APPENDIX

Velocity and penetration of model torpedo anchor

VelocitymodelURI.m

```
%-----------------------------------------------------------------------
---%
%                                                               Joe
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
Nerthlands
% 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)
% Ltip = 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) = -vo*dt;
z(2) = 0;

for i = 2:N
    if z(i) < L
    z(i+1) = 2*z(i)+((w*dt^2)/m)-z(i-1)-((dt^2*(1+lambda*log((z(i)-z(i-
1))/dt))*(Nq*(gamma*z(i))*Ap+beta*(gamma*z(i))*pi*D*z(i)))/m);%
    v(i) = (z(i+1)-z(i-1))/(2*dt);
    else
    z(i+1) = 2*z(i)+((w*dt^2)/m)-z(i-1)-((dt^2*(1+lambda*log((z(i)-z(i-
1))/dt))*(Nq*(gamma*z(i))*Ap+beta*(gamma*z(i))*pi*D*L))/m);%
    v(i) = (z(i+1)-z(i-1))/(2*dt);
    end
end

 maxz = max(z);

 %Import URI predicted model embedment

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

 %Experimental URI model penetration

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

% figure (1)
% plot(v(2:N),z(2:(N))./L,'k','LineWidth',1.5);
% set(gca,'YDir','reverse');
% set(gca, 'XAxisLocation', 'top')
% xlabel('Velocity (m/s)')
% ylabel('Prototype Embedment/Prototype Length')
% Title('Typical Velocity Behavior','FontWeight','bold')
% axis([0 10 0 2])
% saveas(gcf,'Typical Velocity Behavior.emf')
%
figure (2)
hold on
plot(vm,Nq25e,'k','LineWidth',1.5);
plot(vm,Nq45e,'k:','LineWidth',1.5);
plot(vm,Nq50e,'k-.','LineWidth',1.5);
plot(av,ae,'ro');
hold off
set(gca,'YDir','reverse');
set(gca, 'XAxisLocation', 'top')
xlabel('Impact Velocity (m/s)')
ylabel('Model Embedment (m)')
```

```
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

```
%--------------------------------------------------------------------
---%
%                                              Nikolaus Benedikt
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;% fluke length (m)
Lf = 0.0211582; % fluke length to middle (m)
B = 0.127; % fluke width (m)
tp = 0.0127;% thickness of plate (m)
roe = 8000; % density of steel in air (kg/m3)
m = 1.71;% 1.71 for added weight/ 0.68 just the anchor; anchor mass in
(kg)((L-Lf)*B*0.5*tp+Lf*B*0.5*tp)*roe+1.04
Wd = m*9.81; %anchor dry weight (N)
Fb = 0;%((L-Lf)*B*0.5+Lf*B*0.5)*tp*1000*9.81 % buoyant force (N)
W = Wd-Fb;% buoyant weight of anchor (N)

% Constants

Nq = 46;% 60 for blunt edge; 46 for sharp edge bearing capacity factor
beta = 0.28;% theoretical beta calculation
lambda = 0.0;% constant 2% per log cycle
dt = 0.0001;% time step (sec)
vo = 7.0;% entrance velocity (m/s)
gamma = 14970;% Unit weight N/m3)
N = 1000;
```

```
% Calculate Penetration


x(1) = -vo*dt;
x(2) = 0;
Ap=B*tp;

for i = 2:N
    if x(i) < Lf
        x(i+1) = 2*x(i)+((W*dt^2)/m)-x(i-1)-(dt^2*((1+lambda*log((x(i)-
x(i-1))/dt))*((Nq*gamma*x(i))*Ap+beta*(gamma*(x(i)-
x(i)/2))*(x(i)/Lf*B*x(i)/2*2)))/m);%
        v(i) = (x(i+1)-x(i-1))/(2*dt); %assumes surcharge is at toe
which is conservative (high)
    elseif Lf < x(i) < L
        x(i+1) = 2*x(i)+((W*dt^2)/m)-x(i-1)-(dt^2*((1+lambda*log((x(i)-
x(i-1))/dt))*((Nq*gamma*x(i))*Ap+beta*(gamma*(x(i)-
x(i)/2))*((Lf*B)+(((x(i)-Lf)/(L-Lf)*B)+B)/2*(x(i)-Lf)/2*2)))/m);%
        v(i) = (x(i+1)-x(i-1))/(2*dt); %assumes surcharge is at toe
which is conservative (high)
    else
        x(i+1) = 2*x(i)+((W*dt^2)/m)-x(i-1)-((dt^2*(1+lambda*log((x(i)-
x(i-1))/dt))*((Nq*gamma*x(i))*Ap+beta*(gamma*(x(i)-
x(i)/2))*B*L/2*2))/m);%
        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');
set(gca, 'XAxisLocation', 'top')
xlabel('Impact Velocity (m/s)')
ylabel('Embedment (m)')
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+(1/(2+pi)*(B/L)))*((1+(2/(2+pi)))*atan(x(i)/B)));
        x(i+1)=2*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*((dt^2)/m)*(2/(1+(Ce*((x(i)-x(i-
1))/(2*dt))/(Su*De)+1)^(-0.5)))*(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)= ((Lf*B/2)+(((x(i)-Lf)/(L-Lf)*B)+B)/2*(x(i)-
Lf))*tp*1000*9.81;
        W = (Wd-Fb(i));
        Nti(i) =
((2+pi)*(1+(1/(2+pi)*(B/L)))*((1+(2/(2+pi)))*atan(x(i)/B)));
        x(i+1)=2*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*((dt^2)/m)*(2/(1+(Ce*((x(i)-x(i-
1))/(2*dt))/(Su*De)+1)^(-0.5)))*((Lf*B)+(((x(i)-Lf)/(L-
Lf)*B)+B)/2*(x(i)-Lf)/2*2)-
        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+(1/(2+pi)*(B/L)))*((1+(2/(2+pi)))*atan(x(i)/B)));
        x(i+1)=2*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*((dt^2)/m)*(2/(1+(Ce*((x(i)-x(i-
1))/(2*dt))/(Su*De)+1)^(-0.5)))*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');
set(gca, 'XAxisLocation', 'top')
xlabel('Impact Velocity (m/s)')
ylabel('Embedment (m)')
```

```
axis([0 15 0 0.2])
```