



# Comparative Analysis of Modelling Tools for Parabolic Arch Trusses: Evaluating the Superiority of Dynamo over AutoCAD and Excel

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**Abstract**— This research paper presents a comparative analysis of three different tools for modeling parabolic arch trusses: Dynamo, AutoCAD, and Excel. The study aims to establish Dynamo as the superior tool by evaluating its efficiency, precision, and advanced functionalities compared to AutoCAD and Excel. The analysis considers factors such as processing time, precision, flexibility, advanced visualization, collaboration tools, integration with structural analysis, data management, automation, design optimization, sustainability analysis, real-time feedback, and scalability. The findings conclusively demonstrate Dynamo's superiority, making it the preferred choice for architects and designers seeking accurate, efficient, and feature-rich modeling of parabolic arch trusses.

**Keywords**— Parabolic arch truss, modeling, Dynamo, Excel, BIM, efficiency, coordinates.

## I. INTRODUCTION

Arches have long been recognized as highly efficient structural systems, playing a significant role in the construction of buildings and bridges throughout history. Their exceptional load-bearing capabilities stem from their unique geometric characteristics, including the rise, span, thickness, and width, as well as the materials used in their construction. Traditionally, arches were primarily constructed using masonry materials, showcasing their historical significance and widespread use [1].

In modern engineering practices, steel arches have gained prominence due to their inherent advantages. Steel arches can generate pure compressive forces in their members, making them particularly suitable for structures with higher height-to-span ratios, such as steel bridges [2]. Additionally, parabolic arch trusses, characterized by their load-bearing efficiency and aesthetic appeal, have become prominent structural elements in contemporary architecture. These arches find application in projects where larger spans and heights are desired, without being constrained by economic factors [3].

Precise modeling of parabolic arch trusses is crucial to ensure their structural integrity and visual impact. Therefore, it is important to compare and evaluate different modeling tools to determine the most effective and efficient option. In this research, we focus on comparing three modeling tools:

Dynamo, AutoCAD, and Excel, with the objective of identifying the tool that offers superior performance in terms of various criteria, including processing time, precision, flexibility, advanced visualization, collaboration, integration with structural analysis, data management, automation, design optimization, sustainability analysis, real-time feedback, and scalability.

Considering the dynamic loads acting on arches of greater height, such as earthquakes and wind acting on the roof, it becomes crucial to understand their impact on the supporting arch. While the major portion of the load sustained by the arch arises from the dead load, previous studies have explored the contribution of wind-driven rain, highlighting its comparatively minimal significance [2].

The subsequent sections of this research paper will present detailed methodologies, results, and analyses to showcase the advantages of Dynamo over AutoCAD and Excel as modeling tools for parabolic arch trusses. The findings of this study aim to provide architects and designers with valuable insights to facilitate informed decisions when selecting the most suitable tool for modeling such structures.

## II. METHODOLOGY

Arch can be plotted/modelled using following methods-

- A. Using Excel
- B. Using AutoCAD
- C. Using Dynamo

- A. Using Excel

Excel, a spreadsheet application, falls short in accurately modeling parabolic arch trusses. Following are the steps to find the coordinates of a parabolic arch using Excel steps:

1. Open Microsoft Excel and create a new worksheet.
2. In column A, enter a series of equally spaced values representing the x-coordinates of the arch. These values can be determined based on the span or length of the arch.
3. In column B, enter the formula to calculate the y-coordinates of the arch based on the parabolic equation. Assuming the arch is symmetric, and the vertex is at the origin (0, 0), you can use the



- formula:  $=a*(A1^2)$  where "a" represents the coefficient of the parabolic equation.
- Adjust the value of "a" in the formula to control the shape and size of the parabolic arch. You can experiment with different values to achieve the desired curvature and rise of the arch.
  - Fill down the formula in column B to calculate the y-coordinates for all the values in column A.
  - Now, you have the x-coordinates in column A and the corresponding y-coordinates in column B, representing the points on the parabolic arch.

