Pushover_Model

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0.0.1 OpenSeesPY Pushover analysis

In this example a Displacement-Controlled Analysis is performed on the Intermediate Bent. The nonlinear/inelastic behavior of a fiber section is defined by the stress-strain response of the uniaxial materials used to define it. This is a 3D model (to capture the local z coordinate in the section, but only 3 dofs (axial, shear, rot).

{image}pushover.png :alt: Fiber_coordinates :class: bg-primary mb-1 :width: 600px :align: center

0.0.2 Reference

https://opensees.berkeley.edu/wiki/index.php/Linear_Transformation
https://portwooddigital.com/2023/11/21/losing-displacement-control/

0.0.3 Moment-Curvature Plot Subrountine

[1]:
```
def MC_plot(Kn, Mn, curvature, moment, lab_x, lab_y, plot_title,
            K1y, Ksp, Kcu_UL, K_Rebc_UL, K_Rebt_UL, Kcu_LL, K_Rebt_LL,
            M1y, Msp, Mcu_UL, M_Rebc_UL, M_Rebt_UL, Mcu_LL, M_Rebt_LL,
            Ky, Ku, Mp, P, r):

    Kmax = 1.05 * Kn
    Mmax = 1.05 * Mn

    plt.figure()

    # Major ticks every 20, minor ticks every 5
    major_xticks = np.arange(0, Kmax, Kmax/10)
    minor_xticks = np.arange(0, Kmax, Kmax/50)
    major_yticks = np.arange(0, Mmax, Mmax/10)
    minor_yticks = np.arange(0, Kmax, Mmax/50)

    ax = plt.axes()
    ax.set_xticks(major_xticks)
    ax.set_xticks(minor_xticks, minor=True)
    ax.set_yticks(major_yticks)
    ax.set_yticks(minor_yticks, minor=True)
```

```
    ax.grid(which='both')
    ax.grid(which='minor', alpha=0.2)
    ax.grid(which='major', alpha=0.5)
#   ax.fill_between(curvature, moment, alpha = 0.2)

    plt.xlim(0, Kmax)
    plt.ylim(0, Mmax)
    plt.plot(curvature, moment, color = 'mediumblue', marker = 'o',␣
 ↪markersize=2)
    plt.plot([0, Ky, Ku], [0, Mp, Mp], color = 'red')

    # strain limit MC plots
    plt.plot([K1y, K1y], [0, M1y], marker="o", markersize=4, markevery=[1])
    plt.plot([Ksp, Ksp], [0, Msp], marker="o", markersize=4, markevery=[1])
    plt.plot([K_Rebt_UL, K_Rebt_UL], [0, M_Rebt_UL], marker="o", markersize=4,␣
 ↪markevery=[1])
    plt.plot([K_Rebt_LL, K_Rebt_LL], [0, M_Rebt_LL], linestyle='--', marker="o",
             markersize=4, markevery=[1])
    plt.plot([Kcu_LL, Kcu_LL], [0, Mcu_LL], linestyle='--', color='magenta',
             marker="o",markersize=4, markevery=[1])

    ax.fill_between(curvature, moment, alpha = 0.2)
    message = f"Axial Load = {P} kip\nAxial Ratio = {round(r, 2)}"
    plt.text(4.5, 4000, message, fontsize = 12, bbox=dict(facecolor='white',␣
 ↪edgecolor='black'))


    plt.legend(["Moment-Curvature", "Idealized", "First Yield", "Cover␣
 ↪Spalling",
                "UL Reinf. Tens. Limit (PL2)", "LL Reinf. Tens. Limit (PL3)",
                "LL Conc. Compr. Limit (PL3)"], loc='lower center')

    plt.xlabel(lab_x)
    plt.ylabel(lab_y)
    plt.title(plot_title)
    current_values = plt.gca().get_yticks()
    plt.gca().set_yticklabels(['{:,.0f}'.format(x) for x in current_values])

    plt.show()

    return
```

[ ]:

[2]:
```
# OpenSees -- Open System for Earthquake Engineering Simulation
# Pacific Earthquake Engineering Research Center
# http://opensees.berkeley.edu/
```

```
#
# Portal Frame Example 3.2
# ------------------------
#  Reinforced concrete one-bay, one-story frame
#  Distributed vertical load on girder
#  Lateral Load at top of frame
#
#
# Example Objectives
# ------------------
#  Nonlinear pushover analysis using Portal Frame Example 3.1 as starting point
#
#  Units: kips, in, sec
#
# %load_ext autoreload
%reload_ext autoreload
%autoreload 2

import openseespy.opensees as ops
import opsvis as opsv

#     %matplotlib ipympl
import matplotlib.pyplot as plt
from matplotlib.gridspec import GridSpec
import cv2
from PIL import Image

import numpy as np
import math
import pandas as pd

plt.rcParams['figure.constrained_layout.use'] = True
plt.rcParams["figure.figsize"] = (10, 5)

ops.wipe()
plt.close('all')

# ------------------------------------------------------
# Start of Model Generation & Initial Gravity Analysis
# ------------------------------------------------------

# remove existing model
ops.wipe()

# create ModelBuilder (with 3-dimensions and 6 DOF/node)
ops.model("BasicBuilder", "-ndm", 3, "-ndf", 6)
```

```
# set default units
ops.defaultUnits("-force", "kip", "-length", "in", "-time", "sec", "-temp", "F")
```

0.0.4 Basic Input Data

[3]:
```
# Bent Cap Properties:
h_cap = 5*12
b_cap = 6*12

# ------------
# Frame Geometry
width = 30*12
height = 25*12

# Column Properties:
D_col = 60.0
n_cols = 2

cover = 2.0          # to hoops outside
Reb_cover = 3.58     # to cl longit. reinf.
As = 1.56            # area of no. 11 bars
n_bars = 22

r_col = D_col / 2
r_core = D_col / 2 - cover
r_reinf = D_col / 2 - Reb_cover
r_core_int = r_core - 6
r_center = 0

n_wedges = 88
n_rings_int = 6        # number of rings in the interior core
n_rings = 12           # number of rings in the core around reinf
n_rings_cover = 6

# Define gravity loads
# --------------------
# Set a parameter for the axial load
Psuper = -1500.0

# Set some parameters
maxU = 5.0                  # Max displacement
dU = 0.1                    # Displacement increment
numSteps = int(maxU/dU) + 1
```

0.0.5 Concrete Materials

[4]:
```
# Define materials for nonlinear columns
# ------------------------------------------
fpcc = -7.89
ecpeak = -0.0073
e_cu = -0.020

# Unconfined
fpc = -5.2
eco = -0.002
esp = -0.005

ecu_UL = -0.0196      # ultimate concrete strain
esc_UL = -0.043       # bar buckling strain limit
est_UL = 0.036        # tensile strain limit

ecu_LL = -0.004
est_LL = 0.010

Econc = 4347

# ------------------------------------------------------------------------
# Core concrete (confined)
ops.uniaxialMaterial("Concrete04", 1, fpcc, ecpeak, e_cu, Econc, 0.0, 0.0, 0.1)
# Cover concrete (unconfined)
#uniaxialMaterial("Concrete04", 2, fpc, eco, esp, Econc, 0.0, 0.0, 0.1)
ops.uniaxialMaterial("Concrete01", 2, fpc,eco, 0., esp)
```

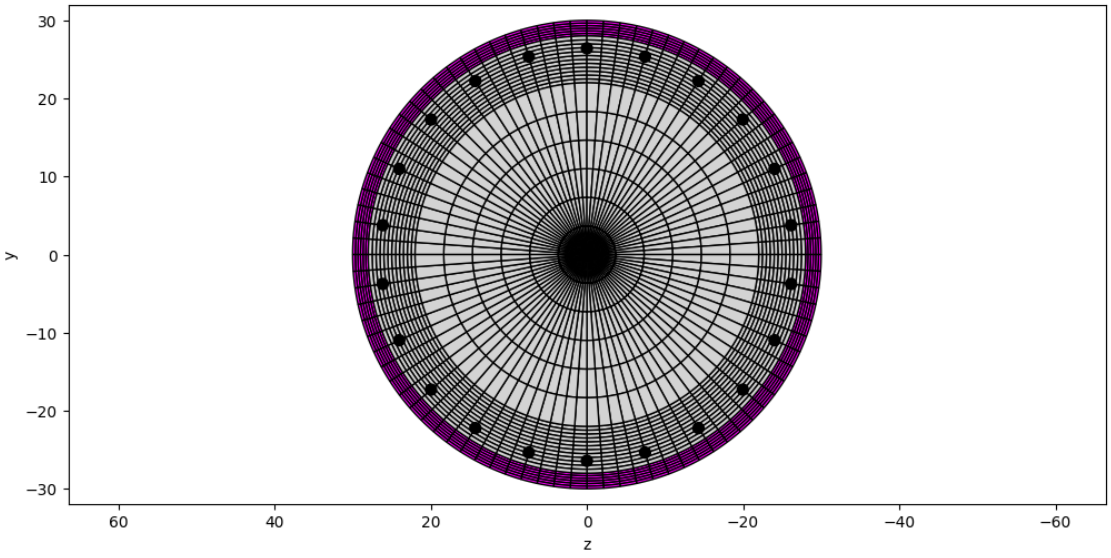
0.0.6 Reinforcing

[5]:
```
# Reinforcing steel
# https://openseespydoc.readthedocs.io/en/latest/src/steel4.html
# https://opensees.berkeley.edu/wiki/index.php?title=Steel4_Material
# ------------------------------------------------------------------------
fye    = 68.0      # Yield stress
fue    = 95.0
Es     = 29000.0    # Young's modulus

Esh = 1500
esh = 0.0115
e_suR = 0.06
esy = fye/Es

ops.uniaxialMaterial("ReinforcingSteel", 3, fye, fue, Es, Esh, esh, e_suR)
```

0.0.7 Cross Section Definition

[6]:
```
# Define cross-section for nonlinear columns
# https://opensees.berkeley.edu/community/viewtopic.php?
 ↪p=78841&hilit=overlap#p78841
# ----------------------------------------
secTag = 1

# Do NOT overlap fibers, reinforcement fiber is overlapping concrete fiber.
# ------------------------------------------------------------------------
# n_bars defines the number of reinforcement around the perimeter and the
# number of radial concrete fibers (wedges)
# patch('circ', matTag, numWedges, numRings, *center, *rad, *ang)
# *center: y & z-coordinates of the center of the circle.
# *rad: internal and external radius

delta_conc = 360/n_wedges
delta_rebar = 360/n_bars

ops.section("Fiber", secTag, secTag, '-GJ', 1.0e6)
ops.patch("circ", 2, n_wedges, n_rings_cover, 0, 0, r_core, D_col/2, 0, 360)  ␣
 ↪  # cover
ops.patch("circ", 1, n_wedges, n_rings, 0, 0, r_core_int, r_core, 0, 360)     ␣
 ↪  # core
ops.patch("circ", 1, n_wedges, n_rings_int, 0, 0, r_center, r_core_int, 0, 360)␣
 ↪  # core_int
ops.layer("circ", 3, n_bars, As, 0, 0, r_reinf, 360/n_bars, 360)              ␣
 ↪  # reinf

# For figure only:
# -----------------
Fib_sec = [["section", "Fiber"],
           ["patch", "circ", 2, n_wedges, n_rings_cover, 0, 0, r_core, D_col/2,␣
 ↪0, 360],      # cover
           ["patch", "circ", 1, n_wedges, n_rings, 0, 0, r_core_int, r_core, 0,␣
 ↪360],         # core
           ["patch", "circ", 1, n_wedges, n_rings_int, 0, 0, r_center,␣
 ↪r_core_int, 0, 360],   # core_int
           ["layer", "circ", 3, n_bars, As, 0, 0, r_reinf, 360/n_bars, 360],   ␣
 ↪              # reinf
         ]

#opsv.fib_sec_list_to_cmds(Fib_sec)
matcolor = ['lightgrey', 'magenta', 'gold', 'w', 'w', 'w']
opsv.plot_fiber_section(Fib_sec, matcolor=matcolor)
plt.axis('equal')
plt.savefig('fibsec_rc.png')
```

```
plt.show()
```



[7]:
```
# Create nodes
# ------------

# create nodes & add to Domain - command: node nodeId xCrd yCrd, zCrd
ops.node(1, 0.0,   0.0,   0.0)
ops.node(2, width, 0.0,   0.0)
ops.node(3, 0.0,   0.0,   height)
ops.node(4, width, 0.0,   height)

# set the boundary conditions - command: fix nodeID uxRestrnt? uyRestrnt?␣
 ↪rzRestrnt?
ops.fix(1, 1, 1, 1, 1, 1, 1)
ops.fix(2, 1, 1, 1, 1, 1, 1)
```

0.0.8 Frame connectivity

[8]:
```
# define beam integration
n_gpnts = 10;  # number of integration points along length of element
               # This variable defines how many fiber cross-sections are
               # considered, per element.
intgTag = 1
ops.beamIntegration("Lobatto", intgTag, secTag, n_gpnts)

#  Define column elements
#  ----------------------
#  Geometry of column elements
```

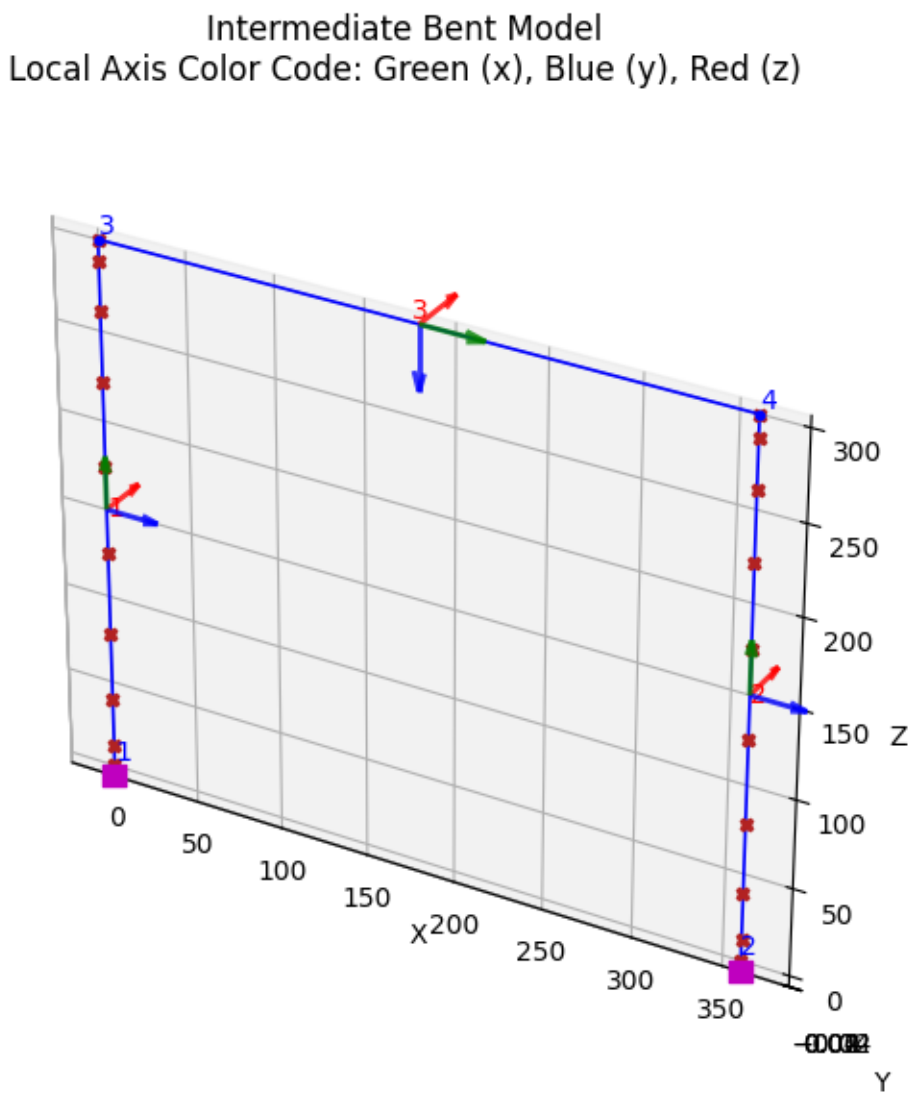
```
#  Tag, VecXZ components (plane defined by local axes x and z)
#  direction of the vector z, relative to x, along XYZ
#  In figure: Green (x), Blue (y), red (z)
transfTag = 1
ops.geomTransf("PDelta", transfTag, 0., 1., 0.)

# Create the columns using FORCE Beam-column elements
#                                tag ndI ndJ transfTag integrationTag
colTag1 = 1
colTag2 = 2
ops.element("forceBeamColumn", colTag1, 1, 3, transfTag, intgTag)
ops.element("forceBeamColumn", colTag2, 2, 4, transfTag, intgTag)

# Define beam element
# ----------------------------
#                   tag
transfTag = 2
ops.geomTransf("Linear", transfTag, 0., 1., 0.)

# ------------------------------------
# Bent Cap
# ------------------------------------
# Create the beam element
#                             tag      ndI ndJ    A     E       Iz    transfTag
beamTag = 3

Ab = h_cap * b_cap
Ec = 4347
mu = 0.20
Gc = Ec / (2*(1 + mu))
Jb = 1/3 * h_cap * pow(h_cap, 3)
Iy = 1/12 * h_cap * pow(b_cap, 3)
Iz = 1/12 * b_cap * pow(h_cap, 3)

ops.element("elasticBeamColumn", beamTag, 3, 4, Ab, Ec, Gc, Jb, Iy, Iz,␣
 ↪transfTag)

# Node mass for each dof
lmass = 200.
ops.mass(3, lmass, lmass, lmass, 0.001, 0.001, 0.001)
ops.mass(4, lmass, lmass, lmass, 0.001, 0.001, 0.001)
```

0.0.9 Frame Model Plot

[9]:
```
plt.figure()
sfac = 2.0
fig_wi_he = 25., 15.

opsv.plot_model(az_el=(-60., 30.), fig_wi_he=fig_wi_he)
plt.title('Intermediate Bent Model\nLocal Axis Color Code: Green (x), Blue (y),␣
 ↪Red (z)')
```

[9]:
```
Text(0.5, 0.92, 'Intermediate Bent Model\nLocal Axis Color Code: Green (x), Blue
(y), Red (z)')
```

```
<Figure size 1000x500 with 0 Axes>
```



0.0.10 Fiber Section Check

[10]:
```
# section output: using fiberdata option:
# https://portwooddigital.com/2022/05/15/plane-sections-do-remain-plane/
data = ops.eleResponse(1,'section',1,'fiberData')
Ndata = len(data)
Nfibers = int(Ndata/5)
print("Nfibers = ", Nfibers)

y =[]
z =[]

# Python indices indicate to grab every fifth list entry: y, z, A, stress,␣
 ↪strain
y = data[0:Ndata:5]
z = data[1:Ndata:5]
Afiber = data[2:Ndata:5]

As_reinf = 0
A_col = 0
n_rebar = 0
I_col = 0

for i in range(0, Nfibers, 1):
    if Afiber[i] == As:
        As_reinf = As_reinf + As
        n_rebar = n_rebar + 1
    else:
        A_col = A_col + Afiber[i]
        I_col = I_col + Afiber[i] * y[i] **2


print("n_rebar =", n_rebar)
print("A_reinf =", round(As_reinf,1), "in2")
print("A_col = ", round(A_col, 1), " in2")
print("I_col = ", round(I_col, 1), " in4")

Matrix = {'z (in)': np.round(z,2),
          'y (in)': np.round(y, 2),
          'Afiber (in2)': np.round(Afiber, 2)}

df10 = pd.DataFrame(Matrix, columns = ['z (in)', 'y (in)', 'Afiber (in2)'] )
pd.set_option('display.max_rows', None)     # Set to None to display all rows
pd.set_option('display.max_columns', None)  # Set to None to display all columns
```

```
display(df10)
```

```
Nfibers =  2134
n_rebar = 22
A_reinf = 34.3 in2
A_col =  2827.4  in2
I_col =  635054.2  in4
```

	z (in)	y (in)	Afiber (in2)
0	1.01	28.14	0.67
1	3.01	28.00	0.67
2	5.00	27.71	0.67
3	6.96	27.29	0.67
4	8.89	26.72	0.67
5	10.78	26.02	0.67
6	12.61	25.18	0.67
7	14.37	24.22	0.67
8	16.06	23.13	0.67
9	17.67	21.93	0.67
10	19.19	20.61	0.67
11	20.61	19.19	0.67
12	21.93	17.67	0.67
13	23.13	16.06	0.67
14	24.22	14.37	0.67
15	25.18	12.61	0.67
16	26.02	10.78	0.67
17	26.72	8.89	0.67
18	27.29	6.96	0.67
19	27.71	5.00	0.67
20	28.00	3.01	0.67
21	28.14	1.01	0.67
22	28.14	-1.01	0.67
23	28.00	-3.01	0.67
24	27.71	-5.00	0.67
25	27.29	-6.96	0.67
26	26.72	-8.89	0.67
27	26.02	-10.78	0.67
28	25.18	-12.61	0.67
29	24.22	-14.37	0.67
30	23.13	-16.06	0.67
31	21.93	-17.67	0.67
32	20.61	-19.19	0.67
33	19.19	-20.61	0.67
34	17.67	-21.93	0.67
35	16.06	-23.13	0.67
36	14.37	-24.22	0.67
37	12.61	-25.18	0.67
38	10.78	-26.02	0.67

39	8.89	-26.72	0.67
40	6.96	-27.29	0.67
41	5.00	-27.71	0.67
42	3.01	-28.00	0.67
43	1.01	-28.14	0.67
44	-1.01	-28.14	0.67
45	-3.01	-28.00	0.67
46	-5.00	-27.71	0.67
47	-6.96	-27.29	0.67
48	-8.89	-26.72	0.67
49	-10.78	-26.02	0.67
50	-12.61	-25.18	0.67
51	-14.37	-24.22	0.67
52	-16.06	-23.13	0.67
53	-17.67	-21.93	0.67
54	-19.19	-20.61	0.67
55	-20.61	-19.19	0.67
56	-21.93	-17.67	0.67
57	-23.13	-16.06	0.67
58	-24.22	-14.37	0.67
59	-25.18	-12.61	0.67
60	-26.02	-10.78	0.67
61	-26.72	-8.89	0.67
62	-27.29	-6.96	0.67
63	-27.71	-5.00	0.67
64	-28.00	-3.01	0.67
65	-28.14	-1.01	0.67
66	-28.14	1.01	0.67
67	-28.00	3.01	0.67
68	-27.71	5.00	0.67
69	-27.29	6.96	0.67
70	-26.72	8.89	0.67
71	-26.02	10.78	0.67
72	-25.18	12.61	0.67
73	-24.22	14.37	0.67
74	-23.13	16.06	0.67
75	-21.93	17.67	0.67
76	-20.61	19.19	0.67
77	-19.19	20.61	0.67
78	-17.67	21.93	0.67
79	-16.06	23.13	0.67
80	-14.37	24.22	0.67
81	-12.61	25.18	0.67
82	-10.78	26.02	0.67
83	-8.89	26.72	0.67
84	-6.96	27.29	0.67
85	-5.00	27.71	0.67
86	-3.01	28.00	0.67

