

Use of computer programming for the development of a CAD-CAE system on the Revit platform applied in urban drainage projects

Utilização de programação computacional para o desenvolvimento de um sistema CAD-CAE na plataforma Revit aplicada em projetos de drenagem urbana

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ABSTRACT: Urban storm drainage emerged with the evolution of society in search of improvements in health and comfort going through different phases and today it connects with a sustainable and technological bias. Through Python programming, it is possible to integrate a Computer Aided Design/Computer Aided Engineering (CAD/CAE) system into the Revit platform using the Dynamo tool as an intermediary. This work presents the development and validation of a computational tool for dimensioning urban drainage coupled to the graphical project modeling platform Revit. The results obtained with the numerical code point to a good agreement when compared with those generated by conventional tools, using a calculator and an Excel spreadsheet. It shows that, due to the direct and automatic communication between drawing and dimensioning is possible to reduce the time spent filling out spreadsheets and facilitate analyses such as minimum inclinations of the pipe through warnings and factors such as the ratio of the water sheet and diameter through color scales.

Keywords: Revit. Urban storm drainage. API. Python. Dynamo.

RESUMO: A drenagem pluvial urbana surgiu com a evolução da sociedade em busca de melhorias na saúde e conforto, passando por distintas fases e, hoje, se conecta com um viés sustentável e tecnológico. Através da programação em Python, é possível integrar um sistema Computer Aided Design/Computer Aided Engineering (CAD/CAE) na plataforma Revit utilizando a ferramenta Dynamo como intermediário. Este trabalho apresenta o desenvolvimento e validação de uma ferramenta computacional de dimensionamento das redes de condutos de drenagem urbana e a determinação das vazões que afluem a esses condutos acoplada na plataforma de modelagem gráfica de projetos Revit. Os resultados obtidos com o código numérico apontam para uma boa concordância quando comparados com aqueles gerados por ferramentas convencionais, utilizando calculadora e planilha do Excel. Esses resultados mostram que, pela comunicação direta e automática entre desenho e dimensionamento é possível reduzir o tempo gasto em preenchimento de planilhas de cálculo e facilitar análises como inclinações mínimas na tubulação através de avisos e fatores como a relação da lâmina d'água e diâmetro através de escalas de cores.

Palavras-chave: Revit. Drenagem pluvial urbana. API. Python. Dynamo.

INTRODUCTION

The development of sanitation, along with urban drainage, can be divided into four phases. The first, known as the Pre-Hygienic phase, extends to the early 20th century and is characterized by sewers in pits or without collection (on the streets), contaminating water and causing public health problems (TUCCI, 2012).

To make water supply safer and reduce the incidence of diseases, the second phase, called the Hygienic phase, began, extending until the 1970s. During this period, the channelling and transportation of sewage began, without treatment, downstream from the city's water source (TUCCI, 2012).

Although this reduced diseases, it resulted in water source contamination and floods. Hence, the third phase, the corrective phase, took place between 1970 and 1990, aiming to restore rivers by treating domestic and industrial sewage and dampening the flow. At the same time, it was observed that drainage works that increased surface runoff were no longer sustainable. Despite procedure revisions and the implementation of dampening systems, pollution caused by urban and rural floods, known as diffuse source pollution, persisted (TUCCI, 2012).

Thus, the fourth phase, Sustainable Development, extending from 1990 to the present, brings a sustainable and technological perspective to sanitation and urban drainage, aiming to reduce floods, preserve the environment, and improve quality of life (TUCCI, 2012).

Urban drainage projects emerged to enhance population well-being, devising ways to drain rainwater. Initially, the design and calculations of the projects were done manually, requiring time, effort, and meticulous analysis to avoid errors. With engineering advancements, software became available for both project creation and respective analyses.

CAD – Computer Aided Design – was created in 1971 with the help of computer scientists Dr. Patrick J. Hanratty and Douglas T. Ross while working at General Motors research labs (BELLUOMINI, 2017). In the subsequent decades, with the advancement of computer technology, the software gained prominence among engineers and architects for its ease and advantages over manual drawing. Besides conventional two-dimensional drawing, it was possible to view in three dimensions (BELLUOMINI, 2017). With the software's incorporation into engineers' daily lives, the possibility of using this new drawing method to assist in necessary analyses arose. The term CAE – Computer Aided Engineering – refers to a set of techniques that allow the evaluation of aspects of a product generally conceived through CAD (FERREIRA, 2003). The use of the CAD/CAE system in Civil Engineering brings significant advantages, such as reducing calculation efforts, greater accuracy in analyzing elements and situations, and optimizing analysis and project time.

