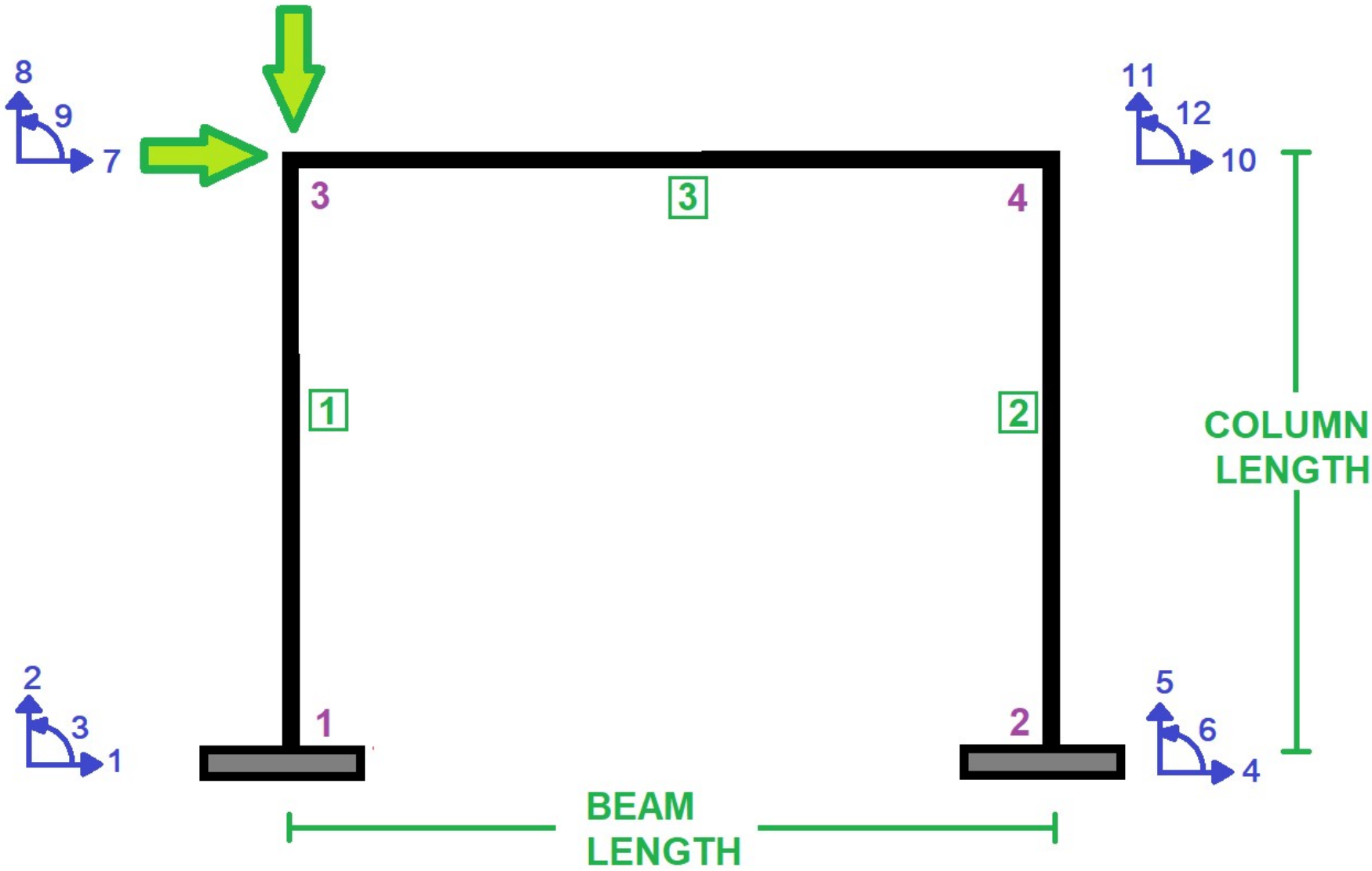
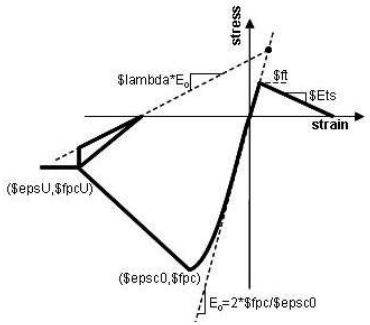
IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL

CONSTRAINED OPTIMIZATION OF REINFORCED CONCRETE COLUMN DESIGN USING NONLINEAR PUSHOVER ANALYSIS IN OPENSEES

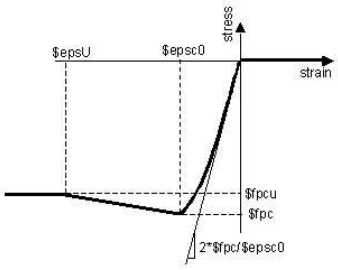
WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)


8
9
7
11
12
10
3
3
4
1
2
COLUMN
LENGTH
2
3
1
1
2
5
6
4
BEAM
LENGTH

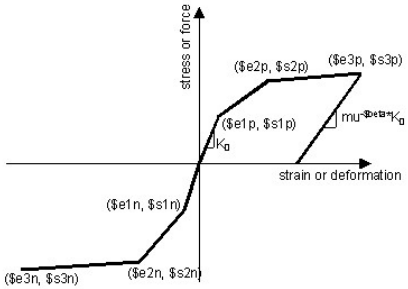
Concrete02 Material -- Linear Tension Softening



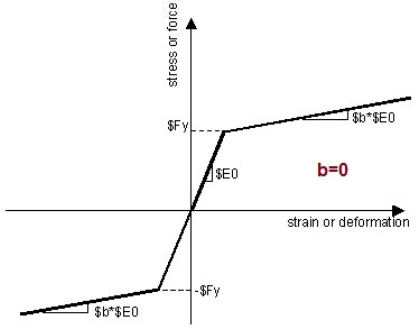
Concrete01 Material -- Zero Tensile Strength



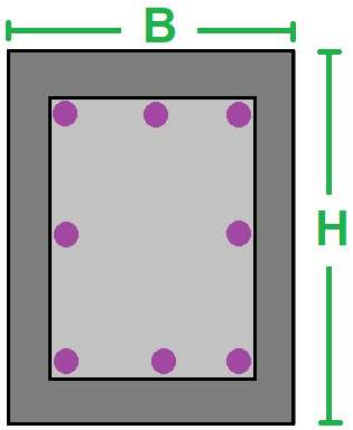
CORE AND COVER CONCRETE REALTION



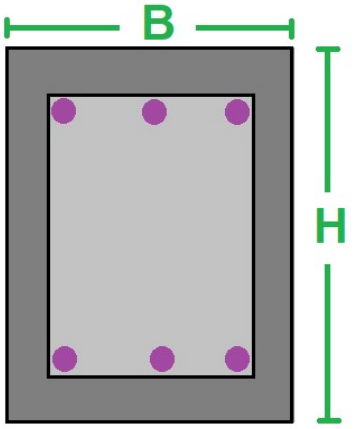
WITH HARDENING AND ULTIMATE STRAIN



WITHOUT HARDENING AND ULTIMATE STRAIN



COLUMN SECTION



BEAM SECTION

Spyder (Python 3.12)

File Edit Search Source Run Debug Consoles Projects Tools View Help

...MPLES\OPTIMIZATION\PUSHOVER_REBAR_Cdepth_DUCT_OPTIMIZATION

C:\Users\Dell\Desktop\OPENSEES_FILES\CONCRETE_FRA...HOVER_REBAR_Cdepth_DUCT_OPTIMIZATION_CONSTRAIN.py

