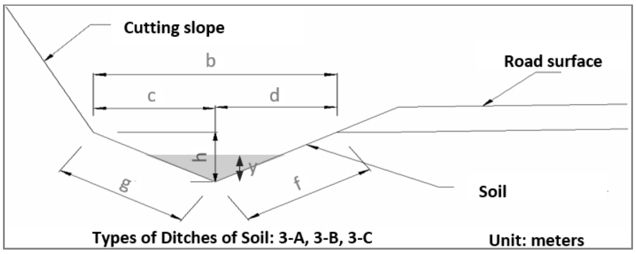

Figure-7. Ground ditch with triangular (symmetrical) cross section: 3-A or 3-B or 3-C.

2.2 SDDRoads

SDDRoads® is an application developed in the Hypertext Preprocessor (Php) programming language. This application is capable of making concrete ditches with non-symmetrical and symmetrical triangular sections. Furthermore, for ground ditches with a symmetrical triangular cross-section. The soils are fine sands and silts, clays, fine sands and silts and other soils that the user can enter. The ground is a function of the speed of the water. SDDRoads® has three shared interfaces, two pre-processor and one post-processor. The first preprocessor option have entries such as choosing the most suitable ditch for your project, see Figures 8, 11, 14 and 17. The second option of the preprocessor have entries such as the longitudinal slope of the ditch [*S*], the runoff coefficient [*C*], the rainfall intensity [*I*] and the width of the impluvium [*B*] for the concrete ditches, shown in Figures 9, 12, 15 and 18; furthermore, a new entry for the ground ditches such as the water speed [*v*] which is limited to speeds exceeding 1.5 m/s, because the design is focused on first overflowing and then eroding, and at the overflow site a spillway or culvert is located for the evacuation of the water from the ditch, see Figures 10, 13, 16 and 19. The third, mentioned a post-processor, contains the answers of a possible lateral drainage design for roads, as the theoretical and constructive length of the ditch and the constructive dimensions of the ditch, are shown in Figures 20 to 35.

Figure 8. SDDRoads® preprocess entries for concrete and ground ditches - English language (Computer).

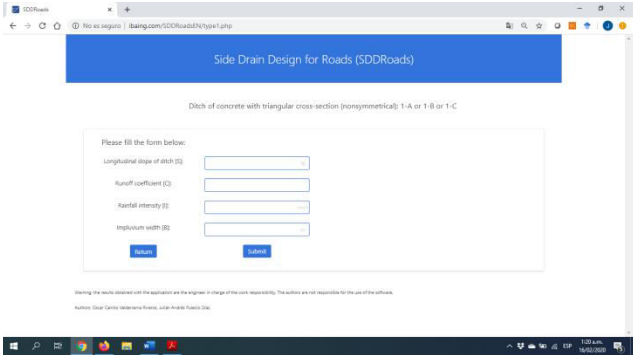

Figure 9. SDDRoads® preprocess entries for concrete ditch - English language (Computer).

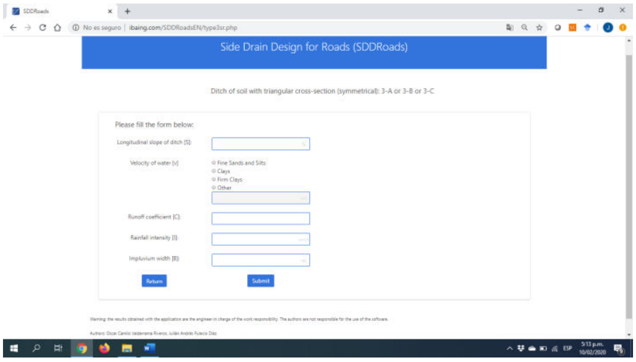

Figure-10. SDDRoads® preprocess entries for ground ditch - English language (Computer).

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Figure-11. SDDRoads® preprocess entries for concrete and ground ditches - Spanish language (Computer).

