Appendices.

Appendix A.

MATLAB prediction program code.

```
clear all

%=====================================================================
===================
%                  Program to determine the effect of the
%                  taper strip moving through a series of
%                  rollers.


sigy = 280E6;                          %static yeild of material.
D = 40.4;                              %emp cnstant for mild steel.
p = 5;                                 %emp cnstant for mild steel.

v(1,1) = 0;                            %m/s
M = input(What it is the mass of the conveyance? kg - );  %kg
n = input(How many roller sets are needed? - );
N = input(Number of rollers in the set?  - );            %#
t = input(What is the thickness of the sheet used? m  );
dia = input(What is the diameter of the rollers? - );    %m

s = pi*dia/4;                          %qrtr dstnce of roller.
R = dia/2;

tme(1,1) = 0;
delta_t = 0.0003125;

start_w = input(The thinnest width of the taper? m  - );
stop_w = input(The thickest width of the taper? m  -  );
overdst = input(Over what distance does the taper occur? m  -  );
itter = 15000;                         %must be more than 2000
xdrop = input(How high above the arrestors is the mass? - );

x(1,1) = 0;
x(1,N) = (2*N - 3)*s;

strp_taper_in = x(1,N);
strp_taper_end = x(1,N) + overdst;     %the taper geometry

for p = 2:(N-1)                        %Initial locations of the strp
   x(1,p) = (2*p-2)*s;                 %position on the rollers.
end                                    %Before any motion

r = 1;
x(r,:) = x(r,:) - xdrop;               %The initial position of
                                       %the mass
```

```
%-------------------------------------------------------------------------
              %Main program for the forces with fixed delta time.

     while x(r,:) <= strp_taper_in
         tme(1,(r+1)) = tme(1,r) + delta_t;
         accel(1,r) = -8;                                  %The rated G with
         v(1,(r+1)) = v(1,r) - accel(1,r)*delta_t); %friction factor
         delta_x(1,r) = 0.5*(v(1,r)+v(1,(r+1)))*delta_t;
         x((r+1),:) = x(r,:) + delta_x(1,r);
         r = r+1;
     end


for z = r:itter;                              %For  itter time increments.
      for y = 1:N;
         if x(z,y) <= strp_taper_in
         w(z,y) = start_w;
         elseif x(z,y) <= strp_taper_end
         w(z,y) = ((stop_w - start_w)/(strp_taper_end -
strp_taper_in))*x(z,y) + (start_w - ((stop_w -
start_w)/(strp_taper_end - strp_taper_in))*strp_taper_in);
         else
         w(z,y) = stop_w;
         end

         if v(1,z) <= 0;
            v(1,z) = 0;
         end

   strnrate(1,z) = v(1,z)/(12*R + 6*t);%strain rate.
                                          %Same for each roller.
   sigyd(1,z) = (1 + (strnrate(1,z)/D)^1/p)*sigy;  %Dynamc yield,
                                                     also the same.
                                                     %for each
                                                     %roller
F(z,y) = (4*sigyd(1,z)*w(z,y)/sqrt(3))*(t - 2*R*sqrt(1 + t/R) + 2*R);

      end

%for
%------------------------ End of the independant roller calcs-----

 Fset = sum(F,2);                     %sums all the rollers in the set.

   Ftot = n*Fset;                     %Combined force of n brakes


   accel(1,z) = Ftot(z,1)/M;          %combined decceleration that the
                                      %strip applies

   if v(1,z) <= 0;
      accel(1,z) = 0;
   end
```

```
----------                         %The motion part.

tme(1,(z+1)) = tme(1,z) + delta_t;              %next time step
v(1,(z+1)) = v(1,z) - (accel(1,z)*delta_t);%velocity change with
                                              %accel

delta_x(1,z) = 0.5*(v(1,z)+v(1,(z+1)))*delta_t; %movement in
                                                 %time increments
x(z+1,:) = x(z,:) + delta_x(1,z);          %adds displacement increment
                                             %to the individual roller pos.
end

sig_strp = max(Fset)/(start_w*t);
Safety_Factor = sigy/sig_strp

                                     %MAIN END!!!!!!

secs = linspace(1,(itter/3200),(length(tme)-1));%3200 is the sampling
                                                  %frq in experiment.

figure(1)
plot(secs,Ftot,.)
hold
grid
plot(secs,F)
title(Independant forces (one roller) and then the combined effect
(both))
xlabel(seconds)
ylabel(Newtons)

gs = accel/9.8;

figure(2)
plot(secs,gs,r)
grid
title(The decceleration experienced by the mass in Gs)
xlabel(seconds)

figure(3)
plot(tme,v)
hold
plot(tme(1,r),strp_taper_in,r.)
plot(tme(1,r),strp_taper_in,r+)
plot(tme(1,r),strp_taper_in,ro)
grid
title(The velocity profile of the skip/mass)
ylabel(m/s)
xlabel(seconds)

figure(4)
plot(tme,x(:,3))
hold
grid
plot(tme(1,r),strp_taper_in,r.)
plot(tme(1,r),strp_taper_in,r+)
plot(tme(1,r),strp_taper_in,ro)
title(Displacement of the mass/skip, from fall to stop. Mark is
contact with brakes.)
ylabel(meters)
xlabel(seconds)
```

