Vehicle-Barrier Tracking of a Scaled Crash Test for Roadside Barrier Design

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VEHICLE-BARRIER TRACKING OF A SCALED CRASH TEST FOR ROADSIDE BARRIER DESIGN

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ABSTRACT

In this paper the tracking system used to perform a scaled vehicle-barrier crash test is reported. The scaled crash test was performed as part of a wider project aimed at designing a new safety barrier making use of natural building materials.
The scaled crash test was designed and performed as a proof of concept of the new mass-based safety barriers and the study was composed of two parts: the scaling technique and of a series of performed scaled crash tests.

The scaling method was used for 1) setting the scaled test impact velocity so that energy dissipation and momentum transferring, from the car to the barrier, can be reproduced and 2) predicting the acceleration, velocity and displacement values occurring in the full-scale impact from the results obtained in a scaled test.

To achieve this goal the vehicle and barrier displacements were to be recorded together with the vehicle accelerations and angular velocities. These quantities were measured during the tests using acceleration sensors and a tracking system. The tracking system was composed of a high speed camera and a set of targets to measure the vehicle linear and angular velocities. A code was developed to extract the target velocities from the videos and the velocities obtained were then compared with those obtained integrating the accelerations provided by the sensors to check the reliability of the method.

KEYWORDS : *scaled test, tracking, safety barriers, crash test.*

INTRODUCTION

In this paper the scaled tests and the tracking system performed as a proof of concept of a new roadside safety barrier are described. In developing a novel barrier design concept, a full-scale physical test is ultimately required for regulatory compliance. However, crash testing is expensive and not appropriate for design iterations, and therefore it is advantageous to have a cost-effective evaluation tool which can predict the likely response of the new design according to the European Standard EN 1317. The crash test prescribed by the EN1317 TB31 consists of a 1500 kg vehicle impacting the safety barrier at an angle of 20° at 80 km/h.

Finite Element (FE) and Multibody (MB) formulations can be an effective evaluation tool in barrier design in some circumstances such as the design optimization phase and they have been used successfully to estimate safety barrier performance [5-8, 10-12]. On the other hand scaled tests work as a proof of concept in the initial design steps of a new idea and they allow an initial assessment of how close the numerical modelling is to the physical reality of the vehicle-barrier impact. Scaled testing may thus be a cost effective method to evaluate novel design concepts, but then a set of scaling laws is required to predict the performance of the design in a full-scale environment.

The scaling method consists of determining the scaled vehicle-barrier impact velocity and the scaling factors for the output quantities measured during the test: vehicle and barrier accelerations, duration of the impact and displacements of the barrier and vehicle. With these scale factors, it is possible to predict the values one would obtain in a full scale test. In particular, the vehicle linear and angular velocity and acceleration are needed to compute the ASI score which measures global occupant injury risk while the barrier displacement is needed to fulfil the barrier working width class criterion.

The scaling procedure used to perform the experimental tests is described in [4]. In this paper the experimental setup and in particular the tracking system used to measure the target quantities are described.

1 SCALED CRASH TEST SETUP

1.1 Scaled test setup

The studied gabion roadside barrier is a modular chain of gabions laced end-to-end together by selvage wire, see Figure 1-a. The barrier working mechanism is mixed: similar to concrete barriers, the impacting vehicle is slowed down because of the momentum exchange with the barrier, seeFigure 1-b. On the other hand, the gabion units connected on the front face only should behave as a chain and redirect the vehicle into the road lane as a steel w-beam or cable guardrails would do.