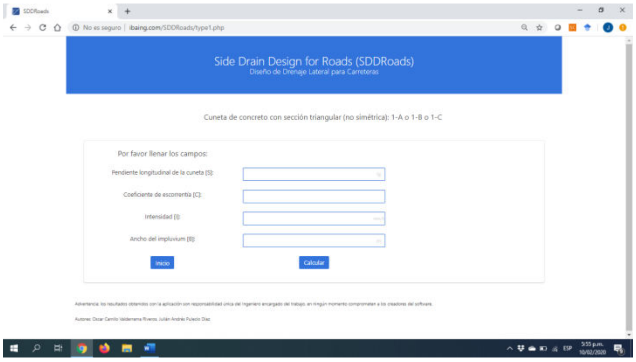

Figure-12. SDDRoads® preprocess entries for concrete ditch - Spanish language (Computer).

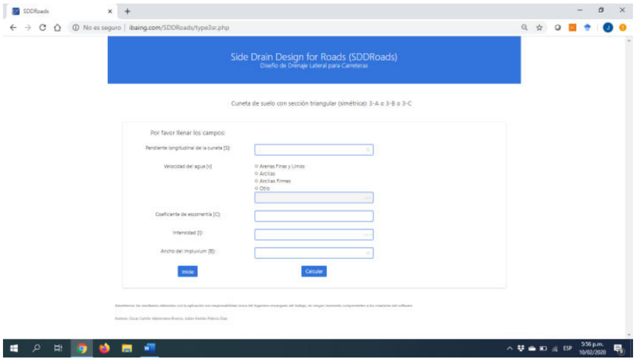

Figure-13. SDDRoads® preprocess entries for ground ditch - Spanish language (Computer).

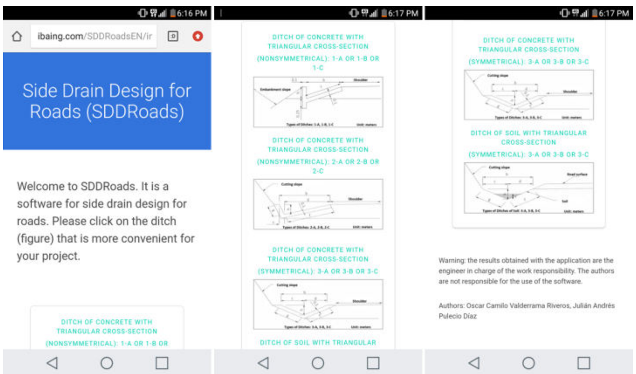

Figure-14. SDDRoads® preprocess entries for concrete and ground ditches - English language (Smartphone).

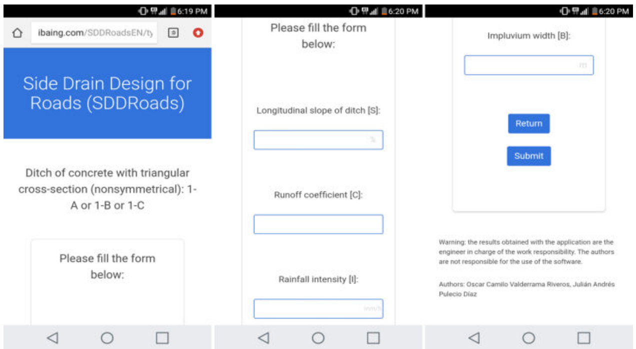

Figure-15. SDDRoads® preprocess entries for concrete ditch - English language (Smartphone).

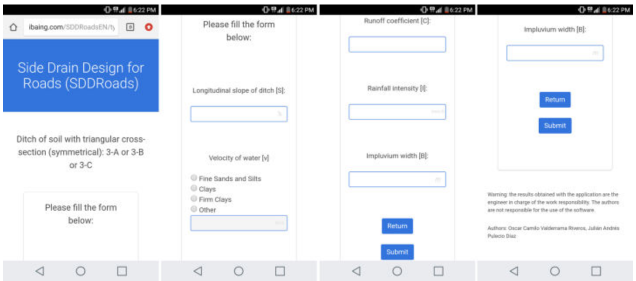

Figure-16. SDDRoads® preprocess entries for ground ditch - English language (Smartphone).