In this context, this paper compares the process for sizing and analyzing an urban drainage project when conducted using a CAD system combined with a calculation spreadsheet and a developed CAD/CAE system. The CAD/CAE system was conceived using Python due to its contemporary nature, free access and use, a wide range of support libraries, and interpreters on major operating systems (SOUBHIA, 2019). When searching the literature for other works that apply programming to Revit for sizing and project analysis, different applications were found, also aiming to automate the process efficiently and effectively. Ferreira (2022) discusses the benefits of using Python programming in Revit for sizing and analyzing cold and hot water systems. Dalsenter (2022) applies this method to

booster pump sizing. Matos, Azenha, and Ramísio (2003) applied CAD/CAE in hydraulic infrastructure management, and Teixeira (2018) in sizing and analyzing water supply network projects.

This work, based on the development of a computational tool for sizing and analyzing stormwater gallery projects coupled with the Revit graphic modeling tool, presents itself as a viable alternative in the CAD/CAE technological context due to its application specificity and the accuracy of the results obtained. Moreover, the reduction in time allocated to project development, coupled with the achieved final product quality, contributes to the adoption of this software in the context of an increasingly dynamic, economical, and environmentally sustainable professional market.

LITERATURE REVIEW

Rational Method

The rational method is recommended for determining the maximum design flow in basins considered small, that is, with an area less than 2 km². The rational method (Equation 1) considers that the duration of maximum project precipitation is equal to the basin's concentration time, that a unique loss coefficient is admitted estimated from the basin's characteristics, and that it is not possible to evaluate the flood volume and the temporal distribution of flows (TUCCI, 2003).

$$Q = C \cdot I \cdot A \quad (1)$$

In equation (1), Q is the maximum design flow in L/s, C is the runoff coefficient, which can be found through tables that take into account the type of surface to determine its value, I is the rain intensity in L/s.ha, and A is the basin area in ha.

Flow In Open Channels

For the determination of flow, velocity, and section capacity of the pipe, the effects of inertia forces, gravity, pressure, friction with the channel walls, and the viscosity of the liquid analyzed should be considered. Also, the regime considered for sizing is steady and uniform, due to constancy in hydraulic parameters such as roughness, diameter, consequently hydraulic radius, among other parameters. With this, it is possible to determine the flow rate that flows in an open channel through Manning's equation (Equation 2):

$$\frac{n \cdot Q}{\sqrt{I_0}} = S_m \cdot R_h^{\frac{2}{3}} \quad (2)$$

In equation (2), n is the roughness coefficient, this value can be found in tables, for this work, a tabulated value of 0.013 for concrete pipes and 0.011 for PVC was adopted, Q is the flow in m³/s, I_0 is the conduit slope in m/m, S_m is the wetted area of the section in m², and R_h is the hydraulic radius of the section, given by the ratio of the wetted perimeter to the wetted area in meters.

Knowing the diameter and the flow rate that flows through it, it is possible to determine the flow velocity, substituting the simplified continuity equation (Equation 3) into Manning's equation (Equation 2):

$$Q = S_m \cdot V \quad (3)$$

In equation (3), V is the flow velocity in m/s.

Full Section Capacity

Since the piping used in drainage networks generally has a circular section, the section is analyzed as a circumference. Mathematically, the geometric relations indicated by Equations 4 and 5 can be reached:

$$S_m = \frac{D^2(\theta - \sin\theta)}{8} \quad (4)$$

$$R_h = \frac{D \left(1 - \frac{\sin\theta}{\theta}\right)}{4} \quad (5)$$

In equations (4) and (5), D is the diameter of the circular section in meters, and θ is the internal angle of the section in radians.

According to Tucci (2003), to determine the flow in circular sections, the design criterion should consider the operation of stormwater galleries in full section, that is, the internal angle of the section (θ) is equal to 2π . As $\sin\theta = 0$, the relationships represented by Equations 6 and 7 can be simplified:

$$S_m = \frac{\pi \cdot D^2}{4} \quad (6)$$

$$R_h = \frac{D}{4} \quad (7)$$

Tools And Softwares

In 1961, with the support of Dr. Patrick J. Hanratty, General Motors developed the DAC (Design Automated by Computer), a software for design and technical documentation that replaced manual drawing. Douglas T. Ross, a pioneer of computer science, named the tool as CAD (BELLUOMINI, 2017).

