

AN UPHILL BATTLE

*Which street really is
the world's steepest -
Ffordd Pen Llech
or Baldwin Street?*

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This report provides a comparison of the current world's steepest street: Ffordd Pen Llech in Harlech, Wales, with its predecessor: Baldwin Street in Dunedin, New Zealand. The analysis covers the three-dimensional shape of both streets, a review of the Guinness World Record parameters used to award the world record to Ffordd Pen Llech, and suggestions for future measurements of the world's steepest street.

This report finds that Baldwin Street is steeper than Ffordd Pen Llech by 5.2 per cent when the average of left-hand side, centreline and right-hand side gradients of the steepest 10-metre sections of both streets are compared. This report also finds that the centreline of Baldwin Street is 6.2 per cent steeper than Ffordd Pen Llech.

This is largely due to the different shape of both streets. Baldwin Street is straight with uniform gradient across the width of the carriageway. Ffordd Pen Llech has many horizontal curves which all affect the road gradient.

Our view is that a minor rule change is necessary to enable straight streets and curved streets to be assessed fairly. This can be achieved by requiring steepness to be measured at the centreline of the street.

Measuring on the centreline:

- is standard practice in the surveying and engineering professions
- provides a reasonable approximation of average gradient over the full width
- allows straight and curved streets to be assessed equally without using overly sophisticated measurement and analysis techniques.

All calculations are in the appendices.

Introduction

This report is a comparison of the steepest 10m long sections of Ffordd Pen Llech and Baldwin streets. Its purpose is to compare the gradient of each street; a challenging task as they have very different shapes. The history, function, setting within the road hierarchy, and performance of each street is beyond the scope of this report. Suffice it to say they both satisfy the criteria of a "street" as it relates to the rules of Guinness World Records.

Description of Baldwin Street

Baldwin Street is located in Dunedin City, Otago, New Zealand. The road controlling authority is the Dunedin City Council.

It starts 1.4 kilometres north-east along North Road from the intersection of Bank Street, North Road, Opoho Road and Great King Street. Baldwin Street is 374m long

and rises 69m from North Road to Buchanan Street. The horizontal alignment is entirely straight.

The first (lowest) 180m section of Baldwin Street is a flexible chip seal pavement. It is a two-way carriageway with parking on both sides. From there it steepens significantly and changes to a rigid concrete pavement with no parking on either side. Kerb and channel are provided on both sides over the full length. A footpath is provided over the full length of the south side. A footpath is provided over 80 per cent of the north side. The footpaths have long sections of steps owing to the steep topography.

Vehicular access is provided to houses on both sides of Baldwin Street over its full length.

Baldwin Street held the Guinness World Record for steepest street from 1987 until 2019 with a gradient of 35 per cent (1 in 2.86). There was some initial confusion over the gradient of Baldwin Street as its published value was 1 in 1.286 – an apparent typographical error.



Figure 1: Baldwin Street location diagram – satellite imagery courtesy of Google Earth



Figure 2: Baldwin Street steepest section – satellite imagery courtesy of Google Earth

Description of Ffordd Pen Llech

Ffordd Pen Llech is located in the town of Harlech, in the North Wales county of Gwynedd. The road controlling authority is the Gwynedd Council.

Ffordd Pen Llech starts in central Harlech, 80m south-east of Harlech Castle at the intersection of Twitl, Pen Dref, Ffordd Pen Llech and Stryd Fawr (B4573).

Ffordd Pen Llech is 343m long and falls 57m to Hwylfar Nant. The gradient is steep for the first (top) 240m until the end of the world record hairpin curve. The gradient reduces for the final 100m until it is moderately flat at the intersection with Hwylfar Nant. The alignment is complex and contains 12 horizontal curves up to 145 degrees deflection (at the world record corner).

It has a flexible chip seal pavement over its full length. Some sections of pavement rehabilitation are apparent with sections of new asphalt – around both sides of the steepest section in particular.



Figure 3: Ffordd pen Llech location diagram – satellite imagery courtesy of Google Earth



Figure 4: Ffordd Pen Llech steepest section – satellite imagery courtesy of Google Earth

The carriageway is entirely one way. There are occasional no-parking lines near the top of the street although parking for considerable portions is left to the discretion of road users. Long sections are too narrow to allow any parking on the carriageway. Short sections of concrete kerb and channel are provided, as required, to direct stormwater runoff into mud tanks. Ffordd Pen Llech is a shared space street. No footpaths are provided.

While relatively informal, the engineering is in keeping with its heritage setting. Its purpose is to provide vehicular access to a small number of residential properties and businesses, and to provide a pedestrian link to lower Harlech. Here amenity values predominate.

Ffordd Pen Llech was awarded the Guinness record of world's steepest street in July 2019 with a published steepness of 37.45 per cent.

The record is lost

Tuesday, 16 July 2019 – The *Otago Daily Times* published an article confirming that Baldwin Street lost the world's steepest street record to Ffordd Pen Llech in Wales.