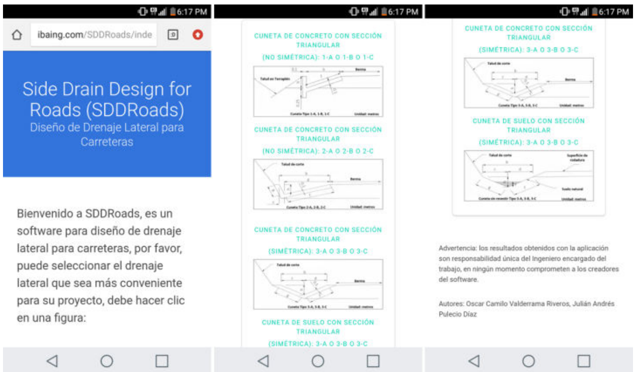

Figure-17. SDDRoads® preprocess entries for concrete and ground ditches - Spanish language (Smartphone).

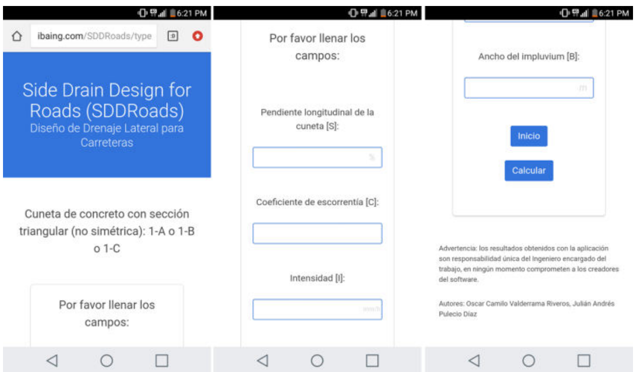

Figure-18. SDDRoads® preprocess entries for concrete ditch - Spanish language (Smartphone).

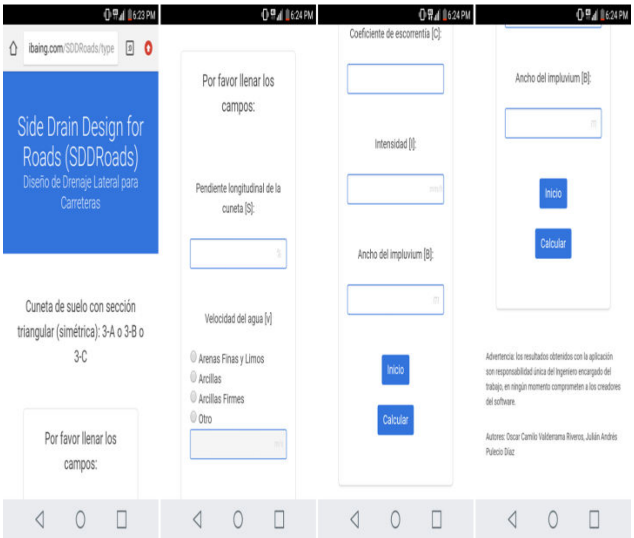

Figure-19. SDDRoads® preprocess entries for ground ditch - Spanish language (Smartphone).

The English and Spanish computer SDDRoads® preprocessor is shown in Figures 8 to 13.

The SDDRoads® preprocessor in English and Spanish for smartphones is shown in figures 14 to 19.

Currently, SDDRoads® can be accessed on the Internet by typing in the URL ibaing.com/SDDRoadsEN/index.php for English, or ibaing.com/SDDRoads/index.php for Spanish. Contact sddroadsengineering@gmail.com for more information.

2.3 Use of SDDRoads

The SDDRoads® verification was made with a case of study proposed by INVIAS (2007) in the Design Manual for Asphalt Pavements for Roads with Low Traffic Volumes, applied to Colombia [24].

The case of study proposes to estimate the length of ditches lined in concrete using dimensions for construction. The starting entries are: Longitudinal slope of ditch 0.50 %, Runoff coefficient 0.45, Rainfall intensity 50 mm/h and Impluvium width 40 m.

Furthermore, to demonstrate the applicability of the SDDRoads® what would be the dimensions for construction and length of a ditch composed of soil fine sands and silts also are calculated.

3. RESULTS AND DISCUSSIONS

Table-1 shows the results of the case proposed by INVIAS (2007) [24] -*which was used for verification*- and the results obtained with SDDRoads®. The length of the ditch using SDDRoads® is equal to the INVIAS (2007) [24], which shows that SDDRoads® are accurate. The results of SDDRoads® are shown in figures 20 to 35, both in English and Spanish, for computer and smartphone.

Table-1. Verification of the results - SDDRoads®.