The software was introduced in 1971 by Hanratty, and in 1983 Autodesk launched AutoCAD, one of the most widely used CAD methodologies. In the following decades, CAD underwent evolutions with the emergence of three-dimensional modeling and paved the way for other solutions, such as BIM (Building Information Modeling) and digital prototyping (BELLUOMINI, 2017). The term CAE is used to designate a set of graphic analysis techniques – visual design. This analysis occurs through digital models using comparative numerical methods that simulate physical phenomena (FERREIRA, 2003). An example of CAE software is SolidWorks, which is used for modeling and mechanical analysis.

Revit is a CAD/BIM software with tools for modeling accurately and with parametric ease of shapes, three-dimensional systems, and structures (AUTODESK, 2022). This software allows a simplified approach as it automatically generates a 3D model with integrated information from the 2D work. This provides the ability to generate automatic views and sections, such as floor plans, and identify potential interferences between pipes. It can be used for both three-dimensional CAD modeling and analysis (CAE), but requires the help of plugins or external programs, thus unifying the work in just one tool. This can be done by inserting parameters for reading and inserting information into the desired model's families.

A family in Revit is a group of elements with a common set of properties called parameters and related graphical representation (AUTODESK, 2022). The parameters store and communicate information about all the elements of a model. Parameters can be divided into two types, instance parameters and type parameters (AUTODESK, 2022).

When the parameters are instance, the values can vary between the elements of a family. When they are of type, the inserted values cannot vary between the elements of a family. These parameters can be created and linked to the model's families as needed. To facilitate the development of daily tasks, Autodesk created an open-source tool called Dynamo to allow users of its products to collaboratively develop numerical communication codes. The tool uses visual programming resources with a relatively more user-friendly interface. Additionally, the platform does not remove the possibility for programmers to use known languages such as C# and Python (DYNAMO, 2022).

For more complex programming within Revit itself, Autodesk made the program's API available. API stands for "Application Programming Interface," a tool that communicates the programmer with the program through standards and rules in the code. The Autodesk Revit API was designed to reflect the same user interaction paradigms as the program's Graphical User Interface (AUTODESK, 2021).

The language used in this work was the Python language. This computational language, created in the 1980s by Guido Van Rossum, emerged due to the need to optimize and speed up the software programming process (COUTINHO, 2019). Like many other scripting languages, it is provided for free, even if used for commercial purposes, and can be installed on any current computer.

METHODOLOGICAL PROCEDURES

To carry out this study, the following steps were adopted, involving the definition of the object of study, the project methods, and the analysis of the results.

Definition of the object of study

The object of study used in the software analysis is a drainage project provided by the Vitta Residencial company, with participation in the development of the former, referring to a venture that will be installed in the city of Ribeirão Preto – SP – Brazil, consisting of a tower and a road system around it. The choice of the project comes from access to data provided by the said company, whose characteristics are suitable for the purpose of testing and analysis of the numerical code. The project consists of a land area of 5,159.84m², of which 15% were designated as permeable areas. The Municipal Prefecture of Ribeirão

Preto provides a calculation guide for approval projects through guidelines (PMRP, 2017). In this document, the equations for concentration time (Equation 8), Runoff coefficient (Equation 9), and rain intensity (Equation 10) are defined:

- Concentration time (Equation 8):

$$tc = 10 + \frac{L}{300} \quad (8)$$

In equation (8), tc is the concentration time in minutes, L is the longest length of the gallery in meters.

- Surface Runoff Coefficient (Equation 9):

$$C = 0,364 \cdot \log tc + 0,0042 \cdot p - 0,145 \quad (9)$$

In equation (9), p is the impermeabilization percentage of the area, and C is the surface runoff coefficient.

- Rain Intensity (Equation 10):

