```
%% Define Constitutive Properties
% Steel01
% uniaxialMaterial Steel01 matTag Fy E0 b a1 a2 a3 a4
Fy = 455.0;
E = 215000;
b = 0.01;
matDef_Steel01 = join(["uniaxialMaterial Steel01 1",Fy, E, b],' ');

% Steel02
% uniaxialMaterial Steel02 matTag Fy E b RO cR1 cR2 a1 a2 a3 a4
Fy = 455.0;
E = 215000;
b = 0.01;
ROm = 20.0;
cR1 = 0.925;
cR2 = 0.15;
a1 = 0;
a2 = 1;
a3 = 0;
a4 = 1;
matDef_Steel02 = join(["uniaxialMaterial Steel02 1",Fy, E, b, ROm cR1, cR2, a1, a2, a3, a4],' ');

% Concrete01 Cover
% uniaxialMaterial Concrete01 matTag fpc epsc0 fpcu epsU
fpc = -32.5;
epsc0 = -0.0024074074;
fpcu = -6.5;
epsU = -0.004;
matDef_Concrete01_Cover = join(["uniaxialMaterial Concrete01 1",fpc, epsc0, fpcu, epsU],' ');

% Concrete01
% uniaxialMaterial Concrete01 matTag fpc epsc0 fpcu epsU
fpc = -47.9;
epsc0 = -0.003548148;
fpcu = -40.715;
epsU = -0.0276;
matDef_Concrete01_Core = join(["uniaxialMaterial Concrete01 1",fpc, epsc0, fpcu, epsU],' ');

% Concrete02
% uniaxialMaterial Concrete02 matTag fpc epsc0 fpcu epsU lambda ft Ets
fpc = -32.5;
epsc0 = -0.0024074074;
fpcu = -6.5;
epsU = -0.004;
lambda = 0.25;
ft = 1.9;
Ets = 2700.0;
matDef_Concrete02_Cover = join(["uniaxialMaterial Concrete02 1",fpc, epsc0, fpcu, epsU, lambda, ft, Ets],' ');

% Concrete02
% uniaxialMaterial Concrete02 matTag fpc epsc0 fpcu epsU lambda ft Ets
fpc = -47.9;
epsc0 = -0.003548148;
fpcu = -40.715;
epsU = -0.0276;
lambda = 0.25;
ft = 1.9;
```

```
Ets = 2700.0;
matDef_Concrete02_Core = join(["uniaxialMaterial Concrete02 1",fpc, epsc0, fpcu, epsU, lambda, ft, Ets],' ');
%%
close all; clc;
localOpenSeesPath = "C:\Users\Louis Lin\Workspace\Academic\UCSD\SE 201B\Opensees\bin\OpenSees.exe";
i = 1;
numIncr = 1000;
%%  Steel
Steel_strain_history = [0, 0.002, -0.002, -0.01, 0.01,-0.02,0.02,-0.03,0.03,-0.04,0.04,-0.05,0.05,-0.06,0];

close all;
for matDef = [matDef_Steel01, matDef_Steel02]
    inputData = Steel_strain_history;
    figure(3); hold on;
    inputs = strsplit(matDef);
    out = get_materialHysteresis(matDef, inputData, numIncr, localOpenSeesPath);
    plot(out(:,1), out(:,2), 'linewidth', 1.5,'DisplayName',inputs(2)); grid on;
    xline(0,"HandleVisibility",'off'); yline(0,"HandleVisibility",'off');
    title("Material Hysteresis for Steel Reinforcement");
    ylabel('Stress [MPa]'); xlabel('Strain [-]'); legend('Location','southeast');
    xlim([-0.07, 0.07]);
end
set(gca,'FontSize',14);
ax2 = axes('Position',[.2 .8 .1 .1],'FontSize',14);
plot(Steel_strain_history); xline(0); yline(0);
title('Strain History'); box on; grid minor;
xticks('');
print_figure("Part A Steel ", [13,5], 14)
%% Cover
Cover_Concrete_strain_history = [0, 0.002, -0.002, -0.003, 0.003,-0.004,0.004,-0.005,0.005,-0.006,0.006,-0.007,0.007,0];
close all;
for matDef = [ matDef_Concrete01_Cover, matDef_Concrete02_Cover]
    inputData = Cover_Concrete_strain_history;
    figure(3); hold on;
    inputs = strsplit(matDef);
    out = get_materialHysteresis(matDef, inputData, numIncr, localOpenSeesPath);
    plot(out(:,1), out(:,2), 'linewidth', 1.5,'DisplayName',inputs(2)); grid on;
    xline(0,"HandleVisibility",'off'); yline(0,"HandleVisibility",'off');
    title("Material Hysteresis for Cover Concrete");
    ylabel('Stress [MPa]'); xlabel('Strain [-]'); legend('Location','southeast');
    xlim([-0.008, 0.001]);
end
set(gca,'FontSize',14);
ax2 = axes('Position',[.2 .2 .1 .1],'FontSize',14);
plot(Cover_Concrete_strain_history); xline(0); yline(0);
title('Strain History'); box on; grid minor;
xticks('');
print_figure("Part A Cover Concrete ", [13, 5], 14)

%% CORE
Core_Concrete_strain_history = [0,0.002, -0.002, 0.005,-0.005, 0.01, -0.01, 0.02, -0.02,0.03,-0.03, 0.04,-0.04, 0];
close all;
for matDef = [ matDef_Concrete01_Core, matDef_Concrete02_Core]