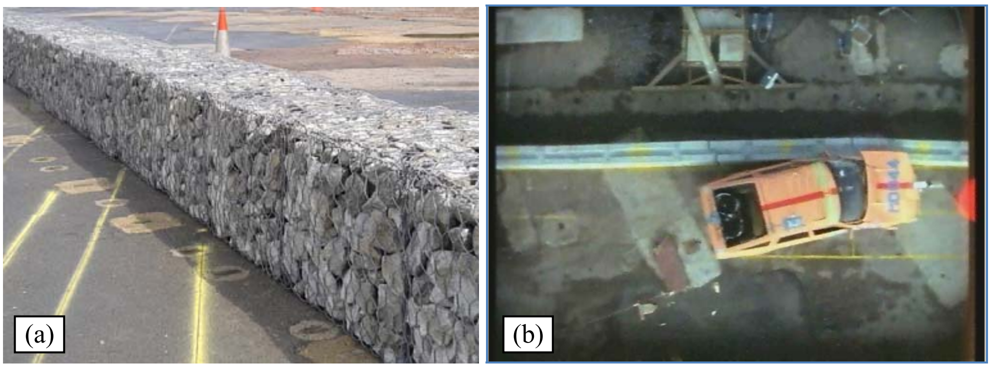

Figure 1: (a) Gabion barrier; (b) Concrete barrier crash test[9].

A scaled car-barrier impact test was carried out based on a scaling method developed by applying physical scaling theorems to the impact test problem. The method was previously validated by running numerical simulations.

The full scale barrier investigated is the gabion preliminary design having 1x0.75x0.75 m size. The barrier mass is equal to 980 kg. The full scale test car has a mass equal to 1500 kg and it impacts the barrier at an angle of 20 degree and with an initial velocity of 80 km/h.

The scale factors of mass S_M, length S_L and elastic modulus S_E, were chosen independently according to the scaling method and are reported in the following table.

Table 1: Scaling Factors.

Quantity	Symbol	Independent	Dependent
Mass	S_M	24^3	
Length	S_L	24	
Young modulus	S_E	4.7	
Velocity	S_v		2.17

According to the values chosen for the length and mass factors a scaled car and barrier were made.

The scaled barrier is composed of 30 units built using paper and 2 mm stones.

A foam material was used as base for the car and two steel weights were added at the front and back of it for reaching, together with the sensor box, the necessary mass; the same weight distribution as in the real car was obtained by scaling the original momentum of inertia along the three principal axes. To impose the correct value of mass and inertia a system of steel weights was used (see Figure 2).

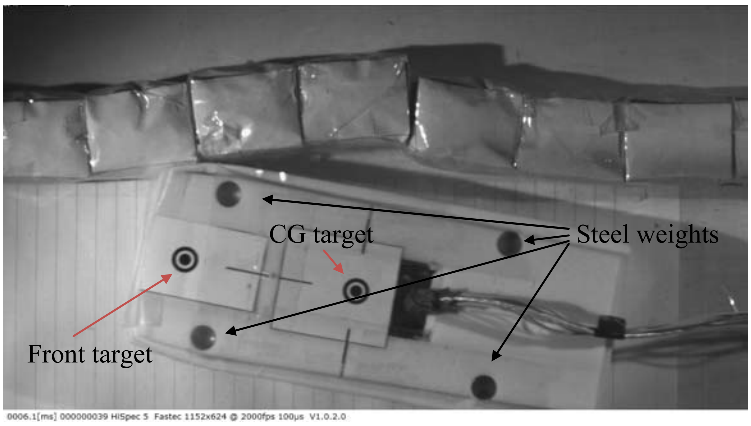

Figure 2: scaled car and barrier.

The value of the elastic modulus factor SE equal to 4.7 was obtained by comparing the real car and barrier modulus and that of the experimental set-up. For the full scale components these quantities have been estimated using real car accident data and the experimental test results on full size gabions reported in[3].

The elastic modulus of the scaled gabion and car were obtained through compression tests carried out on the scaled gabions, and on the foam used for the car specimen see Figure 3 and Figure 4.

