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1. Introduction

The stiffness of a mountain bike frame is somewhat subjective and therefore hard to quantify. The response of a frame will change with an individual's weight and power distributions. When considering in plane deflection, the double triangle structure of a bicycle frame makes it extremely stiff relative to a rider's weight and power. Considering out of plane deflection, the frame is far less stiff relative to the rider's weight and power. The test described in this report was designed by Damon Rinard for the quantification of static out of plane bending. Modern frame design is very complex; therefore the stiffness of a frame cannot be quantified by this test alone. More detailed frame tests are defined by British Standards. These tests are loaded to match actual riding conditions and will therefore be better for the quantification of frame stiffness.

This report will compare the out of plane static deflections of the Zappi custom frame (Figure 1) with various frame designs both old and new. Frames are detailed below:

- Zappi Custom Made Carbon Fibre (1)
- Kestrel KM40 (650c Wheels) Carbon Fibre (2)
- Serotta Colorado Legend Titanium (2)
- Cannondale 3.0 road Aluminium (2)



Figure 1: The Zappi Bike Frame (1)

1.1. Test Description

The frame should be orientated in a horizontal position and rigidly clamped at the bottom bracket. The front and rear frame triangles are tested separately both with 21.6 Kg's hung directly below the locations shown in Figure 2 and Figure 3. Test apparatus and setup is outlined in section 1.2. (2)

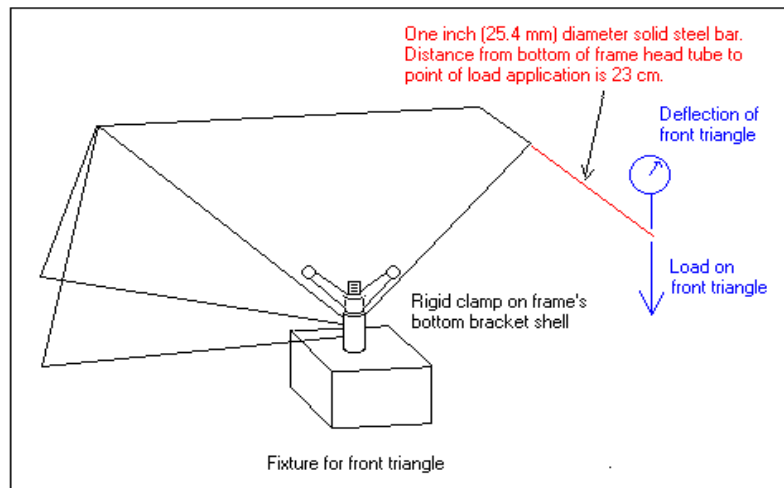


Figure 2: Front Deflection Test (2)

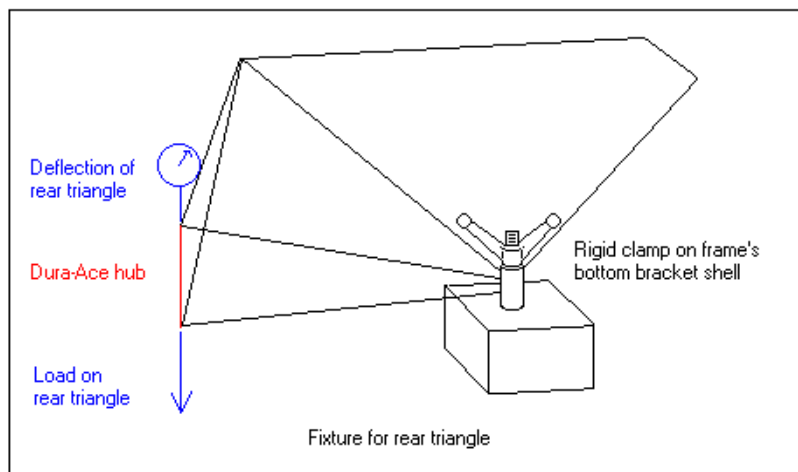


Figure 3: Rear Deflection Test (2)

