```
% C. Petersen, H. Werkle, Dynamik der Baukonstruktionen
% 2. Auflage, Springer Vieweg, Wiesbaden, 2018
%
% ML_13_3_Antwortspektrum_Schicht_ueber_Halbraum: Antwortspektrum für
% Schicht über Halbraum
%
% Version 1.0, April 2018
% Softwareentwicklung:
% Andrei Firus, M.Eng (andrei.firus@gmail.com)

% Aufbau Eingabedatei: Eingabedatei nicht notwendig
%
% Ausgabedateien:
% Outputdatei_1: Eingaben- und Ergebnisübersicht

%---------------------------- EINGABEBLOCK -------------------------------
% Bodenkennwerte für die Schicht:
hs=27;                      % Schichthöhe [m]
css=70;                     % Scherwellengeschwindigkeit Schicht [m/s]
rhos=1.9;                   % Dichte Schicht [t/m^3]
xis=7;                      % Schicht-Dämpfung [%]

% Bodenkennwerte für den Halbraum (Untergrund-/Bodenklasse C-S)
csh=220;                   % Scherwellengeschwindigkeit Halbraum [m/s]
rhoh=2.2;                  % Dichte Halbraum [t/m^3]

% Erdbebenkennwerte
agr=0.67;                   % Referenzwert der Bodenbeschleunigung [m/s^2]
gammai=1.2;                 % Bedeutungsbeiwert
ita=0.67;                   % Dämpfungskontrollbeiwert (1/q mit q als
                            % Verhaltensbeiwert)

Tmax=3;                     % obere Grenze der Eigenschwingzeiten bei der
                            % Erstellung der Antwortspektren

T_0=0.5;                    % Eigenschwingzeit des Antwortsystems [s]
%-------------------------------------------------------------------------

%-------------------------- BERECHNUNGSBLOCK -----------------------------
% Berechnung des Antwortspektrums nach EUROCODE 8 - DIN EN 1998 (2010-12)
% für das Bodenverhältnis C-S

% Kontrollperioden
T_A=0;
T_B=0.10;
T_C=0.50;
T_D=2.00;

S=0.75;          % Untergrundbeiwert
beta_0=2.5;       % Verstärkungsbeiwert der Spektralbeschleunigung

% Definition des Vektors der Eigenschwingzeiten
T=0:0.01:Tmax;

Sa=zeros(length(T),1);
for i=1:1:length(T)
```

```
    if T(i)<=T_B
        Sa(i)=agr*gammai*S*(1+(T(i)/T_B)*(ita*beta_0-1));
    elseif T(i)>T_B && T(i)<=T_C
        Sa(i)=agr*gammai*S*beta_0*ita;
    elseif T(i)>T_C && T(i)<=T_D
        Sa(i)=agr*gammai*S*ita*beta_0*T_C/T(i);
    else
        Sa(i)=agr*gammai*S*ita*beta_0*T_C*T_D/T(i)^2;
    end
end

% Berechnung des Antwortspektrums für die Schicht

% Die ersten 4 Eigenschwingzeiten der Bodenschicht
h_ts=1:1:4;
TS=zeros(length(h_ts),1);
for i=1:1:length(h_ts)
    TS(i)=4*hs/(css*(2*i-1));
end

% Berechnung der TL - Perioden
TL1=max(0.5,TS(1));
if TL1==TS(1)
   TL2=max(0.5,TS(2));
elseif TL1==0.5
   TL2=TS(1);
end
TL3=TS(3);
TL=[TL1 TL2 TL3];

% Deklaration der Vektoren für die Kontrollperioden
T_A_S=zeros(2,1);
T_B_S=zeros(2,1);
T_C_S=zeros(2,1);
T_D_S=zeros(2,1);

for i=1:1:2
    T_A_S(i)=0;
    T_B_S(i)=TL(i+1);
    T_C_S(i)=TL(i);
    T_D_S(i)=max(T_C_S(i),T_D);
end

% Impedanzverhältnis
beta=rhos*css/(rhoh*csh);

% Interpolation der Vergrößerungs- und Abklingfaktoren

% Ausgangswerte
aa1=[1 1.62 2.24 2.75 3.15 3.37 4.35; 1 1.46 1.96 2.35 2.63 2.81 3.49;...
