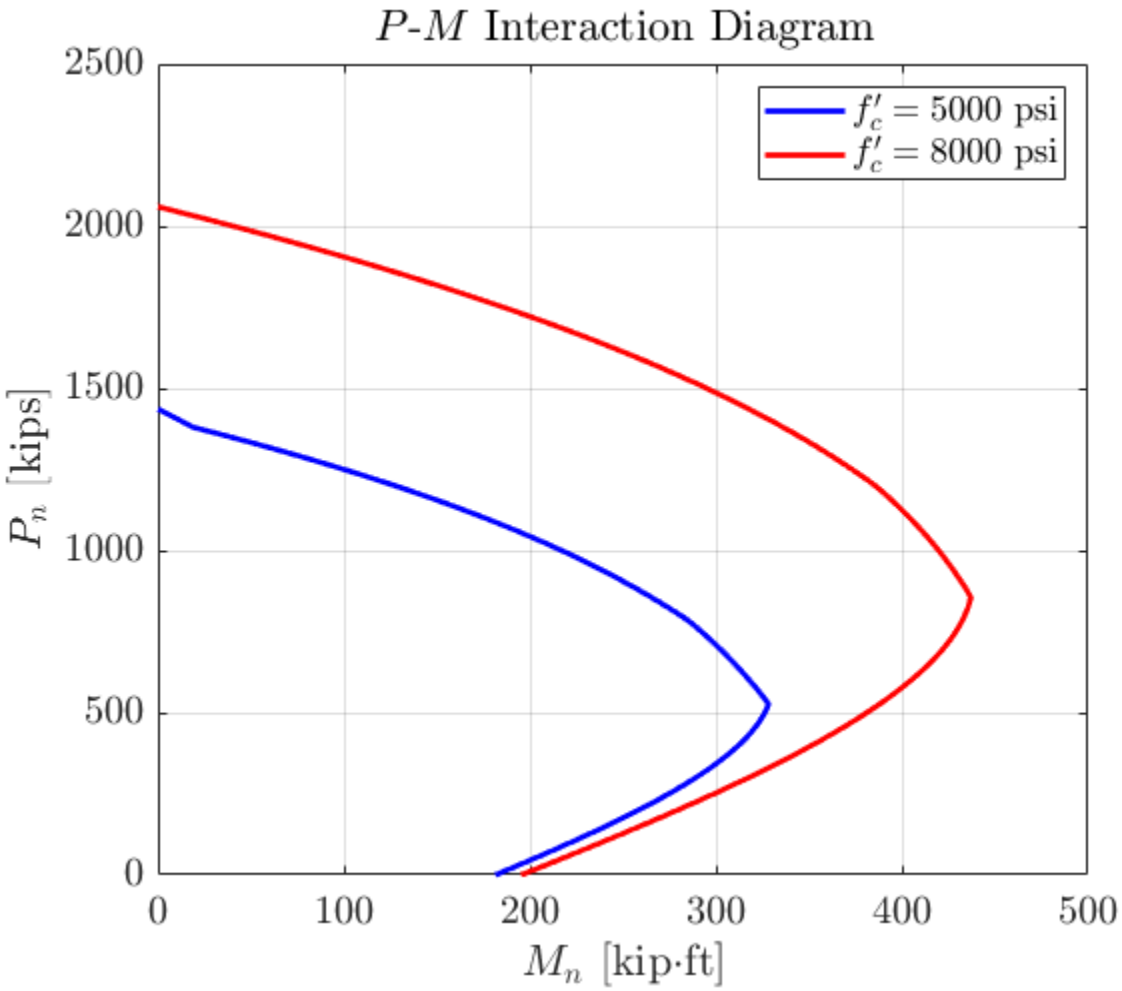
9.1. A 16 in. square column is reinforced with four No. 11 (No. 36) bars, one in each corner, with cover distances 3 in. to the steel center in each direction. Material strengths are $f_c' = 5000$ psi and $f_y = 60{,}000$ psi. Construct the interaction diagram relating axial strength P_n and flexural strength M_n. Bending will be about an axis parallel to one face. Calculate the coordinates for P_o, P_b, and at least three other representative points on the curve.