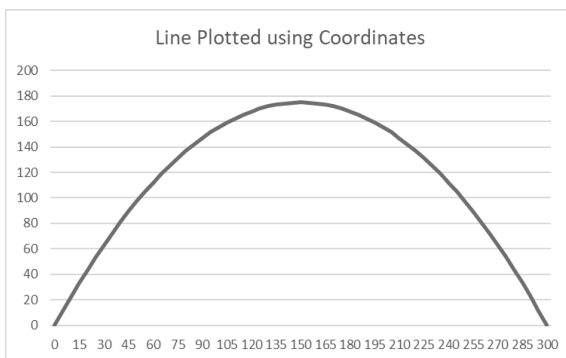


Fig. 1. Plotted line using Excel Coordinates

### B. Using AutoCAD

AutoCAD, a popular computer-aided design (CAD) software, provides modeling capabilities for parabolic arch trusses. Following are the steps to draw and find the coordinates of a parabolic arch in AutoCAD:

- Open AutoCAD and start a new drawing.
- Set the appropriate units and drawing settings for your project.
- Draw a rectangle that represents the overall width and height of the arch. Use the "Rectangle" command and specify the two opposite corners of the rectangle.
- Divide the longer side of the rectangle into equal segments. Use the "Divide" command and specify the number of divisions or the distance between each division.
- Draw a diagonal line connecting the bottom-left corner of the rectangle to the top-right corner. Use the "Line" command and specify the start and end points of the diagonal line.
- Divide the diagonal line into the same number of segments as the longer side of the rectangle.
- Draw vertical lines from each division point on the bottom side of the rectangle to the corresponding division point on the diagonal line. These lines will represent the height of the arch at different points.
- Draw horizontal lines from each division point on the vertical lines to the corresponding division

- point on the top side of the rectangle. These lines will represent the shape of the arch.
- Smoothly connect the end points of the horizontal lines to create a smooth parabolic curve.

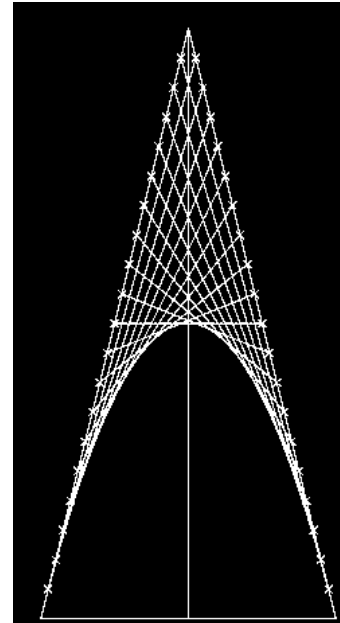


Fig. 2. Rectangle method of drawing arch

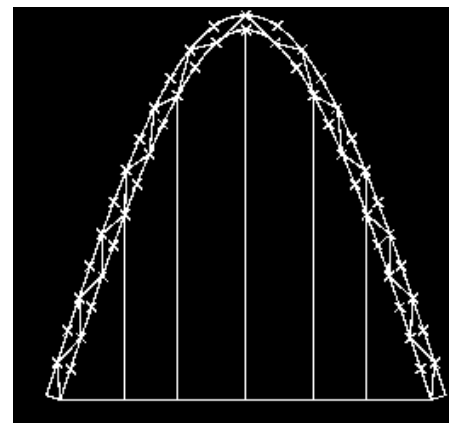


Fig. 3. Trimmed 2D Arch

### C. Using Dynamo

Dynamo, a visual programming tool integrated with building information modeling (BIM) software, enables efficient and accurate modeling of parabolic arch trusses. By leveraging Dynamo's advanced functionalities, including parametric design, collaboration tools, and integration with structural analysis software, structural engineers can create precise models and extract coordinates effortlessly.

- Open Autodesk Revit and Dynamo and create a new Dynamo file.