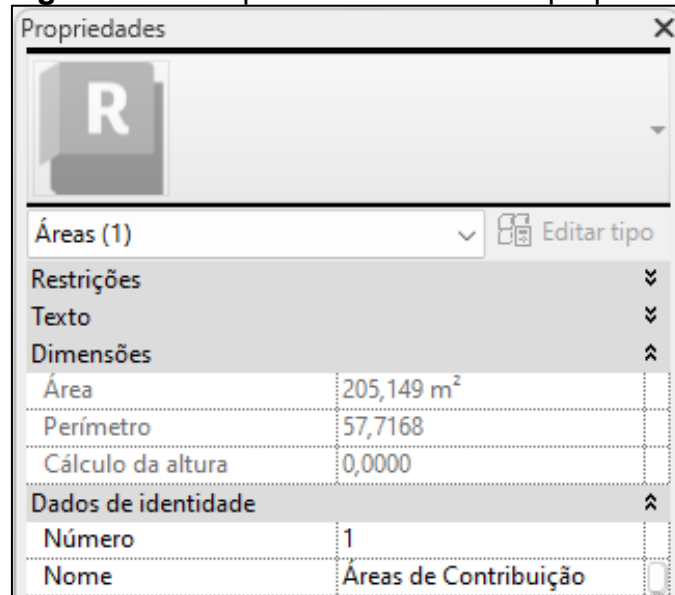
$$i = \frac{24521,27 \cdot Tr^{-0,0846}}{(tc+40)^{1,3581} \cdot Tr^{-0,0454}} 2,78 \quad (10)$$

In equation (10), Tr is the return time, 10 years in this case, and i is the rain intensity in L/s.ha.

Project Methods

To obtain the first set of data for this analysis, a CAE system was developed using Dynamo, a Revit tool for visual/computational programming. The programming language used was Python 3.8, together with the Revit API. To obtain the contribution areas of the project, Revit has a tool in which it is possible to draw and delimit the areas automatically. For this, a plan of areas must be created. On the area plan, it is possible to delimit a desired area and include a countable area within this limit. Revit informs through the parameters linked to this area some information such as perimeter and total area. In the family of areas, there is an existing type "Number" parameter that can be used for individual identification of the areas. In Figure 1, it is possible to visualize this parameter in the properties tab, in addition to other parameters such as area and perimeter.

Figure 1 - Exemplification of the area properties



With the creation of the areas, it is possible to check through a table generated by Revit, all the areas made and their desired data. These data will be used by the program as a reference for inserting the areas into an instance parameter inserted into the pipe family. After delimiting the contribution areas, the next step is positioning the drainage elements and the path the network will take. With this, it is possible to determine which areas will be drained by which piping and the path the water flow will follow. For example, the pipeline designated as section 1 will drain area A1. In the next section, the pipeline will drain area A1+A2, and so on. So that the program understands this, the "Contribution Areas" type parameter inserted in the pipe family must be filled out, which can be seen in Figure 2. This parameter is easily filled with the desired value with the help of a pipe identifier for this same parameter.

Figure 2 - Part of the project's area board.

| <QUADRO DE ÁREAS> | |
|-------------------|-----------------------|
| A | B |
| Trecho | Áreas de Contribuição |
| 1 | A1 |
| 2 | A1+A2 |
| 3 | A1+A2+A3 |
| 4 | A1+A2+A3+A4 |

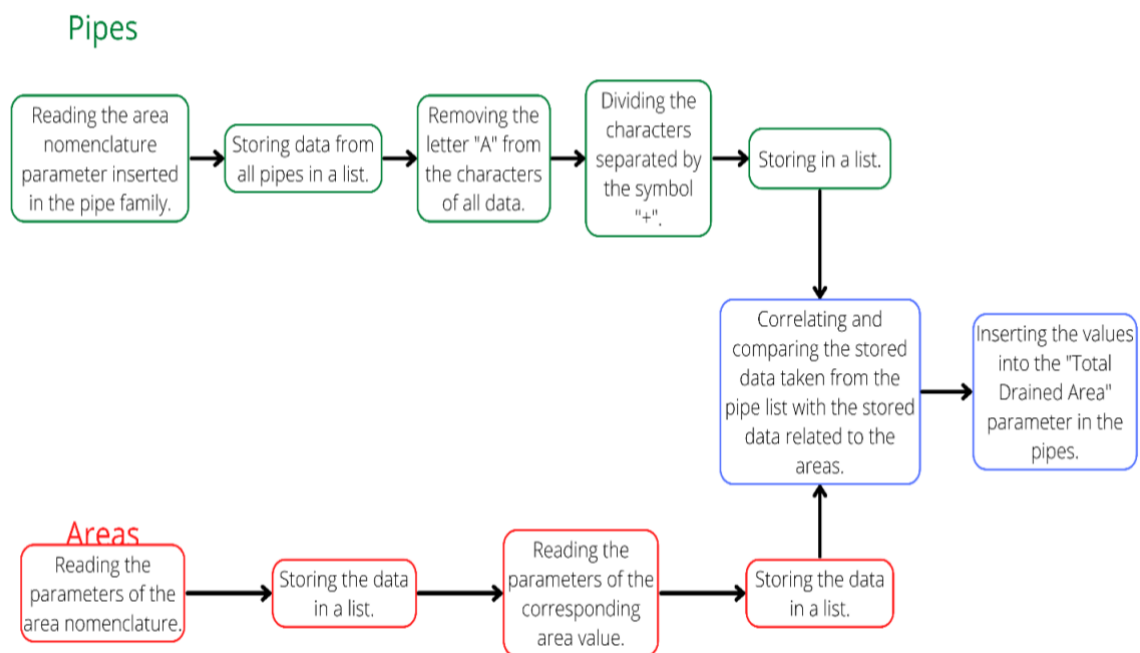
With the filling in the entire pipeline, it is also possible to present this data in table format, which is used in the documentation part of the project to aid in identifying the area