Appendix B.

Technique for converting velocity profile to acceleration.

The technique used to determine the gradient of the velocity profile was as follows:

1. The data files of the time series and velocity series were loaded.
2. A number of points between which to sample in the data string were chosen.
3. The values of the positions were determined.
4. A spline was fitted through the positions.
5. The gradient of the spline was derived.
6. The derivation was plotted as an acceleration curve.

```
clear all
clear session
close all

eval(load vel)          %loading FEM velocity data
eval(load tt)           %loading FEM time data

vel_orig = vel;
time_orig = tt;

no_int = 8;                %the number of sampling points through which
                           %to fit the spline

temp = length(vel_orig);

interval = linspace(1,temp,no_int);

for j=1:length(interval)
    interval(j) = round(interval(j));
end

for j=1:length(interval)
    t_samp(j) = time_orig(interval(j)); %sampling values determined
    v_samp(j) = vel_orig(interval(j));
end

t_fit = time_orig;
v_fit = interp1(t_samp,v_samp,t_fit,spline); %spline fit

figure(1)                       %plot of sample positions vs spline fit
plot(t_samp,v_samp,o,t_fit,v_fit)

for j=1:(length(t_fit)-1)                %determining of gradient
    del_y = v_fit(j+1) - v_fit(j);
    del_x = t_fit(j+1) - t_fit(j);
    a_fit(j) = del_y/del_x;
end

figure(2)                                %plot of derived acceleration
t_acc = t_fit(1:(temp-1));
plot(t_acc,a_fit)
```

Appendix C.

Parallel profile strip results.

The experimental procedure regarding this section was done with two inline dampers (refer: Figure 79). The damper system consisted of a steel tube with a coil spring inside. The spring absorbed the initial impact and then activated the decelerating strip systems. The problem with this application was the spring back and the mass ratio of the tubes with the springs compared to the conveyance/mass itself. The masses of the tubes were 15kg each and the conveyance was 130kg. In section 8.1.3.4 a conclusion of mass ratio not exceeding 10% was reached. In this case the ratio was over 20%. The arrangement is shown in the following figures.

