APPENDIX

Velocity and penetration of model torpedo anchor

VelocitymodelURI.m

```matlab
%---------------------------------------------------------------------
---
% Giampa %
% 10/03/13 %
% Velocity and penetration of model torpedo anchor
%---------------------------------------------------------------------
---

%%Velocity model adapted from:
% Richardson, M.D., O'Loughlin, C.D., Randolph, M.F. 2005,
% The geotechnical performance of deep penetrating anchors in
calcareous sand
% International Symposium on Frontiers in Offshore Geotechnics, The
Netherlands
% n/a, pp. 357-363.

close all
clear all
clc

% Anchor specifications

m = 0.464;% anchor mass in (kg)
L = 0.3048;% length in (m)
Lt = 2.28;% tip length in (m)
D = 0.0254;% diameter in (m)
Ap = (pi*D^2)/4;% projected area of anchor in (m^2)
w = m*9.81;% weight of submerged anchor (N)

% Constants

Nq = 25;% bearing capacity factor Richardson et al.
beta = 0.42;% ratio of shaft friction to effective overburden stress
Richardson et al.
lambda = 0.02;% constant 2% per log cycle
dt = 0.01;% time step (sec)
vo = 35;% entrance velocity (m/s)
gamma = 14520;% (N/m3)
N = 10
% Calculate Penetration
```
\[ z(1) = -v_0 \cdot dt; \]
\[ z(2) = 0; \]

\textbf{for} \ i = 2:N \\
\textbf{if} \ z(i) < L \\
\quad z(i+1) = 2z(i) + ((w \cdot dt^2)/m) - (z(i-1) - (dt^2 \cdot (1 + \lambda \cdot \log(z(i) - z(i-1))/dt)) \cdot (N_q \cdot (\gamma \cdot z(i)) \cdot A_p + \beta \cdot (\gamma \cdot z(i)) \cdot \pi \cdot D \cdot z(i))/m); \%
\quad v(i) = (z(i+1) - z(i-1))/(2 \cdot dt); \%
\textbf{else} \\
\quad z(i+1) = 2z(i) + ((w \cdot dt^2)/m) - (z(i-1) - (dt^2 \cdot (1 + \lambda \cdot \log(z(i) - z(i-1))/dt)) \cdot (N_q \cdot (\gamma \cdot z(i)) \cdot A_p + \beta \cdot (\gamma \cdot z(i)) \cdot \pi \cdot D \cdot L))/m); \%
\quad v(i) = (z(i+1) - z(i-1))/(2 \cdot dt); \%
\textbf{end} \\
\textbf{end} \\
maxz = max(z);

%Import URI predicted model embedment

\texttt{vm = [1 5 10 15 20 25 30 35]; \% impact velocity of model (m/s)}
\texttt{Nq25e = [0.0762 0.2294 0.4024 0.5774 0.7570 0.9351 1.1109 1.2708]; \%}
\texttt{Nq=25 embedment (m)}
\texttt{Nq45e = [0.0539 0.1836 0.3343 0.4807 0.6304 0.7793 0.9262 1.0765]; \%}
\texttt{Nq=45 embedment (m)}
\texttt{Nq50e = [0.0502 0.1768 0.3212 0.4611 0.6042 0.7466 0.8871 1.0308]; \%}
\texttt{Nq=50 embedment (m)}

%Experimental URI model penetration

\texttt{av = [7.73316 7.73316 8.11060 8.11060]; \% impact velocity of model (m/s)}
\texttt{ae = [0.2032 0.1905 0.2032 0.2159]; \% experimental embedment depth (m)}

\begin{verbatim}
% figure (1)
\texttt{plot(v(2:N),z(2:(N))./L,'k','LineWidth',1.5)}
\texttt{set(gca,'YDir','reverse')}
\texttt{set(gca,'XAxisLocation', 'top')}
\texttt{xlabel('Velocity (m/s)')}
\texttt{ylabel('Prototype Embedment/Prototype Length')}\%
\texttt{Title('Typical Velocity Behavior','FontWeight','bold')}\%
\texttt{axis([0 10 0 2])}
\texttt{saveas(gcf,'Typical Velocity Behavior.emf')}\%