    1.00 1.29 1.68 1.94 2.12 2.24 2.62];
aa2=[1 1.20 1.50 1.73 1.86 1.93 2.22; 1 0.98 1.20 1.36 1.45 1.49 1.69;...
    1 0.75 0.89 0.98 1.02 1.05 1.15];
nn1=[1 1.30 1.50 1.50 1.83 1.90 2.10; 1 1.18 1.35 1.35 1.60 1.65 1.85;...
    1 1.05 1.20 1.20 1.37 1.40 1.60];
nn2=[1 1.20 1.40 1.50 1.57 1.60 1.50; 1 1 1.10 1.20 1.27 1.30 1.25;...
    1 0.80 0.80 0.90 0.97 1 1];
```

```
beta_v=[1 0.50 0.31 0.22 0.17 0.15 0.08];
xi_v=[5 10 15];

% Interpolation
for jj=1:1:length(beta_v)-1
    if beta<=beta_v(jj) && beta>=beta_v(jj+1)
        x_1=jj;
        x_2=jj+1;
    end
end

for jj=1:1:length(xi_v)-1
    if xis>=xi_v(jj) && xis<=xi_v(jj+1)
        y_1=jj;
        y_2=jj+1;
    end
end

% Vergrößerungsfaktor alpha1
h_a1_xi_1=aa1(y_1,x_1)+(aa1(y_2,x_1)-aa1(y_1,x_1))/(xi_v(y_2)-...
    xi_v(y_1))*(xis-xi_v(y_1));
h_a1_xi_2=aa1(y_1,x_2)+(aa1(y_2,x_2)-aa1(y_1,x_2))/(xi_v(y_2)-...
    xi_v(y_1))*(xis-xi_v(y_1));

alpha1=h_a1_xi_1+(h_a1_xi_2-h_a1_xi_1)/(beta_v(x_2)-beta_v(x_1))...
    *(beta-beta_v(x_1));

% Vergrößerungsfaktor alpha2
h_a2_xi_1=aa2(y_1,x_1)+(aa2(y_2,x_1)-aa2(y_1,x_1))/(xi_v(y_2)-...
    xi_v(y_1))*(xis-xi_v(y_1));
h_a2_xi_2=aa2(y_1,x_2)+(aa2(y_2,x_2)-aa2(y_1,x_2))/(xi_v(y_2)-...
    xi_v(y_1))*(xis-xi_v(y_1));

alpha2=h_a2_xi_1+(h_a2_xi_2-h_a2_xi_1)/(beta_v(x_2)-beta_v(x_1))...
    *(beta-beta_v(x_1));

% Abkliungfaktor n1
h_n1_xi_1=nn1(y_1,x_1)+(nn1(y_2,x_1)-nn1(y_1,x_1))/(xi_v(y_2)-...
    xi_v(y_1))*(xis-xi_v(y_1));
h_n1_xi_2=nn1(y_1,x_2)+(nn1(y_2,x_2)-nn1(y_1,x_2))/(xi_v(y_2)-...
    xi_v(y_1))*(xis-xi_v(y_1));

n1=h_n1_xi_1+(h_n1_xi_2-h_n1_xi_1)/(beta_v(x_2)-beta_v(x_1))...