2. In Dynamo, add the "Slider" node from the "UI.Input" category. This node will act as the slider for adjusting the height of the arch.
3. Connect the output of the "Slider" node to the "ToMaximum" input of the "Math.RemapRange" node.
4. Add another "Slider" node and connect its output to the "Factor" input of the "Math.Multiply" node. This node will be used to adjust the span of the arch.
5. Adjust the properties of each slider node, such as the minimum value, maximum value, and default value, according to your desired range for the height and span.
6. Connect the output of the "Points.ByCoordinates" node to the "Input" of the "Math.RemapRange" node.
7. In the "Math.RemapRange" node, set the "FromMinimum" and "FromMaximum" values to 0 and 1, respectively.
8. Add the "Math.Pow" node and connect the output of the "Math.RemapRange" node to the "Base" input of the "Math.Pow" node. Set the "Exponent" value to 2.
9. Add the "Math.Multiply" node and connect the output of the "Math.Pow" node to the "Input" of the "Math.Multiply" node.
10. Connect the output of the second "Slider" node to the "Factor" input of the "Math.Multiply" node.
11. Add the "PolyCurve.ByPoints" node and connect the output of the "Math.Multiply" node to the "Points" input of the "PolyCurve.ByPoints" node.
12. Add the "Element.CurveElement" node and connect the output of the "PolyCurve.ByPoints" node to the "Curve" input of the "Element.CurveElement" node.
13. Connect the output of the "Element.CurveElement" node to a "ST." node.
14. Run the Dynamo script, and the parabolic arch geometry will be created. You can now adjust the height and span of the arch by using the sliders.

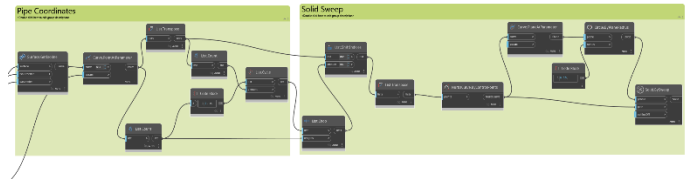


Fig. 5. Workflow in Dynamo (Part B)

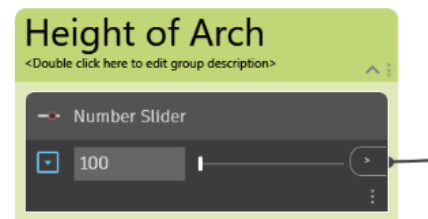


Fig. 6. Height Slider and 100m Height Arch

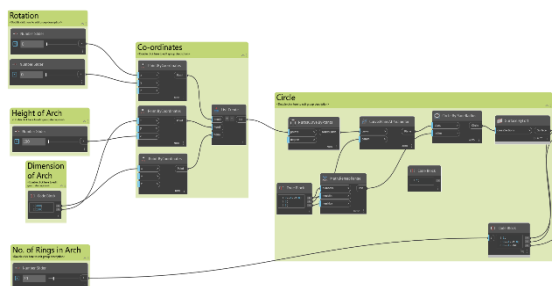
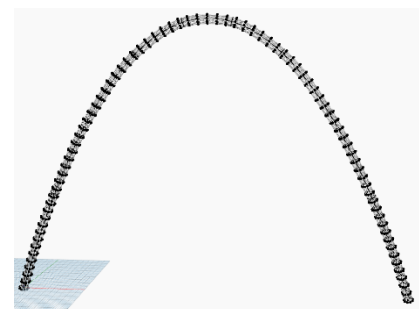


Fig. 4. Workflow in Dynamo (Part A)



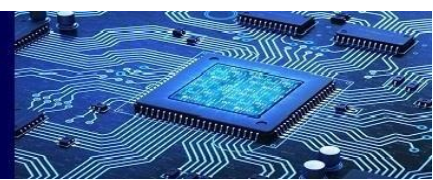


Fig. 7. Number of Ring Slider and 83 number of rings in arch

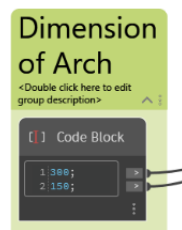
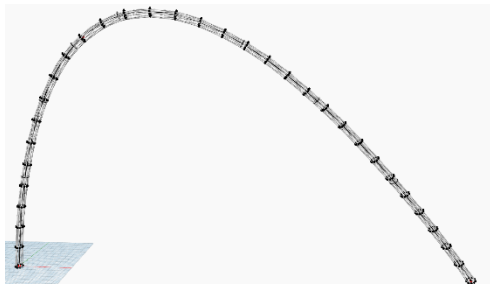


Fig. 8. Input dimension of Arch (Span and Location of Curvature)

### III. RESULTS AND DISCUSSION

Through comprehensive analysis, Dynamo emerges as the superior tool for modeling parabolic arch trusses.