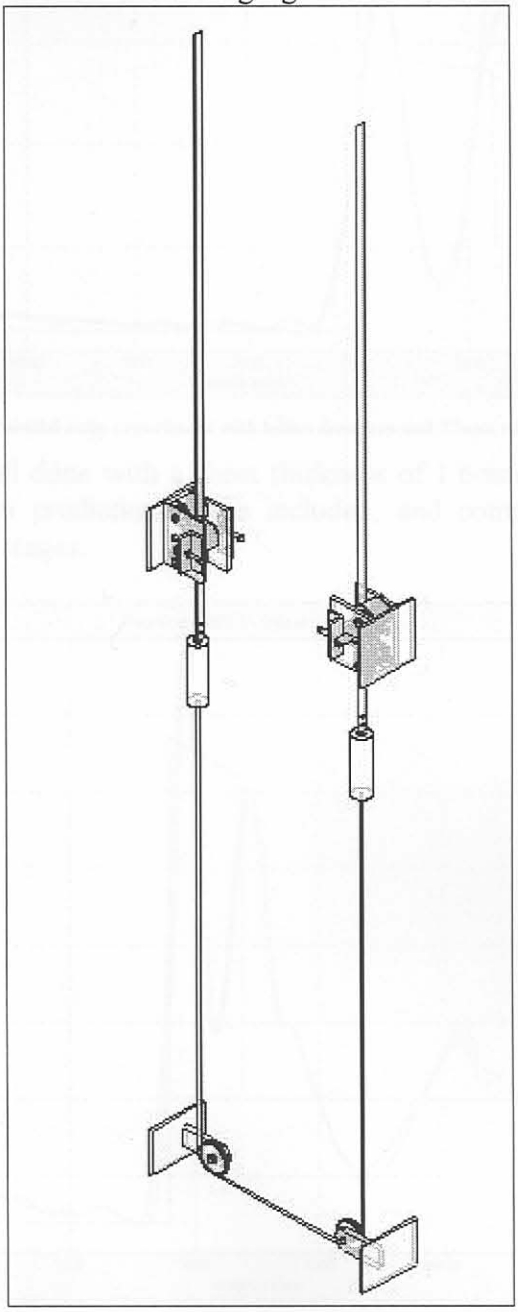

Figure 79 Schematic representation with inline damping systems included.

The double acceleration peak was generated by the spring back of the coil spring. The dynamic performance was similar to a two-mass-spring-damper-system, under an impulse excitation, with the double stage action. For this reason the arrangement was changed to the tapered strip set-up, where the mass of the tube could be eliminated.

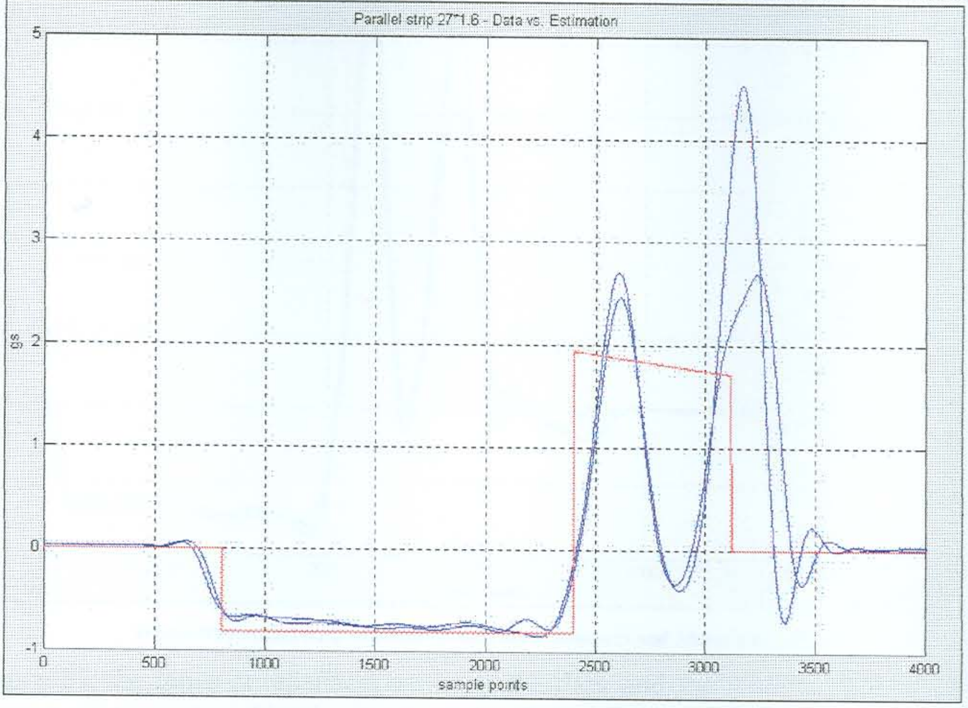

Figure 80 Parallel strip experiment with inline dampers and 27mm wide strip.

The experiments were all done with a sheet thickness of 1.6mm and parallel sections. The MATLAB program predictions were included, and compared reasonably well during the development stages.