    *(beta-beta_v(x_1));

% Abkliungfaktor n2
h_n2_xi_1=nn2(y_1,x_1)+(nn2(y_2,x_1)-nn2(y_1,x_1))/(xi_v(y_2)-...
    xi_v(y_1))*(xis-xi_v(y_1));
h_n2_xi_2=nn2(y_1,x_2)+(nn2(y_2,x_2)-nn2(y_1,x_2))/(xi_v(y_2)-...
    xi_v(y_1))*(xis-xi_v(y_1));

n2=h_n2_xi_1+(h_n2_xi_2-h_n2_xi_1)/(beta_v(x_2)-beta_v(x_1))...
    *(beta-beta_v(x_1));

% Ermittlung des Antwortspektrums für die erste Eigenschwingung der
```

```matlab
% Bodenschicht

% Ermittlung der Spektralwerte des Halbraumsantwortspektrums für die
% Schwingzeit TL1
if TL1<=T_B
        Sa_TL1=agr*gammai*S*(1+(TL1/T_B)*(ita*beta_0-1));
    elseif TL1>T_B && TL1<=T_C
        Sa_TL1=agr*gammai*S*beta_0*ita;
    elseif TL1>T_C && TL1<=T_D
        Sa_TL1=agr*gammai*S*ita*beta_0*T_C/TL1;
    else
        Sa_TL1=agr*gammai*S*ita*beta_0*T_C*T_D/TL1^2;
end

% Antwortspektrum der Schicht für die erste Eigenschwingung
Se1=zeros(length(T),1);
for i=1:1:length(T)
    if T(i)<=T_B_S(1)
        Se1(i)=Sa(1)+T(i)/T_B_S(1)*(alpha1*Sa_TL1-Sa(1));
    elseif T(i)>T_B_S(1) && T(i)<=T_C_S(1)
        Se1(i)=alpha1*Sa_TL1;
    elseif T(i)>T_C_S(1) && T(i)<=T_D_S(1)
        Se1(i)=alpha1*Sa_TL1*(T_C_S(1)/T(i))^n1;
    else
        Se1(i)=alpha1*Sa_TL1*(T_C_S(1)/T(i))^n1*(T_D_S(1)/T(i));
    end
end

% Ermittlung des Antwortspektrums für die zweite Eigenschwingung der
% Bodenschicht

% Ermittlung der Spektralwerte des Halbraumsantwortspektrums für die
% Schwingzeit TL2
if TL2<=T_B
        Sa_TL2=agr*gammai*S*(1+(TL2/T_B)*(ita*beta_0-1));
    elseif TL2>T_B && TL2<=T_C
        Sa_TL2=agr*gammai*S*beta_0*ita;
    elseif TL2>T_C && TL2<=T_D
        Sa_TL2=agr*gammai*S*ita*beta_0*T_C/TL2;
    else
        Sa_TL2=agr*gammai*S*ita*beta_0*T_C*T_D/TL2^2;
end

% Antwortspektrum der Schicht für die zweite Eigenschwingung
Se2=zeros(length(T),1);
for i=1:1:length(T)
    if T(i)<=T_B_S(2)
        Se2(i)=Sa(1)+T(i)/T_B_S(2)*(alpha2*Sa_TL2-Sa(1));
    elseif T(i)>T_B_S(2) && T(i)<=T_C_S(2)
        Se2(i)=alpha2*Sa_TL2;
    elseif T(i)>T_C_S(2) && T(i)<=T_D_S(2)
        Se2(i)=alpha2*Sa_TL2*(T_C_S(2)/T(i))^n2;
    else
        Se2(i)=alpha2*Sa_TL2*(T_C_S(2)/T(i))^n2*(T_D_S(2)/T(i));
    end
end
```

```matlab
% Einhüllende der Antwortspektren für die zwei Eigenschwingungen
Se=zeros(length(T),1);
for i=1:1:length(T)
    Se(i)=max(Se1(i),Se2(i));
end

% Ermittlung der Spektralwerte für das Antwortsystem mit der
% Eigenschwingzeit T_0

if T_0<=T_B
        Sa_T_0=agr*gammai*S*(1+(T_0/T_B)*(ita*beta_0-1));
    elseif T_0>T_B && T_0<=T_C
        Sa_T_0=agr*gammai*S*beta_0*ita;
    elseif T_0>T_C && T_0<=T_D
        Sa_T_0=agr*gammai*S*ita*beta_0*T_C/T_0;
    else
        Sa_T_0=agr*gammai*S*ita*beta_0*T_C*T_D/T_0^2;
end

if T_0<=T_B_S(1)
        Se1_T_0=Sa(1)+T_0/T_B_S(1)*(alpha1*Sa_TL1-Sa(1));
    elseif T_0>T_B_S(1)  && T_0<=T_C_S(1)