PUSHOVER_REBAR_Cde...ATION_CONSTRAIN.py

```
##########################################################################################################
#                  >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
#         CONSTRAINED OPTIMIZATION OF REINFORCED CONCRETE COLUMN DESIGN USING NONLINEAR PUSHOVER
#                                        ANALYSIS IN OPENSEES
#--------------------------------------------------------------------------------------------------------
#     FIND BEST COLUMN REBAR DIAMETER AND COLUMN SECTION DEPTH WITH TARGET STRUCTURAL DUCTILITY RATIO
#--------------------------------------------------------------------------------------------------------
#                          THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
#                                  EMAIL: salar.d.ghashghaei@gmail.com
##########################################################################################################
"""
# 1. Import OpenSeesPy, NumPy, SciPy, and custom analysis modules
#    Used for nonlinear FEM analysis, optimization, and post-processing

# 2. Define concrete and steel material properties
#    Includes confined/unconfined concrete and nonlinear reinforcing steel

# 3. Define column and beam geometry (section sizes, cover, rebar diameter)
#    These parameters control stiffness, strength, and ductility

# 4. Define pushover analysis parameters
#    Maximum displacement, increment size, element lengths, and solver settings

# 5. Define PUSHOVER_ANALYSIS() function
#    Builds a 2D RC frame model, applies loads, and performs nonlinear pushover

# 6. Inside PUSHOVER_ANALYSIS():
#    - Create nodes, boundary conditions, sections, and elements
#    - Apply displacement-controlled static analysis
#    - Record forces, displacements, rotations, and stiffness values

# 7. Fit a bilinear curve to base-shear vs displacement
#    Used to compute ductility ratio (μ) and over-strength factor (Ω₀)

# 8. Return structural response data including μ and Ω₀
#    These are the key performance indicators for optimization
```

Console 1/A

```
=   Analysis curve fitted =
     Disp       Base Shear
--------------------------
[[0.00000000e+00 0.00000000e+00]
 [2.15547996e+01 7.12212466e+04]
 [1.61597448e+02 7.12027367e+04]]
+-------------------------+
+-----------------------------------------------------+
 Structure Elastic Stiffness :     3304.19
 Structure Plastic Stiffness :     440.62
 Structure Tangent Stiffness :     -0.13
 Structure Ductility Ratio :       7.50
 Structure Over Strength Factor:   1.00
+-----------------------------------------------------+
DIAc=15.04 mm | Hc=401.5 mm | DUCT=7.49705 | OSF=0.99974 | Obj=6.754e-08



=== OPTIMIZATION COMPLETED ===
Optimal DIAc = 15.035 mm
Optimal Hc   = 401.478 mm
Final Objective = 1.007e-02
Iterations = 9
Success: True
Message: CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Duration (sec):

 407.21875
NormDispIncr KrylovNewton 0
WARNING analysis Static - no Integrator specified,
 StaticIntegrator default will be used
WARNING: CTestNormUnbalance::test() - failed to converge
after: 25 iterations  current Norm: 5.67249e-06 (max: 1e-06, Norm deltaX: 3.66914e-13)
NewtonRaphson::solveCurrentStep() -the ConvergenceTest object failed in test()
StaticAnalysis::analyze() - the Algorithm failed at step: 0 with domain at load factor 29.5906
OpenSees > analyze failed, returned: -3 error flag
+-------------------------+
=   Analysis curve fitted =
     Disp       Base Shear
--------------------------
[[0.00000000e+00 0.00000000e+00]
 [2.15547996e+01 7.12212466e+04]
 [1.61597448e+02 7.12027367e+04]]
+-------------------------+
+-----------------------------------------------------+
 Structure Elastic Stiffness :     3304.19
 Structure Plastic Stiffness :     440.62
 Structure Tangent Stiffness :     -0.13
 Structure Ductility Ratio :       7.50
 Structure Over Strength Factor:   1.00
+-----------------------------------------------------+
+-------------------------+
=   Analysis curve fitted =
```

IPython Console | Files | Help | Variable Explorer | Debugger | Plots | History

Spyder (Python 3.12)

File Edit Search Source Run Debug Consoles Projects Tools View Help

C:\Users\Dell\Desktop\OPENSEES_FILES\CONCRETE_FRA...HOVER_REBAR_Cdepth_DUCT_OPTIMIZATION_CONSTRAIN.py