distribution by pipeline sections. After this step, the program is used to read the “Contribution Areas” parameter and relate it to the desired area values. The program uses the Revit API to access the data from the desired family elements through a set of specifications. To access the data from the area family, for example, the program must declare a variable that will act as a door. Every time access to the data from the family elements is needed, this door must also be accessed. To declare the door variable, the "FilteredElementCollector" command is used, which accesses all elements, as at this stage of the program the objective is only to access area information, the "OfCategory" command is used to filter elements by category and the "OST_Areas" command to select the area category. With access to the elements, it is possible to extract the desired data, such as the value of a parameter, through the "LookUpParameter" command combined with accessing the door variable. Using lists in Python, it is possible to store the data collected from the parameters and perform the desired calculations. To insert data into the Revit parameters, it must be declared that such an insertion is taking place. This is called a transaction. Thus, Revit recognizes this procedure as a command and that, if necessary, can be undone. The flowchart in Figure 3 represents the logical reasoning behind the computational code developed to automate the process of filling in the contribution area parameter that will be used later in the calculations.

This contribution area value is used to calculate volume parameters using the rational method. The program calculates the flow in all pipelines and inserts the values into the corresponding parameter based on previously calculated pluviometric intensity and Runoff coefficient data. With this, it is possible to calculate the other parameters through computational and logical comparison using Manning's formula, leaving the flow as a function of the internal angle of the section, as shown in Equation 11:

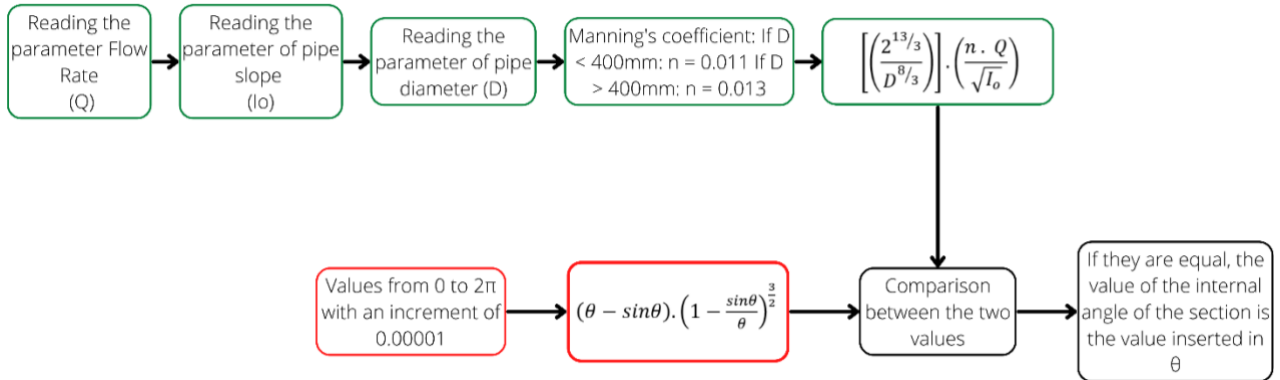
$$\left[\left(\frac{13}{2 \frac{3}{8}} \right) \right] \cdot \left(\frac{n \cdot Q}{\sqrt{I_o}} \right) = (\theta - \sin \theta) \cdot \left(1 - \frac{\sin \theta}{\theta} \right)^{\frac{3}{2}} \quad (11)$$

Figure 3 - Code rationale.