87	-1.01	28.14	0.67
88	1.02	28.48	0.68
89	3.05	28.33	0.68
90	5.06	28.04	0.68
91	7.05	27.61	0.68
92	9.00	27.04	0.68
93	10.90	26.33	0.68
94	12.75	25.48	0.68
95	14.54	24.51	0.68
96	16.25	23.41	0.68
97	17.88	22.19	0.68
98	19.42	20.85	0.68
99	20.85	19.42	0.68
100	22.19	17.88	0.68
101	23.41	16.25	0.68
102	24.51	14.54	0.68
103	25.48	12.75	0.68
104	26.33	10.90	0.68
105	27.04	9.00	0.68
106	27.61	7.05	0.68
107	28.04	5.06	0.68
108	28.33	3.05	0.68
109	28.48	1.02	0.68
110	28.48	-1.02	0.68
111	28.33	-3.05	0.68
112	28.04	-5.06	0.68
113	27.61	-7.05	0.68
114	27.04	-9.00	0.68
115	26.33	-10.90	0.68
116	25.48	-12.75	0.68
117	24.51	-14.54	0.68
118	23.41	-16.25	0.68
119	22.19	-17.88	0.68
120	20.85	-19.42	0.68
121	19.42	-20.85	0.68
122	17.88	-22.19	0.68
123	16.25	-23.41	0.68
124	14.54	-24.51	0.68
125	12.75	-25.48	0.68
126	10.90	-26.33	0.68
127	9.00	-27.04	0.68
128	7.05	-27.61	0.68
129	5.06	-28.04	0.68
130	3.05	-28.33	0.68
131	1.02	-28.48	0.68
132	-1.02	-28.48	0.68
133	-3.05	-28.33	0.68
134	-5.06	-28.04	0.68

135	-7.05	-27.61	0.68
136	-9.00	-27.04	0.68
137	-10.90	-26.33	0.68
138	-12.75	-25.48	0.68
139	-14.54	-24.51	0.68
140	-16.25	-23.41	0.68
141	-17.88	-22.19	0.68
142	-19.42	-20.85	0.68
143	-20.85	-19.42	0.68
144	-22.19	-17.88	0.68
145	-23.41	-16.25	0.68
146	-24.51	-14.54	0.68
147	-25.48	-12.75	0.68
148	-26.33	-10.90	0.68
149	-27.04	-9.00	0.68
150	-27.61	-7.05	0.68
151	-28.04	-5.06	0.68
152	-28.33	-3.05	0.68
153	-28.48	-1.02	0.68
154	-28.48	1.02	0.68
155	-28.33	3.05	0.68
156	-28.04	5.06	0.68
157	-27.61	7.05	0.68
158	-27.04	9.00	0.68
159	-26.33	10.90	0.68
160	-25.48	12.75	0.68
161	-24.51	14.54	0.68
162	-23.41	16.25	0.68
163	-22.19	17.88	0.68
164	-20.85	19.42	0.68
165	-19.42	20.85	0.68
166	-17.88	22.19	0.68
167	-16.25	23.41	0.68
168	-14.54	24.51	0.68
169	-12.75	25.48	0.68
170	-10.90	26.33	0.68
171	-9.00	27.04	0.68
172	-7.05	27.61	0.68
173	-5.06	28.04	0.68
174	-3.05	28.33	0.68
175	-1.02	28.48	0.68
176	1.03	28.81	0.69
177	3.08	28.66	0.69
178	5.12	28.37	0.69
179	7.13	27.93	0.69
180	9.10	27.35	0.69
181	11.03	26.63	0.69
182	12.90	25.78	0.69

183	14.71	24.79	0.69
184	16.44	23.68	0.69
185	18.09	22.45	0.69
186	19.64	21.10	0.69
187	21.10	19.64	0.69
188	22.45	18.09	0.69
189	23.68	16.44	0.69
190	24.79	14.71	0.69
191	25.78	12.90	0.69
192	26.63	11.03	0.69
193	27.35	9.10	0.69
194	27.93	7.13	0.69
195	28.37	5.12	0.69
196	28.66	3.08	0.69
197	28.81	1.03	0.69
198	28.81	-1.03	0.69
199	28.66	-3.08	0.69
200	28.37	-5.12	0.69
201	27.93	-7.13	0.69
202	27.35	-9.10	0.69
203	26.63	-11.03	0.69
204	25.78	-12.90	0.69
205	24.79	-14.71	0.69
206	23.68	-16.44	0.69
207	22.45	-18.09	0.69
208	21.10	-19.64	0.69
209	19.64	-21.10	0.69
210	18.09	-22.45	0.69
211	16.44	-23.68	0.69
212	14.71	-24.79	0.69
213	12.90	-25.78	0.69
214	11.03	-26.63	0.69
215	9.10	-27.35	0.69
216	7.13	-27.93	0.69
217	5.12	-28.37	0.69
218	3.08	-28.66	0.69
219	1.03	-28.81	0.69
220	-1.03	-28.81	0.69
221	-3.08	-28.66	0.69
222	-5.12	-28.37	0.69
223	-7.13	-27.93	0.69
224	-9.10	-27.35	0.69
225	-11.03	-26.63	0.69
226	-12.90	-25.78	0.69
227	-14.71	-24.79	0.69
228	-16.44	-23.68	0.69
229	-18.09	-22.45	0.69
230	-19.64	-21.10	0.69

231	-21.10	-19.64	0.69
232	-22.45	-18.09	0.69
233	-23.68	-16.44	0.69
234	-24.79	-14.71	0.69
235	-25.78	-12.90	0.69
236	-26.63	-11.03	0.69
237	-27.35	-9.10	0.69
238	-27.93	-7.13	0.69
239	-28.37	-5.12	0.69
240	-28.66	-3.08	0.69
241	-28.81	-1.03	0.69
242	-28.81	1.03	0.69
243	-28.66	3.08	0.69
244	-28.37	5.12	0.69
245	-27.93	7.13	0.69
246	-27.35	9.10	0.69
247	-26.63	11.03	0.69
248	-25.78	12.90	0.69
249	-24.79	14.71	0.69
250	-23.68	16.44	0.69
251	-22.45	18.09	0.69
252	-21.10	19.64	0.69
253	-19.64	21.10	0.69
254	-18.09	22.45	0.69
255	-16.44	23.68	0.69
256	-14.71	24.79	0.69
257	-12.90	25.78	0.69
258	-11.03	26.63	0.69
259	-9.10	27.35	0.69
260	-7.13	27.93	0.69
261	-5.12	28.37	0.69
262	-3.08	28.66	0.69
263	-1.03	28.81	0.69
264	1.04	29.14	0.69
265	3.12	28.99	0.69
266	5.18	28.70	0.69
267	7.21	28.25	0.69
268	9.21	27.67	0.69
269	11.16	26.94	0.69
270	13.05	26.08	0.69
271	14.88	25.08	0.69
272	16.63	23.95	0.69
273	18.30	22.71	0.69
274	19.87	21.34	0.69
275	21.34	19.87	0.69
276	22.71	18.30	0.69
277	23.95	16.63	0.69
278	25.08	14.88	0.69

279	26.08	13.05	0.69
280	26.94	11.16	0.69
281	27.67	9.21	0.69
282	28.25	7.21	0.69
283	28.70	5.18	0.69
284	28.99	3.12	0.69
285	29.14	1.04	0.69
286	29.14	-1.04	0.69
287	28.99	-3.12	0.69
288	28.70	-5.18	0.69
289	28.25	-7.21	0.69
290	27.67	-9.21	0.69
291	26.94	-11.16	0.69
292	26.08	-13.05	0.69
293	25.08	-14.88	0.69
294	23.95	-16.63	0.69
295	22.71	-18.30	0.69
296	21.34	-19.87	0.69
297	19.87	-21.34	0.69
298	18.30	-22.71	0.69
299	16.63	-23.95	0.69
300	14.88	-25.08	0.69
301	13.05	-26.08	0.69
302	11.16	-26.94	0.69
303	9.21	-27.67	0.69
304	7.21	-28.25	0.69
305	5.18	-28.70	0.69
306	3.12	-28.99	0.69
307	1.04	-29.14	0.69
308	-1.04	-29.14	0.69
309	-3.12	-28.99	0.69
310	-5.18	-28.70	0.69
311	-7.21	-28.25	0.69
312	-9.21	-27.67	0.69
313	-11.16	-26.94	0.69
314	-13.05	-26.08	0.69
315	-14.88	-25.08	0.69
316	-16.63	-23.95	0.69
317	-18.30	-22.71	0.69
318	-19.87	-21.34	0.69
319	-21.34	-19.87	0.69
320	-22.71	-18.30	0.69
321	-23.95	-16.63	0.69
322	-25.08	-14.88	0.69
323	-26.08	-13.05	0.69
324	-26.94	-11.16	0.69
325	-27.67	-9.21	0.69
326	-28.25	-7.21	0.69

327	-28.70	-5.18	0.69
328	-28.99	-3.12	0.69
329	-29.14	-1.04	0.69
330	-29.14	1.04	0.69
331	-28.99	3.12	0.69
332	-28.70	5.18	0.69
333	-28.25	7.21	0.69
334	-27.67	9.21	0.69
335	-26.94	11.16	0.69
336	-26.08	13.05	0.69
337	-25.08	14.88	0.69
338	-23.95	16.63	0.69
339	-22.71	18.30	0.69
340	-21.34	19.87	0.69
341	-19.87	21.34	0.69
342	-18.30	22.71	0.69
343	-16.63	23.95	0.69
344	-14.88	25.08	0.69
345	-13.05	26.08	0.69
346	-11.16	26.94	0.69
347	-9.21	27.67	0.69
348	-7.21	28.25	0.69
349	-5.18	28.70	0.69
350	-3.12	28.99	0.69
351	-1.04	29.14	0.69
352	1.05	29.48	0.70
353	3.15	29.33	0.70
354	5.24	29.03	0.70
355	7.29	28.58	0.70
356	9.31	27.98	0.70
357	11.29	27.25	0.70
358	13.20	26.37	0.70
359	15.05	25.37	0.70
360	16.82	24.23	0.70
361	18.51	22.97	0.70
362	20.10	21.59	0.70
363	21.59	20.10	0.70
364	22.97	18.51	0.70
365	24.23	16.82	0.70
366	25.37	15.05	0.70
367	26.37	13.20	0.70
368	27.25	11.29	0.70
369	27.98	9.31	0.70
370	28.58	7.29	0.70
371	29.03	5.24	0.70
372	29.33	3.15	0.70
373	29.48	1.05	0.70
374	29.48	-1.05	0.70

375	29.33	-3.15	0.70
376	29.03	-5.24	0.70
377	28.58	-7.29	0.70
378	27.98	-9.31	0.70
379	27.25	-11.29	0.70
380	26.37	-13.20	0.70
381	25.37	-15.05	0.70
382	24.23	-16.82	0.70
383	22.97	-18.51	0.70
384	21.59	-20.10	0.70
385	20.10	-21.59	0.70
386	18.51	-22.97	0.70
387	16.82	-24.23	0.70
388	15.05	-25.37	0.70
389	13.20	-26.37	0.70
390	11.29	-27.25	0.70
391	9.31	-27.98	0.70
392	7.29	-28.58	0.70
393	5.24	-29.03	0.70
394	3.15	-29.33	0.70
395	1.05	-29.48	0.70
396	-1.05	-29.48	0.70
397	-3.15	-29.33	0.70
398	-5.24	-29.03	0.70
399	-7.29	-28.58	0.70
400	-9.31	-27.98	0.70
401	-11.29	-27.25	0.70
402	-13.20	-26.37	0.70
403	-15.05	-25.37	0.70
404	-16.82	-24.23	0.70
405	-18.51	-22.97	0.70
406	-20.10	-21.59	0.70
407	-21.59	-20.10	0.70
408	-22.97	-18.51	0.70
409	-24.23	-16.82	0.70
410	-25.37	-15.05	0.70
411	-26.37	-13.20	0.70
412	-27.25	-11.29	0.70
413	-27.98	-9.31	0.70
414	-28.58	-7.29	0.70
415	-29.03	-5.24	0.70
416	-29.33	-3.15	0.70
417	-29.48	-1.05	0.70
418	-29.48	1.05	0.70
419	-29.33	3.15	0.70
420	-29.03	5.24	0.70
421	-28.58	7.29	0.70
422	-27.98	9.31	0.70

423	-27.25	11.29	0.70
424	-26.37	13.20	0.70
425	-25.37	15.05	0.70
426	-24.23	16.82	0.70
427	-22.97	18.51	0.70
428	-21.59	20.10	0.70
429	-20.10	21.59	0.70
430	-18.51	22.97	0.70
431	-16.82	24.23	0.70
432	-15.05	25.37	0.70
433	-13.20	26.37	0.70
434	-11.29	27.25	0.70
435	-9.31	27.98	0.70
436	-7.29	28.58	0.70
437	-5.24	29.03	0.70
438	-3.15	29.33	0.70
439	-1.05	29.48	0.70
440	1.06	29.81	0.71
441	3.19	29.66	0.71
442	5.30	29.35	0.71
443	7.38	28.90	0.71
444	9.42	28.30	0.71
445	11.41	27.56	0.71
446	13.35	26.67	0.71
447	15.22	25.65	0.71
448	17.01	24.50	0.71
449	18.72	23.22	0.71
450	20.32	21.83	0.71
451	21.83	20.32	0.71
452	23.22	18.72	0.71
453	24.50	17.01	0.71
454	25.65	15.22	0.71
455	26.67	13.35	0.71
456	27.56	11.41	0.71
457	28.30	9.42	0.71
458	28.90	7.38	0.71
459	29.35	5.30	0.71
460	29.66	3.19	0.71
461	29.81	1.06	0.71
462	29.81	-1.06	0.71
463	29.66	-3.19	0.71
464	29.35	-5.30	0.71
465	28.90	-7.38	0.71
466	28.30	-9.42	0.71
467	27.56	-11.41	0.71
468	26.67	-13.35	0.71
469	25.65	-15.22	0.71
470	24.50	-17.01	0.71

471	23.22	-18.72	0.71
472	21.83	-20.32	0.71
473	20.32	-21.83	0.71
474	18.72	-23.22	0.71
475	17.01	-24.50	0.71
476	15.22	-25.65	0.71
477	13.35	-26.67	0.71
478	11.41	-27.56	0.71
479	9.42	-28.30	0.71
480	7.38	-28.90	0.71
481	5.30	-29.35	0.71
482	3.19	-29.66	0.71
483	1.06	-29.81	0.71
484	-1.06	-29.81	0.71
485	-3.19	-29.66	0.71
486	-5.30	-29.35	0.71
487	-7.38	-28.90	0.71
488	-9.42	-28.30	0.71
489	-11.41	-27.56	0.71
490	-13.35	-26.67	0.71
491	-15.22	-25.65	0.71
492	-17.01	-24.50	0.71
493	-18.72	-23.22	0.71
494	-20.32	-21.83	0.71
495	-21.83	-20.32	0.71
496	-23.22	-18.72	0.71
497	-24.50	-17.01	0.71
498	-25.65	-15.22	0.71
499	-26.67	-13.35	0.71
500	-27.56	-11.41	0.71
501	-28.30	-9.42	0.71
502	-28.90	-7.38	0.71
503	-29.35	-5.30	0.71
504	-29.66	-3.19	0.71
505	-29.81	-1.06	0.71
506	-29.81	1.06	0.71
507	-29.66	3.19	0.71
508	-29.35	5.30	0.71
509	-28.90	7.38	0.71
510	-28.30	9.42	0.71
511	-27.56	11.41	0.71
512	-26.67	13.35	0.71
513	-25.65	15.22	0.71
514	-24.50	17.01	0.71
515	-23.22	18.72	0.71
516	-21.83	20.32	0.71
517	-20.32	21.83	0.71
518	-18.72	23.22	0.71

519	-17.01	24.50	0.71
520	-15.22	25.65	0.71
521	-13.35	26.67	0.71
522	-11.41	27.56	0.71
523	-9.42	28.30	0.71
524	-7.38	28.90	0.71
525	-5.30	29.35	0.71
526	-3.19	29.66	0.71
527	-1.06	29.81	0.71
528	0.79	22.23	0.79
529	2.38	22.12	0.79
530	3.95	21.89	0.79
531	5.50	21.56	0.79
532	7.03	21.11	0.79
533	8.51	20.55	0.79
534	9.96	19.89	0.79
535	11.35	19.13	0.79
536	12.69	18.27	0.79
537	13.96	17.32	0.79
538	15.16	16.28	0.79
539	16.28	15.16	0.79
540	17.32	13.96	0.79
541	18.27	12.69	0.79
542	19.13	11.35	0.79
543	19.89	9.96	0.79
544	20.55	8.51	0.79
545	21.11	7.03	0.79
546	21.56	5.50	0.79
547	21.89	3.95	0.79
548	22.12	2.38	0.79
549	22.23	0.79	0.79
550	22.23	-0.79	0.79
551	22.12	-2.38	0.79
552	21.89	-3.95	0.79
553	21.56	-5.50	0.79
554	21.11	-7.03	0.79
555	20.55	-8.51	0.79
556	19.89	-9.96	0.79
557	19.13	-11.35	0.79
558	18.27	-12.69	0.79
559	17.32	-13.96	0.79
560	16.28	-15.16	0.79
561	15.16	-16.28	0.79
562	13.96	-17.32	0.79
563	12.69	-18.27	0.79
564	11.35	-19.13	0.79
565	9.96	-19.89	0.79
566	8.51	-20.55	0.79

567	7.03	-21.11	0.79
568	5.50	-21.56	0.79
569	3.95	-21.89	0.79
570	2.38	-22.12	0.79
571	0.79	-22.23	0.79
572	-0.79	-22.23	0.79
573	-2.38	-22.12	0.79
574	-3.95	-21.89	0.79
575	-5.50	-21.56	0.79
576	-7.03	-21.11	0.79
577	-8.51	-20.55	0.79
578	-9.96	-19.89	0.79
579	-11.35	-19.13	0.79
580	-12.69	-18.27	0.79
581	-13.96	-17.32	0.79
582	-15.16	-16.28	0.79
583	-16.28	-15.16	0.79
584	-17.32	-13.96	0.79
585	-18.27	-12.69	0.79
586	-19.13	-11.35	0.79
587	-19.89	-9.96	0.79
588	-20.55	-8.51	0.79
589	-21.11	-7.03	0.79
590	-21.56	-5.50	0.79
591	-21.89	-3.95	0.79
592	-22.12	-2.38	0.79
593	-22.23	-0.79	0.79
594	-22.23	0.79	0.79
595	-22.12	2.38	0.79
596	-21.89	3.95	0.79
597	-21.56	5.50	0.79
598	-21.11	7.03	0.79
599	-20.55	8.51	0.79
600	-19.89	9.96	0.79
601	-19.13	11.35	0.79
602	-18.27	12.69	0.79
603	-17.32	13.96	0.79
604	-16.28	15.16	0.79
605	-15.16	16.28	0.79
606	-13.96	17.32	0.79
607	-12.69	18.27	0.79
608	-11.35	19.13	0.79
609	-9.96	19.89	0.79
610	-8.51	20.55	0.79
611	-7.03	21.11	0.79
612	-5.50	21.56	0.79
613	-3.95	21.89	0.79
614	-2.38	22.12	0.79

615	-0.79	22.23	0.79
616	0.81	22.73	0.81
617	2.43	22.62	0.81
618	4.04	22.38	0.81
619	5.63	22.04	0.81
620	7.18	21.58	0.81
621	8.70	21.01	0.81
622	10.18	20.34	0.81
623	11.61	19.56	0.81
624	12.97	18.68	0.81
625	14.27	17.71	0.81
626	15.50	16.65	0.81
627	16.65	15.50	0.81
628	17.71	14.27	0.81
629	18.68	12.97	0.81
630	19.56	11.61	0.81
631	20.34	10.18	0.81
632	21.01	8.70	0.81
633	21.58	7.18	0.81
634	22.04	5.63	0.81
635	22.38	4.04	0.81
636	22.62	2.43	0.81
637	22.73	0.81	0.81
638	22.73	-0.81	0.81
639	22.62	-2.43	0.81
640	22.38	-4.04	0.81
641	22.04	-5.63	0.81
642	21.58	-7.18	0.81
643	21.01	-8.70	0.81
644	20.34	-10.18	0.81
645	19.56	-11.61	0.81
646	18.68	-12.97	0.81
647	17.71	-14.27	0.81
648	16.65	-15.50	0.81
649	15.50	-16.65	0.81
650	14.27	-17.71	0.81
651	12.97	-18.68	0.81
652	11.61	-19.56	0.81
653	10.18	-20.34	0.81
654	8.70	-21.01	0.81
655	7.18	-21.58	0.81
656	5.63	-22.04	0.81
657	4.04	-22.38	0.81
658	2.43	-22.62	0.81
659	0.81	-22.73	0.81
660	-0.81	-22.73	0.81
661	-2.43	-22.62	0.81
662	-4.04	-22.38	0.81

663	-5.63	-22.04	0.81
664	-7.18	-21.58	0.81
665	-8.70	-21.01	0.81
666	-10.18	-20.34	0.81
667	-11.61	-19.56	0.81
668	-12.97	-18.68	0.81
669	-14.27	-17.71	0.81
670	-15.50	-16.65	0.81
671	-16.65	-15.50	0.81
672	-17.71	-14.27	0.81
673	-18.68	-12.97	0.81
674	-19.56	-11.61	0.81
675	-20.34	-10.18	0.81
676	-21.01	-8.70	0.81
677	-21.58	-7.18	0.81
678	-22.04	-5.63	0.81
679	-22.38	-4.04	0.81
680	-22.62	-2.43	0.81
681	-22.73	-0.81	0.81
682	-22.73	0.81	0.81
683	-22.62	2.43	0.81
684	-22.38	4.04	0.81
685	-22.04	5.63	0.81
686	-21.58	7.18	0.81
687	-21.01	8.70	0.81
688	-20.34	10.18	0.81
689	-19.56	11.61	0.81
690	-18.68	12.97	0.81
691	-17.71	14.27	0.81
692	-16.65	15.50	0.81
693	-15.50	16.65	0.81
694	-14.27	17.71	0.81
695	-12.97	18.68	0.81
696	-11.61	19.56	0.81
697	-10.18	20.34	0.81
698	-8.70	21.01	0.81
699	-7.18	21.58	0.81
700	-5.63	22.04	0.81
701	-4.04	22.38	0.81
702	-2.43	22.62	0.81
703	-0.81	22.73	0.81
704	0.83	23.23	0.83
705	2.48	23.11	0.83
706	4.13	22.88	0.83
707	5.75	22.52	0.83
708	7.34	22.06	0.83
709	8.90	21.48	0.83
710	10.41	20.79	0.83

711	11.86	19.99	0.83
712	13.26	19.09	0.83
713	14.59	18.10	0.83
714	15.84	17.01	0.83
715	17.01	15.84	0.83
716	18.10	14.59	0.83
717	19.09	13.26	0.83
718	19.99	11.86	0.83
719	20.79	10.41	0.83
720	21.48	8.90	0.83
721	22.06	7.34	0.83
722	22.52	5.75	0.83
723	22.88	4.13	0.83
724	23.11	2.48	0.83
725	23.23	0.83	0.83
726	23.23	-0.83	0.83
727	23.11	-2.48	0.83
728	22.88	-4.13	0.83
729	22.52	-5.75	0.83
730	22.06	-7.34	0.83
731	21.48	-8.90	0.83
732	20.79	-10.41	0.83
733	19.99	-11.86	0.83
734	19.09	-13.26	0.83
735	18.10	-14.59	0.83
736	17.01	-15.84	0.83
737	15.84	-17.01	0.83
738	14.59	-18.10	0.83
739	13.26	-19.09	0.83
740	11.86	-19.99	0.83
741	10.41	-20.79	0.83
742	8.90	-21.48	0.83
743	7.34	-22.06	0.83
744	5.75	-22.52	0.83
745	4.13	-22.88	0.83
746	2.48	-23.11	0.83
747	0.83	-23.23	0.83
748	-0.83	-23.23	0.83
749	-2.48	-23.11	0.83
750	-4.13	-22.88	0.83
751	-5.75	-22.52	0.83
752	-7.34	-22.06	0.83
753	-8.90	-21.48	0.83
754	-10.41	-20.79	0.83
755	-11.86	-19.99	0.83
756	-13.26	-19.09	0.83
757	-14.59	-18.10	0.83
758	-15.84	-17.01	0.83