Types of ditches	Theoretical ditch length		Variation [%]
	INVIAS, 2007 [24]	**SDDRoads®**	
1A	655.117 m	655.117 m	0 %
1B	383.689 m	383.689 m	0 %
1C	156.489 m	156.489 m	0 %
2A	682.158 m	682.158 m	0 %
2B	399.381 m	399.381 m	0 %
2C	164.356 m	164.356 m	0 %
3A	720.132 m	720.132 m	0 %
3B	421.997 m	421.997 m	0 %
3C	172.106 m	172.106 m	0 %
of the Earth 3A	261.458 m	261.458 m	0 %
of the Earth 3B	256.652 m	256.652 m	0 %
of the Earth 3C	236.466 m	236.466 m	0 %

SDDRoads® generates the results of the construction length and the construction section of the ditch including dimensions. Table-2 shows the results of the construction length of the ditches using SDDRoads®.

SDDRoads® takes the level water overflow to calculate the length of ditch (that is, when the water invades the roadway). Therefore, in order to ensure road safety of drivers [27][28] and pedestrians [29][30] divert the water by a spillway or a culvert is necessary.

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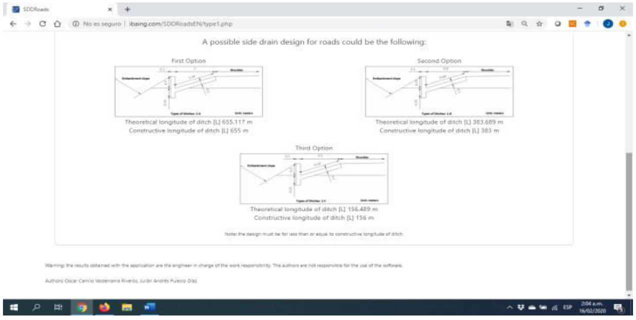

Figure-20. SDDRoads® display output for concrete ditches. Type: 1A, 1B and 1C - English language (Computer).

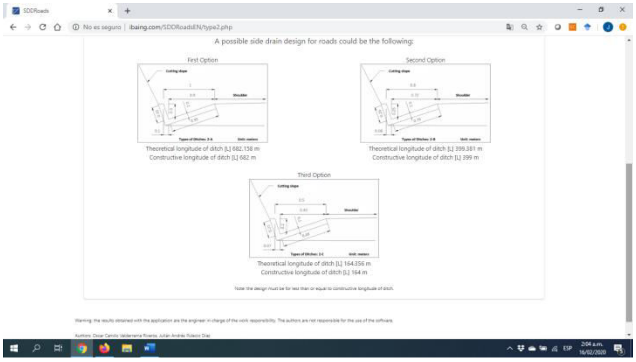

Figure-21. SDDRoads® display output for concrete ditches. Type: 2A, 2B and 2C - English language (Computer).

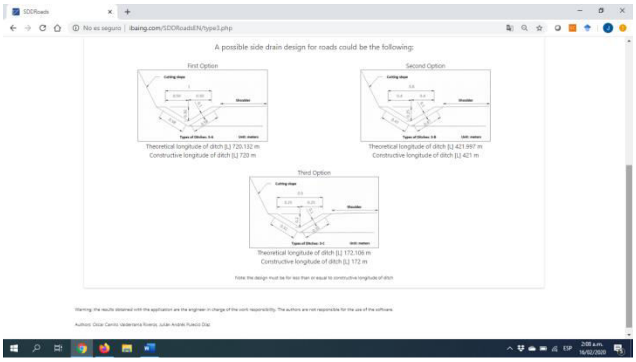

Figure-22. SDDRoads® display output for concrete ditches. Type: 3A, 3B and 3C - English language (Computer).

Figure-23. SDDRoads® display output for ground ditches. Type: 3A, 3B and 3C- English language (Computer).

Table-2. Constructive length of ditch - SDDRoads®.