The flowchart depicted in Figure 4 exemplifies how this occurs:

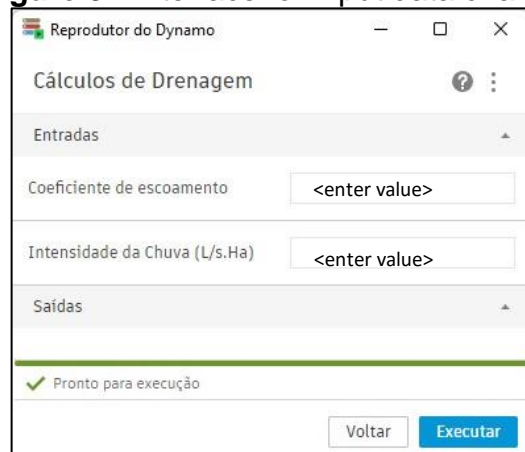
Figure 4 - Comparison methodology applied in the code.



With the calculated internal angle of the section value, it is possible to calculate all the other desired parameters such as water depth and actual speed and insert the values into Revit. The program also calculates, for each pipe and its respective inclination, the flow value corresponding to the full section of the pipe so that it is possible to compare the capacity of the pipe and how much it is receiving from the contribution areas. For comparative purposes, calculations will also be carried out with the help of the Microsoft Excel tool and the mathematical equations highlighted in the theoretical reference of this document. Excel allows the calculation of the necessary parameters using previously inserted data, such as the values of the ratios between the project and the full-section speed, thus allowing the calculation of the other parameters. With this, all instance parameters for all pipes are filled out.

With the data filled in by the program, it's possible to view them in a table within Revit, in the desired calculation memorandum's structure. Through the program, it is possible to easily change Rain Intensity and Runoff coefficient values, allowing its application in other projects for different cities and situations. These parameters can be changed in the program's execution interface, as shown in Figure 5.

Figure 5 - Interface for input data change



RESULTS AND DISCUSSIONS

The results of this project can be divided into two data sets. The first pertains to sizing and analysis performed solely with the assistance of CAD software and Microsoft Excel. The second set is derived from the use of the developed CAE system.

Both systems have the graphical conception as a common step, which includes the delineation of areas, placement of capture devices, initial layout of networks, and the input of rain intensity and runoff coefficient data.

For comparison, the time spent inputting the necessary data for calculations in Microsoft Excel and the time needed for data entry into the program for processing calculations were also considered. This analysis was applied to the entire project. The time spent on project conception and input of rain intensity and runoff coefficient data was not considered in this comparison since these steps are common to both systems.

Results obtained with CAD and Microsoft Excel

For filling out the Microsoft Excel calculation sheet, it's essential to input the values for the surface runoff coefficient, rain intensity (these two parameters, once inserted, remain constant throughout the calculation), the contributing area related to the pipe, the length of each section, pipe diameter, upstream and downstream ground elevations, and upstream gallery elevation. All this data is extracted from the drawing and corresponds to the network segments manually input into Microsoft Excel. For the analyzed project, the time required for this data input was recorded. Although relative in nature, the time factor, when used as a comparison in this study, merely sketches an impact scale posed using automated technologies.

For the input of all segments, several hours of work were recorded as a time scale for data input. This procedure, however, excludes the time spent on drawing preparation and project conception.

Data analysis, derived from calculations, is done by visually comparing the flow in a section to the full-section capacity of the pipe. If a section cannot handle the desired flow, the slope needs to be adjusted to a value where the flow doesn't exceed the full-section capacity. If adjusting the slope is impractical, it's necessary to change the pipe diameter and insert a new slope.

Results obtained with CAD/CAE system

Since the program uses the drawing and the project development to fetch the necessary information for calculations, the time spent on filling out the output data spreadsheet is virtually null. After each program processing, the results are displayed as shown in Figure 6.