PUSHOVER_REBAR_Cde...ATION_CONSTRAIN.py

```
347  # OBJECTIVE FUNCTION
348  def objective(X):
349      DIAc, Hc = X
350
351      try:
352          DATA = PUSHOVER_ANALYSIS(
353              DIAc, Hc,
354              LENGTH_COL, LENGTH_BM,
355              DMAX, DINCR,
356              STEEL_KIND=2,
357              CONCRETE_KIND=1
358          )
359
360          (_, _, _, _, _, _, _, _, _,
361           DUCT_ANA, OSF_ANA, _) = DATA
362
363      except:
364          # Analysis failed → strong penalty
365          return 1e6
366
367      # Main objective: match target values
368      obj = (
369          (DUCT_ANA - TARGET_DUCT)**2 +
370          (OSF_ANA  - TARGET_OSF )**2
371      )
372
373      # Constraint penalties
374      pen = (
375          penalty(DUCT_ANA, DUCT_MIN, DUCT_MAX) +
376          penalty(OSF_ANA,  OSF_MIN,  OSF_MAX)
377      )
378
379      print(f"DIAc={DIAc:.2f} mm | Hc={Hc:.1f} mm | "
380            f"DUCT={DUCT_ANA:.5f} | OSF={OSF_ANA:.5f} | Obj={pen:.3e}")
381      return obj + 100.0 * pen  # penalty weight
382
383  # INITIAL GUESS
```

