# ****Programming Project Report****

## ****1.0 Overview****

The goal of this project was to develop a program capable of solving one-dimensional boundary value problems (BVPs) using the finite element method (FEM). The program was designed to handle various boundary conditions, including essential (EBC), natural (NBC), and mixed (MBC) boundary conditions. The program was developed in GUN C++ compiler based on Linux system.

### ****1.1 General Requirements****

The program was developed with the following requirements in mind:

1. **Formatted Input:** The input values are based on formatted input text file.
2. **Formatted Output:** The output result are stored in text file, and display on the command windows.
3. **Language**: The program was written in ANSI C++.
4. **Units**: The program assumes consistent units for all input data.
5. **Debugging**: A debugging variable was implemented to control the level of debugging output in the output file.

## ****2.0 Program Implementation****

### ****2.1 Input File Format****

The input file is divided into several sections, each containing specific data required for the finite element analysis. The sections are as follows:

1. **Section 1**: Problem identification and description.
2. **Section 2**: Alpha values (only support constant).
3. **Section 3**: Beta values (only support constant).
4. **Section 4**: Force values (only support constant).
5. **Section 5**: Nodal coordinates.
6. **Section 6**: Nodal flux values.
7. **Section 7**: Element data, including element type and connectivity.
8. **Section 8**: Left end boundary condition (EBC, NBC and MBC).
9. **Section 9**: Right end boundary condition (EBC, NBC and MBC).
10. **Section 10**: End of input file.

The program reads the input file, parses the data, and stores it in appropriate data structures.

### ****2.2 Solution building****

**Basing on the 2.1 Input File Format section 7 build the Element System Matrix (ESM) and Element System Load Vector (ELSV) and combine to System Matrix (SM) and System Load Vector (SLV). This based on the Element type: 1C Linear meshing (1DC0L) and 1C Quadratic meshing (1DC0Q).**

**For 1DC0L, Matrix is build as:**

**For 1DC0Q, Matrix is build as:**

**’**

### ****2.3 Debugging Output****

**The program includes a debugging feature that allows users to control the level of detail in the output file. The debugging levels are as follows:**

* **Debug Level 0**: No debugging output (default).
* **Debug Level 1**: Outputs the system stiffness matrix and system load vector.
* **Debug Level 2**: Outputs the element stiffness matrix, element load vector, system stiffness matrix, and system load vector.

## ****3.0 Sample Test Problems****

### ****3.1 Test Model 1****

**With Debug\_Level = 0**

Input file name = Test Model 1.txt

Output file name = Test Model 1.out

result shows on Example 1.

### ****3.1 Test Model 2****

**With Debug\_Level = 2**

Input file name = Test Model 2.txt

Output file name = Test Model 2.out

result shows on Example 2.

## ****4.0 Error Analysis****

The program computes both the absolute and relative error norms for the solution. The absolute error is given by , where R=KD−F, and the relative error is given by . These error measures provide insight into the accuracy of the solution.

## 5.0 Example

### 5.1 Example 1

Contents of the output file:

----------------------------------------

1D Boundary Value Program

Finite Elements for Engineers

(c) 2025, S. CSYH

Version: 1.0. Rev: 1

---------------------------------------------

DETAILS OF FINITE ELEMENT MODEL

-------------------------------

Number of Nodes: 4

Number of Elements: 3

Nodal Data

-------------------------

Node X Coor

-------------------------

1 0

2 0.15

3 0.3

4 0.6

Nodal Boundary Conditions

--------------------------------------------------

Node BC Value 1 Value 2

--------------------------------------------------

1 EBC 0

1 EBC 0

Applied Nodal Flux

-------------------------

Node Flux

-------------------------

2 300000

Element Data

-----------------------------------------------------------------

Element Type Int. Order List of Nodes ...