759	-17.01	-15.84	0.83
760	-18.10	-14.59	0.83
761	-19.09	-13.26	0.83
762	-19.99	-11.86	0.83
763	-20.79	-10.41	0.83
764	-21.48	-8.90	0.83
765	-22.06	-7.34	0.83
766	-22.52	-5.75	0.83
767	-22.88	-4.13	0.83
768	-23.11	-2.48	0.83
769	-23.23	-0.83	0.83
770	-23.23	0.83	0.83
771	-23.11	2.48	0.83
772	-22.88	4.13	0.83
773	-22.52	5.75	0.83
774	-22.06	7.34	0.83
775	-21.48	8.90	0.83
776	-20.79	10.41	0.83
777	-19.99	11.86	0.83
778	-19.09	13.26	0.83
779	-18.10	14.59	0.83
780	-17.01	15.84	0.83
781	-15.84	17.01	0.83
782	-14.59	18.10	0.83
783	-13.26	19.09	0.83
784	-11.86	19.99	0.83
785	-10.41	20.79	0.83
786	-8.90	21.48	0.83
787	-7.34	22.06	0.83
788	-5.75	22.52	0.83
789	-4.13	22.88	0.83
790	-2.48	23.11	0.83
791	-0.83	23.23	0.83
792	0.85	23.73	0.85
793	2.54	23.61	0.85
794	4.22	23.37	0.85
795	5.87	23.01	0.85
796	7.50	22.53	0.85
797	9.09	21.94	0.85
798	10.63	21.23	0.85
799	12.12	20.42	0.85
800	13.54	19.51	0.85
801	14.90	18.49	0.85
802	16.18	17.38	0.85
803	17.38	16.18	0.85
804	18.49	14.90	0.85
805	19.51	13.54	0.85
806	20.42	12.12	0.85

807	21.23	10.63	0.85
808	21.94	9.09	0.85
809	22.53	7.50	0.85
810	23.01	5.87	0.85
811	23.37	4.22	0.85
812	23.61	2.54	0.85
813	23.73	0.85	0.85
814	23.73	-0.85	0.85
815	23.61	-2.54	0.85
816	23.37	-4.22	0.85
817	23.01	-5.87	0.85
818	22.53	-7.50	0.85
819	21.94	-9.09	0.85
820	21.23	-10.63	0.85
821	20.42	-12.12	0.85
822	19.51	-13.54	0.85
823	18.49	-14.90	0.85
824	17.38	-16.18	0.85
825	16.18	-17.38	0.85
826	14.90	-18.49	0.85
827	13.54	-19.51	0.85
828	12.12	-20.42	0.85
829	10.63	-21.23	0.85
830	9.09	-21.94	0.85
831	7.50	-22.53	0.85
832	5.87	-23.01	0.85
833	4.22	-23.37	0.85
834	2.54	-23.61	0.85
835	0.85	-23.73	0.85
836	-0.85	-23.73	0.85
837	-2.54	-23.61	0.85
838	-4.22	-23.37	0.85
839	-5.87	-23.01	0.85
840	-7.50	-22.53	0.85
841	-9.09	-21.94	0.85
842	-10.63	-21.23	0.85
843	-12.12	-20.42	0.85
844	-13.54	-19.51	0.85
845	-14.90	-18.49	0.85
846	-16.18	-17.38	0.85
847	-17.38	-16.18	0.85
848	-18.49	-14.90	0.85
849	-19.51	-13.54	0.85
850	-20.42	-12.12	0.85
851	-21.23	-10.63	0.85
852	-21.94	-9.09	0.85
853	-22.53	-7.50	0.85
854	-23.01	-5.87	0.85

855	-23.37	-4.22	0.85
856	-23.61	-2.54	0.85
857	-23.73	-0.85	0.85
858	-23.73	0.85	0.85
859	-23.61	2.54	0.85
860	-23.37	4.22	0.85
861	-23.01	5.87	0.85
862	-22.53	7.50	0.85
863	-21.94	9.09	0.85
864	-21.23	10.63	0.85
865	-20.42	12.12	0.85
866	-19.51	13.54	0.85
867	-18.49	14.90	0.85
868	-17.38	16.18	0.85
869	-16.18	17.38	0.85
870	-14.90	18.49	0.85
871	-13.54	19.51	0.85
872	-12.12	20.42	0.85
873	-10.63	21.23	0.85
874	-9.09	21.94	0.85
875	-7.50	22.53	0.85
876	-5.87	23.01	0.85
877	-4.22	23.37	0.85
878	-2.54	23.61	0.85
879	-0.85	23.73	0.85
880	0.87	24.23	0.87
881	2.59	24.11	0.87
882	4.30	23.86	0.87
883	6.00	23.49	0.87
884	7.66	23.00	0.87
885	9.28	22.40	0.87
886	10.85	21.68	0.87
887	12.37	20.85	0.87
888	13.83	19.92	0.87
889	15.21	18.88	0.87
890	16.52	17.75	0.87
891	17.75	16.52	0.87
892	18.88	15.21	0.87
893	19.92	13.83	0.87
894	20.85	12.37	0.87
895	21.68	10.85	0.87
896	22.40	9.28	0.87
897	23.00	7.66	0.87
898	23.49	6.00	0.87
899	23.86	4.30	0.87
900	24.11	2.59	0.87
901	24.23	0.87	0.87
902	24.23	-0.87	0.87

903	24.11	-2.59	0.87
904	23.86	-4.30	0.87
905	23.49	-6.00	0.87
906	23.00	-7.66	0.87
907	22.40	-9.28	0.87
908	21.68	-10.85	0.87
909	20.85	-12.37	0.87
910	19.92	-13.83	0.87
911	18.88	-15.21	0.87
912	17.75	-16.52	0.87
913	16.52	-17.75	0.87
914	15.21	-18.88	0.87
915	13.83	-19.92	0.87
916	12.37	-20.85	0.87
917	10.85	-21.68	0.87
918	9.28	-22.40	0.87
919	7.66	-23.00	0.87
920	6.00	-23.49	0.87
921	4.30	-23.86	0.87
922	2.59	-24.11	0.87
923	0.87	-24.23	0.87
924	-0.87	-24.23	0.87
925	-2.59	-24.11	0.87
926	-4.30	-23.86	0.87
927	-6.00	-23.49	0.87
928	-7.66	-23.00	0.87
929	-9.28	-22.40	0.87
930	-10.85	-21.68	0.87
931	-12.37	-20.85	0.87
932	-13.83	-19.92	0.87
933	-15.21	-18.88	0.87
934	-16.52	-17.75	0.87
935	-17.75	-16.52	0.87
936	-18.88	-15.21	0.87
937	-19.92	-13.83	0.87
938	-20.85	-12.37	0.87
939	-21.68	-10.85	0.87
940	-22.40	-9.28	0.87
941	-23.00	-7.66	0.87
942	-23.49	-6.00	0.87
943	-23.86	-4.30	0.87
944	-24.11	-2.59	0.87
945	-24.23	-0.87	0.87
946	-24.23	0.87	0.87
947	-24.11	2.59	0.87
948	-23.86	4.30	0.87
949	-23.49	6.00	0.87
950	-23.00	7.66	0.87

951	-22.40	9.28	0.87
952	-21.68	10.85	0.87
953	-20.85	12.37	0.87
954	-19.92	13.83	0.87
955	-18.88	15.21	0.87
956	-17.75	16.52	0.87
957	-16.52	17.75	0.87
958	-15.21	18.88	0.87
959	-13.83	19.92	0.87
960	-12.37	20.85	0.87
961	-10.85	21.68	0.87
962	-9.28	22.40	0.87
963	-7.66	23.00	0.87
964	-6.00	23.49	0.87
965	-4.30	23.86	0.87
966	-2.59	24.11	0.87
967	-0.87	24.23	0.87
968	0.88	24.73	0.88
969	2.65	24.60	0.88
970	4.39	24.35	0.88
971	6.12	23.98	0.88
972	7.81	23.48	0.88
973	9.47	22.86	0.88
974	11.08	22.13	0.88
975	12.63	21.28	0.88
976	14.11	20.33	0.88
977	15.53	19.27	0.88
978	16.86	18.11	0.88
979	18.11	16.86	0.88
980	19.27	15.53	0.88
981	20.33	14.11	0.88
982	21.28	12.63	0.88
983	22.13	11.08	0.88
984	22.86	9.47	0.88
985	23.48	7.81	0.88
986	23.98	6.12	0.88
987	24.35	4.39	0.88
988	24.60	2.65	0.88
989	24.73	0.88	0.88
990	24.73	-0.88	0.88
991	24.60	-2.65	0.88
992	24.35	-4.39	0.88
993	23.98	-6.12	0.88
994	23.48	-7.81	0.88
995	22.86	-9.47	0.88
996	22.13	-11.08	0.88
997	21.28	-12.63	0.88
998	20.33	-14.11	0.88

999	19.27	-15.53	0.88
1000	18.11	-16.86	0.88
1001	16.86	-18.11	0.88
1002	15.53	-19.27	0.88
1003	14.11	-20.33	0.88
1004	12.63	-21.28	0.88
1005	11.08	-22.13	0.88
1006	9.47	-22.86	0.88
1007	7.81	-23.48	0.88
1008	6.12	-23.98	0.88
1009	4.39	-24.35	0.88
1010	2.65	-24.60	0.88
1011	0.88	-24.73	0.88
1012	-0.88	-24.73	0.88
1013	-2.65	-24.60	0.88
1014	-4.39	-24.35	0.88
1015	-6.12	-23.98	0.88
1016	-7.81	-23.48	0.88
1017	-9.47	-22.86	0.88
1018	-11.08	-22.13	0.88
1019	-12.63	-21.28	0.88
1020	-14.11	-20.33	0.88
1021	-15.53	-19.27	0.88
1022	-16.86	-18.11	0.88
1023	-18.11	-16.86	0.88
1024	-19.27	-15.53	0.88
1025	-20.33	-14.11	0.88
1026	-21.28	-12.63	0.88
1027	-22.13	-11.08	0.88
1028	-22.86	-9.47	0.88
1029	-23.48	-7.81	0.88
1030	-23.98	-6.12	0.88
1031	-24.35	-4.39	0.88
1032	-24.60	-2.65	0.88
1033	-24.73	-0.88	0.88
1034	-24.73	0.88	0.88
1035	-24.60	2.65	0.88
1036	-24.35	4.39	0.88
1037	-23.98	6.12	0.88
1038	-23.48	7.81	0.88
1039	-22.86	9.47	0.88
1040	-22.13	11.08	0.88
1041	-21.28	12.63	0.88
1042	-20.33	14.11	0.88
1043	-19.27	15.53	0.88
1044	-18.11	16.86	0.88
1045	-16.86	18.11	0.88
1046	-15.53	19.27	0.88

1047	-14.11	20.33	0.88
1048	-12.63	21.28	0.88
1049	-11.08	22.13	0.88
1050	-9.47	22.86	0.88
1051	-7.81	23.48	0.88
1052	-6.12	23.98	0.88
1053	-4.39	24.35	0.88
1054	-2.65	24.60	0.88
1055	-0.88	24.73	0.88
1056	0.90	25.23	0.90
1057	2.70	25.10	0.90
1058	4.48	24.84	0.90
1059	6.24	24.46	0.90
1060	7.97	23.95	0.90
1061	9.66	23.32	0.90
1062	11.30	22.58	0.90
1063	12.88	21.71	0.90
1064	14.40	20.74	0.90
1065	15.84	19.66	0.90
1066	17.20	18.48	0.90
1067	18.48	17.20	0.90
1068	19.66	15.84	0.90
1069	20.74	14.40	0.90
1070	21.71	12.88	0.90
1071	22.58	11.30	0.90
1072	23.32	9.66	0.90
1073	23.95	7.97	0.90
1074	24.46	6.24	0.90
1075	24.84	4.48	0.90
1076	25.10	2.70	0.90
1077	25.23	0.90	0.90
1078	25.23	-0.90	0.90
1079	25.10	-2.70	0.90
1080	24.84	-4.48	0.90
1081	24.46	-6.24	0.90
1082	23.95	-7.97	0.90
1083	23.32	-9.66	0.90
1084	22.58	-11.30	0.90
1085	21.71	-12.88	0.90
1086	20.74	-14.40	0.90
1087	19.66	-15.84	0.90
1088	18.48	-17.20	0.90
1089	17.20	-18.48	0.90
1090	15.84	-19.66	0.90
1091	14.40	-20.74	0.90
1092	12.88	-21.71	0.90
1093	11.30	-22.58	0.90
1094	9.66	-23.32	0.90

1095	7.97	-23.95	0.90
1096	6.24	-24.46	0.90
1097	4.48	-24.84	0.90
1098	2.70	-25.10	0.90
1099	0.90	-25.23	0.90
1100	-0.90	-25.23	0.90
1101	-2.70	-25.10	0.90
1102	-4.48	-24.84	0.90
1103	-6.24	-24.46	0.90
1104	-7.97	-23.95	0.90
1105	-9.66	-23.32	0.90
1106	-11.30	-22.58	0.90
1107	-12.88	-21.71	0.90
1108	-14.40	-20.74	0.90
1109	-15.84	-19.66	0.90
1110	-17.20	-18.48	0.90
1111	-18.48	-17.20	0.90
1112	-19.66	-15.84	0.90
1113	-20.74	-14.40	0.90
1114	-21.71	-12.88	0.90
1115	-22.58	-11.30	0.90
1116	-23.32	-9.66	0.90
1117	-23.95	-7.97	0.90
1118	-24.46	-6.24	0.90
1119	-24.84	-4.48	0.90
1120	-25.10	-2.70	0.90
1121	-25.23	-0.90	0.90
1122	-25.23	0.90	0.90
1123	-25.10	2.70	0.90
1124	-24.84	4.48	0.90
1125	-24.46	6.24	0.90
1126	-23.95	7.97	0.90
1127	-23.32	9.66	0.90
1128	-22.58	11.30	0.90
1129	-21.71	12.88	0.90
1130	-20.74	14.40	0.90
1131	-19.66	15.84	0.90
1132	-18.48	17.20	0.90
1133	-17.20	18.48	0.90
1134	-15.84	19.66	0.90
1135	-14.40	20.74	0.90
1136	-12.88	21.71	0.90
1137	-11.30	22.58	0.90
1138	-9.66	23.32	0.90
1139	-7.97	23.95	0.90
1140	-6.24	24.46	0.90
1141	-4.48	24.84	0.90
1142	-2.70	25.10	0.90

1143	-0.90	25.23	0.90
1144	0.92	25.73	0.92
1145	2.75	25.60	0.92
1146	4.57	25.34	0.92
1147	6.37	24.95	0.92
1148	8.13	24.43	0.92
1149	9.85	23.79	0.92
1150	11.52	23.02	0.92
1151	13.14	22.14	0.92
1152	14.68	21.15	0.92
1153	16.15	20.05	0.92
1154	17.54	18.84	0.92
1155	18.84	17.54	0.92
1156	20.05	16.15	0.92
1157	21.15	14.68	0.92
1158	22.14	13.14	0.92
1159	23.02	11.52	0.92
1160	23.79	9.85	0.92
1161	24.43	8.13	0.92
1162	24.95	6.37	0.92
1163	25.34	4.57	0.92
1164	25.60	2.75	0.92
1165	25.73	0.92	0.92
1166	25.73	-0.92	0.92
1167	25.60	-2.75	0.92
1168	25.34	-4.57	0.92
1169	24.95	-6.37	0.92
1170	24.43	-8.13	0.92
1171	23.79	-9.85	0.92
1172	23.02	-11.52	0.92
1173	22.14	-13.14	0.92
1174	21.15	-14.68	0.92
1175	20.05	-16.15	0.92
1176	18.84	-17.54	0.92
1177	17.54	-18.84	0.92
1178	16.15	-20.05	0.92
1179	14.68	-21.15	0.92
1180	13.14	-22.14	0.92
1181	11.52	-23.02	0.92
1182	9.85	-23.79	0.92
1183	8.13	-24.43	0.92
1184	6.37	-24.95	0.92
1185	4.57	-25.34	0.92
1186	2.75	-25.60	0.92
1187	0.92	-25.73	0.92
1188	-0.92	-25.73	0.92
1189	-2.75	-25.60	0.92
1190	-4.57	-25.34	0.92

1191	-6.37	-24.95	0.92
1192	-8.13	-24.43	0.92
1193	-9.85	-23.79	0.92
1194	-11.52	-23.02	0.92
1195	-13.14	-22.14	0.92
1196	-14.68	-21.15	0.92
1197	-16.15	-20.05	0.92
1198	-17.54	-18.84	0.92
1199	-18.84	-17.54	0.92
1200	-20.05	-16.15	0.92
1201	-21.15	-14.68	0.92
1202	-22.14	-13.14	0.92
1203	-23.02	-11.52	0.92
1204	-23.79	-9.85	0.92
1205	-24.43	-8.13	0.92
1206	-24.95	-6.37	0.92
1207	-25.34	-4.57	0.92
1208	-25.60	-2.75	0.92
1209	-25.73	-0.92	0.92
1210	-25.73	0.92	0.92
1211	-25.60	2.75	0.92
1212	-25.34	4.57	0.92
1213	-24.95	6.37	0.92
1214	-24.43	8.13	0.92
1215	-23.79	9.85	0.92
1216	-23.02	11.52	0.92
1217	-22.14	13.14	0.92
1218	-21.15	14.68	0.92
1219	-20.05	16.15	0.92
1220	-18.84	17.54	0.92
1221	-17.54	18.84	0.92
1222	-16.15	20.05	0.92
1223	-14.68	21.15	0.92
1224	-13.14	22.14	0.92
1225	-11.52	23.02	0.92
1226	-9.85	23.79	0.92
1227	-8.13	24.43	0.92
1228	-6.37	24.95	0.92
1229	-4.57	25.34	0.92
1230	-2.75	25.60	0.92
1231	-0.92	25.73	0.92
1232	0.94	26.23	0.94
1233	2.81	26.09	0.94
1234	4.66	25.83	0.94
1235	6.49	25.43	0.94
1236	8.29	24.90	0.94
1237	10.04	24.25	0.94
1238	11.75	23.47	0.94

1239	13.39	22.57	0.94
1240	14.97	21.56	0.94
1241	16.47	20.44	0.94
1242	17.88	19.21	0.94
1243	19.21	17.88	0.94
1244	20.44	16.47	0.94
1245	21.56	14.97	0.94
1246	22.57	13.39	0.94
1247	23.47	11.75	0.94
1248	24.25	10.04	0.94
1249	24.90	8.29	0.94
1250	25.43	6.49	0.94
1251	25.83	4.66	0.94
1252	26.09	2.81	0.94
1253	26.23	0.94	0.94
1254	26.23	-0.94	0.94
1255	26.09	-2.81	0.94
1256	25.83	-4.66	0.94
1257	25.43	-6.49	0.94
1258	24.90	-8.29	0.94
1259	24.25	-10.04	0.94
1260	23.47	-11.75	0.94
1261	22.57	-13.39	0.94
1262	21.56	-14.97	0.94
1263	20.44	-16.47	0.94
1264	19.21	-17.88	0.94
1265	17.88	-19.21	0.94
1266	16.47	-20.44	0.94
1267	14.97	-21.56	0.94
1268	13.39	-22.57	0.94
1269	11.75	-23.47	0.94
1270	10.04	-24.25	0.94
1271	8.29	-24.90	0.94
1272	6.49	-25.43	0.94
1273	4.66	-25.83	0.94
1274	2.81	-26.09	0.94
1275	0.94	-26.23	0.94
1276	-0.94	-26.23	0.94
1277	-2.81	-26.09	0.94
1278	-4.66	-25.83	0.94
1279	-6.49	-25.43	0.94
1280	-8.29	-24.90	0.94
1281	-10.04	-24.25	0.94
1282	-11.75	-23.47	0.94
1283	-13.39	-22.57	0.94
1284	-14.97	-21.56	0.94
1285	-16.47	-20.44	0.94
1286	-17.88	-19.21	0.94

1287	-19.21	-17.88	0.94
1288	-20.44	-16.47	0.94
1289	-21.56	-14.97	0.94
1290	-22.57	-13.39	0.94
1291	-23.47	-11.75	0.94
1292	-24.25	-10.04	0.94
1293	-24.90	-8.29	0.94
1294	-25.43	-6.49	0.94
1295	-25.83	-4.66	0.94
1296	-26.09	-2.81	0.94
1297	-26.23	-0.94	0.94
1298	-26.23	0.94	0.94
1299	-26.09	2.81	0.94
1300	-25.83	4.66	0.94
1301	-25.43	6.49	0.94
1302	-24.90	8.29	0.94
1303	-24.25	10.04	0.94
1304	-23.47	11.75	0.94
1305	-22.57	13.39	0.94
1306	-21.56	14.97	0.94
1307	-20.44	16.47	0.94
1308	-19.21	17.88	0.94
1309	-17.88	19.21	0.94
1310	-16.47	20.44	0.94
1311	-14.97	21.56	0.94
1312	-13.39	22.57	0.94
1313	-11.75	23.47	0.94
1314	-10.04	24.25	0.94
1315	-8.29	24.90	0.94
1316	-6.49	25.43	0.94
1317	-4.66	25.83	0.94
1318	-2.81	26.09	0.94
1319	-0.94	26.23	0.94
1320	0.95	26.73	0.95
1321	2.86	26.59	0.95
1322	4.75	26.32	0.95
1323	6.61	25.91	0.95
1324	8.45	25.38	0.95
1325	10.23	24.71	0.95
1326	11.97	23.92	0.95
1327	13.65	23.00	0.95
1328	15.25	21.97	0.95
1329	16.78	20.82	0.95
1330	18.22	19.57	0.95
1331	19.57	18.22	0.95
1332	20.82	16.78	0.95
1333	21.97	15.25	0.95
1334	23.00	13.65	0.95

