Osdag Screening Task Report

Shear Force and Bending Moment Diagrams Using Xarray

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Tools Used: Python, Xarray, NumPy, Matplotlib, Plotly
Execution Platform: Kaggle Notebook

1. Introduction

Osdag is an open-source structural engineering software developed under the FOSSEE initiative with the objective of promoting transparent and accessible tools for steel structure analysis and design. In modern structural workflows, numerical solvers generate large volumes of result data that require efficient post-processing for interpretation and validation.

This screening task focuses on post-processing structural analysis results using Python. The task emphasizes the use of **Xarray** for handling structured multidimensional data and **visualization libraries** for generating shear force and bending moment diagrams. Two tasks are addressed:

1. Generation of two-dimensional shear force and bending moment diagrams for a selected girder.
2. Generation of three-dimensional force and moment diagrams for all longitudinal girders in a bridge grillage model.

2. Dataset Description

The analysis results are provided in the form of an **Xarray dataset**. The dataset is structured using two primary dimensions:

- **Element:** Represents individual structural elements (indexed from 1 to 85)
- **Component:** Represents force and displacement components associated with each element

The dataset contains a single data variable:

- **forces (Element, Component)**

Key Components Used

- `Mz_i`, `Mz_j` → Bending moment at the start and end nodes of an element
- `Vy_i`, `Vy_j` → Shear force at the start and end nodes of an element

Each element stores internal forces at both its **i-end** and **j-end**, enabling continuous reconstruction of force diagrams along connected elements.

3. Task-1: 2D Shear Force and Bending Moment Diagrams

3.1 Central Longitudinal Girder Identification

For Task-1, the **central longitudinal girder** was selected for analysis. This girder consists of the following sequence of elements:

```
[15, 24, 33, 42, 51, 60, 69, 78, 83]
```

These elements are connected consecutively, forming a continuous structural member along the bridge span. Element connectivity data was used to identify the corresponding start and end nodes, while node coordinate data was used to determine the physical location of each element along the bridge length.

3.2 Data Extraction Using Xarray

All force components are stored within the `forces` variable and indexed using the `Component` dimension. Internal forces were extracted using Xarray's selection mechanism as shown below:

```
ds.forces.sel(Element=e, Component="Mz_i")
```

This method ensures:

- Accurate association of forces with their respective elements
- Direct use of solver output values
- No alteration of sign conventions

3.3 Methodology

The following procedure was adopted to generate continuous two-dimensional diagrams:

1. Iterate through the elements of the central girder in sequence
2. Extract the x-coordinates of the start and end nodes
3. Extract bending moment and shear force values at both element ends
4. Append values sequentially to maintain continuity
5. Sort all data points along the bridge length

Continuity is preserved because the end node of one element coincides with the start node of the next element.

3.4 Results

3.4.1 Bending Moment Diagram

The bending moment diagram was plotted using Matplotlib. The horizontal axis represents the bridge length, while the vertical axis represents the bending moment magnitude (`Mz`). The diagram exhibits smooth continuity across all elements of the girder.

3.4.2 Shear Force Diagram

The shear force diagram was generated using the same methodology. The vertical axis represents shear force (`Vy`), and the diagram correctly reflects sign changes and force distribution along the span.

Both diagrams follow standard structural engineering conventions and are consistent with typical post-processing outputs from structural analysis software.

3.5 Observations

- Xarray provides a robust framework for handling structured solver output
- Component-based indexing simplifies force extraction
- Use of node coordinates ensures geometric accuracy
- No manual sign adjustments were required

4. Task-2: 3D Shear Force and Bending Moment Diagrams

4.1 Objective

The objective of Task-2 is to visualize the distribution of shear force and bending moment across **all longitudinal girders** using three-dimensional plots. The visualization approach aims to replicate the appearance and interpretability of commercial software post-processing tools such as MIDAS.

4.2 Girder Layout and Structural Connectivity

The bridge grillage model consists of five longitudinal girders identified as follows:

- **Girder 1:** [13, 22, 31, 40, 49, 58, 67, 76, 81]
- **Girder 2:** [14, 23, 32, 41, 50, 59, 68, 77, 82]
- **Girder 3:** [15, 24, 33, 42, 51, 60, 69, 78, 83]
- **Girder 4:** [16, 25, 34, 43, 52, 61, 70, 79, 84]
- **Girder 5:** [17, 26, 35, 44, 53, 62, 71, 80, 85]

Element connectivity and node coordinate data were used to construct the three-dimensional bridge geometry.

4.3 Methodology

4.3.1 Force Extraction

For each element in every girder, bending moment and shear force values were extracted using Xarray without modifying the original solver output.

4.3.2 3D Visualization Approach

The three-dimensional diagrams were constructed using the following axis conventions:

- **X-axis:** Longitudinal direction of the bridge
- **Z-axis:** Transverse direction representing girder spacing
- **Y-axis:** Force or moment magnitude

For each girder:

- Node coordinates define the spatial geometry
- Internal force values are extruded vertically

- Each girder is plotted as an independent 3D polyline

Plotly was used to generate interactive diagrams, allowing rotation, zooming, and inspection.

4.4 Results

4.4.1 3D Bending Moment Diagram

The 3D bending moment diagram clearly illustrates how bending moments vary along the span and across different girders. Differences in magnitude between girders are visually apparent, enabling better understanding of load sharing.

4.4.2 3D Shear Force Diagram

The 3D shear force diagram provides a spatial view of shear force distribution across the bridge deck. The diagram enhances interpretability compared to conventional 2D plots.

4.5 Observations

- Three-dimensional visualization improves structural insight
- Xarray ensures consistent and reliable data handling
- The diagrams closely resemble commercial post-processing outputs
- Raw analysis results were preserved without smoothing

5. Conclusion

This screening task successfully demonstrates the use of Python for structural post-processing. By integrating Xarray with visualization libraries, both two-dimensional and three-dimensional shear force and bending moment diagrams were generated accurately. The workflow closely aligns with professional engineering practices and provides a scalable approach for post-processing grillage analysis results.

6. Tools and Libraries Used

- Python
- Xarray
- NumPy
- Matplotlib
- Plotly
- Kaggle Notebook Environment

7. Repository and Submission Details

The GitHub repository associated with this submission contains:

- The complete Kaggle notebook (`.ipynb`)
- Source code
- This report in PDF format

A video demonstration has been recorded and uploaded as an unlisted YouTube link.
The repository has been shared with **osdag-admin** as a collaborator.