This was disappointing, but no real surprise as there had been media reports in the preceding weeks and months advising that something was in the pipeline. It wasn't until later that morning, when photographs began circulating of the Welsh surveyors in action that it became apparent that things had gone awry. The photographs showed the Welsh surveyors measuring the gradient on the inside of a hairpin curve.

Sharp hairpin curves are much steeper on the inside than the outside. It is not realistic to rely on measurements along one side of the road to gain a correct appreciation of the gradient of a road around a curve. Measurements on the centreline give a far better approximation of overall gradient. The average of left, centre and right is better still.

The photograph alone was not proof that the measurements used to award the world record were taken on the inside, but it did raise concerns.

Wednesday, 17 July 2019, we undertook a case study at Lancefield Street, Dunedin, as it was similar in nature to the world record corner and had the potential to challenge Ffordd Pen Llech. While the inside was not steep enough to lodge a claim for a new world record, it demonstrated the flattening effect of horizontal curvature from the inside toward the outside. We were confident that Ffordd Pen Llech would flatten off to a similar degree and that Baldwin Street was likely still steeper than Ffordd Pen Llech overall.

Our findings were discussed with RNZ National reporter Timothy Brown. He managed to contact Guinness which confirmed that the Welsh measurements were indeed

made on the inside of the curve. We recorded a radio interview for RNZ's *Checkpoint* that evening, discussing the issues.

Later that week we demonstrated our findings on television and suggested that straights and curves need to be assessed equally. To do so would involve nothing more complicated than to measure steepness on the centreline. This generated many weeks of media interest.

Work begins

We decided to submit our findings to Guinness World Records in the form of an assessment of the two streets.

The first item to be completed was a full survey of Baldwin Street. This would confirm its published maximum gradient of 35 per cent and would provide valuable graphical information to support our findings.

I discussed this with Ray Copeland of Global Survey who offered to send down a Leica P40 scanner and one of his scanning experts, Lennon Bedford. Lennon would scan Baldwin Street, produce reports and graphics.

Clark Fortune McDonald & Associates established some accurate benchmarks in Baldwin Street so that the scanned point cloud could be oriented into terms of recognised horizontal and vertical reference systems.

Sunday, 4 August 2019, I received a Facebook message from Mike Constable; a classmate from the Otago University School of Surveying, who suggested crowdfunding to send me from New Zealand to Wales. It was unexpected – however it would definitely raise the profile of our mission so I agreed. Mike Constable, Dave Mitchell and Andrew Bonallack set up a Gogetfunding page and began fundraising.

On Wednesday, 7 August 2019, we met Lennon Bedford on site and scanned 120 million points with the Leica P40 laser scanner. The P40 is an excellent piece of kit with the ability to gather a rich, accurate dataset very efficiently.

Meanwhile the crowdfunding had gathered a good head of steam and within a few weeks reached more than \$8000. This was largely made up of very generous donations from the Class of '92, the public and other surveying firms in Dunedin.

The trip to Wales was announced, which sparked more media interest.

Another classmate, Sam Harman, volunteered to travel from his home in Aberdeen to Wales where he would provide technical and logistical support. We decided to rendezvous in Manchester as Air New Zealand flew there direct.

Organising traffic management from the other side of the world was a fun challenge especially given the time difference. For our proposed surveying activity, we needed a stop/go person plus half a dozen signs in English and Welsh. JTM Signs was engaged as it had resources in North Wales and plenty of local knowledge.

We also needed clearance from Gwynedd Council. They were taken slightly aback when they heard that a couple of New Zealanders were coming around the world to measure their street. We assured them that everything was totally legitimate; and once we provided our credentials, and a very thorough job safety analysis, they were most helpful.

The final item to square away was equipment hire. M&P Survey generously offered free total station hire for the project. Dave Langton also offered to travel down with a scanning total station and to scan the steepest section.

At 9am, Thursday, 7 November 2019, Sam and I carried our gear down to the steepest part of Ffordd Pen Llech, media in tow, to take our measurements.

JTM set up the traffic management and stopped the occasional car. Traffic volumes were very low.



Photo 1: Sam Harman selfie, with the author and New Zealand media behind

Although not absolutely necessary, our intention was to include the two survey points (nails in the edge of the seal) from the Welsh world record survey so that our work could be put in terms of the same coordinate reference system. Unfortunately, these had been destroyed in recent pavement repairs.

We were able to measure two circular manhole covers from the original survey. These had dimples in the precise centre of the lid. They were very good reference points and allowed us to put our work in terms of the Welsh survey with a high degree of confidence.

In total we measured 101 survey points around the steep corner which included:



Photo 2: David Langton of M&P Survey scanning Ffordd Pen Llech as a cyclist avoids the steepest side

- both seal edges at approximately 1m intervals
- centreline at approximately 1m intervals
- spot heights between the centreline and seal edge
- six nails to act as reference marks (to allow the scanning total station data to be oriented with ours).

We downloaded our modest (4kb) dataset and made the way clear for David Langton to begin scanning.

This left the rest of the morning free to do interviews. TV3 reporter Lloyd Burr had bought some Jaffas in London so that he could roll them downhill at the end of his interview. He was in the middle of telling us how staggeringly expensive they were when his bag split wide open and £10 worth went rattling into the undergrowth. Luckily most of them were recovered and, once the leaves were cleaned off, they were rebagged for the great rolling downhill.