1335	23.92	11.97	0.95
1336	24.71	10.23	0.95
1337	25.38	8.45	0.95
1338	25.91	6.61	0.95
1339	26.32	4.75	0.95
1340	26.59	2.86	0.95
1341	26.73	0.95	0.95
1342	26.73	-0.95	0.95
1343	26.59	-2.86	0.95
1344	26.32	-4.75	0.95
1345	25.91	-6.61	0.95
1346	25.38	-8.45	0.95
1347	24.71	-10.23	0.95
1348	23.92	-11.97	0.95
1349	23.00	-13.65	0.95
1350	21.97	-15.25	0.95
1351	20.82	-16.78	0.95
1352	19.57	-18.22	0.95
1353	18.22	-19.57	0.95
1354	16.78	-20.82	0.95
1355	15.25	-21.97	0.95
1356	13.65	-23.00	0.95
1357	11.97	-23.92	0.95
1358	10.23	-24.71	0.95
1359	8.45	-25.38	0.95
1360	6.61	-25.91	0.95
1361	4.75	-26.32	0.95
1362	2.86	-26.59	0.95
1363	0.95	-26.73	0.95
1364	-0.95	-26.73	0.95
1365	-2.86	-26.59	0.95
1366	-4.75	-26.32	0.95
1367	-6.61	-25.91	0.95
1368	-8.45	-25.38	0.95
1369	-10.23	-24.71	0.95
1370	-11.97	-23.92	0.95
1371	-13.65	-23.00	0.95
1372	-15.25	-21.97	0.95
1373	-16.78	-20.82	0.95
1374	-18.22	-19.57	0.95
1375	-19.57	-18.22	0.95
1376	-20.82	-16.78	0.95
1377	-21.97	-15.25	0.95
1378	-23.00	-13.65	0.95
1379	-23.92	-11.97	0.95
1380	-24.71	-10.23	0.95
1381	-25.38	-8.45	0.95
1382	-25.91	-6.61	0.95

1383	-26.32	-4.75	0.95
1384	-26.59	-2.86	0.95
1385	-26.73	-0.95	0.95
1386	-26.73	0.95	0.95
1387	-26.59	2.86	0.95
1388	-26.32	4.75	0.95
1389	-25.91	6.61	0.95
1390	-25.38	8.45	0.95
1391	-24.71	10.23	0.95
1392	-23.92	11.97	0.95
1393	-23.00	13.65	0.95
1394	-21.97	15.25	0.95
1395	-20.82	16.78	0.95
1396	-19.57	18.22	0.95
1397	-18.22	19.57	0.95
1398	-16.78	20.82	0.95
1399	-15.25	21.97	0.95
1400	-13.65	23.00	0.95
1401	-11.97	23.92	0.95
1402	-10.23	24.71	0.95
1403	-8.45	25.38	0.95
1404	-6.61	25.91	0.95
1405	-4.75	26.32	0.95
1406	-2.86	26.59	0.95
1407	-0.95	26.73	0.95
1408	0.97	27.23	0.97
1409	2.91	27.09	0.97
1410	4.84	26.81	0.97
1411	6.74	26.40	0.97
1412	8.60	25.85	0.97
1413	10.43	25.17	0.97
1414	12.20	24.36	0.97
1415	13.90	23.43	0.97
1416	15.54	22.38	0.97
1417	17.10	21.21	0.97
1418	18.57	19.94	0.97
1419	19.94	18.57	0.97
1420	21.21	17.10	0.97
1421	22.38	15.54	0.97
1422	23.43	13.90	0.97
1423	24.36	12.20	0.97
1424	25.17	10.43	0.97
1425	25.85	8.60	0.97
1426	26.40	6.74	0.97
1427	26.81	4.84	0.97
1428	27.09	2.91	0.97
1429	27.23	0.97	0.97
1430	27.23	-0.97	0.97

1431	27.09	-2.91	0.97
1432	26.81	-4.84	0.97
1433	26.40	-6.74	0.97
1434	25.85	-8.60	0.97
1435	25.17	-10.43	0.97
1436	24.36	-12.20	0.97
1437	23.43	-13.90	0.97
1438	22.38	-15.54	0.97
1439	21.21	-17.10	0.97
1440	19.94	-18.57	0.97
1441	18.57	-19.94	0.97
1442	17.10	-21.21	0.97
1443	15.54	-22.38	0.97
1444	13.90	-23.43	0.97
1445	12.20	-24.36	0.97
1446	10.43	-25.17	0.97
1447	8.60	-25.85	0.97
1448	6.74	-26.40	0.97
1449	4.84	-26.81	0.97
1450	2.91	-27.09	0.97
1451	0.97	-27.23	0.97
1452	-0.97	-27.23	0.97
1453	-2.91	-27.09	0.97
1454	-4.84	-26.81	0.97
1455	-6.74	-26.40	0.97
1456	-8.60	-25.85	0.97
1457	-10.43	-25.17	0.97
1458	-12.20	-24.36	0.97
1459	-13.90	-23.43	0.97
1460	-15.54	-22.38	0.97
1461	-17.10	-21.21	0.97
1462	-18.57	-19.94	0.97
1463	-19.94	-18.57	0.97
1464	-21.21	-17.10	0.97
1465	-22.38	-15.54	0.97
1466	-23.43	-13.90	0.97
1467	-24.36	-12.20	0.97
1468	-25.17	-10.43	0.97
1469	-25.85	-8.60	0.97
1470	-26.40	-6.74	0.97
1471	-26.81	-4.84	0.97
1472	-27.09	-2.91	0.97
1473	-27.23	-0.97	0.97
1474	-27.23	0.97	0.97
1475	-27.09	2.91	0.97
1476	-26.81	4.84	0.97
1477	-26.40	6.74	0.97
1478	-25.85	8.60	0.97

1479	-25.17	10.43	0.97
1480	-24.36	12.20	0.97
1481	-23.43	13.90	0.97
1482	-22.38	15.54	0.97
1483	-21.21	17.10	0.97
1484	-19.94	18.57	0.97
1485	-18.57	19.94	0.97
1486	-17.10	21.21	0.97
1487	-15.54	22.38	0.97
1488	-13.90	23.43	0.97
1489	-12.20	24.36	0.97
1490	-10.43	25.17	0.97
1491	-8.60	25.85	0.97
1492	-6.74	26.40	0.97
1493	-4.84	26.81	0.97
1494	-2.91	27.09	0.97
1495	-0.97	27.23	0.97
1496	0.99	27.73	0.99
1497	2.97	27.59	0.99
1498	4.93	27.30	0.99
1499	6.86	26.88	0.99
1500	8.76	26.33	0.99
1501	10.62	25.63	0.99
1502	12.42	24.81	0.99
1503	14.16	23.86	0.99
1504	15.82	22.79	0.99
1505	17.41	21.60	0.99
1506	18.91	20.31	0.99
1507	20.31	18.91	0.99
1508	21.60	17.41	0.99
1509	22.79	15.82	0.99
1510	23.86	14.16	0.99
1511	24.81	12.42	0.99
1512	25.63	10.62	0.99
1513	26.33	8.76	0.99
1514	26.88	6.86	0.99
1515	27.30	4.93	0.99
1516	27.59	2.97	0.99
1517	27.73	0.99	0.99
1518	27.73	-0.99	0.99
1519	27.59	-2.97	0.99
1520	27.30	-4.93	0.99
1521	26.88	-6.86	0.99
1522	26.33	-8.76	0.99
1523	25.63	-10.62	0.99
1524	24.81	-12.42	0.99
1525	23.86	-14.16	0.99
1526	22.79	-15.82	0.99

1527	21.60	-17.41	0.99
1528	20.31	-18.91	0.99
1529	18.91	-20.31	0.99
1530	17.41	-21.60	0.99
1531	15.82	-22.79	0.99
1532	14.16	-23.86	0.99
1533	12.42	-24.81	0.99
1534	10.62	-25.63	0.99
1535	8.76	-26.33	0.99
1536	6.86	-26.88	0.99
1537	4.93	-27.30	0.99
1538	2.97	-27.59	0.99
1539	0.99	-27.73	0.99
1540	-0.99	-27.73	0.99
1541	-2.97	-27.59	0.99
1542	-4.93	-27.30	0.99
1543	-6.86	-26.88	0.99
1544	-8.76	-26.33	0.99
1545	-10.62	-25.63	0.99
1546	-12.42	-24.81	0.99
1547	-14.16	-23.86	0.99
1548	-15.82	-22.79	0.99
1549	-17.41	-21.60	0.99
1550	-18.91	-20.31	0.99
1551	-20.31	-18.91	0.99
1552	-21.60	-17.41	0.99
1553	-22.79	-15.82	0.99
1554	-23.86	-14.16	0.99
1555	-24.81	-12.42	0.99
1556	-25.63	-10.62	0.99
1557	-26.33	-8.76	0.99
1558	-26.88	-6.86	0.99
1559	-27.30	-4.93	0.99
1560	-27.59	-2.97	0.99
1561	-27.73	-0.99	0.99
1562	-27.73	0.99	0.99
1563	-27.59	2.97	0.99
1564	-27.30	4.93	0.99
1565	-26.88	6.86	0.99
1566	-26.33	8.76	0.99
1567	-25.63	10.62	0.99
1568	-24.81	12.42	0.99
1569	-23.86	14.16	0.99
1570	-22.79	15.82	0.99
1571	-21.60	17.41	0.99
1572	-20.31	18.91	0.99
1573	-18.91	20.31	0.99
1574	-17.41	21.60	0.99

1575	-15.82	22.79	0.99
1576	-14.16	23.86	0.99
1577	-12.42	24.81	0.99
1578	-10.62	25.63	0.99
1579	-8.76	26.33	0.99
1580	-6.86	26.88	0.99
1581	-4.93	27.30	0.99
1582	-2.97	27.59	0.99
1583	-0.99	27.73	0.99
1584	0.09	2.44	0.48
1585	0.26	2.43	0.48
1586	0.43	2.41	0.48
1587	0.60	2.37	0.48
1588	0.77	2.32	0.48
1589	0.94	2.26	0.48
1590	1.09	2.19	0.48
1591	1.25	2.10	0.48
1592	1.39	2.01	0.48
1593	1.53	1.90	0.48
1594	1.67	1.79	0.48
1595	1.79	1.67	0.48
1596	1.90	1.53	0.48
1597	2.01	1.39	0.48
1598	2.10	1.25	0.48
1599	2.19	1.09	0.48
1600	2.26	0.94	0.48
1601	2.32	0.77	0.48
1602	2.37	0.60	0.48
1603	2.41	0.43	0.48
1604	2.43	0.26	0.48
1605	2.44	0.09	0.48
1606	2.44	-0.09	0.48
1607	2.43	-0.26	0.48
1608	2.41	-0.43	0.48
1609	2.37	-0.60	0.48
1610	2.32	-0.77	0.48
1611	2.26	-0.94	0.48
1612	2.19	-1.09	0.48
1613	2.10	-1.25	0.48
1614	2.01	-1.39	0.48
1615	1.90	-1.53	0.48
1616	1.79	-1.67	0.48
1617	1.67	-1.79	0.48
1618	1.53	-1.90	0.48
1619	1.39	-2.01	0.48
1620	1.25	-2.10	0.48
1621	1.09	-2.19	0.48
1622	0.94	-2.26	0.48

1623	0.77	-2.32	0.48
1624	0.60	-2.37	0.48
1625	0.43	-2.41	0.48
1626	0.26	-2.43	0.48
1627	0.09	-2.44	0.48
1628	-0.09	-2.44	0.48
1629	-0.26	-2.43	0.48
1630	-0.43	-2.41	0.48
1631	-0.60	-2.37	0.48
1632	-0.77	-2.32	0.48
1633	-0.94	-2.26	0.48
1634	-1.09	-2.19	0.48
1635	-1.25	-2.10	0.48
1636	-1.39	-2.01	0.48
1637	-1.53	-1.90	0.48
1638	-1.67	-1.79	0.48
1639	-1.79	-1.67	0.48
1640	-1.90	-1.53	0.48
1641	-2.01	-1.39	0.48
1642	-2.10	-1.25	0.48
1643	-2.19	-1.09	0.48
1644	-2.26	-0.94	0.48
1645	-2.32	-0.77	0.48
1646	-2.37	-0.60	0.48
1647	-2.41	-0.43	0.48
1648	-2.43	-0.26	0.48
1649	-2.44	-0.09	0.48
1650	-2.44	0.09	0.48
1651	-2.43	0.26	0.48
1652	-2.41	0.43	0.48
1653	-2.37	0.60	0.48
1654	-2.32	0.77	0.48
1655	-2.26	0.94	0.48
1656	-2.19	1.09	0.48
1657	-2.10	1.25	0.48
1658	-2.01	1.39	0.48
1659	-1.90	1.53	0.48
1660	-1.79	1.67	0.48
1661	-1.67	1.79	0.48
1662	-1.53	1.90	0.48
1663	-1.39	2.01	0.48
1664	-1.25	2.10	0.48
1665	-1.09	2.19	0.48
1666	-0.94	2.26	0.48
1667	-0.77	2.32	0.48
1668	-0.60	2.37	0.48
1669	-0.43	2.41	0.48
1670	-0.26	2.43	0.48

1671	-0.09	2.44	0.48
1672	0.20	5.70	1.44
1673	0.61	5.67	1.44
1674	1.01	5.61	1.44
1675	1.41	5.53	1.44
1676	1.80	5.41	1.44
1677	2.18	5.27	1.44
1678	2.55	5.10	1.44
1679	2.91	4.90	1.44
1680	3.25	4.68	1.44
1681	3.58	4.44	1.44
1682	3.89	4.17	1.44
1683	4.17	3.89	1.44
1684	4.44	3.58	1.44
1685	4.68	3.25	1.44
1686	4.90	2.91	1.44
1687	5.10	2.55	1.44
1688	5.27	2.18	1.44
1689	5.41	1.80	1.44
1690	5.53	1.41	1.44
1691	5.61	1.01	1.44
1692	5.67	0.61	1.44
1693	5.70	0.20	1.44
1694	5.70	-0.20	1.44
1695	5.67	-0.61	1.44
1696	5.61	-1.01	1.44
1697	5.53	-1.41	1.44
1698	5.41	-1.80	1.44
1699	5.27	-2.18	1.44
1700	5.10	-2.55	1.44
1701	4.90	-2.91	1.44
1702	4.68	-3.25	1.44
1703	4.44	-3.58	1.44
1704	4.17	-3.89	1.44
1705	3.89	-4.17	1.44
1706	3.58	-4.44	1.44
1707	3.25	-4.68	1.44
1708	2.91	-4.90	1.44
1709	2.55	-5.10	1.44
1710	2.18	-5.27	1.44
1711	1.80	-5.41	1.44
1712	1.41	-5.53	1.44
1713	1.01	-5.61	1.44
1714	0.61	-5.67	1.44
1715	0.20	-5.70	1.44
1716	-0.20	-5.70	1.44
1717	-0.61	-5.67	1.44
1718	-1.01	-5.61	1.44

1719	-1.41	-5.53	1.44
1720	-1.80	-5.41	1.44
1721	-2.18	-5.27	1.44
1722	-2.55	-5.10	1.44
1723	-2.91	-4.90	1.44
1724	-3.25	-4.68	1.44
1725	-3.58	-4.44	1.44
1726	-3.89	-4.17	1.44
1727	-4.17	-3.89	1.44
1728	-4.44	-3.58	1.44
1729	-4.68	-3.25	1.44
1730	-4.90	-2.91	1.44
1731	-5.10	-2.55	1.44
1732	-5.27	-2.18	1.44
1733	-5.41	-1.80	1.44
1734	-5.53	-1.41	1.44
1735	-5.61	-1.01	1.44
1736	-5.67	-0.61	1.44
1737	-5.70	-0.20	1.44
1738	-5.70	0.20	1.44
1739	-5.67	0.61	1.44
1740	-5.61	1.01	1.44
1741	-5.53	1.41	1.44
1742	-5.41	1.80	1.44
1743	-5.27	2.18	1.44
1744	-5.10	2.55	1.44
1745	-4.90	2.91	1.44
1746	-4.68	3.25	1.44
1747	-4.44	3.58	1.44
1748	-4.17	3.89	1.44
1749	-3.89	4.17	1.44
1750	-3.58	4.44	1.44
1751	-3.25	4.68	1.44
1752	-2.91	4.90	1.44
1753	-2.55	5.10	1.44
1754	-2.18	5.27	1.44
1755	-1.80	5.41	1.44
1756	-1.41	5.53	1.44
1757	-1.01	5.61	1.44
1758	-0.61	5.67	1.44
1759	-0.20	5.70	1.44
1760	0.33	9.28	2.40
1761	0.99	9.23	2.40
1762	1.65	9.14	2.40
1763	2.30	9.00	2.40
1764	2.93	8.81	2.40
1765	3.55	8.58	2.40
1766	4.16	8.30	2.40

1767	4.74	7.99	2.40
1768	5.30	7.63	2.40
1769	5.83	7.23	2.40
1770	6.33	6.80	2.40
1771	6.80	6.33	2.40
1772	7.23	5.83	2.40
1773	7.63	5.30	2.40
1774	7.99	4.74	2.40
1775	8.30	4.16	2.40
1776	8.58	3.55	2.40
1777	8.81	2.93	2.40
1778	9.00	2.30	2.40
1779	9.14	1.65	2.40
1780	9.23	0.99	2.40
1781	9.28	0.33	2.40
1782	9.28	-0.33	2.40
1783	9.23	-0.99	2.40
1784	9.14	-1.65	2.40
1785	9.00	-2.30	2.40
1786	8.81	-2.93	2.40
1787	8.58	-3.55	2.40
1788	8.30	-4.16	2.40
1789	7.99	-4.74	2.40
1790	7.63	-5.30	2.40
1791	7.23	-5.83	2.40
1792	6.80	-6.33	2.40
1793	6.33	-6.80	2.40
1794	5.83	-7.23	2.40
1795	5.30	-7.63	2.40
1796	4.74	-7.99	2.40
1797	4.16	-8.30	2.40
1798	3.55	-8.58	2.40
1799	2.93	-8.81	2.40
1800	2.30	-9.00	2.40
1801	1.65	-9.14	2.40
1802	0.99	-9.23	2.40
1803	0.33	-9.28	2.40
1804	-0.33	-9.28	2.40
1805	-0.99	-9.23	2.40
1806	-1.65	-9.14	2.40
1807	-2.30	-9.00	2.40
1808	-2.93	-8.81	2.40
1809	-3.55	-8.58	2.40
1810	-4.16	-8.30	2.40
1811	-4.74	-7.99	2.40
1812	-5.30	-7.63	2.40
1813	-5.83	-7.23	2.40
1814	-6.33	-6.80	2.40

1815	-6.80	-6.33	2.40
1816	-7.23	-5.83	2.40
1817	-7.63	-5.30	2.40
1818	-7.99	-4.74	2.40
1819	-8.30	-4.16	2.40
1820	-8.58	-3.55	2.40
1821	-8.81	-2.93	2.40
1822	-9.00	-2.30	2.40
1823	-9.14	-1.65	2.40
1824	-9.23	-0.99	2.40
1825	-9.28	-0.33	2.40
1826	-9.28	0.33	2.40
1827	-9.23	0.99	2.40
1828	-9.14	1.65	2.40
1829	-9.00	2.30	2.40
1830	-8.81	2.93	2.40
1831	-8.58	3.55	2.40
1832	-8.30	4.16	2.40
1833	-7.99	4.74	2.40
1834	-7.63	5.30	2.40
1835	-7.23	5.83	2.40
1836	-6.80	6.33	2.40
1837	-6.33	6.80	2.40
1838	-5.83	7.23	2.40
1839	-5.30	7.63	2.40
1840	-4.74	7.99	2.40
1841	-4.16	8.30	2.40
1842	-3.55	8.58	2.40
1843	-2.93	8.81	2.40
1844	-2.30	9.00	2.40
1845	-1.65	9.14	2.40
1846	-0.99	9.23	2.40
1847	-0.33	9.28	2.40
1848	0.46	12.91	3.36
1849	1.38	12.84	3.36
1850	2.29	12.71	3.36
1851	3.19	12.52	3.36
1852	4.08	12.26	3.36
1853	4.94	11.93	3.36
1854	5.78	11.55	3.36
1855	6.59	11.11	3.36
1856	7.37	10.61	3.36
1857	8.11	10.06	3.36
1858	8.80	9.45	3.36
1859	9.45	8.80	3.36
1860	10.06	8.11	3.36
1861	10.61	7.37	3.36
1862	11.11	6.59	3.36

1863	11.55	5.78	3.36
1864	11.93	4.94	3.36
1865	12.26	4.08	3.36
1866	12.52	3.19	3.36
1867	12.71	2.29	3.36
1868	12.84	1.38	3.36
1869	12.91	0.46	3.36
1870	12.91	-0.46	3.36
1871	12.84	-1.38	3.36
1872	12.71	-2.29	3.36
1873	12.52	-3.19	3.36
1874	12.26	-4.08	3.36
1875	11.93	-4.94	3.36
1876	11.55	-5.78	3.36
1877	11.11	-6.59	3.36
1878	10.61	-7.37	3.36
1879	10.06	-8.11	3.36
1880	9.45	-8.80	3.36
1881	8.80	-9.45	3.36
1882	8.11	-10.06	3.36
1883	7.37	-10.61	3.36
1884	6.59	-11.11	3.36
1885	5.78	-11.55	3.36
1886	4.94	-11.93	3.36
1887	4.08	-12.26	3.36
1888	3.19	-12.52	3.36
1889	2.29	-12.71	3.36
1890	1.38	-12.84	3.36
1891	0.46	-12.91	3.36
1892	-0.46	-12.91	3.36
1893	-1.38	-12.84	3.36
1894	-2.29	-12.71	3.36
1895	-3.19	-12.52	3.36
1896	-4.08	-12.26	3.36
1897	-4.94	-11.93	3.36
1898	-5.78	-11.55	3.36
1899	-6.59	-11.11	3.36
1900	-7.37	-10.61	3.36
1901	-8.11	-10.06	3.36
1902	-8.80	-9.45	3.36
1903	-9.45	-8.80	3.36
1904	-10.06	-8.11	3.36
1905	-10.61	-7.37	3.36
1906	-11.11	-6.59	3.36
1907	-11.55	-5.78	3.36
1908	-11.93	-4.94	3.36
1909	-12.26	-4.08	3.36
1910	-12.52	-3.19	3.36

1911	-12.71	-2.29	3.36
1912	-12.84	-1.38	3.36
1913	-12.91	-0.46	3.36
1914	-12.91	0.46	3.36
1915	-12.84	1.38	3.36
1916	-12.71	2.29	3.36
1917	-12.52	3.19	3.36
1918	-12.26	4.08	3.36
1919	-11.93	4.94	3.36
1920	-11.55	5.78	3.36
1921	-11.11	6.59	3.36
1922	-10.61	7.37	3.36
1923	-10.06	8.11	3.36
1924	-9.45	8.80	3.36
1925	-8.80	9.45	3.36
1926	-8.11	10.06	3.36
1927	-7.37	10.61	3.36
1928	-6.59	11.11	3.36
1929	-5.78	11.55	3.36
1930	-4.94	11.93	3.36
1931	-4.08	12.26	3.36
1932	-3.19	12.52	3.36
1933	-2.29	12.71	3.36
1934	-1.38	12.84	3.36
1935	-0.46	12.91	3.36
1936	0.59	16.55	4.32
1937	1.77	16.47	4.32
1938	2.94	16.30	4.32
1939	4.10	16.05	4.32
1940	5.23	15.72	4.32
1941	6.34	15.30	4.32
1942	7.41	14.81	4.32
1943	8.45	14.25	4.32
1944	9.45	13.61	4.32
1945	10.39	12.90	4.32
1946	11.29	12.12	4.32
1947	12.12	11.29	4.32
1948	12.90	10.39	4.32
1949	13.61	9.45	4.32
1950	14.25	8.45	4.32
1951	14.81	7.41	4.32
1952	15.30	6.34	4.32
1953	15.72	5.23	4.32
1954	16.05	4.10	4.32
1955	16.30	2.94	4.32
1956	16.47	1.77	4.32
1957	16.55	0.59	4.32
1958	16.55	-0.59	4.32