...MPLES\OPTIMIZATION\PUSHOVER_REBAR_Cdepth_DUCT_OPTIMIZATION

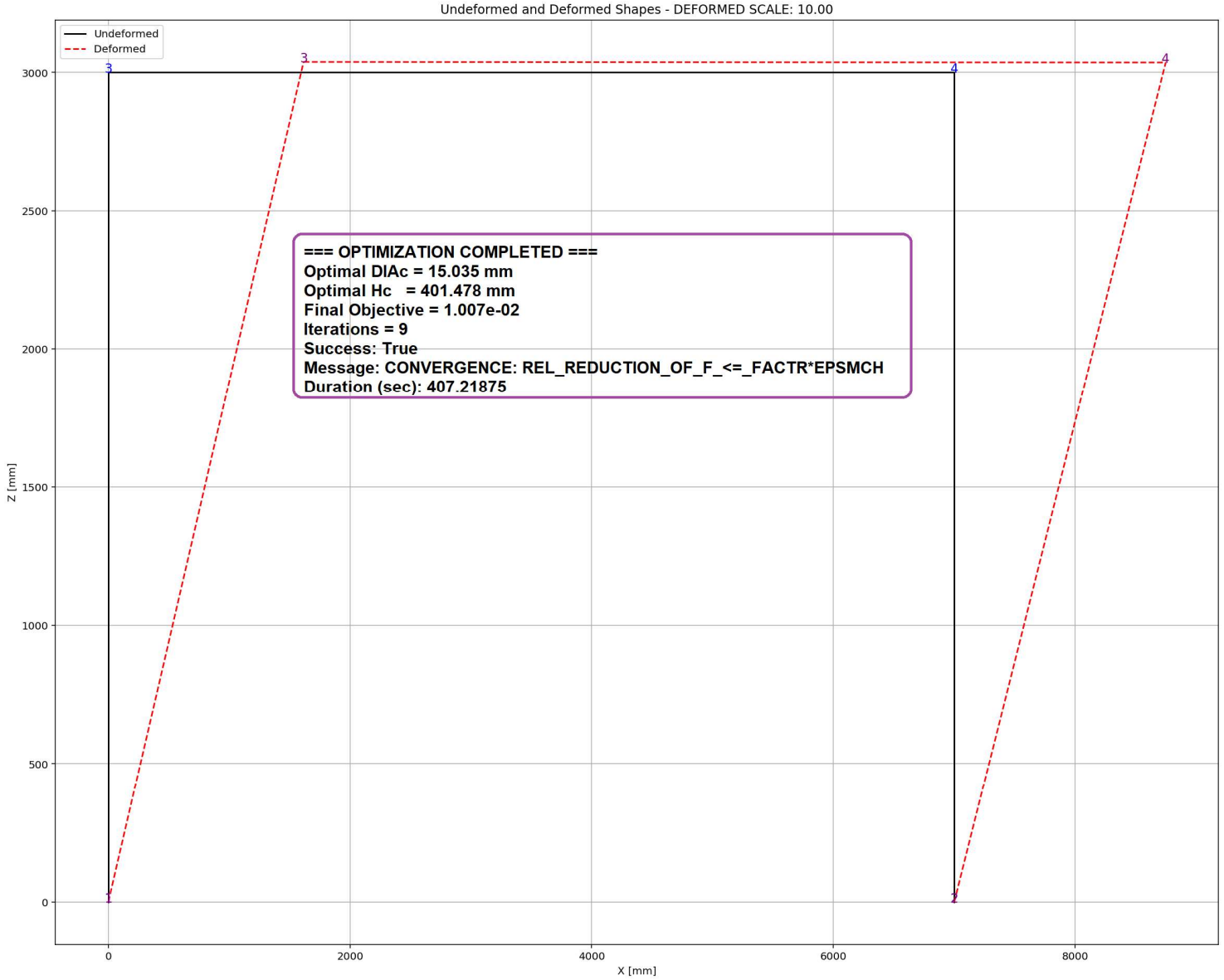
Console 1/A

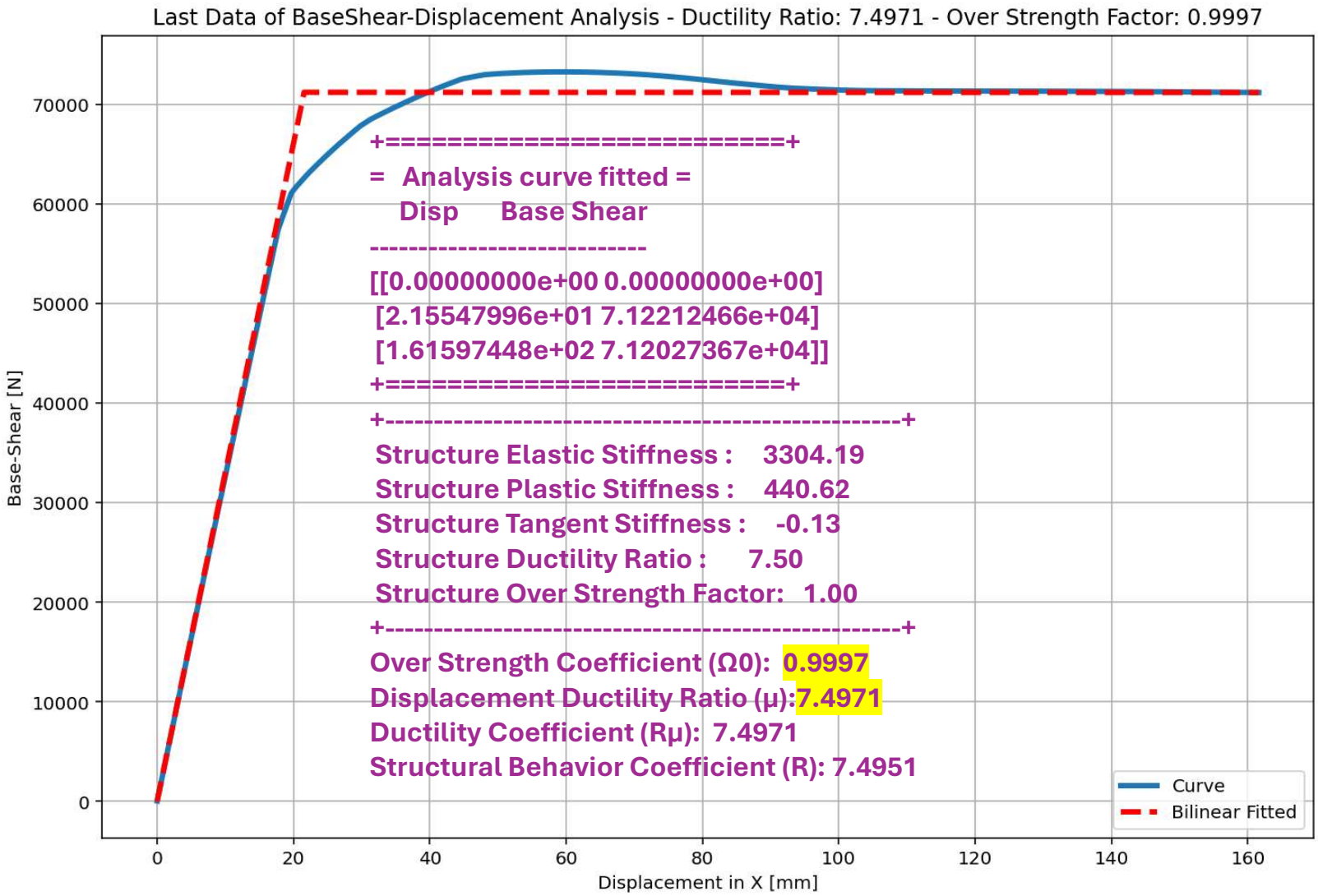
```
    2      9     16      9     0     0   6.173D-04   1.007D-02
  F =  1.0067492714797 41E-002

CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
+-------------------------+
=   Analysis curve fitted =
     Disp          Base Shear
---------------------------
[[0.00000000e+00 0.00000000e+00]
 [2.15547996e+01 7.12212466e+04]
 [1.61597448e+02 7.12027367e+04]]
+-------------------------+
+-----------------------------------------------------+
 Structure Elastic Stiffness :     3304.19
 Structure Plastic Stiffness :     440.62
 Structure Tangent Stiffness :     -0.13
 Structure Ductility Ratio :       7.50
 Structure Over Strength Factor:   1.00
+-----------------------------------------------------+
DIAc=15.04 mm | Hc=401.5 mm | DUCT=7.49705 | OSF=0.99974 | Obj=6.754e-08


=== OPTIMIZATION COMPLETED ===
Optimal DIAc = 15.035 mm
Optimal Hc   = 401.478 mm
Final Objective = 1.007e-02
Iterations = 9
Success: True
Message: CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Duration (sec):

 407.21875
NormDispIncr KrylovNewton 0
WARNING analysis Static - no Integrator specified,
 StaticIntegrator default will be used
WARNING: CTestNormUnbalance::test() - failed to converge
after: 25 iterations  current Norm: 5.67249e-06 (max: 1e-06, Norm deltaX: 3.66914e-13)
NewtonRaphson::solveCurrentStep() -the ConvergenceTest object failed in test()
StaticAnalysis::analyze() - the Algorithm failed at step: 0 with domain at load factor 29.5906
OpenSees > analyze failed, returned: -3 error flag
+-------------------------+
=   Analysis curve fitted =
     Disp          Base Shear
---------------------------
[[0.00000000e+00 0.00000000e+00]
 [2.15547996e+01 7.12212466e+04]
 [1.61597448e+02 7.12027367e+04]]
+-------------------------+
+-----------------------------------------------------+
 Structure Elastic Stiffness :     3304.19
 Structure Plastic Stiffness :     440.62
```