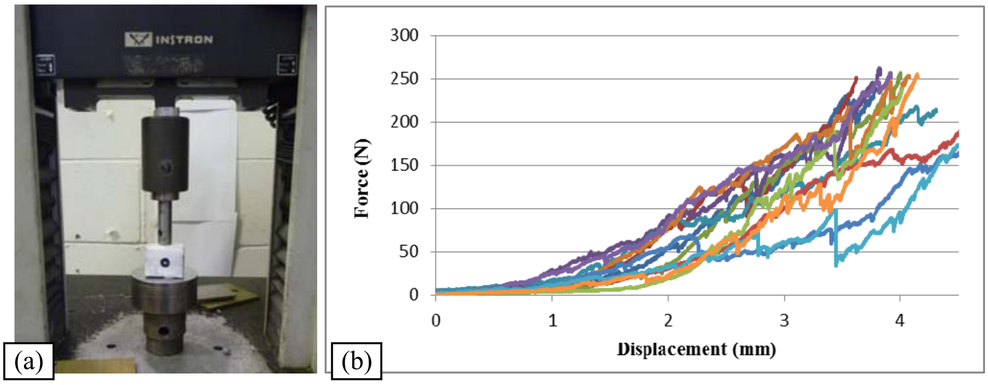

Figure 3: compression test on the scaled gabions (a) photo (b) stress-strain curves.

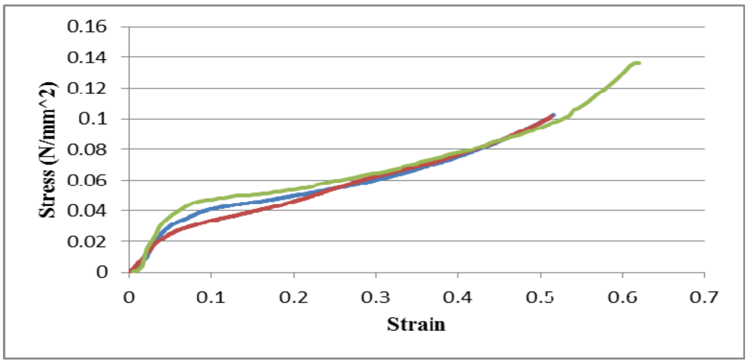

Figure 4: Compression test on the foam used for the scaled car.

The velocity scale ratio Sv and thus the initial velocity of the scaled crash test were calculated as a function of the chosen scale factors for mass, length and young modulus.

1.2 Measurements

Accelerations and angular velocity of the car were measured using a biaxial accelerometer and yaw sensor. A high speed camera Hi Spec 5 from Fastec Imaging with a Navitar 50 mm 0.95f lens was used for measuring the displacement and velocity of both car and barrier. The HiSpec 5 provides full resolution (1696 x 1710 pixels) at 523 frames per second and 1216 x 1216 resolution at 1000 fps. Lights DLH4 Tungsten Light Head Dedolight Aspherics2 Optics were also used. A trigger signal for the camera was setup using Labview.

A biaxial acceleration sensor (ADXL278 Dual Axis High) and an angular velocity sensor (ARS – 04 ATA Sensor SN 458) were also docked in the scaled car.

2 Tracking Algorithm

A Matlab code for tracking the car CG displacement was developed. The code tracks the connected region of interest of the image, in particular the region containing the target. The tracking algorithm can be summarised as follows:

1. Import and read the first image (image counter k).
2. Compute a normalized threshold of the image that can be used to convert the intensity image to a binary image.
3. Convert image to binary image using the normalized threshold computed
4. Filter the image using a morphological structuring element
5. Compute a matrix containing labels for connected regions in the black/white image

6. Measure properties of image regions, in particular the area of the region and the position of the centroid
7. Repeats steps 1-6 for the next image (image counter t=k+1)
8. Compare the area of each connected region of image t-th with the area of the target connected region in image k
9. Compute the distance between the centroid position of each connected regions in image t and the centroid position in image k
10. Choose the connected region in image t having the closest area and minimum distance from that of the target region.
11. Put k=k+1 and repeats steps 1-10.