1959	16.47	-1.77	4.32
1960	16.30	-2.94	4.32
1961	16.05	-4.10	4.32
1962	15.72	-5.23	4.32
1963	15.30	-6.34	4.32
1964	14.81	-7.41	4.32
1965	14.25	-8.45	4.32
1966	13.61	-9.45	4.32
1967	12.90	-10.39	4.32
1968	12.12	-11.29	4.32
1969	11.29	-12.12	4.32
1970	10.39	-12.90	4.32
1971	9.45	-13.61	4.32
1972	8.45	-14.25	4.32
1973	7.41	-14.81	4.32
1974	6.34	-15.30	4.32
1975	5.23	-15.72	4.32
1976	4.10	-16.05	4.32
1977	2.94	-16.30	4.32
1978	1.77	-16.47	4.32
1979	0.59	-16.55	4.32
1980	-0.59	-16.55	4.32
1981	-1.77	-16.47	4.32
1982	-2.94	-16.30	4.32
1983	-4.10	-16.05	4.32
1984	-5.23	-15.72	4.32
1985	-6.34	-15.30	4.32
1986	-7.41	-14.81	4.32
1987	-8.45	-14.25	4.32
1988	-9.45	-13.61	4.32
1989	-10.39	-12.90	4.32
1990	-11.29	-12.12	4.32
1991	-12.12	-11.29	4.32
1992	-12.90	-10.39	4.32
1993	-13.61	-9.45	4.32
1994	-14.25	-8.45	4.32
1995	-14.81	-7.41	4.32
1996	-15.30	-6.34	4.32
1997	-15.72	-5.23	4.32
1998	-16.05	-4.10	4.32
1999	-16.30	-2.94	4.32
2000	-16.47	-1.77	4.32
2001	-16.55	-0.59	4.32
2002	-16.55	0.59	4.32
2003	-16.47	1.77	4.32
2004	-16.30	2.94	4.32
2005	-16.05	4.10	4.32
2006	-15.72	5.23	4.32

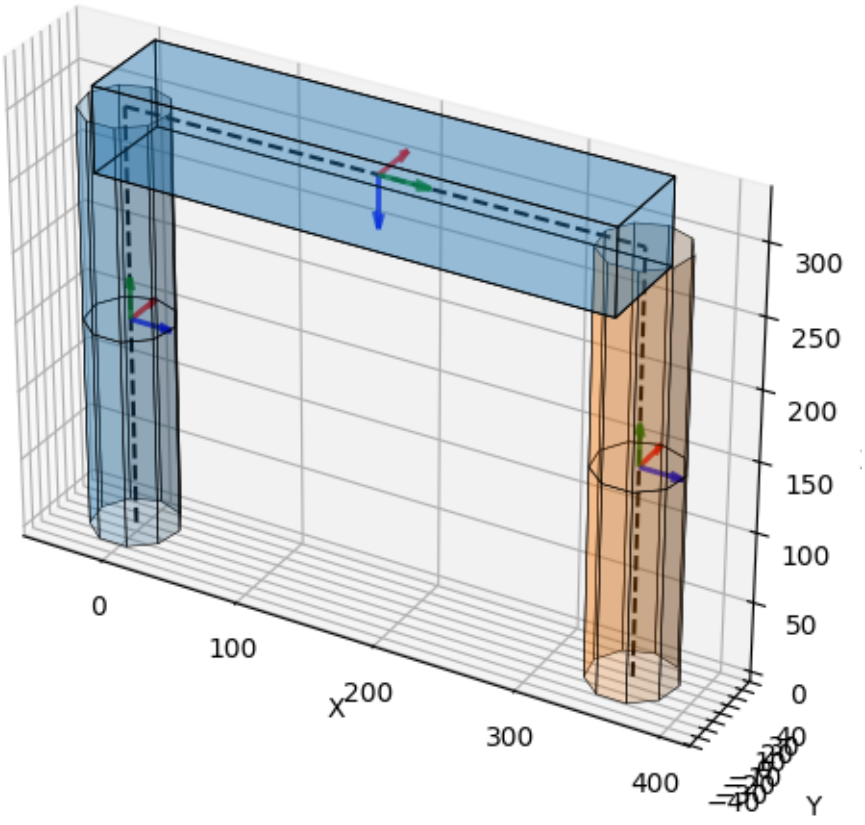
2007	-15.30	6.34	4.32
2008	-14.81	7.41	4.32
2009	-14.25	8.45	4.32
2010	-13.61	9.45	4.32
2011	-12.90	10.39	4.32
2012	-12.12	11.29	4.32
2013	-11.29	12.12	4.32
2014	-10.39	12.90	4.32
2015	-9.45	13.61	4.32
2016	-8.45	14.25	4.32
2017	-7.41	14.81	4.32
2018	-6.34	15.30	4.32
2019	-5.23	15.72	4.32
2020	-4.10	16.05	4.32
2021	-2.94	16.30	4.32
2022	-1.77	16.47	4.32
2023	-0.59	16.55	4.32
2024	0.72	20.21	5.28
2025	2.16	20.10	5.28
2026	3.59	19.90	5.28
2027	5.00	19.59	5.28
2028	6.38	19.18	5.28
2029	7.74	18.68	5.28
2030	9.05	18.08	5.28
2031	10.32	17.39	5.28
2032	11.53	16.61	5.28
2033	12.69	15.74	5.28
2034	13.78	14.80	5.28
2035	14.80	13.78	5.28
2036	15.74	12.69	5.28
2037	16.61	11.53	5.28
2038	17.39	10.32	5.28
2039	18.08	9.05	5.28
2040	18.68	7.74	5.28
2041	19.18	6.38	5.28
2042	19.59	5.00	5.28
2043	19.90	3.59	5.28
2044	20.10	2.16	5.28
2045	20.21	0.72	5.28
2046	20.21	-0.72	5.28
2047	20.10	-2.16	5.28
2048	19.90	-3.59	5.28
2049	19.59	-5.00	5.28
2050	19.18	-6.38	5.28
2051	18.68	-7.74	5.28
2052	18.08	-9.05	5.28
2053	17.39	-10.32	5.28
2054	16.61	-11.53	5.28

2055	15.74	-12.69	5.28
2056	14.80	-13.78	5.28
2057	13.78	-14.80	5.28
2058	12.69	-15.74	5.28
2059	11.53	-16.61	5.28
2060	10.32	-17.39	5.28
2061	9.05	-18.08	5.28
2062	7.74	-18.68	5.28
2063	6.38	-19.18	5.28
2064	5.00	-19.59	5.28
2065	3.59	-19.90	5.28
2066	2.16	-20.10	5.28
2067	0.72	-20.21	5.28
2068	-0.72	-20.21	5.28
2069	-2.16	-20.10	5.28
2070	-3.59	-19.90	5.28
2071	-5.00	-19.59	5.28
2072	-6.38	-19.18	5.28
2073	-7.74	-18.68	5.28
2074	-9.05	-18.08	5.28
2075	-10.32	-17.39	5.28
2076	-11.53	-16.61	5.28
2077	-12.69	-15.74	5.28
2078	-13.78	-14.80	5.28
2079	-14.80	-13.78	5.28
2080	-15.74	-12.69	5.28
2081	-16.61	-11.53	5.28
2082	-17.39	-10.32	5.28
2083	-18.08	-9.05	5.28
2084	-18.68	-7.74	5.28
2085	-19.18	-6.38	5.28
2086	-19.59	-5.00	5.28
2087	-19.90	-3.59	5.28
2088	-20.10	-2.16	5.28
2089	-20.21	-0.72	5.28
2090	-20.21	0.72	5.28
2091	-20.10	2.16	5.28
2092	-19.90	3.59	5.28
2093	-19.59	5.00	5.28
2094	-19.18	6.38	5.28
2095	-18.68	7.74	5.28
2096	-18.08	9.05	5.28
2097	-17.39	10.32	5.28
2098	-16.61	11.53	5.28
2099	-15.74	12.69	5.28
2100	-14.80	13.78	5.28
2101	-13.78	14.80	5.28
2102	-12.69	15.74	5.28

```
2103  -11.53   16.61          5.28
2104  -10.32   17.39          5.28
2105   -9.05   18.08          5.28
2106   -7.74   18.68          5.28
2107   -6.38   19.18          5.28
2108   -5.00   19.59          5.28
2109   -3.59   19.90          5.28
2110   -2.16   20.10          5.28
2111   -0.72   20.21          5.28
2112    7.44   25.35          1.56
2113   14.28   22.23          1.56
2114   19.97   17.30          1.56
2115   24.03   10.98          1.56
2116   26.15    3.76          1.56
2117   26.15   -3.76          1.56
2118   24.03  -10.98          1.56
2119   19.97  -17.30          1.56
2120   14.28  -22.23          1.56
2121    7.44  -25.35          1.56
2122    0.00  -26.42          1.56
2123   -7.44  -25.35          1.56
2124  -14.28  -22.23          1.56
2125  -19.97  -17.30          1.56
2126  -24.03  -10.98          1.56
2127  -26.15   -3.76          1.56
2128  -26.15    3.76          1.56
2129  -24.03   10.98          1.56
2130  -19.97   17.30          1.56
2131  -14.28   22.23          1.56
2132   -7.44   25.35          1.56
2133   -0.00   26.42          1.56
```

0.0.11 Bent Rendering

[11]:
```
ele_shapes = {1: ['circ', [D_col]],
              2: ['circ', [D_col]],
              3: ['rect', [b_cap, h_cap]]}
opsv.plot_extruded_shapes_3d(ele_shapes)
plt.savefig('pushover.png')

plt.show()
```



0.0.12 Static Analysis Definition

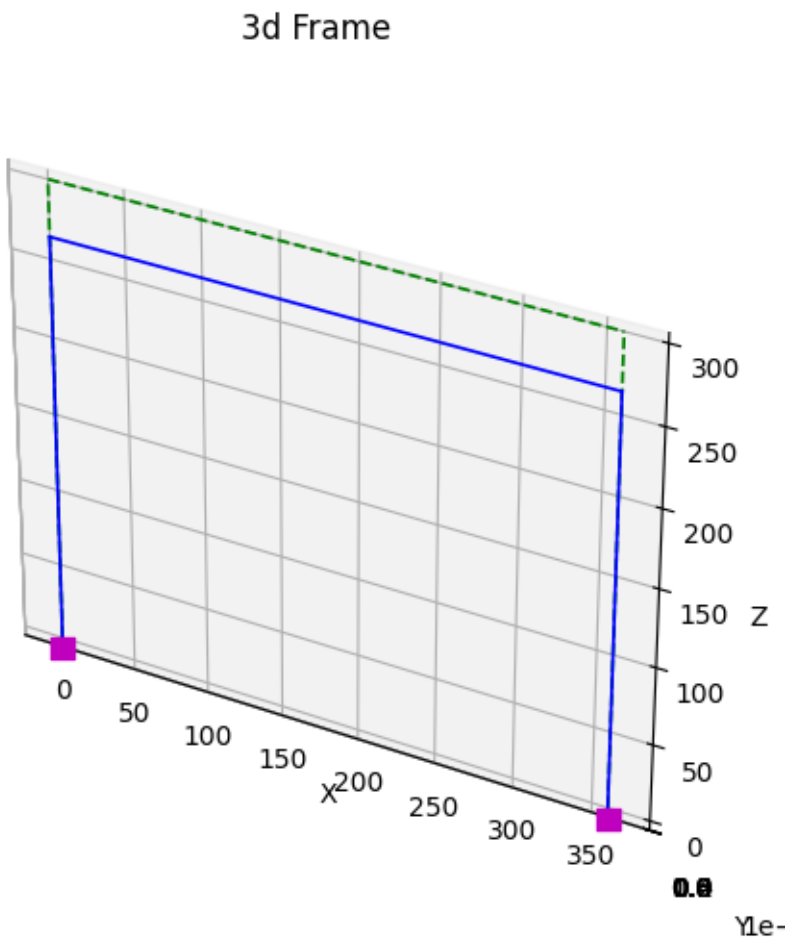
[12]:
```
# create a Linear TimeSeries (load factor varies linearly with time) - command: timeSeries Linear $tag
ops.timeSeries("Linear", 1)

# create a Plain load pattern - command: pattern Plain $tag $timeSeriesTag {$loads }
ops.pattern("Plain", 1, 1, "-fact", 1.0)

# create the nodal load - command: load nodeID xForce yForce, zForce, Moments...
ops.load(3, 0.0 , 0.0, Psuper, 0.0, 0.0, 0.0)
ops.load(4, 0.0 , 0.0, Psuper, 0.0, 0.0, 0.0)

# ------------------------------
# Start of analysis generation
```

```
# ------------------------------
# create the system of equation
ops.system("BandGeneral")
# create the DOF numberer, the reverse Cuthill-McKee algorithm
ops.numberer("RCM")
# create the constraint handler, a Plain handler is used as homo constraints
ops.constraints("Plain")
# create the convergence test, the norm of the residual with a tolerance of
# 1e-12 and a max number of iterations of 10
ops.test("NormDispIncr", 1.0E-12, 10, 3)
# create the solution algorithm, a Newton-Raphson algorithm
ops.algorithm("Newton")
# create the integration scheme, the LoadControl scheme using steps of 0.1
ops.integrator("LoadControl", 0.1)

# create the analysis object
ops.analysis("Static")
```

0.0.13 Gravity and Eigenvalue Analysis

[13]:
```
# ------------------------------
# Perform the analysis
# ------------------------------
# perform the gravity load analysis, requires 10 steps to reach the load level
ops.analyze(10)

print("Gravity load analysis completed\n")

opsv.plot_defo(unDefoFlag=1,
               fmt_defo={'color': 'blue', 'linestyle': 'solid', 'linewidth': 1.
 ↪2, 'marker': '', 'markersize': 1},
               fmt_undefo={'color': 'green', 'linestyle': 'dashed', 'linewidth':
 ↪ 1.2, 'marker': '', 'markersize': 1},
               fmt_defo_faces={'alpha': 0.5, 'edgecolors': 'k', 'linewidths':␣
 ↪1},
               fmt_undefo_faces={'alpha': 0.5, 'edgecolors': 'g', 'facecolors':␣
 ↪'w', 'linestyles': 'dotted', 'linewidths': 1},
               interpFlag=1, endDispFlag=0,
               fmt_nodes={'color': 'red', 'linestyle': 'None', 'linewidth': 1.
 ↪2, 'marker': 's', 'markersize': 6},
               Eo=0, az_el=(-60.0, 30.0), fig_wi_he=False, fig_lbrt=False,␣
 ↪node_supports=True, ax=False)
plt.title('3d Frame')

# Eigenvalue
nfreq = 6
eigValues = ops.eigen(nfreq)
```

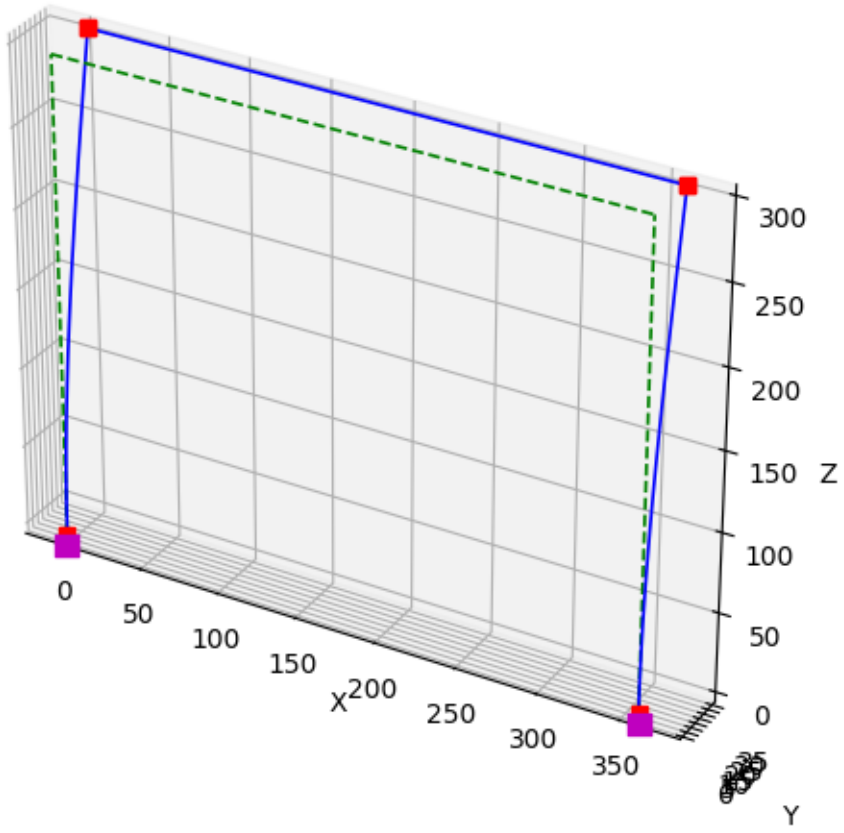
```
Gravity load analysis completed
```

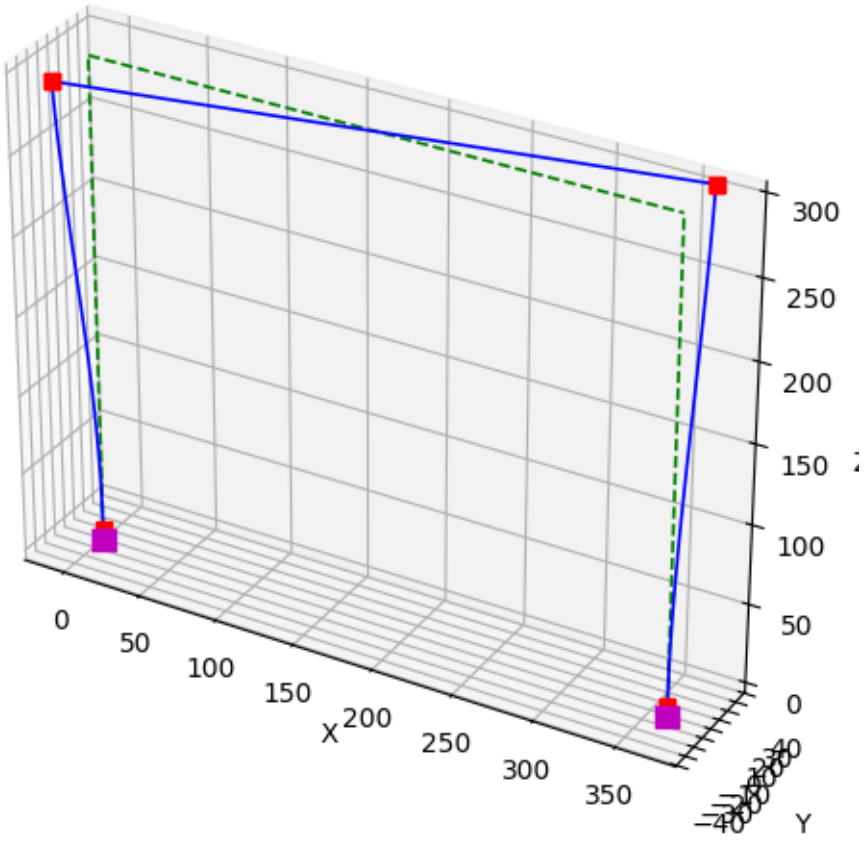


0.0.14 Deformed shapes Plot

[14]:
```
opsv.plot_mode_shape(1, unDefoFlag=1,
                     fmt_defo={'color': 'blue', 'linestyle': 'solid',␣
 ↪'linewidth': 1.2, 'marker': '', 'markersize': 1},
                     fmt_undefo={'color': 'green', 'linestyle': 'dashed',␣
 ↪'linewidth': 1.2, 'marker': '', 'markersize': 1},
                     fmt_defo_faces={'alpha': 0.5, 'edgecolors': 'k',␣
 ↪'linewidths': 1},
                     fmt_undefo_faces={'alpha': 0.5, 'edgecolors': 'g',␣
 ↪'facecolors': 'w', 'linestyles': 'dotted', 'linewidths': 1},
                     interpFlag=1, endDispFlag=1,
                     fmt_nodes={'color': 'red', 'linestyle': 'None',␣
 ↪'linewidth': 1.2, 'marker': 's', 'markersize': 6},
                     Eo=0, az_el=(-60.0, 30.0), fig_wi_he=False,␣
 ↪fig_lbrt=False, node_supports=True, ax=False)
```

```
opsv.plot_mode_shape(2, unDefoFlag=1,
                     fmt_defo={'color': 'blue', 'linestyle': 'solid',␣
 ↪'linewidth': 1.2, 'marker': '', 'markersize': 1},
                     fmt_undefo={'color': 'green', 'linestyle': 'dashed',␣
 ↪'linewidth': 1.2, 'marker': '', 'markersize': 1},
                     fmt_defo_faces={'alpha': 0.5, 'edgecolors': 'k',␣
 ↪'linewidths': 1},
                     fmt_undefo_faces={'alpha': 0.5, 'edgecolors': 'g',␣
 ↪'facecolors': 'w', 'linestyles': 'dotted', 'linewidths': 1},
                     interpFlag=1, endDispFlag=1,
                     fmt_nodes={'color': 'red', 'linestyle': 'None',␣
 ↪'linewidth': 1.2, 'marker': 's', 'markersize': 6},
                     Eo=0, az_el=(-60.0, 30.0), fig_wi_he=False,␣
 ↪fig_lbrt=False, node_supports=True, ax=False)
```





0.0.15 Lateral Analysis Definition

[15]:
```
# ------------------------------------------------
# End of Model Generation & Initial Gravity Analysis
# ------------------------------------------------
# Start of additional modelling for lateral loads
# ------------------------------------------------
# Set the gravity loads to be constant & reset the time in the domain
ops.loadConst("-time", 0.0)

# Define lateral loads
# --------------------
# Set some parameters
H = 10.0;                # Reference lateral load

# Set lateral load pattern with a Linear TimeSeries
```

```
ops.pattern("Plain", 2, 1, "-fact", 1.0)

# create the nodal load - command: load nodeID xForce yForce zMoment
ops.load(3, H, 0.0, 0.0, 0.0, 0.0, 0.0)
ops.load(4, H, 0.0, 0.0, 0.0, 0.0, 0.0)

# Change the integration scheme to be displacement control
#                                    node dof init Jd min max
ops.integrator("DisplacementControl", 3, 1, dU, 1, dU, dU)

# Create a recorder to monitor nodal displacements
ops.recorder("Node", "-file", "node32.out", "-time", "-node", 3, 4, "-dof", 1,␣
 ↪2, 3, "disp")
#recorder plot node32.out hi 10 10 300 300 -columns 2 1
# Create a recorder to monitor element forces in columns
ops.recorder("EnvelopeElement", "-file", "ele32.out", "-time", "-ele", 1, 2,␣
 ↪"localForce")

# record once at time 0
ops.record()
```