9.2. Starting with the column in Problem 9.1, perform enough additional calculations to determine the effects of increasing f'_c from 5000 to 8000 psi on column capacity at both high and low axial loads. Assuming that a compressive strength of 8000 psi is appropriate for the lower stories of a high-rise structure, would you recommend using concrete with $f'_c = 8000$ psi for the columns supporting all stories within the building? Use your analysis to support your answer.

```
% RC Columns P-M Diagram.
% Solution Code for SE151A_WI25_HW8.
% Author: Ruipu Ji.

% Initialization and default plot settings. ------------------------------
clc; clear; close all;

set(0, 'DefaultTextInterpreter', 'latex');
set(0, 'DefaultLegendInterpreter', 'latex');
set(0, 'DefaultAxesTickLabelInterpreter', 'latex');

set(0, 'DefaultAxesFontSize', 15);
set(0, 'DefaultTextFontSize', 15);

% Enter input information. -----------------------------------------------
% Section dimension.
b = 16; % Section width (unit = inch).
h = 16; % Section height (unit = inch).

% Material properties.
fc_1 = 5; % Concrete compressive strength for Problem 1 (unit = ksi).
fc_2 = 8; % Concrete compressive strength for Problem 2 (unit = ksi).
beta_1 = 0.85 - 0.05*(fc_1-4000)/1000;
beta_2 = 0.85 - 0.05*(fc_2-4000)/1000;

fy = 60; % Steel reinforcement yield strength (unit = ksi).
Es = 29000; % Elastic modulus of steel reinforcement (unit = ksi).
eps_cu = -0.003; % Strain of the most compressive fiber at the peak capacity.

% Reinforcement layout.
d = [3 3 13 13]; % Distance between the center of each reinforcement and the
top of the section (unit = inch).
As = [1.56 1.56 1.56 1.56]; % Area of each reinforcement (unit = inch^2).

% Calculate P-M interaction. ---------------------------------------------
% Initialize an 101x9 array for result output.
% (100 rows for P-M interaction and the last row for pure axial load P0).
Results = zeros(101, 9);

for i = 1:100
    % Calculate the neutral axis distance c.
    c = 0.01*i*h;

    % Calculate strain of each reinforcement based on strain profile.
    % Sign convention: Compression is negative (-); Tension is positive (+).
    eps_s = eps_cu*(c-d)/c;

    % Calculate stress of each reinforcement based on stress-strain
relationship.
    % Sign convention: Compression is negative (-); Tension is positive (+).
    fs = Es*eps_s;
    fs = max(min(fs, fy), -fy); % Limit stress values between -fy and fy.
```

```
    % Calculate the axial load capacity Pn (unit = kips).
    % Sign convention: Compression is positive (+); Tension is negative (-).
    Pn_1 = 0.85*fc_1*b*beta_1*c - sum(As.*fs); % Pn for fc = 5 ksi.
    Pn_2 = 0.85*fc_2*b*beta_2*c - sum(As.*fs); % Pn for fc = 8 ksi.

    % Calculate the moment capacity Mn (unit = kip*ft).
    Mn_1 = (0.85*fc_1*b*beta_1*c*(h/2-beta_1*c/2) - sum(As.*fs.*(h/2-d))) /
12; % Mn for fc = 5 ksi.
    Mn_2 = (0.85*fc_2*b*beta_2*c*(h/2-beta_2*c/2) - sum(As.*fs.*(h/2-d))) /
12; % Mn for fc = 8 ksi.

    % Result output.
    Results(i,:) = [c, eps_s(1), fs(1), eps_s(end), fs(end), Pn_1, Mn_1,
Pn_2, Mn_2];
end

% Caclulate P0 (pure axial load capacity). ------------------------------
Ag = b*h; % Gross cross section area.
Ast = sum(As); % Total area of all the steel reinforcement.

% Calculate P0.
P0_1 = 0.85*fc_1*(Ag-Ast) + Ast*fy; % P0 for fc = 5 ksi.
P0_2 = 0.85*fc_2*(Ag-Ast) + Ast*fy; % P0 for fc = 8 ksi.

% Result output.