Figure 6 – Program's output data table

| Tabela de Cálculo | | | | | | | | | | | | |
|-------------------|----------------------|---------------------|------|--------------|--------------|--------------|-----------------------|---------------|---------|---------|----------|----------|
| Trecho | Área de Contribuição | Área Acumulada (ha) | C | Int (L/s.ha) | Vazões (l/s) | Extensão (m) | Decliv. Terreno (m/m) | Decliv. (m/m) | Ø | v (m/s) | Vp (m/s) | Qp (l/s) |
| 1 | 205,15 | 0,021 | 0,67 | 421,97 | 6,27 | 18,42 | 0,046 | 0,046 | 150 mmø | 1,61 | 2,19 | 38,68 |
| 2 | 687,37 | 0,069 | 0,67 | 421,97 | 18,90 | 26,50 | 0,015 | 0,015 | 200 mmø | 1,41 | 1,25 | 22,11 |
| 3 | 1254,08 | 0,125 | 0,67 | 421,97 | 34,48 | 30,76 | 0,028 | 0,028 | 200 mmø | 2,09 | 2,06 | 64,83 |
| 4 | 1254,08 | 0,125 | 0,67 | 421,97 | 34,48 | 25,35 | 0,059 | 0,061 | 200 mmø | 2,80 | 3,05 | 95,94 |
| 5 | 466,89 | 0,047 | 0,67 | 421,97 | 12,84 | 8,50 | 0,000 | 0,012 | 150 mmø | 1,19 | 1,12 | 19,75 |
| 6 | 780,04 | 0,078 | 0,67 | 421,97 | 21,45 | 14,93 | 0,057 | 0,044 | 150 mmø | 2,21 | 2,14 | 37,86 |
| 7 | 921,55 | 0,092 | 0,67 | 421,97 | 25,34 | 30,37 | 0,062 | 0,062 | 150 mmø | 2,62 | 2,54 | 44,95 |
| 8 | 1369,97 | 0,137 | 0,67 | 421,97 | 37,67 | 9,15 | 0,043 | 0,044 | 200 mmø | 2,53 | 2,58 | 81,09 |
| 9 | 3545,60 | 0,355 | 0,67 | 421,97 | 97,49 | 28,81 | 0,020 | 0,020 | 300 mmø | 2,40 | 2,29 | 162,18 |
| 10 | 394,15 | 0,039 | 0,67 | 421,97 | 10,84 | 13,80 | 0,005 | 0,012 | 150 mmø | 1,15 | 1,13 | 19,98 |
| 11 | 661,98 | 0,066 | 0,67 | 421,97 | 18,20 | 18,26 | 0,045 | 0,025 | 150 mmø | 1,71 | 1,61 | 28,50 |

The sizing analysis is done by the program with visual aids and alerts. If a segment cannot handle the desired flow, the program can issue two types of warnings: if the pipe diameter has a feasible slope, it indicates there's an error in the pipe and will suggest the minimum slope needed to handle the desired flow. If the slope is not feasible, the program sends an alert about which segment needs a diameter increase, as shown in Figure 7.

Visual analysis is also possible using color scales, ranging from blue to red, for desired parameters. An example is the y/D ratio of the pipe. Using this scale, Revit colors the pipe based on the program's output data, as seen in Figure 8.

For instance, if the analyzed ratio is closer to 0%, the pipe may appear in shades close to blue. As the ratio approaches 100%, the pipe colors shift to orange/red hues. Various parameters, such as pipe velocity, flow, the relationship between flow and full-section capacity, and others, can be analyzed using this color scale.

Figure 7 - Warning about feasible and unfeasible slopes

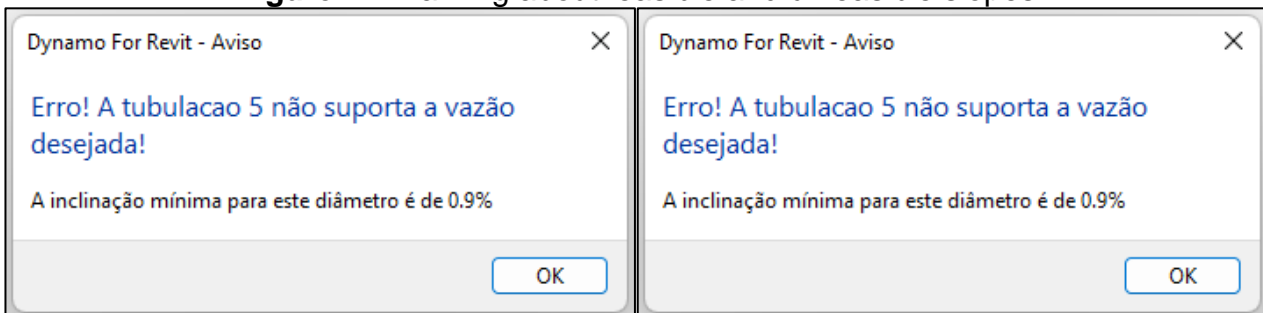
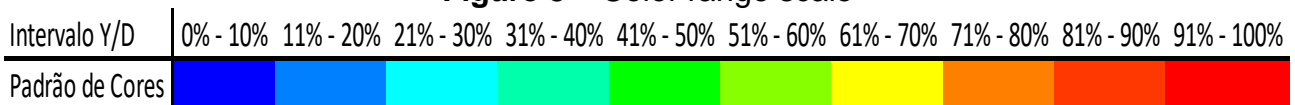


Figure 8 – Color range scale



Software Validation

For comparison, data obtained from project segment 1, mentioned earlier, were calculated using the software, the calculation spreadsheet, and analytical results acquired with a graphic calculator.