% figure (2)
\texttt{figure (2)}\texttt{hold on}
\texttt{plot(vm,Nq25e,'k','LineWidth',1.5)}
\texttt{plot(vm,Nq45e,'k-','LineWidth',1.5)}
\texttt{plot(vm,Nq50e,'k-.','LineWidth',1.5)}
\texttt{plot(av,ae,'ro')}\texttt{hold off}
\texttt{set(gca,'YDir','reverse')}
\texttt{set(gca,'XAxisLocation', 'top')}\%
\texttt{xlabel('Impact Velocity (m/s)')}\%
\texttt{ylabel('Model Embedment (m)')}\%
\end{verbatim}
Title('URI Predicted Model Embedment Depths','FontWeight','bold')
legend('Predicted [Nq = 25]','Predicted [Nq = 45]','Predicted [Nq = 50]','Measured')
axis([0 35 0 1])
saveas(gcf,'URI Predicted Model Embedment.emf')
Drained Model for the kite shape

velocitymodelflukeURI.m

%-------------------------------------------------------------------------------------------------
---
%
Breithaupt %
%
07/22/15 %
%
Velocity and penetration of fluke anchor
%
%-------------------------------------------------------------------------------------------------
---

%%%Velocity model adapted from:
% Richardson, M.D., O'Loughlin, C.D., Randolph, M.F. 2005,
% The geotechnical performance of deep penetrating anchors in
calcareous sand
% International Symposium on Frontiers in Offshore Geotechnics, The
Netherlands
% n/a, pp. 357-363.

% Applied in earlier projects by Joseph Giampa and Aaron Bradshaw
% University of Rhode Island

close all
clear all
clc

% Anchor specifications (1:40 Scala)

\[ L = 0.105918; \text{ fluke length (m)} \]
\[ L_f = 0.0211582; \text{ fluke length to middle (m)} \]
\[ B = 0.127; \text{ fluke width (m)} \]
\[ t_p = 0.0127; \text{ thickness of plate (m)} \]
\[ \text{roe} = 8000; \text{ density of steel in air (kg/m3)} \]
\[ m = 1.71; \text{ 1.71 for added weight/ 0.68 just the anchor; anchor mass in} \]
\[ \text{(kg)}((L-L_f)*B*0.5*t_p+L_f*B*0.5*t_p)*\text{roe}+1.04 \]
\[ W_d = m*9.81; \text{ anchor dry weight (N)} \]
\[ F_b = 0; \text{ buoyant force (N)} \]
\[ W = W_d-F_b; \text{ buoyant weight of anchor (N)} \]

% Constants

\[ N_q = 46; \text{ 60 for blunt edge; 46 for sharp edge bearing capacity factor} \]
\[ \beta = 0.28; \text{ theoretical beta calculation} \]
\[ \lambda = 0.0; \text{ constant 2% per log cycle} \]
\[ dt = 0.0001; \text{ time step (sec)} \]
\[ v_o = 7.0; \text{ entrance velocity (m/s)} \]
\[ \gamma = 14970; \text{ Unit weight N/m3} \]
\[ N = 1000; \]
% Calculate Penetration

\( x(1) = -v_0 \cdot dt; \)
\( x(2) = 0; \)
\( Ap = B \cdot tp; \)

\( \textbf{for} \ i = 2:N \)
\( \textbf{if} \ x(i) < Lf \)
\( x(i+1) = 2 \cdot x(i) + (W \cdot dt^2)/m - x(i-1) - (dt^2 \cdot \text{log}((x(i) - x(i-1))/dt)) \cdot (Nq \cdot \gamma \cdot x(i)) \cdot Ap + \beta \cdot (\gamma \cdot (x(i) - x(i-1)/2)) \cdot (x(i)/Lf \cdot B \cdot x(i)/2 \cdot 2))/m; \% \)
\( v(i) = (x(i+1) - x(i-1))/(2 \cdot dt); \% \text{assumes surcharge is at toe} \)
\textbf{which is conservative (high)}
\( \textbf{elseif} \ Lf < x(i) < L \)
\( x(i+1) = 2 \cdot x(i) + (W \cdot dt^2)/m - x(i-1) - (dt^2 \cdot \text{log}((x(i) - x(i-1))/dt)) \cdot (Nq \cdot \gamma \cdot x(i)) \cdot Ap + \beta \cdot (\gamma \cdot (x(i) - x(i-1)/2)) \cdot (Lf \cdot B + ((x(i) - Lf)/(L - Lf) \cdot B) + B)/2 \cdot (x(i) - Lf)/2 \cdot 2))/m; \% \)
\( v(i) = (x(i+1) - x(i-1))/(2 \cdot dt); \% \text{assumes surcharge is at toe} \)
\textbf{which is conservative (high)}
\( \textbf{else} \)
\( x(i+1) = 2 \cdot x(i) + (W \cdot dt^2)/m - x(i-1) - (dt^2 \cdot (1 + \text{log}((x(i) - x(i-1))/dt)) \cdot (Nq \cdot \gamma \cdot x(i)) \cdot Ap + \beta \cdot (\gamma \cdot (x(i) - x(i-1)/2)) \cdot B \cdot L/2 \cdot 2))/m; \% \)
\( v(i) = (x(i+1) - x(i-1))/(2 \cdot dt); \% \text{assumes surcharge is at toe} \)
\textbf{which is conservative (high)}
\( \textbf{end} \)
\textbf{end} \\

maxdepth = max(x)