Results(end,:) = [0, -fy/Es, -fy, -fy/Es, -fy, P0_1, 0, P0_2, 0];

% Plot P-M interaction diagram. -----------------------------------------
Results = array2table(Results, 'VariableNames', {'c [inch]', 'Epsilon''',
'fs'' [ksi]', 'Epsilon', 'fs [ksi]', 'Pn_1 [kips]', 'Mn_1 [kip*ft]', 'Pn_2
[kips]', 'Mn_2 [kip*ft]'});

figure('Position', [0, 0, 600, 500]);
hold on;

plot(Results{:,7}, Results{:,6}, 'Color', 'b', 'LineWidth', 2);
plot(Results{:,9}, Results{:,8}, 'Color', 'r', 'LineWidth', 2);
grid on;
box on;
xlim([0 500]);
xticks(0:100:500);
ylim([0 2500]);
yticks(0:500:2500);
xlabel('$M_n$ [kip$\cdot$ft]');
ylabel('$P_n$ [kips]');
legend('$f''_c = 5000$ psi', '$f''_c = 8000$ psi', 'Location', 'northeast');
title('$P$-$M$ Interaction Diagram');
```



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Summarized Calculation Results:

c [inch]	ε'_s	f'_s [ksi]	ε_s	f_s [ksi]	f'_c = 5000 psi		f'_c = 8000 psi		Note	Controlled Category
					P_n [kips]	M_n [kip*ft]	P_n [kips]	M_n [kip*ft]		
0.16	0.0533	60.00	0.2408	60.00	-362.98	7.53	-356.13	12.05		
0.32	0.0251	60.00	0.1189	60.00	-351.56	14.91	-337.86	23.85		
0.48	0.0158	60.00	0.0783	60.00	-340.14	22.12	-319.59	35.39		
0.64	0.0111	60.00	0.0579	60.00	-328.71	29.18	-301.31	46.68		
0.80	0.0083	60.00	0.0458	60.00	-317.29	36.07	-283.04	57.71		
0.96	0.0064	60.00	0.0376	60.00	-305.87	42.81	-264.77	68.48		
1.12	0.0050	60.00	0.0318	60.00	-294.45	49.38	-246.50	79.00		
1.28	0.0040	60.00	0.0275	60.00	-283.03	55.80	-228.23	89.27		
1.44	0.0033	60.00	0.0241	60.00	-271.61	62.05	-209.96	99.27		
1.60	0.0026	60.00	0.0214	60.00	-260.19	68.15	-191.69	109.02		
1.76	0.0021	60.00	0.0192	60.00	-248.77	74.08	-173.41	118.52		
1.92	0.0017	48.94	0.0173	60.00	-202.83	94.24	-120.63	142.14		
2.08	0.0013	38.48	0.0158	60.00	-158.78	113.45	-69.73	164.72		
2.24	0.0010	29.52	0.0144	60.00	-119.40	130.56	**-23.50**	**185.10**	**M_0 = 195.36 kip*ft**	
2.40	0.0008	21.75	0.0133	60.00	-83.74	145.95	**19.01**	**203.67**	**(f'_c = 8000 psi)**	
2.56	0.0005	14.95	0.0122	60.00	-51.11	159.93	58.49	220.73		**Tension Controlled**
2.72	0.0003	8.96	0.0113	60.00	**-20.98**	**172.70**	95.47	236.48	**M_0 = 181.49 kip*ft**	
2.88	0.0001	3.63	0.0105	60.00	**7.07**	**184.45**	130.38	251.12	**(f'_c = 5000 psi)**	
3.04	0.0000	-1.14	0.0098	60.00	33.38	195.30	163.53	264.77		
3.20	-0.0002	-5.44	0.0092	60.00	58.19	205.38	195.19	277.55		
3.36	-0.0003	-9.32	0.0086	60.00	81.73	214.77	225.58	289.54		
3.52	-0.0004	-12.85	0.0081	60.00	104.17	223.53	254.87	300.81		
3.68	-0.0006	-16.08	0.0076	60.00	125.65	231.74	283.20	311.43		
3.84	-0.0007	-19.03	0.0072	60.00	146.29	239.44	310.69	321.44		
4.00	-0.0008	-21.75	0.0068	60.00	166.19	246.67	337.45	330.89		