IPython Console | Files | Help | Variable Explorer | Debugger | Plots | History

Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 359, Col 1 UTF-8 CRLF RW Mem 43%

NONLINEAR STATIC ANALYSIS (PUSHOVER)


Undeformed and Deformed Shapes - DEFORMED SCALE: 10.00
Undeformed
Deformed
3
3
4
4
1
1
=== OPTIMIZATION COMPLETED ===
Optimal DIAc = 15.035 mm
Optimal Hc = 401.478 mm
Final Objective = 1.007e-02
Iterations = 9
Success: True
Message: CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
Duration (sec): 407.21875
Z [mm]
3000
2500
2000
1500
1000
500
0
0
2000
4000
6000
8000
X [mm]


Last Data of BaseShear-Displacement Analysis - Ductility Ratio: 7.4971 - Over Strength Factor: 0.9997
+==========================+
= Analysis curve fitted =
Disp Base Shear

[[0.00000000e+00 0.00000000e+00]
[2.15547996e+01 7.12212466e+04]
[1.61597448e+02 7.12027367e+04]]
+==========================+
+--+
Structure Elastic Stiffness : 3304.19
Structure Plastic Stiffness : 440.62
Structure Tangent Stiffness : -0.13
Structure Ductility Ratio : 7.50
Structure Over Strength Factor: 1.00
+--+
Over Strength Coefficient (Ω0): 0.9997
Displacement Ductility Ratio (μ):7.4971
Ductility Coefficient (Rμ): 7.4971
Structural Behavior Coefficient (R): 7.4951
Curve
Bilinear Fitted
Base-Shear [N]
Displacement in X [mm]
0
10000
20000
30000
40000
50000
60000
70000
0
20
40
60
80
100
120
140
160