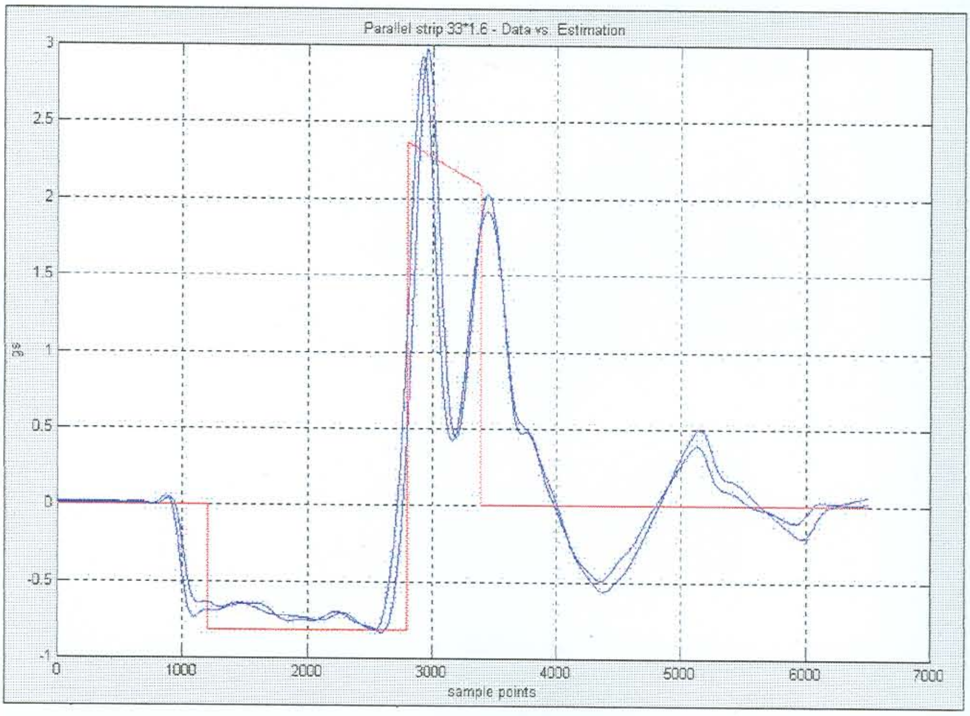

Figure 81 Parallel strip experiment with inline dampers and 33mm wide strip.