0.0.16 Variable Initialization for Lateral Analysis

[16]:
```
ndisp  = np.zeros(numSteps + 1)
V_base = np.zeros(numSteps + 1)
time   = np.zeros(numSteps + 1)
V_col  = np.zeros(numSteps + 1)

Kn = np.zeros((numSteps + 1, n_cols, n_gpnts))
Pn = np.zeros((numSteps + 1, n_cols, n_gpnts))
Mn = np.zeros((numSteps + 1, n_cols, n_gpnts))

EIsecant = np.zeros((numSteps + 1, n_cols, n_gpnts))
c_na     = np.zeros((numSteps + 1, n_cols, n_gpnts))

eConfc = np.zeros((numSteps + 1, n_cols, n_gpnts))
eConft = np.zeros((numSteps + 1, n_cols, n_gpnts))
eUncfc = np.zeros((numSteps + 1, n_cols, n_gpnts))
eUncft = np.zeros((numSteps + 1, n_cols, n_gpnts))
eRebc  = np.zeros((numSteps + 1, n_cols, n_gpnts))
eRebt  = np.zeros((numSteps + 1, n_cols, n_gpnts))

sConfc = np.zeros((numSteps + 1, n_cols, n_gpnts))
sConft = np.zeros((numSteps + 1, n_cols, n_gpnts))
sUncfc = np.zeros((numSteps + 1, n_cols, n_gpnts))
sUncft = np.zeros((numSteps + 1, n_cols, n_gpnts))
sRebc  = np.zeros((numSteps + 1, n_cols, n_gpnts))
```

```
sRebt  = np.zeros((numSteps + 1, n_cols, n_gpnts))

Ksp      = np.zeros(( n_cols, n_gpnts))
Msp      = np.zeros(( n_cols, n_gpnts))
K1y      = np.zeros(( n_cols, n_gpnts))
M1y      = np.zeros(( n_cols, n_gpnts))
EI_1y    = np.zeros(( n_cols, n_gpnts))
K_Rebt_LL= np.zeros(( n_cols, n_gpnts))
M_Rebt_LL= np.zeros(( n_cols, n_gpnts))
Kcu_LL   = np.zeros(( n_cols, n_gpnts))
Mcu_LL   = np.zeros(( n_cols, n_gpnts))
Kcu_UL   = np.zeros(( n_cols, n_gpnts))
Mcu_UL   = np.zeros(( n_cols, n_gpnts))

Ku       = np.zeros(( n_cols, n_gpnts))
Mu       = np.zeros(( n_cols, n_gpnts))

K_Rebc_UL= np.zeros(( n_cols, n_gpnts))
M_Rebc_UL= np.zeros(( n_cols, n_gpnts))
K_Rebt_UL= np.zeros(( n_cols, n_gpnts))
M_Rebt_UL= np.zeros(( n_cols, n_gpnts))

n_u      = np.full(( n_cols, n_gpnts), numSteps, dtype=np.int32)
n_1y     = np.zeros(( n_cols, n_gpnts),          dtype=np.int32)
Mp       = np.zeros(( n_cols, n_gpnts))
Ky       = np.zeros(( n_cols, n_gpnts))

Pu      = np.zeros(( n_cols, n_gpnts))
Ky        = np.zeros(( n_cols, n_gpnts))
Mp        = np.zeros(( n_cols, n_gpnts))
r_axial   = np.zeros(( n_cols, n_gpnts))
ra        = np.zeros(( n_cols, n_gpnts))

dsp      = np.zeros(( n_cols, n_gpnts))
d1y      = np.zeros(( n_cols, n_gpnts))
dcu_LL   = np.zeros(( n_cols, n_gpnts))
dcu_UL   = np.zeros(( n_cols, n_gpnts))
d_Rebc_UL= np.zeros(( n_cols, n_gpnts))
d_Rebt_UL= np.zeros(( n_cols, n_gpnts))
d_Rebt_LL= np.zeros(( n_cols, n_gpnts))

Vsp      = np.zeros(( n_cols, n_gpnts))
V1y      = np.zeros(( n_cols, n_gpnts))
Vcu_LL   = np.zeros(( n_cols, n_gpnts))
Vcu_UL   = np.zeros(( n_cols, n_gpnts))
V_Rebc_UL= np.zeros(( n_cols, n_gpnts))
V_Rebt_UL= np.zeros(( n_cols, n_gpnts))
```

```
V_Rebt_LL= np.zeros(( n_cols, n_gpnts))


#ops.recorder('Element','-file','sectionForces1.
 ↪out','-time','-ele',1,'section',1,'force')
#ops.recorder('Element','-file','sectionForces10.
 ↪out','-time','-ele',1,'section',1,'force')
```

0.0.17 Pushover Analysis

OUTPUT FORMAT

The format of the output is typically dependent on the element and/or section type. In general, however, the output follows the order of the degrees of freedom. Here are some cases:

element	**globalForce**	2D, 3dof: FX FY MZ 3D, 6dof: FX FY FZ MX MY MZ
	localForce	2D, 3dof: Fx Fy Mz 3D, 6dof: Fx Fy Fz Mx My Mz
section	**force**	Fx Mx
	deformation	axial-strain curvature
	stressStrain	stress strain

https://portwooddigital.com/2022/11/04/simple-loads-on-a-cantilever/

https://portwooddigital.com/2021/07/25/how-to-record-fiber-response/

[17]:
```
currentDisp = ops.nodeDisp(3, 1)
i = 1
while currentDisp < maxU:
    ok = ops.analyze(1)

    # if the analysis fails try initial tangent iteration
    if (ok != 0):
        print("regular Newton failed .. lets try an initial stiffness for this␣
 ↪step")
        ops.test("NormDispIncr", 1.0E-12, 1000)
        ops.algorithm("ModifiedNewton", "-initial")
        ok = ops.analyze(1)
        if (ok == 0):
            print("that worked .. back to regular newton")
        ops.test("NormDispIncr", 1.0E-12, 10)
        ops.algorithm("Newton")

    time[i] = np.round(ops.getTime(),2)

    # ALL Cross sections for each column:
    # -----------------------------------
    strType = 'stressStrain'

    for j in range(0, n_cols, 1):
```

```
      for k in range(0, n_gpnts, 1):
          Pn[i, j, k] = round(ops.eleResponse(j +1, 'section','force')[k *␣
↪4], 0)
          Mn[i, j, k] = round(ops.eleResponse(j +1, 'section','force')[k * 4␣
↪+ 1] / 12, 0)
          Kn[i, j, k] = ops.eleResponse(j +1, 'section','deformation')[k * 4␣
↪+ 1] * 12

          eRebt[i, j, k]  = ops.eleResponse(j +1, 'section', 'fiber',␣
↪-r_reinf, 0,  3, strType)[1 + 2 * k]
          if eRebt[i, j, k] >= 0:
              r_sign = 1
          else:
              r_sign = -1

          # yCoord and zCoord for fiber results:
          eConfc[i, j, k] = ops.eleResponse(j +1, 'section', 'fiber',  r_core␣
↪ * r_sign, 0,  1, strType)[1 + 2 * k]
          eConft[i, j, k] = ops.eleResponse(j +1, 'section', 'fiber', -r_core␣
↪ * r_sign, 0,  1, strType)[1 + 2 * k]
          eUncfc[i, j, k] = ops.eleResponse(j +1, 'section', 'fiber',  r_col ␣
↪ * r_sign, 0,  2, strType)[1 + 2 * k]
          eUncft[i, j, k] = ops.eleResponse(j +1, 'section', 'fiber', -r_col ␣
↪ * r_sign, 0,  2, strType)[1 + 2 * k]
          eRebc[i, j, k]  = ops.eleResponse(j +1, 'section', 'fiber', ␣
↪r_reinf * r_sign, 0,  3, strType)[1 + 2 * k]
          eRebt[i, j, k]  = ops.eleResponse(j +1, 'section', 'fiber',␣
↪-r_reinf * r_sign, 0,  3, strType)[1 + 2 * k]

          sConfc[i, j, k] = ops.eleResponse(j +1, 'section', 'fiber',  r_core␣
↪ * r_sign, 0,  1, strType)[0 + 2 * k]
          sConft[i, j, k] = ops.eleResponse(j +1, 'section', 'fiber', -r_core␣
↪ * r_sign, 0,  1, strType)[0 + 2 * k]
          sUncfc[i, j, k] = ops.eleResponse(j +1, 'section', 'fiber',  r_col ␣
↪ * r_sign, 0,  2, strType)[0 + 2 * k]
          sUncft[i, j, k] = ops.eleResponse(j +1, 'section', 'fiber', -r_col ␣
↪ * r_sign, 0,  2, strType)[0 + 2 * k]
          sRebc[i, j, k]  = ops.eleResponse(j +1, 'section', 'fiber', ␣
↪r_reinf * r_sign, 0,  3, strType)[0 + 2 * k]
          sRebt[i, j, k]  = ops.eleResponse(j +1, 'section', 'fiber',␣
↪-r_reinf * r_sign, 0,  3, strType)[0 + 2 * k]

          if abs( abs(Kn[i, j, k]) ) > 0:
              EIsecant[i, j, k] = Mn[i, j, k] / Kn[i, j, k]
              c_na[i, j, k] = round(abs(eUncfc[i, j, k]) / abs(Kn[i, j, k])␣
↪,2)
```

```
            if i > 1:
                if eUncfc[i-1, j, k] > esp and eUncfc[i, j, k] < esp:        #␣
↪Unc. conc. spalling
                    Ksp[j, k] = round(Kn[i-1, j, k]*1000,2)
                    dsp[j, k] = ndisp[i-1]
                    Msp[j, k] = Mn[i-1, j, k]
                    Vsp[j, k] = V_base[i-1]
                if eRebt[i-1, j, k] < esy and eRebt[i, j, k] > esy:          #␣
↪rebar 1st yield
                    K1y[j, k] = round(Kn[i-1, j, k]*1000,2)
                    M1y[j, k] = Mn[i-1, j, k]
                    d1y[j, k] = ndisp[i-1]
                    V1y[j, k] = V_base[i-1]
                    n_1y[j, k] = i - 1

                    if abs(Kn[i, j, k]) > 0:
                        EI_1y[j, k] = M1y[j, k] / Kn[i-1, j, k]

                if eRebt[i-1, j, k] < est_LL and eRebt[i, j, k] > est_LL:    #␣
↪rebar tension Strain Limit
                    K_Rebt_LL[j, k] = round(Kn[i-1, j, k]*1000,2)
                    d_Rebt_LL[j, k] = ndisp[i-1]
                    M_Rebt_LL[j, k] = Mn[i-1, j, k]
                    V_Rebt_LL[j, k] = V_base[i-1]
                if eUncfc[i-1, j, k] > ecu_LL and eUncfc[i, j, k] < ecu_LL:  #␣
↪Conf. Conc. Ult. Strain
                    Kcu_LL[j, k] = round(Kn[i-1, j, k]*1000,2)
                    dcu_LL[j, k] = ndisp[i-1]
                    Mcu_LL[j, k] = Mn[i-1, j, k]
                    Vcu_LL[j, k] = V_base[i-1]
                if eConfc[i-1, j, k] > ecu_UL and eConfc[i, j, k] < ecu_UL:  #␣
↪Conf. Conc. Ult. Strain
                    Kcu_UL[j, k] = round(Kn[i-1, j, k]*1000,2)
                    d_cu_UL[j, k] = ndisp[i-1]
                    Mcu_UL[j, k] = Mn[i-1, j, k]
                    Vcu_UL[j, k] = V_base[i-1]
                    n_u[j, k] = i - 1
                if eRebc[i-1, j, k]> esc_UL and eRebc[i, j, k] < esc_UL:     #␣
↪rebar compr. Strain limit
                    K_Rebc_UL[j, k] = round(Kn[i-1, j, k]*1000,2)
                    d_Rebc_UL[j, k] = ndisp[i-1]
                    M_Rebc_UL[j, k] = Mn[i-1, j, k]
                    V_Rebc_UL[j, k] = V_base[i-1]
                    n_u[j, k] = i - 1
```

```
                if eRebt[i-1, j, k] < est_UL and eRebt[i, j, k] > est_UL:    #␣
 ↪rebar tension Strain Limit
                    K_Rebt_UL[j, k] = round(Kn[i-1, j, k]*1000,2)
                    d_Rebt_UL[j, k] = ndisp[i-1]
                    M_Rebt_UL[j, k] = Mn[i-1, j, k]
                    V_Rebt_UL[j, k] = V_base[i-1]
                    n_u[j, k] = i - 1

    currentDisp = ops.nodeDisp(3, 1)
    ndisp[i] = ops.nodeDisp(3, 1)
    ops.reactions()
    V_base[i] = ops.nodeReaction(1)[0] + ops.nodeReaction(2)[0]
    i = i + 1

# Print a message to indicate if analysis successful or not
if (ok == 0):
    print("\nPushover analysis completed SUCCESSFULLY\n")
else:
    print("\nPushover analysis FAILED\n")
```

```
Pushover analysis completed SUCCESSFULLY
```

0.0.18 Idealized Moment-Curvature

[18]:
```
print(n_u, "\n", n_1y)
```

```
[[44 51 51 51 51 51 51 51 51 47]
 [42 51 51 51 51 51 51 51 51 46]]
 [[ 8  9 17  0  0  0  0 20 10  9]
 [ 8 10 25  0  0  0  0 30 12 10]]
```

[ ]:
```

```

[20]:
```
for j in range(0, n_cols, 1):
    for k in range(0, n_gpnts, 1):

        Ku[j, k] = np.round(Kn[n_u[j, k], j, k]*1000,2)
        Mu[j, k] = Mn[n_u[j, k], j, k]
        Pu[j, k] = np.round(np.min(Pn[:, j, k]))

        flag = 0
        ii = n_u[j, k] - 2          # to consider 2nd from last
        Mp[j, k] = 0

        if n_1y[j, k] > 0:
```

```
            while flag == 0 and ii >= n_1y[j, k]:          # changes Mp to match␣
↪Areas
                A_above = 0
                A_below = 0
                Mp[j, k] = Mn[ii, j, k]

                # numerical integration under the curve difference:
                for iii in range(n_u[j, k] - 2, n_1y[j, k], -1):
                    DA = 1/2 * ( Mn[iii + 1, j, k] + Mn[iii, j, k] ) * ( Kn[iii␣
↪+ 1, j, k] - Kn[iii, j, k] )

                    DAp = Mp[j, k] * (Kn[iii + 1, j, k] - Kn[iii, j, k])
                    if Mn[iii + 1, j, k] > Mp[j, k]:
                        A_above = round(A_above + DA - DAp, 4)
                    else:
                        A_below = round(A_below + DAp - DA, 4)

                ra[j, k] = round(min(abs(A_above), abs(A_below)) / ␣
↪max(abs(A_above), abs(A_below)), 2)
                if ra[j, k]  > 0.90:
                    flag = 1
                else:
                    ii = ii - 1
        if EI_1y[j, k] > 0:
            Ky[j, k] = round(Mp[j, k] / EI_1y[j, k] * 1000, 2)

        r_axial[j, k] = Pu[j, k]/(fpc * A_col)
```

[21]:
```
print("K1y = ", K1y, "\n\n", "Ku = ", Ku, "\n\n", "Mu = ", Mu,
      "\n\n", "Ky = ",Ky, "\n\n", "Mp = ", Mp, "\n\n", "ra = ",ra ,
      "\n\n", "Pu = ", Pu)
```

```
K1y =  [[ 0.73  0.72  0.76  0.    0.    0.    0.   -0.76 -0.72 -0.74]
 [ 0.75  0.82  0.84  0.    0.    0.    0.   -0.84 -0.83 -0.81]]

 Ku =  [[  9.86   6.8    1.1    0.5    0.07  -0.07  -0.48  -1.06  -6.39  -9.98]
 [ 10.34   6.67   1.     0.43   0.07  -0.07  -0.41  -0.95  -6.07 -10.35]]

 Mu =  [[ 7184.  6758.  5436.  3528.  1241. -1176. -3463. -5371. -6693. -7188.]
 [ 8621.  8168.  6573.  4270.  1510. -1408. -4168. -6470. -8066. -8631.]]

 Ky =  [[ 1.    0.96  0.76  0.    0.    0.    0.   -0.82 -0.95 -1.01]
 [ 1.06  1.06  0.88  0.    0.    0.    0.   -0.84 -1.06 -0.81]]

 Mp =  [[ 6567.  6270.  4739.     0.     0.     0.     0. -5111. -6231. -6553.]
```

```
[ 7848.  7627.  6338.     0.     0.     0.     0. -6085. -7580. -5835.]]

ra =  [[0.94 0.98 0.   0.   0.   0.   0.   0.97 0.97 1.  ]
[0.99 0.92 0.98 0.   0.   0.   0.   0.   0.93 0.  ]]

Pu =  [[-1421. -1421. -1421. -1421. -1421. -1421. -1421. -1421. -1421. -1421.]
[-2035. -2035. -2035. -2035. -2035. -2035. -2035. -2035. -2035. -2035.]]
```

0.0.19 Report Summary

[22]:
```
# ----------------------------------------
# Display Results Table:
# ----------------------------------------
j = 1
k = 0
RMatrix1 = {'Concrete Spalling Strain, esp [--]': esp,
            'Concrete Ultimate Strain, ecu_UL [--]': ecu_UL,
            'Reinf. buckling Strain, esc_UL [--]': esc_UL,
            'Reinf. tensile limit Strain, est_UL [--]': est_UL,
            'LL Unconf. Conc. Comp. Strain Limit, ecu_LL [--]': ecu_LL,
            'LL Reinf. tensile limit Strain Limit, est_LL [--]': est_LL,
            'Curvature at First Yield, K1y [--]': K1y[j, k],
            'Effective Yield Curvature, Ky [mrad/ft]': Ky[j, k],
            'Curvature at Cover Spalling, Ksp [--]': Ksp[j, k],
            'Ultimate Curvature, Ku [mrad/ft]': Ku[j, k],
            '1st Yield Secant Stiffness, EI_1y [k-ft2]': EI_1y[j, k],
            '1st Yield Moment, M1y [k-ft]': M1y[j, k],
            'Plastic Moment, Mp [k-ft]': Mp[j, k],
            'Ultimate Moment, Mu [k-ft]': Mu[j, k],
            'UL Curvature for Conf. concrete ultimate strain, Kcu_UL [--]':␣
 ↪Kcu_UL[j, k],
            'UL Curvature for Rebar compr. Limit Strain, K_Rebc_UL [--]':␣
 ↪K_Rebc_UL[j, k],
            'UL Curvature for Rebar tension Limit Strain, K_Rebt_UL [--]':␣
 ↪K_Rebt_UL[j, k],
            'LL Curvature for Unconf. Concr. compr. Limit Strain, Kcu_LL [--]':
 ↪ Kcu_LL[j, k],
            'LL Curvature for Rebar Tens. Limit Strain, K_Rebt_LL [--]':␣
 ↪K_Rebt_LL[j, k]}

df1 = pd.DataFrame(RMatrix1, columns = ['Concrete Spalling Strain, esp [--]',
                                        'Concrete Ultimate Strain, ecu_UL [--]',
                                        'Reinf. buckling Strain, esc_UL [--]',
                                        'Reinf. tensile limit Strain, est_UL [--]',
                                        'LL Unconf. Conc. Comp. Strain Limit,␣
 ↪ecu_LL [--]',
```

```
                                    'LL Reinf. tensile limit Strain Limit,␣
 ↪est_LL [--]',
                                    'Curvature at First Yield, K1y [--]',
                                    'Effective Yield Curvature, Ky [mrad/ft]',
                                    'Curvature at Cover Spalling, Ksp [--]',
                                    'Ultimate Curvature, Ku [mrad/ft]',
                                    '1st Yield Secant Stiffness, EI_1y [k-ft2]',
                                    '1st Yield Moment, M1y [k-ft]',
                                    'Plastic Moment, Mp [k-ft]',
                                    'Ultimate Moment, Mu [k-ft]',
                                    'UL Curvature for Conf. concrete ultimate␣
 ↪strain, Kcu_UL [--]',
                                    'UL Curvature for Rebar compr. Limit␣
 ↪Strain, K_Rebc_UL [--]',
                                    'UL Curvature for Rebar tension Limit␣
 ↪Strain, K_Rebt_UL [--]',
                                    'LL Curvature for Unconf. Concr. compr.␣
 ↪Limit Strain, Kcu_LL [--]',
                                    'LL Curvature for Rebar Tens. Limit Strain,␣
 ↪K_Rebt_LL [--]'], index=[0])

df1['Concrete Spalling Strain, esp [--]'] = df1['Concrete Spalling Strain, esp␣
 ↪[--]'].map('{:.4f}'.format)
df1['Concrete Ultimate Strain, ecu_UL [--]'] = df1['Concrete Ultimate Strain,␣
 ↪ecu_UL [--]'].map('{:.4f}'.format)
df1['Reinf. buckling Strain, esc_UL [--]'] = df1['Reinf. buckling Strain,␣
 ↪esc_UL [--]'].map('{:.4f}'.format)
df1['Reinf. tensile limit Strain, est_UL [--]'] = df1['Reinf. tensile limit␣
 ↪Strain, est_UL [--]'].map('{:.4f}'.format)
df1['LL Unconf. Conc. Comp. Strain Limit, ecu_LL [--]'] = df1['LL Unconf. Conc.␣
 ↪Comp. Strain Limit, ecu_LL [--]'].map('{:.4f}'.format)
df1['LL Reinf. tensile limit Strain Limit, est_LL [--]'] = df1['LL Reinf.␣
 ↪tensile limit Strain Limit, est_LL [--]'].map('{:.4f}'.format)

df1['1st Yield Secant Stiffness, EI_1y [k-ft2]'] = df1['1st Yield Secant␣
 ↪Stiffness, EI_1y [k-ft2]'].map('{:,.0f}'.format)

#pd.options.display.float_format = '{:.4f}'.format
#pd.set_option('display.max_rows', None)     # Set to None to display all rows
#pd.set_option('display.max_columns', None)  # Set to None to display all␣
 ↪columns

df1_transposed = df1.T

#left_aligned_df = df1_transposed.style.set_properties(**{'text-align': 'left'})
display(df1_transposed)
```

	0
Concrete Spalling Strain, esp [--]	-0.0050
Concrete Ultimate Strain, ecu_UL [--]	-0.0196
Reinf. buckling Strain, esc_UL [--]	-0.0430
Reinf. tensile limit Strain, est_UL [--]	0.0360
LL Unconf. Conc. Comp. Strain Limit, ecu_LL [--]	-0.0040
LL Reinf. tensile limit Strain Limit, est_LL [--]	0.0100
Curvature at First Yield, K1y [--]	0.75
Effective Yield Curvature, Ky [mrad/ft]	1.06
Curvature at Cover Spalling, Ksp [--]	2.78
Ultimate Curvature, Ku [mrad/ft]	10.34
1st Yield Secant Stiffness, EI_1y [k-ft2]	7,391,962
1st Yield Moment, M1y [k-ft]	5571.0
Plastic Moment, Mp [k-ft]	7848.0
Ultimate Moment, Mu [k-ft]	8621.0
UL Curvature for Conf. concrete ultimate strain…	0.0
UL Curvature for Rebar compr. Limit Strain, K_R…	0.0
UL Curvature for Rebar tension Limit Strain, K_…	10.34
LL Curvature for Unconf. Concr. compr. Limit St…	2.13
LL Curvature for Rebar Tens. Limit Strain, K_Re…	2.78