1.2. Apparatus and Setup

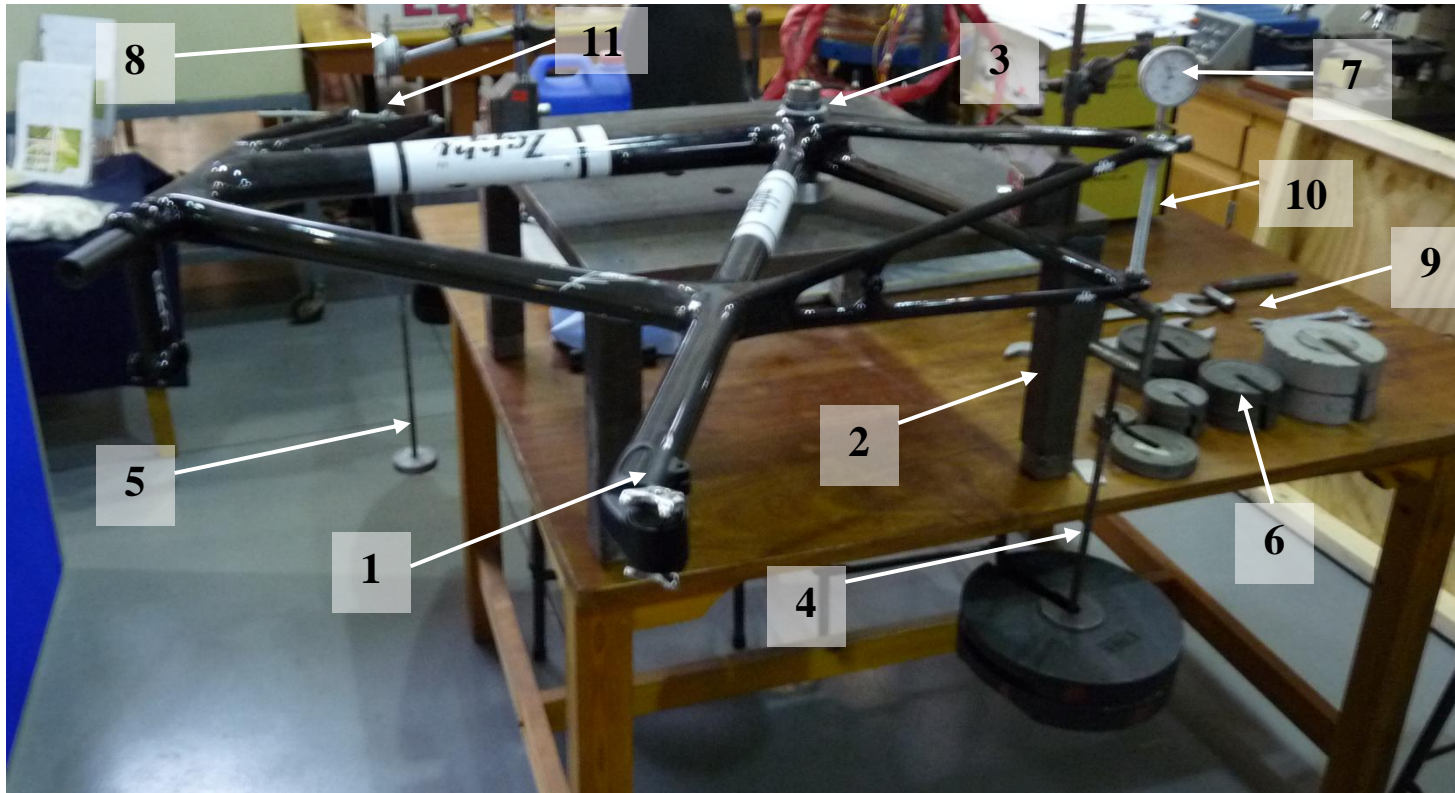


Figure 4: Test Apparatus

Table 1: Key for Figure 4

1: Bike Frame	5: Front Weight Hanger	9: Assembly Tools
2: Heavy Steel Table with Holes	6: Weights	10: 10mm Threaded Bar with Nuts
3: Long Bolt and Nut with Spacers	7: Rear Dial Gauge (measures to 100 th of a mm)	11: 8mm Threaded Bar with Nuts
4: Rear Weight Hanger	8: Front Dial Gauge (measures to 100 th of a mm)	

2. Results

Table 2: Frame Deflections (Tabulated)

	Front Deflection (mm)	Rear Deflection (mm)
Zappi Custom Carbon (1)	8.36	4.73
Kestrel KM40 Carbon (2)	11.68	4.57
Serotta Colorado Legend Titanium (2)	9.4	5.33
Cannondale 3.0 Road Aluminium (2)	3.81	4.06