-----------------------------------------------------------------

1 C0-Linear 2 1 2

2 C0-Linear 2 2 3

3 C0-Linear 2 3 4

Element Properties

----------------------------------------------------------------------

Element Qty x\*\*2 x constant

----------------------------------------------------------------------

1 Alpha 0 0 5e+07

Beta 0 0 0

f 0 0 0

2 Alpha 0 0 5e+07

Beta 0 0 0

f 0 0 0

3 Alpha 0 0 8e+07

Beta 0 0 0

f 0 0 0

Nodal Values

----------------------------------------

Node Location Value

----------------------------------------

1 0 0

2 0.15 0.000623077

3 0.3 0.000346154

4 0.6 0

Max and Min Nodal Values

----------------------------------------

Min Nodal Value: 0 at Node 0

Max Nodal Value: 0.000623077 at Node 0.15

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Element Flux

----------------------------------------

Element Location Flux

----------------------------------------

1 0 -207692

2 0.15 92307.7

3 0.3 92307.7

Max and Min Flux Values

----------------------------------------

Min Flux: -207692 at Location 0

Max Flux: 92307.7 at Location 0.3

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Error Measures:

----------------------------------------

Absolute Error (||R||): 227281

Relative Error (||R|| / ||F||): 0.757604

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### 5.2 Example 2

Contents of the output file:

----------------------------------------

1D Boundary Value Program

Finite Elements for Engineers

(c) 2025, S. CSYH

Version: 1.0. Rev: 1

---------------------------------------------

DETAILS OF FINITE ELEMENT MODEL

-------------------------------

Number of Nodes: 5

Number of Elements: 2

Nodal Data

-------------------------

Node X Coor

-------------------------

1 0

2 1

3 2

4 3

5 4

Nodal Boundary Conditions

--------------------------------------------------

Node BC Value 1 Value 2

--------------------------------------------------

1 EBC 0

1 NBC 0

Applied Nodal Flux

-------------------------

Node Flux

-------------------------

Element Data

-----------------------------------------------------------------

Element Type Int. Order List of Nodes ...

-----------------------------------------------------------------

1 C0-Quadratic 3 1 2 3

2 C0-Quadratic 3 3 4 5

Element Properties

----------------------------------------------------------------------

Element Qty x\*\*2 x constant

----------------------------------------------------------------------

1 Alpha 0 0 6e+07

Beta 0 0 0

f 0 0 1

2 Alpha 0 0 6e+07

Beta 0 0 0

f 0 0 9

Nodal Values

----------------------------------------

Node Location Value

----------------------------------------

1 0 0

2 1 3.25e-07

3 2 6.33333e-07

4 3 8.58333e-07

5 4 9.33333e-07

Max and Min Nodal Values

----------------------------------------

Min Nodal Value: 0 at Node 0

Max Nodal Value: 9.33333e-07 at Node 4

----------------------------------------

Element Flux

----------------------------------------

Element Location Flux

----------------------------------------

1 0 -9.75

2 1 -9.25

Max and Min Flux Values

----------------------------------------

Min Flux: -9.75 at Location 0

Max Flux: -9.25 at Location 1

----------------------------------------

Error Measures:

----------------------------------------

Absolute Error (||R||): 20

Relative Error (||R|| / ||F||): 1.5523

----------------------------------------

System Stiffness Matrix

--------------------------------

7e+07 -8e+07 1e+07 0 0

-8e+07 1.6e+08 -8e+07 0 0

1e+07 -8e+07 1.4e+08 -8e+07 1e+07

0 0 -8e+07 1.6e+08 -8e+07

0 0 1e+07 -8e+07 7e+07

System Load Vector

--------------------------------

0.333333

1.33333

3.33333

12

3

Element Stiffness Matrix 1

--------------------------------

7e+07 -8e+07 1e+07

-8e+07 1.6e+08 -8e+07

1e+07 -8e+07 7e+07

Element Stiffness Vector 1

--------------------------------

0.333333

1.33333

0.333333 Element Stiffness Matrix 2

--------------------------------

7e+07 -8e+07 1e+07

-8e+07 1.6e+08 -8e+07

1e+07 -8e+07 7e+07

Element Stiffness Vector 2

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3

12

3