0.0.20 Report Details

[23]:
```
# ----------------------------------------
# Display Results Table:
# ----------------------------------------
ResultMatrix = {'Kn [mrad/ft]': np.round(Kn[:, j, k]*1000,2),
                'Mn [k-ft]': np.round(Mn[:, j, k], 0),
                'Pn [k]': np.round(Pn[:, j, k], 0),
                'EIsec  [k-ft2]': EIsecant[:, j, k],
                'c [in]': c_na[:, j, k],
                '\u03B5Confc [--]': eConfc[:, j, k],
                '\u03B5Conft [--]': eConft[:, j, k],
                '\u03B5Uncfc [--]': eUncfc[:, j, k],
                '\u03B5Uncft [--]': eUncft[:, j, k],
                '\u03B5Rebc [--]': eRebc[:, j, k],
                '\u03B5Rebt [--]': eRebt[:, j, k],
                '\u03C3Confc [ksi]': sConfc[:, j, k],
                '\u03C3Conft [ksi]': sConft[:, j, k],
                '\u03C3Uncfc [ksi]': sUncfc[:, j, k],
                '\u03C3Uncft [ksi]': sUncft[:, j, k],
                '\u03C3Rebc [ksi]': sRebc[:, j, k],
                '\u03C3Rebt [ksi]': sRebt[:, j, k]}

df = pd.DataFrame(ResultMatrix, columns = ['Kn [mrad/ft]', 'Mn [k-ft]', 'Pn␣
 ↪[k]', 'EIsec  [k-ft2]', 'c [in]',
```

```
                                                '\u03B5Confc [--]', '\u03B5Conft␣
 ↪[--]', '\u03B5Uncfc [--]',
                                                '\u03B5Uncft [--]', '\u03B5Rebc␣
 ↪[--]', '\u03B5Rebt [--]',
                                                '\u03C3Confc [ksi]', '\u03C3Conft␣
 ↪[ksi]', '\u03C3Uncfc [ksi]',
                                                '\u03C3Uncft [ksi]', '\u03C3Rebc␣
 ↪[ksi]', '\u03C3Rebt [ksi]'])

df['EIsec  [k-ft2]'] = df['EIsec  [k-ft2]'].map('{:,.0f}'.format)

df['\u03B5Confc [--]'] = df['\u03B5Confc [--]'].map('{:.5f}'.format)
df['\u03B5Conft [--]'] = df['\u03B5Conft [--]'].map('{:.5f}'.format)
df['\u03B5Uncfc [--]'] = df['\u03B5Uncfc [--]'].map('{:.5f}'.format)
df['\u03B5Uncft [--]'] = df['\u03B5Uncft [--]'].map('{:.5f}'.format)
df['\u03B5Rebc [--]'] = df['\u03B5Rebc [--]'].map('{:.5f}'.format)
df['\u03B5Rebt [--]'] = df['\u03B5Rebt [--]'].map('{:.5f}'.format)

df['\u03C3Confc [ksi]'] = df['\u03C3Confc [ksi]'].map('{:.1f}'.format)
df['\u03C3Conft [ksi]'] = df['\u03C3Conft [ksi]'].map('{:.1f}'.format)
df['\u03C3Uncfc [ksi]'] = df['\u03C3Uncfc [ksi]'].map('{:.1f}'.format)
df['\u03C3Uncft [ksi]'] = df['\u03C3Uncft [ksi]'].map('{:.1f}'.format)
df['\u03C3Rebc [ksi]'] = df['\u03C3Rebc [ksi]'].map('{:.1f}'.format)
df['\u03C3Rebt [ksi]'] = df['\u03C3Rebt [ksi]'].map('{:.1f}'.format)

pd.set_option('display.max_rows', None)     # Set to None to display all rows
pd.set_option('display.max_columns', None)  # Set to None to display all columns

display(df)
```

	Kn [mrad/ft]	Mn [k-ft]	Pn [k]	EIsec [k-ft2]	c [in]	Confc [--]	\
0	0.00	0.0	0.0	0	0.00	0.00000	
1	0.07	1456.0	-1579.0	20,726,542	4.15	-0.00028	
2	0.17	2477.0	-1638.0	14,383,569	2.89	-0.00047	
3	0.28	3165.0	-1679.0	11,385,429	2.45	-0.00063	
4	0.38	3729.0	-1712.0	9,856,154	2.23	-0.00078	
5	0.47	4233.0	-1741.0	8,923,468	2.10	-0.00091	
6	0.57	4702.0	-1769.0	8,282,479	2.01	-0.00104	
7	0.66	5146.0	-1795.0	7,799,406	1.95	-0.00117	
8	0.75	5571.0	-1819.0	7,391,962	1.90	-0.00130	
9	0.86	5976.0	-1843.0	6,974,724	1.85	-0.00143	
10	0.98	6353.0	-1865.0	6,458,962	1.79	-0.00159	
11	1.15	6692.0	-1886.0	5,818,406	1.73	-0.00179	
12	1.38	6980.0	-1904.0	5,068,848	1.65	-0.00204	
13	1.69	7214.0	-1919.0	4,268,651	1.58	-0.00238	
14	2.13	7396.0	-1932.0	3,477,835	1.51	-0.00283	
15	2.78	7521.0	-1943.0	2,701,764	1.44	-0.00352	

16	3.83	7582.0	-1951.0	1,978,542	1.38	-0.00461
17	4.46	7677.0	-1958.0	1,719,903	1.36	-0.00528
18	4.94	7770.0	-1962.0	1,573,444	1.34	-0.00577
19	5.35	7848.0	-1966.0	1,466,671	1.33	-0.00620
20	5.75	7926.0	-1971.0	1,377,806	1.33	-0.00663
21	6.12	7999.0	-1976.0	1,307,923	1.32	-0.00701
22	6.44	8061.0	-1980.0	1,251,148	1.32	-0.00736
23	6.73	8114.0	-1984.0	1,206,133	1.31	-0.00767
24	6.98	8158.0	-1988.0	1,169,451	1.31	-0.00794
25	7.19	8196.0	-1991.0	1,139,210	1.31	-0.00817
26	7.38	8228.0	-1994.0	1,114,338	1.31	-0.00838
27	7.54	8254.0	-1996.0	1,094,270	1.31	-0.00855
28	7.66	8274.0	-1998.0	1,079,590	1.31	-0.00868
29	7.74	8287.0	-1999.0	1,071,055	1.31	-0.00876
30	7.76	8292.0	-2001.0	1,068,226	1.31	-0.00879
31	7.81	8301.0	-2002.0	1,062,447	1.31	-0.00884
32	7.92	8318.0	-2003.0	1,050,015	1.30	-0.00896
33	8.08	8342.0	-2004.0	1,032,274	1.30	-0.00914
34	8.26	8369.0	-2005.0	1,012,617	1.30	-0.00934
35	8.46	8397.0	-2006.0	992,559	1.30	-0.00955
36	8.68	8427.0	-2008.0	971,213	1.30	-0.00978
37	8.93	8460.0	-2009.0	947,530	1.30	-0.01006
38	9.19	8494.0	-2011.0	924,064	1.30	-0.01034
39	9.46	8526.0	-2013.0	900,876	1.30	-0.01064
40	9.75	8558.0	-2015.0	878,090	1.30	-0.01095
41	10.04	8590.0	-2017.0	855,557	1.30	-0.01127
42	10.34	8621.0	-2019.0	833,416	1.29	-0.01160
43	10.66	8652.0	-2021.0	811,372	1.29	-0.01195
44	11.01	8683.0	-2023.0	788,540	1.29	-0.01233
45	11.38	8714.0	-2025.0	766,014	1.29	-0.01273
46	11.75	8743.0	-2026.0	744,089	1.29	-0.01314
47	12.14	8772.0	-2028.0	722,610	1.29	-0.01357
48	12.54	8800.0	-2030.0	701,754	1.29	-0.01401
49	12.95	8827.0	-2032.0	681,623	1.29	-0.01446
50	13.37	8853.0	-2034.0	662,199	1.29	-0.01492
51	13.80	8879.0	-2035.0	643,213	1.29	-0.01540

	Conft [--]	Uncfc [--]	Uncft [--]	Rebc [--]	Rebt [--]	Confc [ksi]	\
0	0.00000	0.00000	0.00000	0.00000	0.00000	0.0	
1	0.00005	-0.00029	0.00006	-0.00027	0.00004	-1.2	
2	0.00033	-0.00050	0.00036	-0.00045	0.00031	-1.9	
3	0.00065	-0.00068	0.00070	-0.00060	0.00062	-2.5	
4	0.00097	-0.00084	0.00103	-0.00074	0.00093	-2.9	
5	0.00128	-0.00100	0.00136	-0.00086	0.00123	-3.3	
6	0.00158	-0.00114	0.00168	-0.00098	0.00152	-3.7	
7	0.00188	-0.00128	0.00199	-0.00110	0.00181	-4.0	
8	0.00218	-0.00143	0.00232	-0.00122	0.00210	-4.3	
9	0.00252	-0.00158	0.00267	-0.00134	0.00243	-4.6	

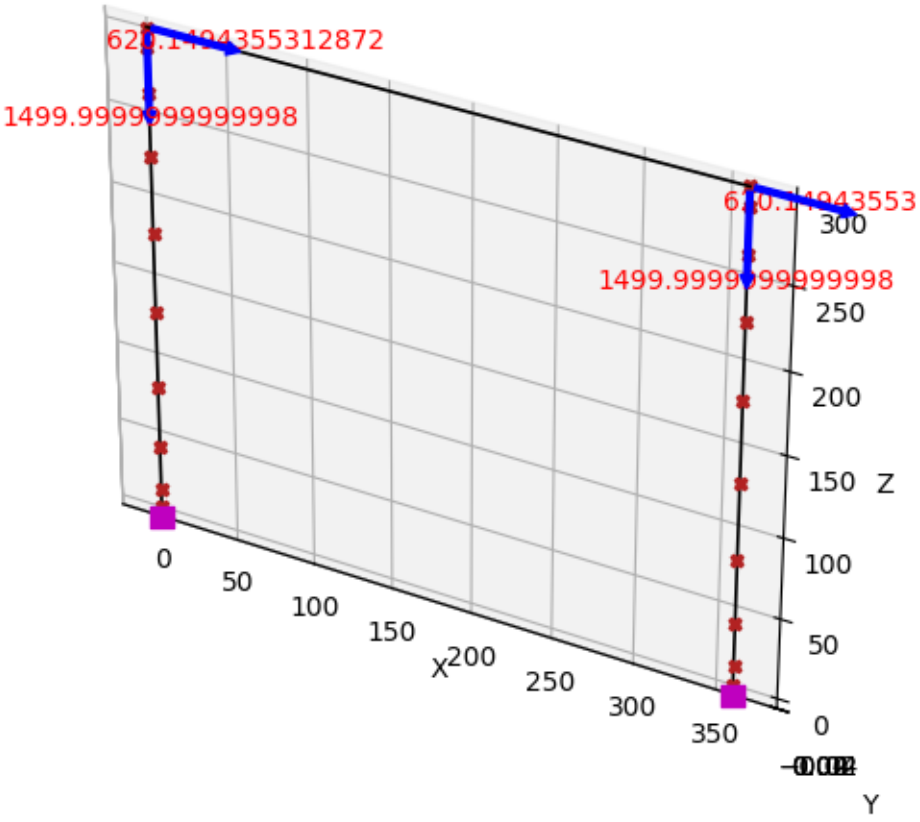
10	0.00295	-0.00176	0.00312	-0.00149	0.00284	-5.0
11	0.00353	-0.00199	0.00373	-0.00166	0.00340	-5.3
12	0.00432	-0.00228	0.00456	-0.00189	0.00417	-5.7
13	0.00543	-0.00267	0.00573	-0.00219	0.00525	-6.2
14	0.00700	-0.00320	0.00736	-0.00260	0.00676	-6.6
15	0.00935	-0.00400	0.00983	-0.00321	0.00904	-7.1
16	0.01310	-0.00528	0.01376	-0.00420	0.01268	-7.6
17	0.01535	-0.00605	0.01612	-0.00479	0.01486	-7.7
18	0.01705	-0.00663	0.01790	-0.00524	0.01651	-7.8
19	0.01852	-0.00713	0.01945	-0.00562	0.01794	-7.9
20	0.01996	-0.00762	0.02095	-0.00600	0.01933	-7.9
21	0.02125	-0.00807	0.02231	-0.00635	0.02058	-7.9
22	0.02241	-0.00848	0.02353	-0.00666	0.02171	-7.9
23	0.02342	-0.00883	0.02459	-0.00694	0.02269	-7.9
24	0.02430	-0.00915	0.02551	-0.00718	0.02354	-7.9
25	0.02508	-0.00942	0.02632	-0.00739	0.02429	-7.9
26	0.02575	-0.00966	0.02703	-0.00757	0.02494	-7.9
27	0.02631	-0.00986	0.02762	-0.00773	0.02549	-7.9
28	0.02674	-0.01001	0.02807	-0.00785	0.02590	-7.9
29	0.02699	-0.01010	0.02834	-0.00792	0.02615	-7.8
30	0.02708	-0.01014	0.02843	-0.00794	0.02624	-7.8
31	0.02726	-0.01020	0.02862	-0.00799	0.02641	-7.8
32	0.02764	-0.01034	0.02902	-0.00810	0.02678	-7.8
33	0.02821	-0.01054	0.02961	-0.00826	0.02733	-7.8
34	0.02886	-0.01077	0.03029	-0.00843	0.02796	-7.8
35	0.02955	-0.01101	0.03102	-0.00863	0.02863	-7.8
36	0.03031	-0.01129	0.03182	-0.00884	0.02937	-7.8
37	0.03120	-0.01160	0.03275	-0.00908	0.03023	-7.8
38	0.03214	-0.01194	0.03373	-0.00934	0.03113	-7.7
39	0.03310	-0.01228	0.03474	-0.00961	0.03207	-7.7
40	0.03409	-0.01264	0.03578	-0.00988	0.03303	-7.7
41	0.03513	-0.01301	0.03687	-0.01017	0.03404	-7.7
42	0.03620	-0.01339	0.03800	-0.01047	0.03508	-7.6
43	0.03733	-0.01380	0.03918	-0.01079	0.03617	-7.6
44	0.03855	-0.01424	0.04046	-0.01113	0.03736	-7.6
45	0.03984	-0.01470	0.04181	-0.01149	0.03860	-7.5
46	0.04116	-0.01518	0.04319	-0.01186	0.03988	-7.5
47	0.04253	-0.01568	0.04463	-0.01225	0.04121	-7.5
48	0.04394	-0.01618	0.04611	-0.01264	0.04257	-7.4
49	0.04539	-0.01670	0.04763	-0.01305	0.04398	-7.4
50	0.04686	-0.01724	0.04918	-0.01346	0.04540	-7.3
51	0.04839	-0.01780	0.05078	-0.01390	0.04688	-7.3

	Conft [ksi]	Uncfc [ksi]	Uncft [ksi]	Rebc [ksi]	Rebt [ksi]
0	0.0	0.0	0.0	0.0	0.0
1	0.0	-1.4	0.0	-7.9	1.1
2	0.0	-2.3	0.0	-13.1	9.0
3	0.0	-2.9	0.0	-17.6	18.1

4	0.0	-3.5	0.0	-21.5	27.0
5	0.0	-3.9	0.0	-25.1	35.6
6	0.0	-4.2	0.0	-28.6	44.0
7	0.0	-4.5	0.0	-32.0	52.1
8	0.0	-4.8	0.0	-35.4	59.3
9	0.0	-5.0	0.0	-39.1	64.5
10	0.0	-5.1	0.0	-43.3	67.1
11	0.0	-5.2	0.0	-48.4	67.8
12	0.0	-4.7	0.0	-54.6	68.0
13	0.0	-4.0	0.0	-61.4	68.0
14	0.0	-3.1	0.0	-66.4	68.0
15	0.0	-1.7	0.0	-68.2	68.0
16	0.0	0.0	0.0	-68.6	69.7
17	0.0	0.0	0.0	-68.7	72.7
18	0.0	0.0	0.0	-68.7	74.9
19	0.0	0.0	0.0	-68.8	76.6
20	0.0	0.0	0.0	-68.8	78.2
21	0.0	0.0	0.0	-68.9	79.5
22	0.0	0.0	0.0	-68.9	80.7
23	0.0	0.0	0.0	-69.0	81.6
24	0.0	0.0	0.0	-69.0	82.4
25	0.0	0.0	0.0	-69.0	83.1
26	0.0	0.0	0.0	-69.0	83.7
27	0.0	0.0	0.0	-69.1	84.1
28	0.0	0.0	0.0	-69.1	84.5
29	0.0	0.0	0.0	-69.1	84.7
30	0.0	0.0	0.0	-69.1	84.8
31	0.0	0.0	0.0	-69.1	84.9
32	0.0	0.0	0.0	-69.1	85.2
33	0.0	0.0	0.0	-69.1	85.6
34	0.0	0.0	0.0	-69.2	86.1
35	0.0	0.0	0.0	-69.2	86.6
36	0.0	0.0	0.0	-69.2	87.1
37	0.0	0.0	0.0	-69.3	87.7
38	0.0	0.0	0.0	-69.3	88.2
39	0.0	0.0	0.0	-69.3	88.8
40	0.0	0.0	0.0	-69.4	89.4
41	0.0	0.0	0.0	-69.4	89.9
42	0.0	0.0	0.0	-69.4	90.4
43	0.0	0.0	0.0	-69.5	90.9
44	0.0	0.0	0.0	-69.5	91.4
45	0.0	0.0	0.0	-69.8	91.9
46	0.0	0.0	0.0	-70.4	92.4
47	0.0	0.0	0.0	-71.1	92.8
48	0.0	0.0	0.0	-71.7	93.2
49	0.0	0.0	0.0	-72.4	93.6
50	0.0	0.0	0.0	-73.1	93.9
51	0.0	0.0	0.0	-73.8	94.1

[24]:
```
opsv.plot_load()
```

[24]:
```
<Axes3D: xlabel='X', ylabel='Y', zlabel='Z'>
```



0.0.21 Moment Diagrams for Last Step

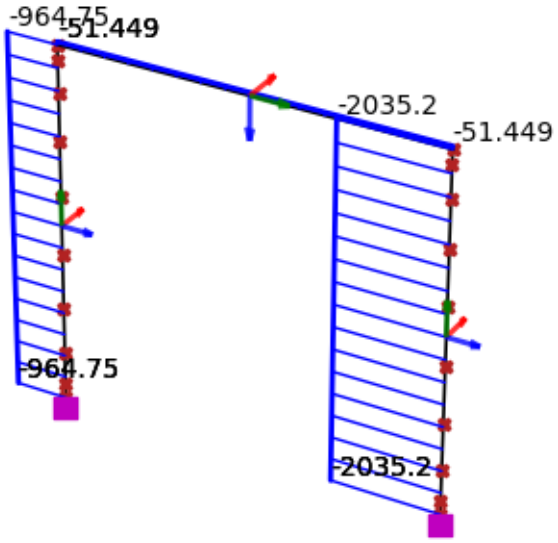
[25]:
```
sfacN = 5.e-2
sfacVy = 5.e-2
sfacMz = 0.5e-3

MinN, MaxN, ax = opsv.section_force_diagram_3d('N', sfacN,
                                fmt_secforce1={'color': 'blue', 'dash_capstyle':␣
 ↪'butt', 'dash_joinstyle': 'round',
                                               'linestyle': 'solid', 'linewidth':␣
 ↪2.0, 'marker': '', 'markersize': 1,
```

```
                                                'solid_capstyle': 'round',␣
 ↪'solid_joinstyle': 'round'},
                                fmt_secforce2={'color': 'blue', 'dash_capstyle':␣
 ↪'butt', 'dash_joinstyle': 'round',
                                                'linestyle': 'solid', 'linewidth':␣
 ↪1.0, 'marker': '', 'markersize': 1,
                                                'solid_capstyle': 'round',␣
 ↪'solid_joinstyle': 'round'},
                                ref_vert_lines=True, end_max_values=True,␣
 ↪dir_plt=0, node_supports=True, ax=False, alt_model_plot=1)
ax.set_axis_off()
plt.title('Axial force N')

MinVy, MaxVy, ax = opsv.section_force_diagram_3d('Vy', sfacVy)
ax.set_axis_off()
plt.title('Transverse force Vy')

MinMz, MaxMz, ax = opsv.section_force_diagram_3d('Mz', sfacMz)
ax.set_axis_off()
plt.title('Bending moments Mz')
```

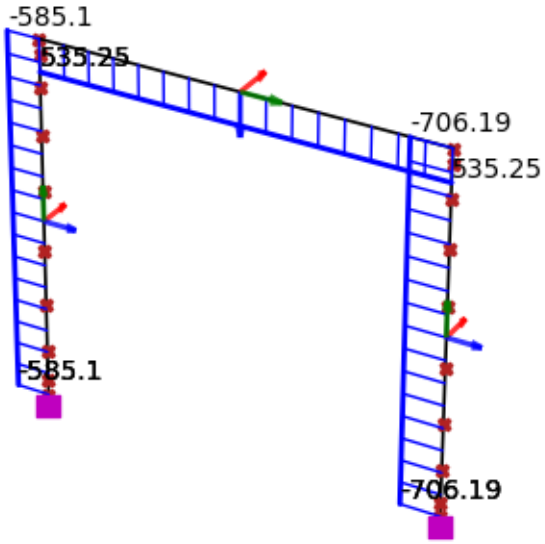
```
C:\Users\p003375J\AppData\Local\Programs\Python\Python312\Lib\site-
packages\opsvis\secforces.py:659: UserWarning: This figure was using a layout
engine that is incompatible with subplots_adjust and/or tight_layout; not
calling subplots_adjust.
  fig.subplots_adjust(left=0.08, bottom=0.08, right=0.985, top=0.94)
```

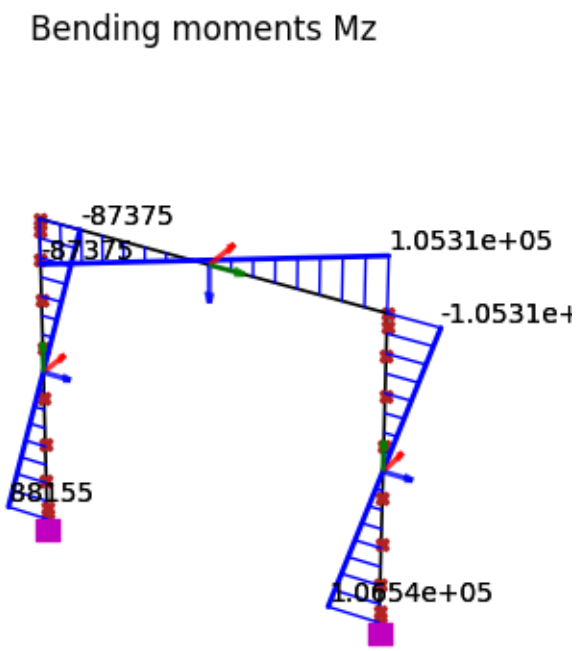
[25]: `Text(0.5, 0.92, 'Bending moments Mz')`