        Se1_T_0=alpha1*Sa_TL1;
    elseif T_0>T_C_S(1)  && T_0<=T_D_S(1)
        Se1_T_0=alpha1*Sa_TL1*(T_C_S(1)/T_0)^n1;
    else
        Se1_T_0=alpha1*Sa_TL1*(T_C_S(1)/T_0)^n1*(T_D_S(1)/T_0);
end

if T_0<=T_B_S(2)
        Se2_T_0=Sa(1)+T_0/T_B_S(2)*(alpha2*Sa_TL2-Sa(1));
    elseif T_0>T_B_S(2)  && T_0<=T_C_S(2)
        Se2_T_0=alpha2*Sa_TL2;
    elseif T_0>T_C_S(2)  && T_0<=T_D_S(2)
        Se2_T_0=alpha2*Sa_TL2*(T_C_S(2)/T_0)^n2;
    else
        Se2_T_0=alpha2*Sa_TL2*(T_C_S(2)/T_0)^n2*(T_D_S(2)/T_0);
end
Se_T_0=max(Se1_T_0,Se2_T_0);
%--------------------------------------------------------------------------

%------------------------- DARSTELLUNGSBLOCK ------------------------------
%Grafische Darstellung der Ergebnisse
name_fig1 = 'Antworspektren';
fig1=figure('Name',name_fig1,'NumberTitle','off');
set(fig1,'Position',[500 350 700 500]);

plot(T,Sa,'r',T,Se1,'--',T,Se2,'--',T,Se,T_0,Se_T_0,'og','LineWidth', 1);
title('Antwortspektrum');
ylabel('Spektralbeschleunigung [m/s^2]');
xlabel('Schwingzeit [s]');
legend('Halbraum C-S nach EUROCODE 8','Erste Eigenschwingung Schicht',...
    'Zweite Eigenschwingung der Schicht','Einhüllende','Ausgabe')
grid on;
%--------------------------------------------------------------------------

%---------------------------- AUSGABEBLOCK --------------------------------
```

```matlab
% Ausgabe der Ergebnisse in eine Datei
fid = fopen('Outputdatei_1_Allgemein.txt', 'w');
fprintf(fid,...
    '%s\n','C. Petersen, H. Werkle, Dynamik der Baukonstruktionen');
fprintf(fid,...
    '%s\n','2. Auflage, Springer Vieweg, Wiesbaden, 2018');
fprintf(fid,...
    '%s\n','Softwareentwicklung: Andrei Firus (andrei.firus@gmail.com)');
fprintf(fid,'%s\n','Programm ML_13_3: Eingaben- und Ergebnisuebersicht');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','EINGABEDATEN:');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Bodenkennwerte der Schicht:');
fprintf(fid,'%s \t %d\n','Schichthoehe [m]:',hs);
fprintf(fid,'%s \t %d\n','Scherwellengeschwindigkeit Schicht [m/s]:',css);
fprintf(fid,'%s \t %.2f\n','Dichte Schicht [t/m^3]:',rhos);
fprintf(fid,'%s \t %d\n','Schicht-Daempfung [%]:',xis);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Bodenkennwerte für den Halbraum:');
fprintf(fid,'%s \t %d\n','Scherwellengeschwindigkeit Halbraum [m/s]:',...
    csh);
fprintf(fid,'%s \t %.2f\n','Dichte Halbraum [t/m^3]:',rhoh);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Erdbebenkennwerte:');
fprintf(fid,'%s\n','Referenzwert der Bodenbeschleunigung [m/s^2]:');
fprintf(fid,'%.4f\n',agr);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Bedeutungsbeiwert [-]:');
fprintf(fid,'%.3f\n',gammai);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s %s\n','Daempfungskontrollbeiwert (Kehrwert des',...