Results

Methods of analysis included:

- resurveying both streets using conventional surveying methods
- laser scanning both streets as an independent check, for micro-level evaluation, and for graphical representations
- locating the steepest 10m section of Ffordd Pen Llech on the inside of the hairpin curve and confirming the world record gradient
- projecting this section onto a) the centreline; and b) the outside of the road; then determining the

average gradient of the road base on left, centreline and right-hand side gradients

- demonstrating the amount of gradient reduction from the inside of the curve to the outside
- locating the steepest 10m section of Baldwin Street on the centreline and confirming the previous world record gradient
- projecting the 10m steepest section onto a) the left; and b) right hand sides of the road; then determining the average gradient of the road based on the left, centreline and right-hand side gradients
- comparing the centreline gradients of both streets.

Baldwin Street

Baldwin Street analysis was carried out on the P40 scan data from chainage 160.00 onwards.

From chainage 0-00 to 160.00 the carriageway is quite flat and not worth analysing. The method of analysis is as follows:

- calculating the CL gradient between chainage 160.00 and 170.00
- calculating the gradient between chainage 160.20 and 170.20, then by moving up on the centreline in 200mm increments through to the gradient between 360.00 and 370.00 (approximately 1000 gradient values)
- ordering the results based on highest gradient to find the steepest 10m section of the centreline
- determining the corresponding gradient of the 10m section on the left-hand side
- determining the corresponding gradient of the right-hand side
- taking the average of the three gradients.

Baldwin Street	From (Chainage)	To (Chainage)	Gradient (%)
CL	289.8	299.8	34.8
LHS	289.8	299.8	34.5
RHS	289.8	299.8	35
Average			34.8

It is interesting to note that our maximum measured steepness on the centreline is 34.8 per cent, whereas 35 per cent was measured on the right-hand side.

The results show a small difference in left, centre and right-hand side gradients. For a straight street the centreline gives a good indication of overall steepness.

Ffordd Pen Llech

The world record is based on the inside seal edge over the steepest 10m section. This was located by analysing 10m long sections around the inside seal edge from the beginning of our survey data and moving up in 200mm increments per the Baldwin Street centreline. Refer below.

Once the steepest 10m long section had been found on the inside, the gradients of the adjacent 10m-long sections were found on the centreline and the outside seal edge.

The road outline in the study area is irregular and care was taken to achieve a best estimate of the centreline. The centreline is a critical to any road: it is the fundamental design string around which the three-dimensional shape of the road is built. The centreline of the study area comprises an approach straight, followed by a sharp curve to the left and a straight exit.

In residential situations, straights and circular horizontal curves are the most common element types. Spirals transition curves are generally used where operating speeds are higher than 50 km/h and where extreme gradients are unlikely to be present.

The centreline in the study area was determined by:

- plotting the midpoint between left and right-hand sides around the curve
- estimating a circular curve through these points using linear regression
- estimating the straights on either side using linear regression of the road midpoints along the straights
- offsetting these lines so they were tangential to the circular curve (maximum 6.6mm offset required).

The average of inside centre and outside was determined as follows:

Ffordd Pen Llech	From	To	Gradient (%)
Inside (LHS)	5.4	15.4	-38.6
CL	5.8	15.8	-28.6
RHS	10.2	20.2	-21.7
Average			-29.6

"From" and "to" relate to the distances from the start of each line as surveyed. Chainage is not used to avoid confusion – the inside line around a curve is shorter than the outside line. Refer to the plans and spreadsheets in the appendices.

Interestingly our study found the steepest 10m-long section around the inside (38.6%) to be steeper than the world record gradient by 1.1 per cent.

The study also demonstrates the significant difference in gradient between the inside and the outside (16.9%), such is the nature of steep curves.

Summary of results

	Ffordd Pen Llech	Baldwin Street
Centreline gradient	-28.6%	34.8%
Average gradient (left, centre & right)	-29.6%	34.8%

Although the steepest 10m section of Ffordd Pen Llech is steeper than Baldwin Street by 3.6 per cent, the centreline gradient of the steepest 10m section of Baldwin Street is 6.2 per cent steeper than Ffordd Pen Llech. The average gradient of Baldwin Street is 5.2 per cent steeper than Ffordd Pen Llech. This difference is significant and illustrates the effect that horizontal curvature has on the steepness of streets.

Recommendations

In addition to Guinness's existing rules for awarding the world record for steepest street, we recommend the following:

- Steepness to be determined on the centreline as this equalises straights and curves
- Steepness to be expressed as a per cent as this avoids confusion
- Steepness to be expressed to one decimal place of a per cent – two decimal places corresponds to 1mm over 10m which is an unrealistic degree of accuracy given the irregular nature of street carriageways.

Conclusion

Although steep on the inside of the curve, Ffordd Pen Llech is not steeper than Baldwin Street overall. The difference between the two gradients is significant. We recommend that future world records be decided on steepness at the centreline as this allows straights and curves to be assessed equally.

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