Axial force N



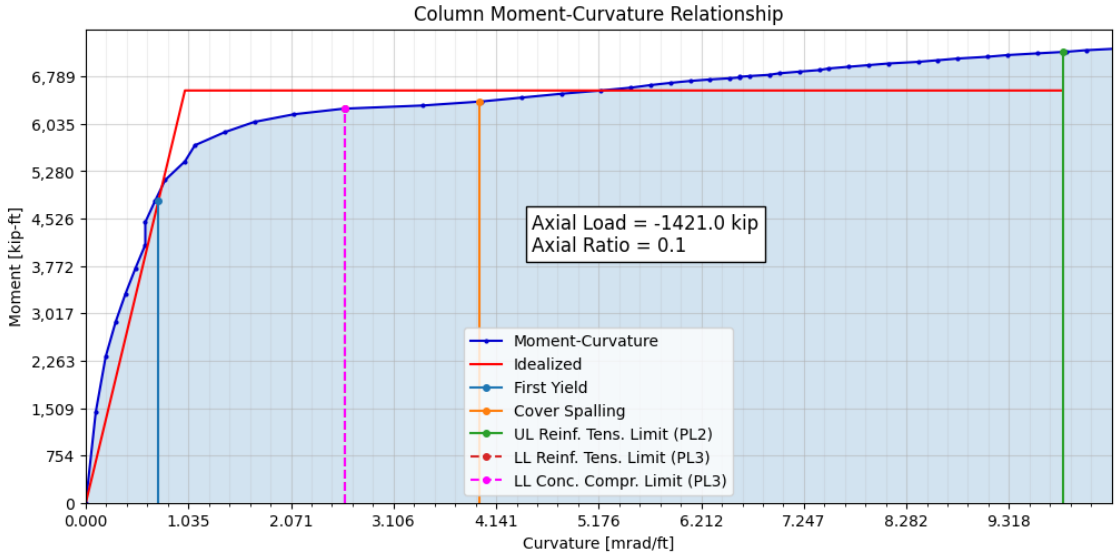
Transverse force Vy

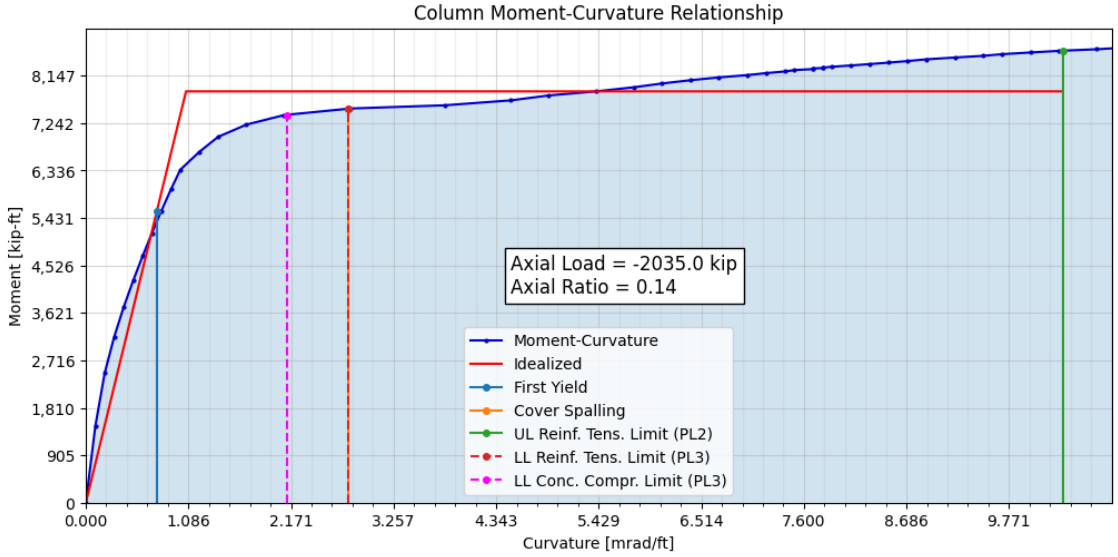




0.0.22 Moment-Curvature Plot

[26]:
```
for j in range(0, n_cols, 1):
    k = 0
    lab_x = 'Curvature [mrad/ft]'
    lab_y = 'Moment [kip-ft]'
    plot_title = 'Column Moment-Curvature Relationship'
    MC_plot(Ku[j, k], Mu[j, k], np.round(Kn[:, j, k]*1000,1), Mn[:, j, k],␣
 ↪lab_x, lab_y, plot_title,
                        K1y[j, k], Ksp[j, k], Kcu_UL[j, k], K_Rebc_UL[j, k],␣
 ↪K_Rebt_UL[j, k],
                        Kcu_LL[j, k], K_Rebt_LL[j, k], M1y[j, k], Msp[j, k],␣
 ↪Mcu_UL[j, k],
                        M_Rebc_UL[j, k], M_Rebt_UL[j, k], Mcu_LL[j, k],␣
 ↪M_Rebt_LL[j, k],
                        Ky[j, k], Ku[j, k], Mp[j, k], Pu[j, k], r_axial[j, k])
```





0.0.23 Pushover results - Element Forces

[27]:
```
print("----GLOBAL ELEM FORCES------")
print("    FX     FY     FZ     MX     MY     MZ")
print(np.round(ops.eleResponse(1, 'globalForce'), 1))
print(np.round(ops.eleResponse(2, 'globalForce'), 1))

print("----LOCAL ELEM FORCES------")
print("    Fx     Fy     Fz     Mx     My     Mz")
```

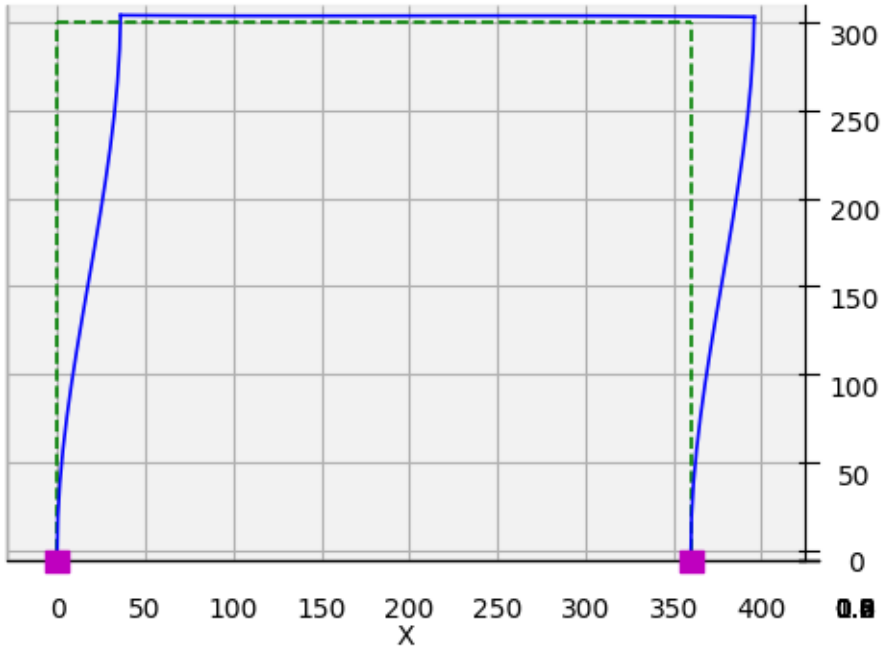
```
print(np.round(ops.eleResponse(1, 'localForce'), 1))
print(np.round(ops.eleResponse(2, 'localForce'), 1))

print("---REACTIONS NODES 1 & 2---------------")
ops.reactions()
print(np.round(ops.nodeReaction(1)))
print(np.round(ops.nodeReaction(2)))

print("-----UNBALANCE NODES 3 & 4-------------")
print(np.round(ops.nodeUnbalance(3)))
print(np.round(ops.nodeUnbalance(4)))
```

```
----GLOBAL ELEM FORCES------
    FX     FY     FZ     MX     MY     MZ
[  -568.7      0.     964.8     -0.  -88155.      -0.     568.7     -0.
   -964.8     -0.  -87375.5      0. ]
[   -671.6       0.     2035.2      -0.  -106543.9      -0.       671.6
      -0.    -2035.2       0.  -105313.3       0. ]
----LOCAL ELEM FORCES------
    Fx     Fy     Fz     Mx     My     Mz
[   964.8   -585.1      0.      -0.      -0.  -88155.    -964.8    585.1
     -0.       0.      -0.  -87375.5]
[   2035.2    -706.2      -0.       -0.       -0.  -106543.9   -2035.2
     706.2       0.        0.        0.  -105313.3]
---REACTIONS NODES 1 & 2---------------
[  -569.      0.    965.     -0. -88155.     -0.]
[   -672.       0.    2035.      -0. -106544.      -0.]
-----UNBALANCE NODES 3 & 4-------------
[  620.     0. -1500.     0.     0.     0.]
[  620.     0. -1500.     0.     0.     0.]
```

0.0.24 Pushover Deformed Shape

[28]:
```
opsv.plot_defo(unDefoFlag=1,
               fmt_defo={'color': 'blue', 'linestyle': 'solid', 'linewidth': 1.
 ↪2, 'marker': '', 'markersize': 1},
               fmt_undefo={'color': 'green', 'linestyle': 'dashed', 'linewidth':
 ↪ 1.2, 'marker': '', 'markersize': 1},
               fmt_defo_faces={'alpha': 0.5, 'edgecolors': 'k', 'linewidths':␣
 ↪1},
               fmt_undefo_faces={'alpha': 0.5, 'edgecolors': 'g', 'facecolors':␣
 ↪'w', 'linestyles': 'dotted', 'linewidths': 1},
               interpFlag=1, endDispFlag=0,
               fmt_nodes={'color': 'red', 'linestyle': 'None', 'linewidth': 1.
 ↪2, 'marker': 's', 'markersize': 6},
               Eo=0, az_el=(-90.0, 0.0), fig_wi_he=False, fig_lbrt=False,␣
 ↪node_supports=True, ax=False)
```

```
plt.savefig('pushover_deformed.png')
```

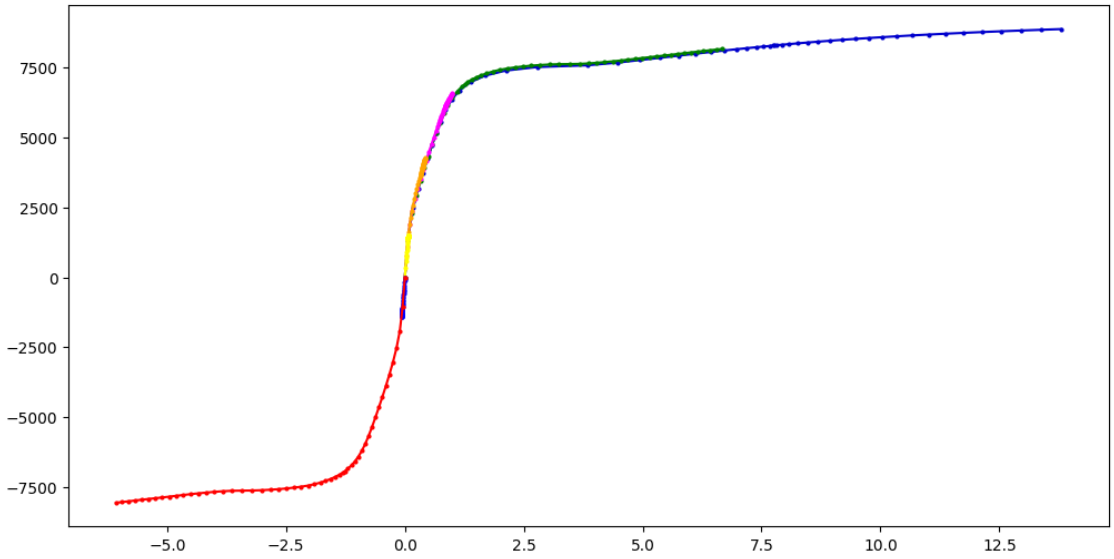


0.0.25 Moment - Curvature

[29]:
```
plt.plot(Kn[:, 1, 0]*1000, Mn[:, 1, 0], color = 'mediumblue', marker = 'o',␣
 ↪markersize=2)
plt.plot(Kn[:, 1, 1]*1000, Mn[:, 1, 1], color = 'green', marker = 'o',␣
 ↪markersize=2)
plt.plot(Kn[:, 1, 2]*1000, Mn[:, 1, 2], color = 'magenta', marker = 'o',␣
 ↪markersize=2)
plt.plot(Kn[:, 1, 3]*1000, Mn[:, 1, 3], color = 'orange', marker = 'o',␣
 ↪markersize=2)
plt.plot(Kn[:, 1, 4]*1000, Mn[:, 1, 4], color = 'yellow', marker = 'o',␣
 ↪markersize=2)
plt.plot(Kn[:, 1, 5]*1000, Mn[:, 1, 5], color = 'blue', marker = 'o',␣
 ↪markersize=2)
```

```
plt.plot(Kn[:, 1, n_gpnts - 2]*1000, Mn[:, 1, n_gpnts - 2], color = 'red',␣
 ↪marker = 'o', markersize=2)
```

[29]: [<matplotlib.lines.Line2D at 0x19e078cb410>]



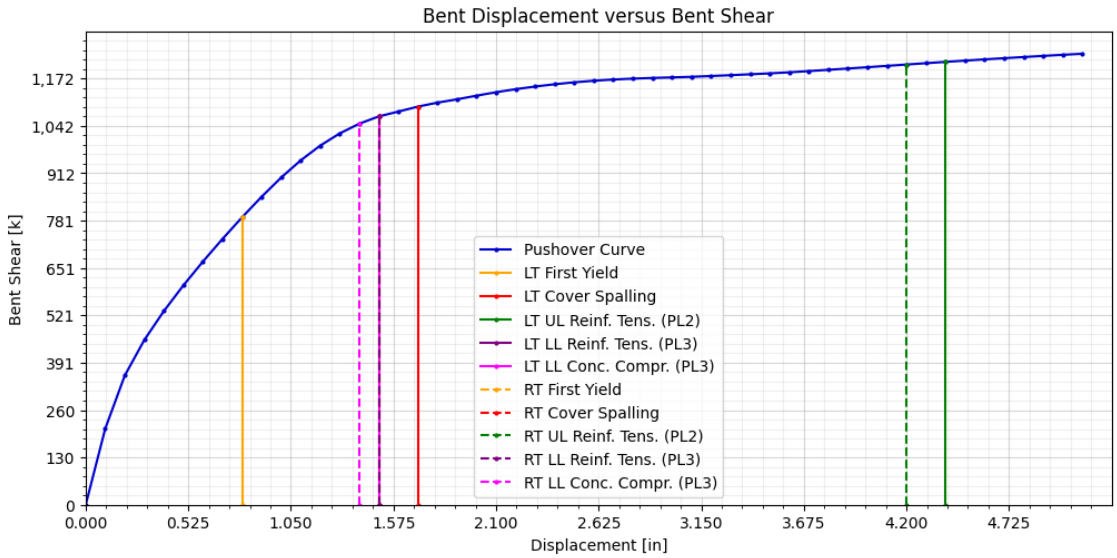
0.0.26 Pushover Curve

[30]:
```
# Opens a image in RGB mode
im = Image.open(r"pushover_deformed.png")

# Size of the image in pixels (size of original image)
# (This is not mandatory)
im_w, im_h = im.size

# Setting the points for cropped image
left = 0.25 * im_w
top = 0.20 * im_h
right = 0.85 * im_w
bottom = 0.85 * im_h

# Cropped image of above dimension
# (It will not change original image)
im_crop = im.crop((left, top, right, bottom))
```

[40]:
```
fig, ax = plt.subplots()

Vmax = 1.05*max(abs(V_base))
```

```
# Major ticks every 20, minor ticks every 5
major_xticks = np.arange(0, 1.05*maxU, 1.05*maxU/10)
minor_xticks = np.arange(0, 1.05*maxU, 1.05*maxU/50)
major_yticks = np.arange(0, Vmax, Vmax/10)
minor_yticks = np.arange(0, Vmax, Vmax/50)

ax.set_xticks(major_xticks)
ax.set_xticks(minor_xticks, minor=True)
ax.set_yticks(major_yticks)
ax.set_yticks(minor_yticks, minor=True)

ax.grid(which='both')
ax.grid(which='minor', alpha=0.2)
ax.grid(which='major', alpha=0.5)
#   ax.fill_between(curvature, moment, alpha = 0.2)

plt.xlim(0, 1.05*maxU)
plt.ylim(0, Vmax)
plt.plot(ndisp, abs(V_base), color = 'mediumblue', marker = 'o', markersize=2)

j = 0
k = 0
plt.plot([d1y[j, k], d1y[j, k]], [0, abs(V1y[j, k])], color = 'orange', marker␣
 ↪= 'o', markersize=2)
plt.plot([dsp[j, k], dsp[j, k]], [0, abs(Vsp[j, k])], color = 'red', marker =␣
 ↪'o', markersize=2)
#plt.plot([d_Rebc_UL[j, k], d_Rebc_UL[j, k]], [0, abs(V_Rebc_UL[j, k])], color␣
 ↪= 'mediumblue', marker = 'o', markersize=2)
plt.plot([d_Rebt_UL[j, k], d_Rebt_UL[j, k]], [0, abs(V_Rebt_UL[j, k])], color =␣
 ↪'green', marker = 'o', markersize=2)
plt.plot([d_Rebt_LL[j, k], d_Rebt_LL[j, k]], [0, abs(V_Rebt_LL[j, k])], color =␣
 ↪'purple', marker = 'o', markersize=2)
plt.plot([dcu_LL[j, k], dcu_LL[j, k]], [0, abs(Vcu_LL[j, k])], color =␣
 ↪'magenta', marker = 'o', markersize=2)

j = 1
k = 0
plt.plot([d1y[j, k], d1y[j, k]], [0, abs(V1y[j, k])], color = 'orange', marker␣
 ↪= 'o', linestyle='dashed', markersize=2)
plt.plot([dsp[j, k], dsp[j, k]], [0, abs(Vsp[j, k])], color = 'red', marker =␣
 ↪'o', linestyle='dashed', markersize=2)
#plt.plot([d_Rebc_UL[j, k], d_Rebc_UL[j, k]], [0, abs(V_Rebc_UL[j, k])], color␣
 ↪= 'mediumblue', marker = 'o', markersize=2)
plt.plot([d_Rebt_UL[j, k], d_Rebt_UL[j, k]], [0, abs(V_Rebt_UL[j, k])],␣
 ↪linestyle='dashed', color = 'green', marker = 'o', markersize=2)
```

```
plt.plot([d_Rebt_LL[j, k], d_Rebt_LL[j, k]], [0, abs(V_Rebt_LL[j, k])],␣
 ↪linestyle='dashed', color = 'purple', marker = 'o', markersize=2)
plt.plot([dcu_LL[j, k], dcu_LL[j, k]], [0, abs(Vcu_LL[j, k])], color =␣
 ↪'magenta', linestyle='dashed', marker = 'o', markersize=2)

plt.legend(["Pushover Curve", "LT First Yield", "LT Cover Spalling",
            "LT UL Reinf. Tens. (PL2)", "LT LL Reinf. Tens. (PL3)",
            "LT LL Conc. Compr. (PL3)",
            "RT First Yield", "RT Cover Spalling",
            "RT UL Reinf. Tens. (PL2)", "RT LL Reinf. Tens. (PL3)",
            "RT LL Conc. Compr. (PL3)"], loc='lower center')


plt.xlabel("Displacement [in]")
plt.ylabel("Bent Shear [k]")
plt.title("Bent Displacement versus Bent Shear")
current_values = plt.gca().get_yticks()
plt.gca().set_yticklabels(['{:,.0f}'.format(x) for x in current_values])

# Define the position and size parameters
"""image_xaxis = 2.1
image_yaxis = 500
image_width = 4.2
image_height = 500

# Define the position for the image axes
ax_image = fig.add_axes( [image_xaxis,
                          image_yaxis,
                          image_width,
                          image_height] )

# Display the image
ax_image.imshow(im_crop)
ax_image.axis('off')  # Remove axis of the image"""

plt.show()
```



0.0.27 Pushover results - Node status

[32]:
```
ops.printModel("node", 3)
ops.printModel("node", 4)
ops.printModel("-ele", 1)
ops.printModel("-ele", 2)
ops.printModel("-ele", 3)
```

```
 Node: 3
        Coordinates  : 0 0 300
        Disps: 5.1 4.7827e-17 0.565352 3.06643e-19 0.00111274 3.17258e-19
         unbalanced Load: 620.149 0 -1500 0 0 0
         reaction: 1.53975e-11 -2.06925e-14 -5.91172e-12 -4.39935e-12
-5.82077e-11 -1.05037e-26
        Mass :
200 0 0 0 0 0
0 200 0 0 0 0
0 0 200 0 0 0
0 0 0 0.001 0 0
0 0 0 0 0.001 0
0 0 0 0 0 0.001

         Rayleigh Factor: alphaM: 0
         Rayleigh Forces: 0 0 0 0 0 0
         Eigenvectors:
-6.93889e-18 -9.71445e-17 -0.0499916 2.08167e-17 -0.000916419 -0.05
0.05 -0.05 6.89896e-17 -2.00949e-19 -4.01571e-18 9.48837e-19
0 -6.50521e-18 -0.000916419 -0.05 0.0499916 -9.06482e-18
```

```
-0.00025 0.00012265 -1.2711e-19 -5.40657e-20 -1.09528e-19 6.09202e-20
0 -2.03288e-19 -8.0603e-05 -6.17995e-18 0.000190672 -0.000143054
-4.06576e-20 0.000277771 -5.14006e-19 7.10486e-19 1.49478e-18 -5.9474e-19

        ID : 6 7 8 9 10 11


 Node: 4
        Coordinates  : 360 0 300
        Disps: 5.09901 1.62043e-16 0.430995 3.34111e-19 0.00168586 3.17258e-19
         unbalanced Load: 620.149 0 -1500 0 0 0
         reaction: -1.46017e-11 -6.23285e-16 -9.09495e-12 9.46105e-13
-1.01863e-10 -1.05037e-26
        Mass :
200 0 0 0 0 0
0 200 0 0 0 0
0 0 200 0 0 0
0 0 0 0.001 0 0
0 0 0 0 0.001 0
0 0 0 0 0 0.001

         Rayleigh Factor: alphaM: 0
         Rayleigh Forces: 0 0 0 0 0 0
         Eigenvectors:
-6.93889e-18 -8.32667e-17 -0.0499916 4.68375e-17 -0.000916419 0.05
0.05 0.05 -1.02738e-16 -2.68283e-19 1.14323e-18 2.21328e-18
4.33681e-19 7.80626e-18 0.000916419 -0.05 -0.0499916 3.68204e-17
-0.00025 -0.00012265 1.8793e-19 -5.09169e-19 -1.06383e-18 4.33625e-19
-1.35525e-20 -1.6263e-19 -8.0603e-05 -6.23416e-18 0.000190672 0.000143054
-3.38813e-20 0.000277771 -4.74546e-19 7.0316e-20 1.60251e-19 -4.43865e-20

        ID : 0 1 2 3 4 5


Element: 1 Type: ForceBeamColumn3d      Connected Nodes: 1 3
        Number of Sections: 10  Mass density: 0
Lobatto
        End 1 Forces (P MZ VY MY VZ T): 964.753 -88155 -585.102 -2.35752e-12
2.05328e-14 1.05753e-15
        End 2 Forces (P MZ VY MY VZ T): -964.753 -87375.5 585.102 -3.80233e-12
-2.05328e-14 -1.05753e-15

Element: 2 Type: ForceBeamColumn3d      Connected Nodes: 2 4
        Number of Sections: 10  Mass density: 0
Lobatto
        End 1 Forces (P MZ VY MY VZ T): 2035.25 -106544 -706.191 -2.08031e-13
-4.70162e-16 1.05753e-15
        End 2 Forces (P MZ VY MY VZ T): -2035.25 -105313 706.191 3.4908e-13
```

```
4.70162e-16 -1.05753e-15

ElasticBeam3d: 3
        Connected Nodes: 3 4
        CoordTransf: 2
        mass density:  0, cMass: 0
        release about z:  0
        release about y:  0
        End 1 Forces (P Mz Vy My Vz T): 51.4487 87375.5 535.247 1.05753e-15
-5.87514e-18 -5.97026e-13
        End 2 Forces (P Mz Vy My Vz T): -51.4487 105313 -535.247 1.05753e-15
5.87514e-18 5.97026e-13
```

[33]:
```
ops.wipe()
```