    'Verhaltenbeiwertes [-]:');
fprintf(fid,'%.4f\n',ita);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Obere Grenze der Eigenschwingzeiten [s]:');
fprintf(fid,'%d\n',Tmax);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Eigenschwingzeit des Antwortsystems:');
fprintf(fid,'%.3f\n',T_0);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
fprintf(fid,...
    '%s\n','ERGEBNISSE:');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Kontrollperioden des Antwortspektrums am Halbraum:');
fprintf(fid,'%s \t %.3f\n','T_A:',T_A);
fprintf(fid,'%s \t %.3f\n','T_B:',T_B);
fprintf(fid,'%s \t %.3f\n','T_C:',T_C);
fprintf(fid,'%s \t %.3f\n','T_D:',T_D);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Untergrundbeiwert [-]:');
fprintf(fid,'%.3f\n',S);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Verstärkungsbeiwert der Spektralbeschleunigung [-]:');
fprintf(fid,'%.3f\n',beta_0);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Erste vier Eigenschwingzeiten der Bodenschicht [s]:');
fprintf(fid,'%.4f\n',TS(1));
fprintf(fid,'%.4f\n',TS(2));
fprintf(fid,'%.4f\n',TS(3));
fprintf(fid,'%.4f\n',TS(4));
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Kontrollperioden des Antwortspektrums - Schicht:');
fprintf(fid,'%s \t %s\n','1. Eigenschwingung','2. Eigenschwingung');
fprintf(fid,'%s \t %.4f \t %.4f\n','T_A_S:',T_A_S(:,1));
fprintf(fid,'%s \t %.4f \t %.4f\n','T_B_S:',T_B_S(:,1));
fprintf(fid,'%s \t %.4f \t %.4f\n','T_C_S:',T_C_S(:,1));
fprintf(fid,'%s \t %.4f \t %.4f\n','T_D_S:',T_D_S(:,1));
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Impedanzverhaeltnis [-]:');
fprintf(fid,'%d\n',beta);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Interpolierte Vergroesserungsfaktoren [-]:');
fprintf(fid,'%s \t %d\n','alpha1=',alpha1);
fprintf(fid,'%s \t %d\n','alpha2=',alpha2);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Abklingfaktoren [-]:');
fprintf(fid,'%s \t %d\n','n1=',n1);
fprintf(fid,'%s \t %d\n','n2=',n2);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Ergebnisse für das Antwortsystem:');
fprintf(fid,'%s \t %.3f\n','Eigenschwingzeit [s]:',T_0);
fprintf(fid,'%s \t %d\n','Spektralbeschl. Halbraum [m/s^2]:',Sa_T_0);
fprintf(fid,'%s \t %d\n','Spektralbeschl. Schicht [m/s^2]:',Se_T_0);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Antwortspektren:');
fprintf(fid,'%s \t %s \t %s \t %s \t %s\n','Eigenschwingzeit',...
    'Halbraum [m/s^2]:','Schicht [m/s^2]:',...
    'Schicht 1. Eigenschwingung [m/s^2]:',...
```

```
    'Schicht 2. Eigenschwingung [m/s^2]:' );
for jj = 1:1:length(T)
     fprintf(fid, '%d \t%d \t %d \t %d\n',T(jj),Sa(jj),Se(jj),...
         Se1(jj),Se2(jj));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fclose(fid);
%--------------------------------------------------------------------------
```