Types of ditches	Constructive length of ditch
1A	655 m
1B	383 m
1C	156 m
2A	682 m
2B	399 m
2C	164 m
3A	720 m
3B	421 m
3C	172 m
of Soil 3A	261 m
of Soil 3B	256 m
of Soil 3C	236 m

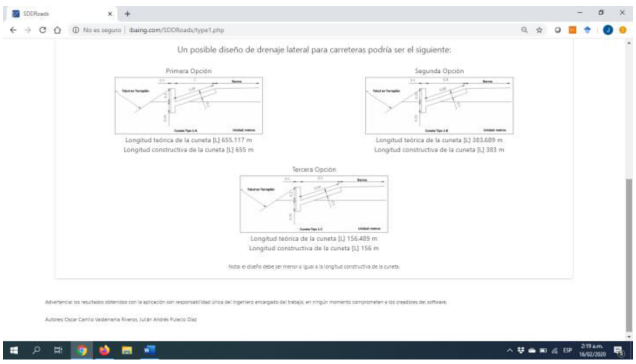

Figure-24. SDDRoads® display output for concrete ditches. Type: 1A, 1B and 1C - Spanish language (Computer).

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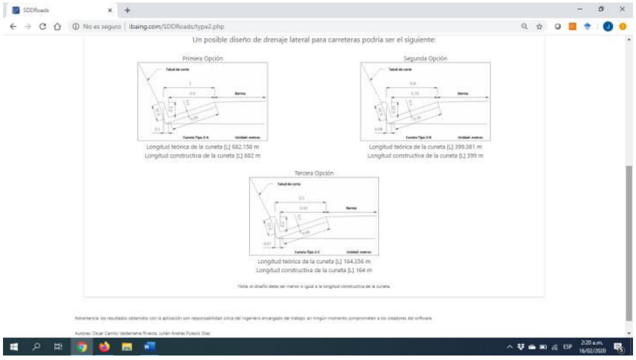

Figure-25. SDDRoads® display output for concrete ditches. Type: 2A, 2B and 2C - Spanish language (Computer).

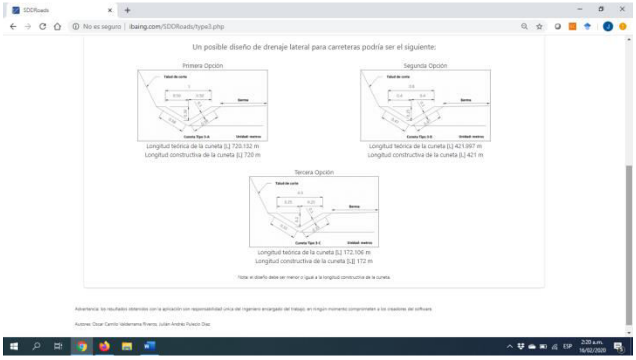

Figure-26. SDDRoads® display output for concrete ditches. Type: 3A, 3B and 3C - Spanish language (Computer).

Figure-27. SDDRoads® display output for ground ditches. Type: 3A, 3B and 3C- Spanish language (Computer).

Figures 28 to 35 show one of the major contributions of the SDDRoads® which is to be able to observe the side drain design for roads by smartphone with several ditch alternatives according to the needs of the project.

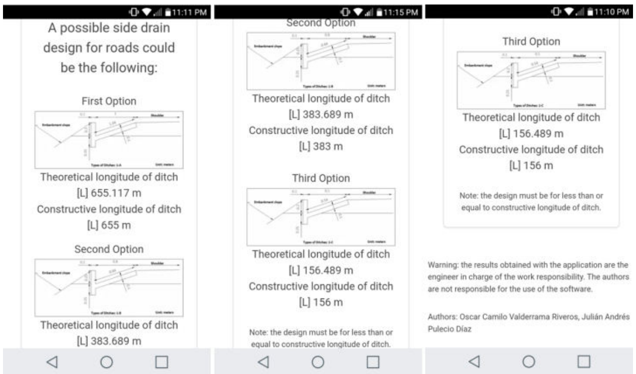

Figure-28. SDDRoads® display output for concrete ditches. Type: 1A, 1B and 1C - English language (Smartphone).

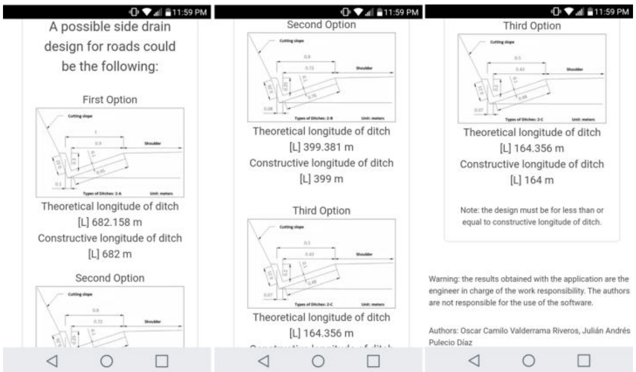

Figure-29. SDDRoads® display output for concrete ditches. Type: 2A, 2B and 2C - English language (Smartphone).