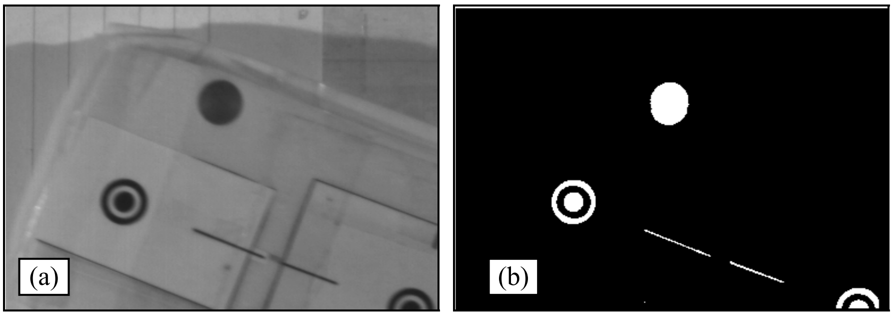

Figure 5: Image (a) imported and (b) converted to black/white for a grey threshold equal to 0.2.

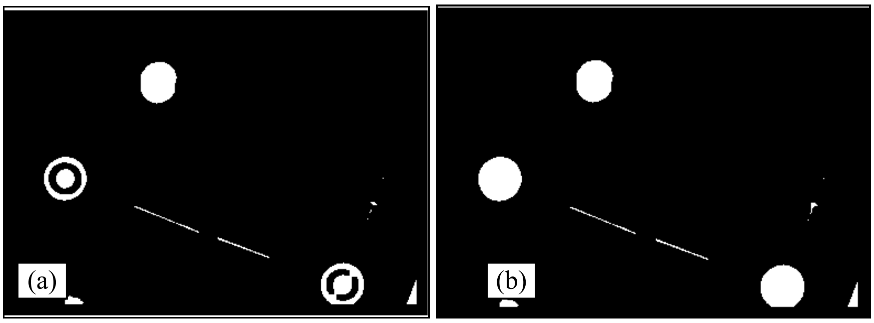

Figure 6: Image (a) before and (b) after filtering (step 4). The effect of filtering is to reduce the number of connected regions as shown in this example for a high level of filtering (disk size 6).

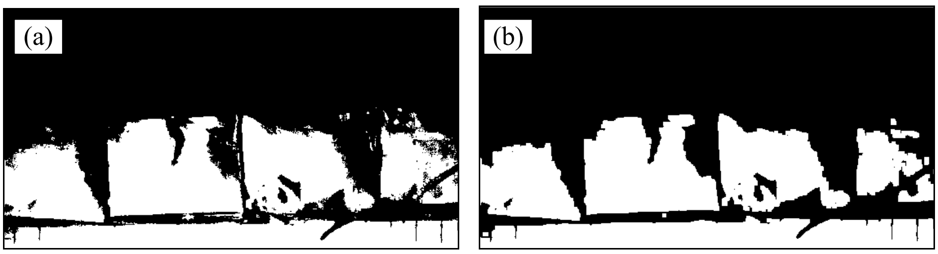

Figure 7: Another example of the effect of filtering (a) before, (b) after, using the STREL command (step 4).

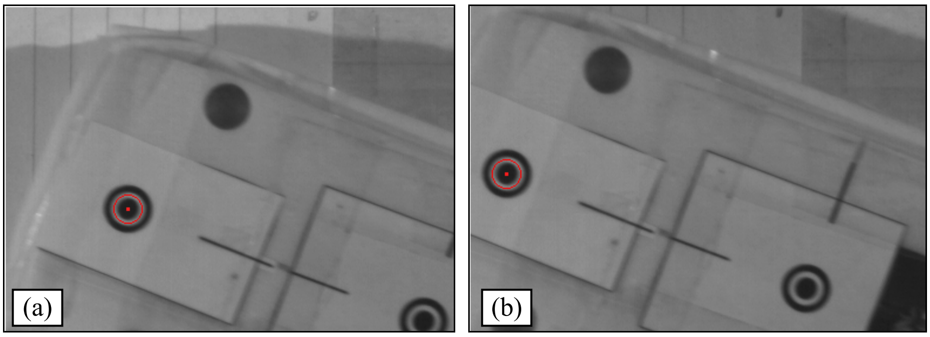

Figure 8: Target tracked in two different images, (a) k=1, (b) k=3.