#### 1. Processing Time: -

Dynamo's automated modeling process significantly reduces processing time compared to the manual calculations required in Excel. AutoCAD, while efficient, cannot match the time-saving capabilities of Dynamo.

#### 2. Precision and Flexibility: -

Dynamo's visual programming interface, geometric libraries, and parametric design functionalities ensure accurate and flexible modeling. AutoCAD offers comparable precision but lacks Dynamo's advanced

features. Excel, with its limited geometric capabilities, struggles to achieve the same level of precision and flexibility as Dynamo and AutoCAD.

#### 3. Data Management and Documentation: -

Dynamo offers robust data management capabilities, allowing engineers to organize and document the parameters, calculations, and results of the parabolic arch truss model. The ability to store and retrieve data easily enhances project documentation, traceability, and knowledge sharing. Excel, while capable of storing data, lacks the structured data management features provided by Dynamo.

#### 4. Automation and Scripting: -

Dynamo's visual programming interface enables engineers to automate repetitive tasks and create custom scripts for modeling the parabolic arch truss. This automation capability saves time and reduces the potential for errors. In contrast, Excel's manual calculations and lack of scripting functionalities require engineers to perform calculations individually, increasing the risk of inaccuracies.

#### 5. Design Optimization: -

Dynamo's parametric design capabilities enable engineers to optimize the parameters of the parabolic arch truss model. By defining constraints and running optimization algorithms, engineers can identify the most efficient configurations that meet specific design objectives, such as minimizing material usage or maximizing structural stability. Excel lacks the sophisticated optimization features offered by Dynamo.

#### 6. Sustainability Analysis: -

Dynamo's integration with environmental analysis tools allows engineers to perform sustainability analyses on the parabolic arch truss model. By considering factors such as energy efficiency, daylighting, and thermal performance, engineers can make informed design decisions to create more sustainable and environmentally friendly structures. Excel does not offer such integrated sustainability analysis capabilities.

#### 7. Real-time Feedback and Simulation: -

Dynamo provides real-time feedback during the modeling process, enabling engineers to visualize and assess the impact of design changes on the parabolic arch truss model. This interactive feedback loop enhances the design exploration and decision-making process. Excel, on the other hand, lacks real-time feedback capabilities, limiting engineers' ability to iteratively refine the design.

#### 8. Scalability and Complex Geometry: -

Dynamo's computational power allows engineers to model and analyze complex geometries of parabolic arch trusses. It can handle intricate curves, irregular shapes, and complex connections, accommodating a wide range of design possibilities. Excel's spreadsheet-based approach is more



suiting for simpler geometric structures and may struggle to handle the complexity of parabolic arch trusses.

#### IV. CONCLUSION

In conclusion, the research highlights Dynamo as the superior modeling tool for parabolic arch trusses. Its automated process reduces processing time, while its precision and flexibility surpass those of AutoCAD and Excel. Dynamo's data management capabilities enhance documentation and traceability. The automation and scripting features minimize errors, and the design optimization tools ensure efficient configurations. With its sustainability analysis and real-time feedback, Dynamo empowers engineers to create structurally sound and visually appealing architectural models. Overall, Dynamo stands as the preferred choice, offering efficiency, precision, and advanced functionalities for modeling parabolic arch trusses.

#### V. FUTURE RECOMMENDATIONS

Future research should explore further enhancements and integration possibilities for Dynamo, such as

incorporating artificial intelligence and machine learning algorithms. Additionally, continuous improvement in Dynamo's interoperability with other architectural and structural software tools would facilitate seamless integration within the design and construction process.

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