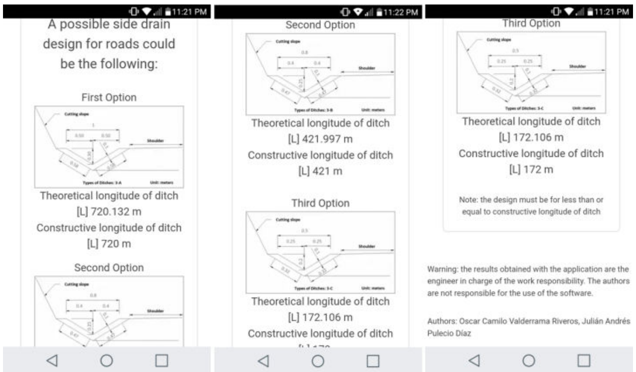

Figure-30. SDDRoads® display output for concrete ditches. Type: 3A, 3B and 3C - English language (Smartphone).

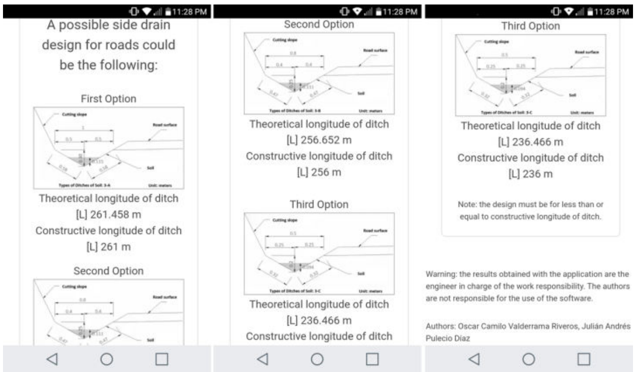

Figure-31. SDDRoads® display output for ground ditches. Type: 3A, 3B and 3C - English language (Smartphone).

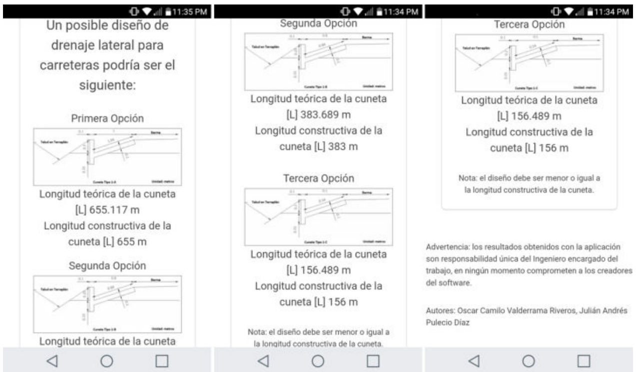

Figure-32. SDDRoads® display output for concrete ditches. Type: 1A, 1B and 1C - Spanish language (Smartphone).

Figure-33. SDDRoads® display output for concrete ditches. Type: 2A, 2B and 2C - Spanish language (Smartphone).

Figure-34. SDDRoads® display output for concrete ditches. Type: 3A, 3B and 3C - Spanish language (Smartphone).

Figure-35. SDDRoads® display output for ground ditches. Type: 3A, 3B and 3C - Spanish language (Smartphone).

4. CONCLUSIONS

- The use of the Hypertext Preprocessor (Php) as a programming language to develop SDDRoads® let software be cross-platform since it is a web application and it works in all operating systems.
- The results obtained with SDDRoads® were satisfactorily verificated against the case of study proposed by INVIAS (2007).
- Results of the length and cross-section of ditches in concrete and soil using SDDRoads® are suitable for construction *in situ*.
- SDDRoads®is a software that helps to estimate the length of ditch for four triangular cross-sections. One of these built on ground and three ones built with concrete. Conditions are the longitudinal slope of ditch would be between 0.5 and 10%, the velocity of water would be less than or equal to 1.5 m/s (this value is required for ground ditches).
- SDDRoads® software proved to be an interesting calculation application to have anywhere in the world, for its versatility.

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