\( \text{figure} \)
\( \text{set(gcf, 'Color', 'w');} \)
\( \text{plot(v, x(1:N));} \)
\( \text{set(gca, 'YDir', 'reverse');} \)
\( \text{set(gca, 'XAxisLocation', 'top')} \)
\( \text{xlabel('Impact Velocity (m/s)')} \)
\( \text{ylabel('Embedment (m)')} \)
\( \text{axis([0 10 0 0.5])} \)
Undrained Model for the kite shape

velocitymodelflukeURI.m

%----------------------------------------------------------------------
---%                                                                 
%                                             Nikolaus Benedikt       
% Breithaupt                                  
% 07/24/15 %                                   
% Velocity and penetration of fluke object (no cavitation)          
%----------------------------------------------------------------------
---%

%%Velocity model adapted from: 
% NAVFAC Naval Facilities Engineering Command 
% SP - 2209-OCN 
% Marine Geotechnical Engineering, 15 March 2011 
% n/a, pp. 305-310.

close all
clear all
clc

% Anchor specifications (Model, 1:40 SCALE)

L = 0.105918; % fluke length (m)
Lf = 0.0211582; % fluke length to middle (m)
B = 0.127; % fluke width (m)
tp = 0.0137; % thickness of plate (m)
m = 0.69; % anchor mass in (kg) B*L*tp*roe
Wd = m*9.81; % anchor dry weight (N)
%Fb = 0; % B*L*tp/2*1000*9.81 buoyant foce (N)
%W = (Wd-Fb); % buoyant weight of anchor (N)

% Constants
dt = 0.001; % time step (sec)
vo = 7.2; % entrance velocity (m/s)
N = 1000;

% Calculate Penetration

x(1) = -vo*dt;
x(2) = 0;
Su= 300000; %N/m2
De = (4*B*tp)^0.5;
Ce = 40 * 47.88;
As = L*B*2/2;
c = 1;
Sur = c*Su; %N/m2

Cd = 1;
roh = 19800; % N/m2

for i = 2:N
    if x(i) < Lf
        At = B*tp;
        Fb(i) = (x(i)/Lf)*B*x(i)*tp*1000*9.81;
        W = (Wd-Fb(i));
        Nti(i) = (((2+pi)*(1+Lf)/(2+pi))*B/L)*((1+(2/(2+pi))*atan(x(i)/B)));
        x(i+1) = x(i) + ((W*dt^2)/m) - x(i-1) - ((dt^2)/m)*Su*2/(1+(Ce*((x(i)-x(i-1))/(2*dt))/(Su*De)+1)^(-0.5))*Nti(i)*At-Sur*/(2*(x(i)/Lf)*B*(x(i)/2)*2
        v(i) = (x(i+1)-x(i-1))/(2*dt); %assumes surcharge is at toe which is conservative (high)
    elseif Lf < x(i) < L
        At = B*tp;
        Fb(i) = (As/2)*tp*1000*9.81;
        W = (Wd-Fb(i));
        Nti(i) = (((2+pi)*(1+Lf)/(2+pi))*B/L)*((1+(2/(2+pi))*atan(x(i)/B)));
        x(i+1) = x(i) + ((W*dt^2)/m) - x(i-1) - ((dt^2)/m)*Su*2/(1+(Ce*((x(i)-x(i-1))/(2*dt))/(Su*De)+1)^(-0.5))*Nti(i)*At-Sur*/(2*(x(i)/Lf)*B*As)
        v(i) = (x(i+1)-x(i-1))/(2*dt); %assumes surcharge is at toe which is conservative (high)
    else
        Ap = B*tp;
        Fb(i) = (As/2)*tp*1000*9.81;
        W = (Wd-Fb(i));
        Nti(i) = (((2+pi)*(1+Lf)/(2+pi))*B/L)*((1+(2/(2+pi))*atan(x(i)/B)));
        x(i+1) = x(i) + ((W*dt^2)/m) - x(i-1) - ((dt^2)/m)*Su*2/(1+(Ce*((x(i)-x(i-1))/(2*dt))/(Su*De)+1)^(-0.5))*Nti(i)*At-Sur*/(2*(x(i)/Lf)*B*As)
        v(i) = (x(i+1)-x(i-1))/(2*dt); %assumes surcharge is at toe which is conservative (high)
    end
end

maxdepth = max(x)

figure
set(gcf,'Color','w');
plot(v, x(1:N));
set(gca,'YDir','reverse');
sct(gca,'XAxisLocation','top')
xlabel('Impact Velocity (m/s)')
ylabel('Embedment (m)')
axis([0 15 0 0.2])