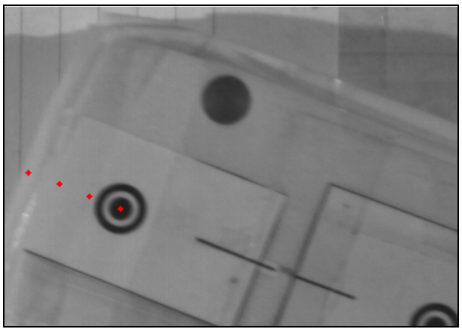

Figure 9: Track of target on the front of the scaled vehicle.

3 EXPERIMENTAL SCALED TEST RESULTS

Several scaled test based on the scaling method and setup previously exposed were carried out. In order to assess the reliability of the results a numerical Multibody model of the car-barrier impact was built using MADYMO[1, 2], a crash simulation software.

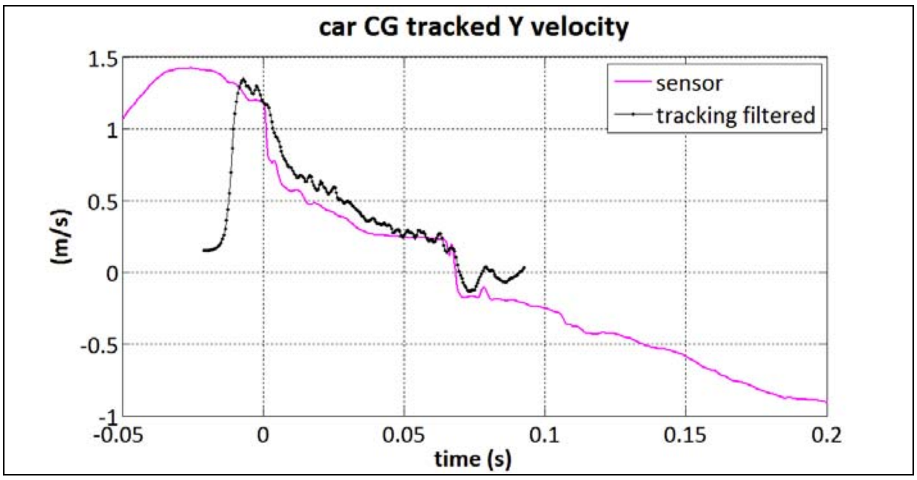

Figure 10: Velocity of the scaled car CG along the global X direction.