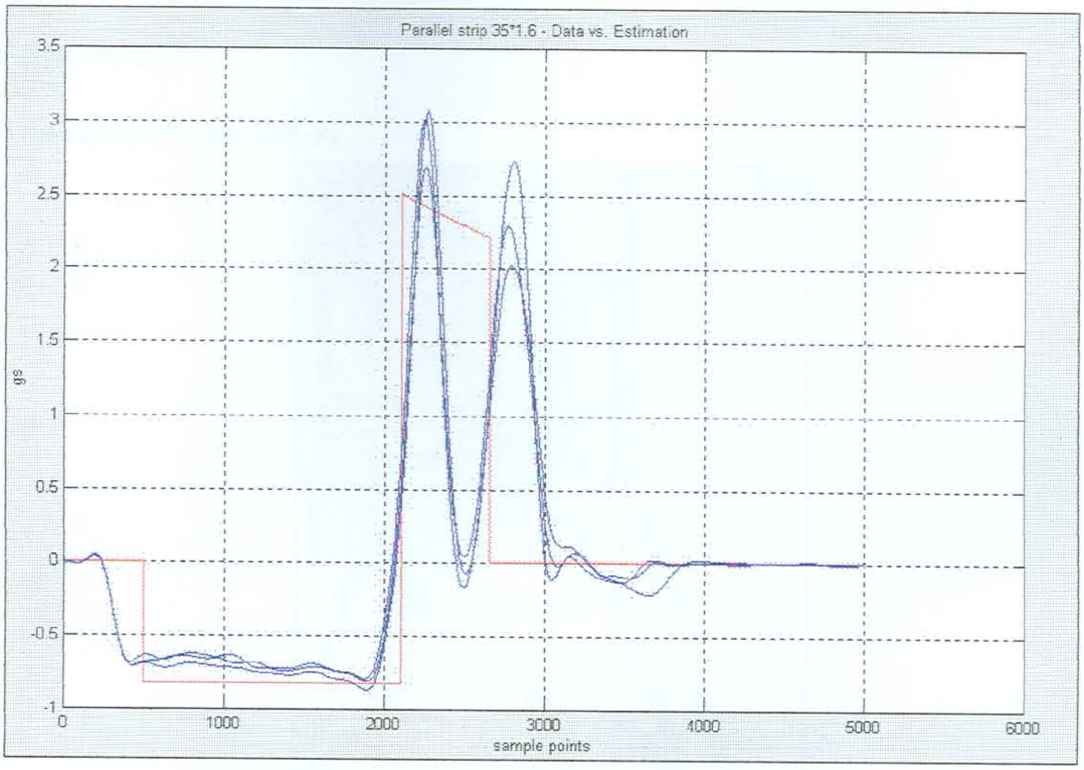

Figure 82 Parallel strip experiment with inline dampers and 35mm wide strip.

In Figure 82 the close comparison between the data and the prediction is evident. In this series of tests the objective was to decelerate the conveyance at no more than 2.5Gs and it can be seen from the resulting acceleration plot that this was achieved. The sizing of the strips was done by means of using the MATLAB prediction program.

Even though the technique was altered it served as a valuable development stage.

Appendix D.

Additional Photo Gallery.

Figure 83 Pulley system at the bottom of the model shaft.

Figure 84 View through the mouth of the shaft.

In Figure 84 the strips can be seen threaded between the rollers. Here the strips had been drawn through the rollers, and the model cage retracted from it's rest position at the bottom of the shaft.

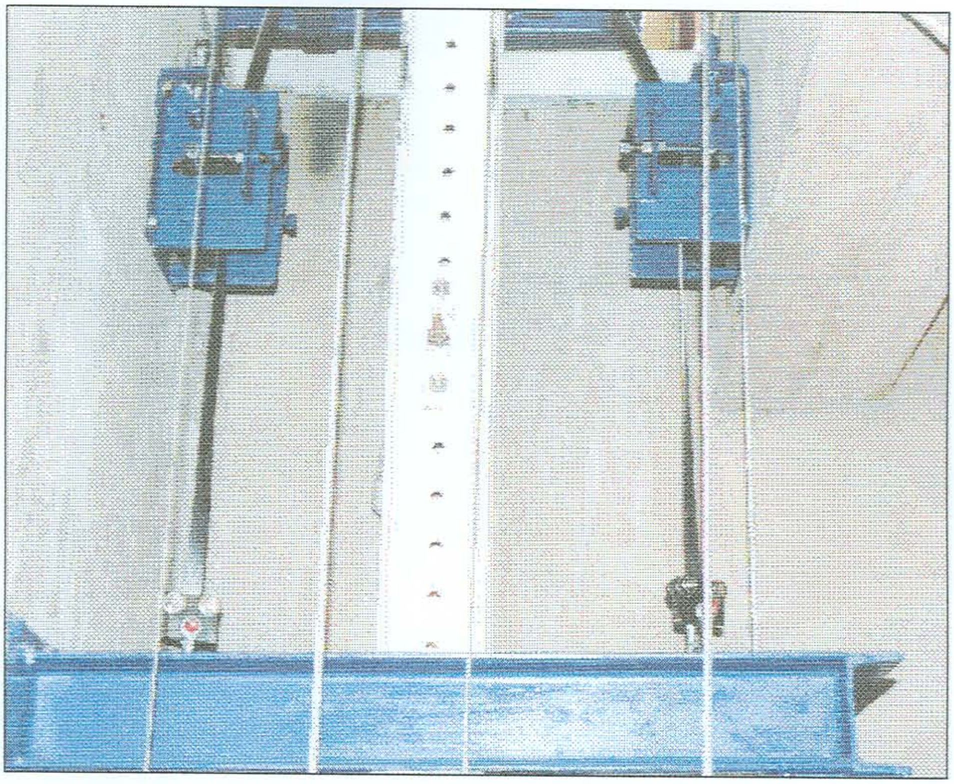

Figure 85 View of strips drawn through the rollers.

Figure 86 View of all the taper strips of which data was recorded.