4.16	-0.0008	-24.26	0.0064	60.00	185.44	253.47	363.55	339.81		
4.32	-0.0009	-26.58	0.0060	60.00	204.11	259.87	389.07	348.24		
4.48	-0.0010	-28.74	0.0057	60.00	222.27	265.90	414.07	356.19		
4.64	-0.0011	-30.75	0.0054	60.00	239.96	271.57	438.61	363.70		
4.80	**-0.0011**	**-32.63**	**0.0051**	**60.00**	**257.23**	**276.90**	**462.73**	**370.78**	**$\varepsilon_s = \varepsilon_y + 0.003$**	
4.96	-0.0012	-34.38	0.0049	60.00	274.12	281.92	486.48	377.44		
5.12	-0.0012	-36.02	0.0046	60.00	290.67	286.64	509.88	383.70		
5.28	-0.0013	-37.57	0.0044	60.00	306.91	291.06	532.97	389.58		
5.44	-0.0013	-39.02	0.0042	60.00	322.87	295.21	555.78	395.09		
5.60	-0.0014	-40.39	0.0040	60.00	338.57	299.09	578.33	400.23		
5.76	-0.0014	-41.69	0.0038	60.00	354.03	302.72	600.64	405.01		
5.92	-0.0015	-42.91	0.0036	60.00	369.27	306.09	622.73	409.45		
6.08	-0.0015	-44.07	0.0034	60.00	384.31	309.21	644.62	413.55		
6.24	-0.0016	-45.17	0.0033	60.00	399.17	312.10	666.33	417.32		**Transition**
6.40	-0.0016	-46.22	0.0031	60.00	413.85	314.76	687.86	420.76		
6.56	-0.0016	-47.21	0.0029	60.00	428.38	317.20	709.23	423.88		
6.72	-0.0017	-48.16	0.0028	60.00	442.76	319.41	730.46	426.68		
6.88	-0.0017	-49.06	0.0027	60.00	456.99	321.40	751.55	429.17		
7.04	-0.0017	-49.93	0.0025	60.00	471.11	323.18	772.51	431.35		
7.20	-0.0018	-50.75	0.0024	60.00	485.10	324.76	793.35	433.22		
7.36	-0.0018	-51.54	0.0023	60.00	498.98	326.12	814.08	434.79		
7.52	-0.0018	-52.29	0.0022	60.00	512.75	327.28	834.71	436.06		
7.68	**-0.0018**	**-53.02**	**0.0021**	**60.00**	**526.43**	**328.24**	**855.24**	**437.04**	**$\varepsilon_s = \varepsilon_y$**	**Balanced Strain**

c [inch]	ε'_s	f'_s [ksi]	ε_s	f_s [ksi]	f'_c = 5000 psi		f'_c = 8000 psi		Note	Controlled Category
					P_n [kips]	M_n [kip*ft]	P_n [kips]	M_n [kip*ft]		
7.84	-0.0019	-53.71	0.0020	57.26	548.56	325.44	884.22	434.16		
8.00	-0.0019	-54.38	0.0019	54.38	571.06	322.26	913.57	430.79		
8.16	-0.0019	-55.01	0.0018	51.60	593.13	319.03	942.49	427.29		
8.32	-0.0019	-55.63	0.0017	48.94	614.79	315.74	970.99	423.64		
8.48	-0.0019	-56.22	0.0016	46.37	636.06	312.40	999.12	419.83		
8.64	-0.0020	-56.79	0.0015	43.90	656.96	308.99	1026.87	415.86		
8.80	-0.0020	-57.34	0.0014	41.52	677.52	305.51	1054.28	411.73		
8.96	-0.0020	-57.87	0.0014	39.23	697.76	301.96	1081.37	407.42		
9.12	-0.0020	-58.38	0.0013	37.01	717.68	298.33	1108.14	402.94		
9.28	-0.0020	-58.88	0.0012	34.88	737.31	294.61	1134.62	398.28		
9.44	-0.0020	-59.35	0.0011	32.81	756.67	290.81	1160.83	393.44		
9.60	-0.0021	-59.81	0.0011	30.81	775.76	286.92	1186.77	388.41		
9.76	-0.0021	-60.00	0.0010	28.88	793.79	282.59	1211.65	382.85		
9.92	-0.0021	-60.00	0.0009	27.01	811.04	277.94	1235.75	376.87		
10.08	-0.0021	-60.00	0.0009	25.20	828.11	273.21	1259.67	370.72		