    inputData = Core_Concrete_strain_history;
    figure(3); hold on;
    out = get_materialHysteresis(matDef, inputData, numIncr, localOpenSeesPath);
    inputs = strsplit(matDef);
```

```
115     plot(out(:,1), out(:,2), 'linewidth', 1.5,'DisplayName',inputs(2)); grid on;
116     xline(0,"HandleVisibility",'off'); yline(0,"HandleVisibility",'off');
117      title("Material Hysteresis for Core Concrete");
118     ylabel('Stress [MPa]'); xlabel('Strain [-]'); legend('Location','southeast');
119     xlim([-0.05, 0.01]);
120 end
121 set(gca,'FontSize',14);
122 ax2 = axes('Position',[.17 .6 .1 .1],'FontSize',14);
123 plot(Core_Concrete_strain_history); xline(0); yline(0);
124 title('Strain History'); box on; grid minor;
125 xticks('');
126 print_figure("Part A Core Concrete ", [13, 5], 14)
127
128 %%
129 close all;
130 figure();hold on;
131 set(gca,'DefaultLineLineWidth',2)
132 plot(Steel_strain_history)
133 plot(Cover_Concrete_strain_history)
134 plot(Core_Concrete_strain_history)
135 legend('Steel','Cover Concrete','Core Concrete','Location','Southwest')
136 grid on; grid minor;
137 xticks('')
138 ylabel('Strain [-]')
139 title('Strain History for Material Hysteris')
140 print_figure("Part A Strain History", [13, 5], 14)
141
142 %%
143 function  [ out ] = get_materialHysteresis( matDef, inputData, numIncr, localOpenSeesPath )
144
145 %% Function
146 [matDef, localOpenSeesPath] = convertStringsToChars(matDef, localOpenSeesPath);
147 inputData = arrayfun(@(x) num2str(x), inputData, 'UniformOutput', 0);
148 temp = strsplit(matDef);
149 matTag = temp{3};
150
151 materialTesterFid = fopen('matTest.tcl','w+');
152 fprintf(materialTesterFid,['wipe;\n']);
153 fprintf(materialTesterFid,['model testUniaxial;\n']);
154 fprintf(materialTesterFid,['set matTag ', num2str(matTag,'%u'), ';\n']);
155 fprintf(materialTesterFid,['set strainHistory {', strjoin(inputData), '};\n']);
156 fprintf(materialTesterFid,['set fileOut "hysteresis_matTag_$matTag.txt";\n']);
157 fprintf(materialTesterFid,['set out [open $fileOut w];\n']);
158 fprintf(materialTesterFid,[matDef '\n']);
159 fprintf(materialTesterFid,...
160     ['uniaxialTest $matTag;\n',...
161     'set strain 0.0;\n',...
162     'set count 1;\n',...
163     'set iTime 0;\n',...
164     'set strain [expr $strain];\n',...
165     'strainUniaxialTest $strain;\n',...
166     'set stress [stressUniaxialTest];\n',...
167     'set tangent [tangUniaxialTest];\n',...
168     'set iTime [expr $iTime+1];\n',...
169     'puts $out "$strain $stress";\n',...
170     'foreach {strainExtremeVal} $strainHistory {\n',...
171     '       set numIncr ' num2str(numIncr,'%u') ';\n',...
```

```
172     '       set strainIncr [expr ($strainExtremeVal - $strain)/$numIncr];\n',...
173     '       for {set i 0} {$i < $numIncr} {incr i 1} {\n',...
174     '           set strain [expr $strain+$strainIncr];\n',...
175     '           strainUniaxialTest $strain;\n',...
176     '           set stress [stressUniaxialTest];\n',...
177     '           set tangent [tangUniaxialTest];\n',...
178     '           set iTime [expr $iTime+1];\n',...
179     '           puts $out "$strain $stress";\n',...
180     '       }\n',...
181     '}\n',...
182     'close $out;\n',...
183     'puts "MATERIAL TESTER RAN SUCCESSFULLY!";\n',...
184     'wipe;\n'...
185     ]);
186 fclose(materialTesterFid);
187
188 [~, ~] = system(['"',localOpenSeesPath,'" "matTest.tcl"']);
189
190 fid = fopen(['hysteresis_matTag_' num2str(matTag,'%u') '.txt'],'r');
191 dataRead = textscan(fid, repmat('%f ',1,2), 'CollectOutput',true);
192 out = dataRead{1};
193 fclose(fid);
194 delete(['hysteresis_matTag_' num2str(matTag,'%u') '.txt']);
195 delete('matTest.tcl');
196
197 end
```