Table 1. Calculation results for section 1 in different analyzed methods.

| Method | Flow rate in Full Section (L/s) | Velocity in Full Section (m/s) | Actual Flow Rate (L/s) | Actual Velocity (m/s) |
|-------------------|---------------------------------|--------------------------------|------------------------|-----------------------|
| Software | 17.9984 | 1.0185 | 5.62182 | 0.9006 |
| Spreadsheet | 17.9979 | 1.0185 | 5.62184 | 0.8957 |
| Analytical method | 17.9984 | 1.0185 | 5.62182 | 0.9010 |

The analyzed section has a 150mm diameter made of PVC ($n = 0.011$), with a slope of 0.01m/m. Also, for flow calculation, this pipe was assigned a contributing area of 0.0205 hectares with a rain intensity of 464.467 L/s.ha and a runoff coefficient of 0.59. Table 1 showcases the results and the indicated methods.

From Table 1, it can be observed that the software is closer to the analytical method, and the calculation spreadsheet diverges more from both. This fact may be related to the different numerical approximation scheme used in computational tools whose source code is not open for review. From Table 2, the variation between the calculation spreadsheet and the analytical method, and between the software and the analytical method can be observed.

Table 2. Percentage difference between the methods analyzed with the analytical method

| Variation | Full section flow (L/s) | Speed in full section (m/s) | Real flow rate (L/s) | Real Speed (m/s) |
|-------------------------|-------------------------|-----------------------------|----------------------|------------------|
| Software/Analytical | 0 | 0 | 0 | -0.00049 |
| Spreadsheet /Analytical | -0.00003 | 0 | 0 | -0.00595 |

The discrepancy highlighted in Table 2 can be explained by the numerical calculation methodology, as previously highlighted. The calculation spreadsheet determines a relationship between the actual flow rate and the full-section flow rate. With this relationship value, it searches for the closest value in a database containing relations used in Manning's equation (AZEVEDO NETTO; FERNÁNDEZ, 1998). With this value, it's possible to find the relationship between the actual velocity and the full-section velocity. From the full-section velocity, the actual velocity value can be derived. This approximation may reflect the difference in output data for both methods.

The software calculates the internal angle of the section through a comparison of the constant side of the equation in terms of the internal angle and scans all angle values until the equation's equality is met. The program scans values in steps of 1×10^{-4} radians. With the angle found, other factors such as velocity can be calculated.

The analytical method is also calculated with the help of relationships based on Manning's equation (AZEVEDO NETTO; FERNÁNDEZ, 1998). However, to achieve a more accurate value, the relations were interpolated, which can also generate numerical residues in the output data, with usually modest diverging characteristics. This fact, in addition to the desired technical precision for the projects, is relevant when acting as a reference for the calibration and validation of numerical codes, as in the present study.

CONCLUSION

From the results, it's noticeable that by using a CAD/CAE system with programming applications, there was a 100%-time reduction for project calculations since the program retrieves information during the graphic modeling conception, inserting, analyzing, and calculating all necessary variables for efficient sizing.

Using the Microsoft Excel tool, there's a possibility of manual errors during spreadsheet feeding. This fact could lead to mistakes during the calculation record or analyses, directly impacting the project's reliability and the time required for revisions. By using the CAD/CAE system, the prerogatives of less time for data processing and analysis, trust, and quality of the results become assured, as tested in this study, from a real project scenario.

Finally, concerning data reading and analysis, when using a conventional calculation spreadsheet, it's important to highlight the need to check each piece of data and follow the project's development and possible changes for spreadsheet updates. In the numerical CAD/CAE code developed in this work, especially with the assistance of color standardization for viewing program output data, these analyses become more intuitive and quicker. In this regard, if any changes are necessary, by altering the project, it's possible to instantly see if any pipe is overloaded or oversized through the color pattern, in addition to warnings/alerts issued by the numerical code and the specific spreadsheet the program generates if needed.

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