10.24	-0.0021	-60.00	0.0008	23.45	845.00	268.40	1283.41	364.39		
10.40	-0.0021	-60.00	0.0008	21.75	861.72	263.49	1306.98	357.87		
10.56	-0.0021	-60.00	0.0007	20.10	878.29	258.49	1330.40	351.16		
10.72	-0.0022	-60.00	0.0006	18.50	894.69	253.40	1353.65	344.25		
10.88	-0.0022	-60.00	0.0006	16.95	910.96	248.21	1376.77	337.16		
11.04	-0.0022	-60.00	0.0005	15.45	927.08	242.91	1399.74	329.87		
11.20	-0.0022	-60.00	0.0005	13.98	943.07	237.51	1422.58	322.37		
11.36	-0.0022	-60.00	0.0004	12.56	958.92	232.01	1445.29	314.68		
11.52	-0.0022	-60.00	0.0004	11.18	974.66	226.39	1467.87	306.78		
11.68	-0.0022	-60.00	0.0003	9.83	990.28	220.67	1490.34	298.67		
11.84	-0.0022	-60.00	0.0003	8.52	1005.78	214.83	1512.69	290.36		
12.00	-0.0023	-60.00	0.0003	7.25	1021.18	208.88	1534.94	281.83		Compression Controlled
12.16	-0.0023	-60.00	0.0002	6.01	1036.47	202.82	1557.08	273.10		
12.32	-0.0023	-60.00	0.0002	4.80	1051.66	196.63	1579.12	264.15		
12.48	-0.0023	-60.00	0.0001	3.63	1066.75	190.33	1601.06	254.98		
12.64	-0.0023	-60.00	0.0001	2.48	1081.75	183.90	1622.91	245.60		
12.80	-0.0023	-60.00	0.0000	1.36	1096.66	177.35	1644.67	236.00		
12.96	-0.0023	-60.00	0.0000	0.27	1111.49	170.68	1666.35	226.17		
13.12	-0.0023	-60.00	0.0000	-0.80	1126.23	163.88	1687.94	216.13		
13.28	-0.0023	-60.00	-0.0001	-1.83	1140.89	156.96	1709.45	205.87		
13.44	-0.0023	-60.00	-0.0001	-2.85	1155.47	149.90	1730.89	195.38		
13.60	-0.0023	-60.00	-0.0001	-3.84	1169.98	142.72	1752.25	184.67		
13.76	-0.0023	-60.00	-0.0002	-4.81	1184.42	135.41	1773.54	173.73		
13.92	-0.0024	-60.00	-0.0002	-5.75	1198.79	127.97	1794.76	162.56		
14.08	-0.0024	-60.00	-0.0002	-6.67	1213.09	120.40	1815.91	151.17		
14.24	-0.0024	-60.00	-0.0003	-7.58	1227.33	112.69	1836.99	139.55		
14.40	-0.0024	-60.00	-0.0003	-8.46	1241.51	104.85	1858.02	127.69		
14.56	-0.0024	-60.00	-0.0003	-9.32	1255.62	96.87	1878.98	115.61		
14.72	-0.0024	-60.00	-0.0004	-10.17	1269.67	88.76	1899.89	103.30		
14.88	-0.0024	-60.00	-0.0004	-10.99	1283.67	80.52	1920.74	90.75		
15.04	-0.0024	-60.00	-0.0004	-11.80	1297.62	72.13	1941.53	77.97		
15.20	-0.0024	-60.00	-0.0004	-12.59	1311.51	63.61	1962.27	64.96		
15.36	-0.0024	-60.00	-0.0005	-13.37	1325.35	54.95	1982.96	51.72		
15.52	-0.0024	-60.00	-0.0005	-14.13	1339.14	46.15	2003.60	38.24		
15.68	-0.0024	-60.00	-0.0005	-14.87	1352.88	37.21	2024.19	24.52		
15.84	-0.0024	-60.00	-0.0005	-15.60	1366.57	28.13	2044.74	10.57		
16.00	**-0.0024**	**-60.00**	**-0.0006**	**-16.31**	**1380.22**	**18.91**	**2065.24**	**-3.62**	**c = h (Last point that stress block assumption holds)**	
c > h	**-0.0021**	**-60.00**	**-0.0021**	**-60.00**	**1435.88**	**0.00**	**2072.77**	**0.00**	**P_0 (Pure Comperession)**	