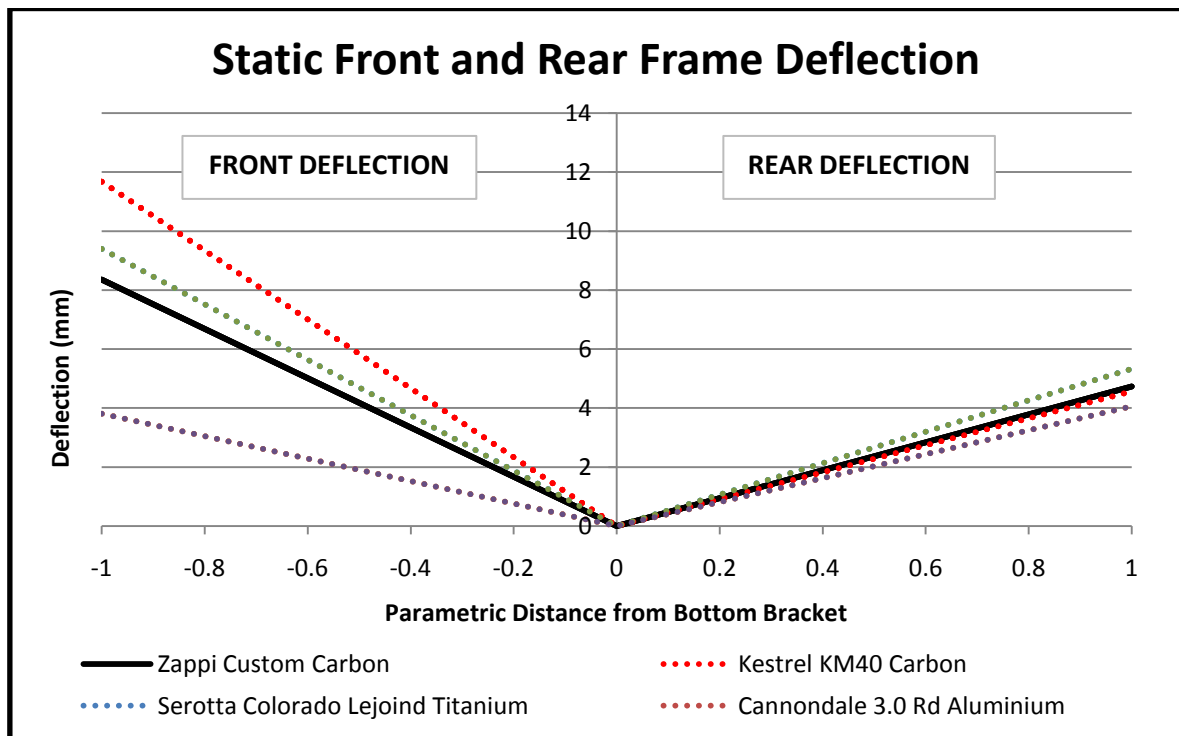


Figure 5: Deflection Mode Shape (Using 3 Nodes) Relative to the Bottom Bracket

3. Discussion

Table 2 lists the front and rear deflections in millimetres for each tested frame. illustrated those deflections in a basic visual format. The zero point of the graph represents the bottom bracket and the left and right of the graph represents the front and rear frame deflections respectively. Front triangle deflections are varied from frame to frame. This is not a key point for torque transmission from the cyclist to the rear wheel. If this triangle is too stiff then the cyclist may feel uncomfortable vibrations throughout the bike especially through the hands.

Rear triangle deflections are similar from frame to frame. For good transmission of peddling force a rigid link between the bottom bracket and the rear wheel hub is required. Both the Zappi and Kestrel frames are designed with this link in place. The Zappi frame differs from the Kestel frame with the main difference being the chain and seat stay design. The Zappi frame is shown below:



Figure 6: The Zappi Frame Schematic (1)

The down tube and chain stays are much thicker than the top tube and seat stays. The majority of the frame stiffness is owed to the down tube and chain stays. Their size and shape creating much more stiffness where required. The top tube and seat stays are much smaller and will therefore allow for more deflection. Allowing for deflection here will reduce the deflection in other areas in the frame. This is because deflections will be effectively absorbed. Not only will this lead to better torque transmission but will also lead to a comfortable ride.

The deflections shown in Figure 5 do not do the Zappi frame justice. It does show that it is as stiff as other frames over all but this has no relation to power transmission and ride quality.