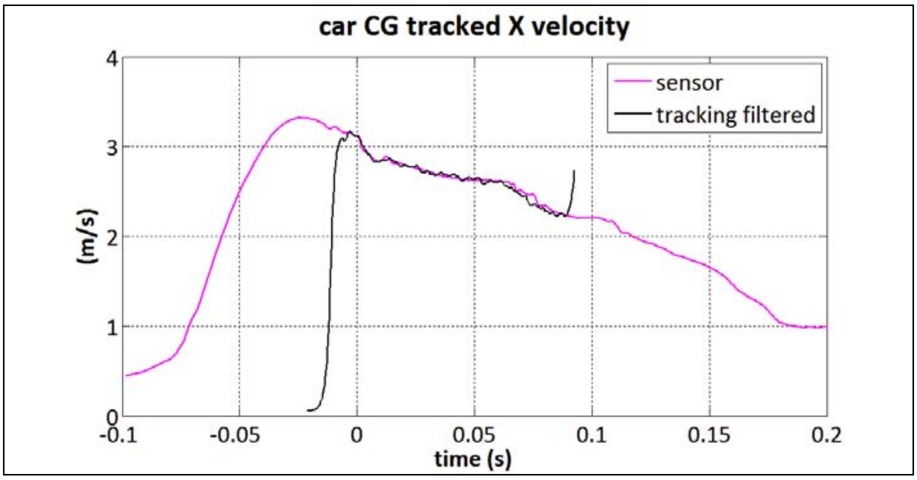

Figure 11: Velocity of the scaled car CG along the global Y direction.

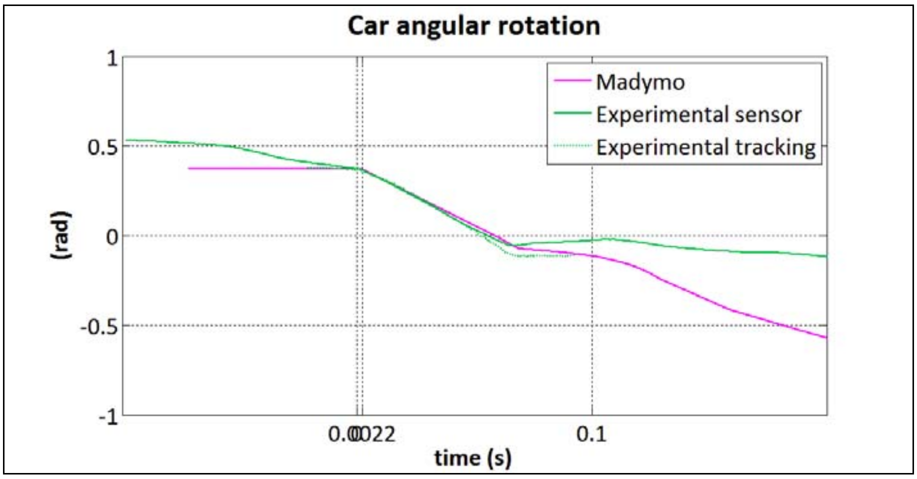

Figure 12: Angular rotation of the scaled car.

In the following figures the results of one of the scaled impact test are reported in order to assess, in particular, the tracking system.

In

Figure 10 and Figure 11 the velocity of the centre of gravity (CG) of the vehicle along the global X and Y direction are plotted and compared to the velocity obtained by integration of the acceleration recorded using the 2D sensor. The time t=0 represents the impact time. The tracking has been carried out from the 10 ms prior to the impact up to 87 ms after it, that is while the targets on the CG of the vehicle were travelling inside the camera window. To measure the vehicle angular velocity (see Figure 12), both targets, the one on the front of the vehicle and the one on the CG, were used.

This angular velocity is compared in the plot with that obtained using the yaw sensor and that of the numerical model. As it can be seen there is a very good agreement between t=0 and t=0.87, that is during the impact of the front of the scaled vehicle against the scaled barrier.

During the impact both X and Y velocity decrease and the vehicle rotates at a constant rate. The change of slope at t=67 ms indicates the end of the front impact and the sliding of the side vehicle along the barrier.

4 CONCLUSIONS

In this paper the setup of a scaled 1:24 roadside barrier crash test is reported. The scaled test was designed as a proof of concept for the design of an alternative barrier made of gabion units laced on the front face.

In particular a MATLAB code has been developed for tracking the position and the linear and angular velocity of the scaled vehicle and barrier.

The tracking algorithm works by labelling of the connected regions in the black/white image and by comparing the area and centroid position of these regions in different snapshots.

The displacements obtained with the developed Matlab code have been compared with those obtained by integration of the recorded acceleration and yaw rate. The comparison exhibits a very good agreement and shows the reliability of the tracking algorithm.

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