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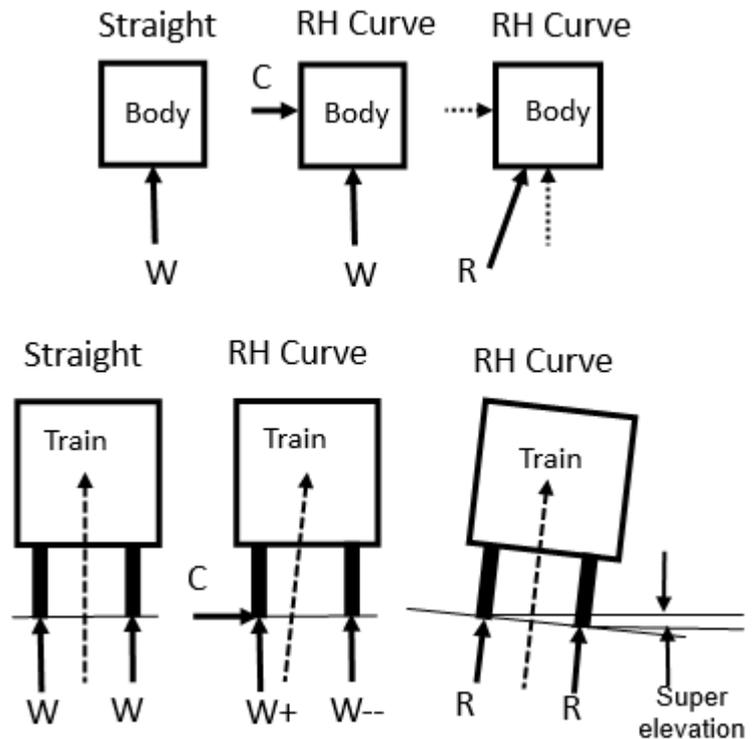
Super Elevation in 5 inch gauge

This document was written by Mike Wheelwright and was originally published by Worthing and District SME in their newsletter in the Spring of 2015.

Super elevation is not a subject that crops up frequently in the miniature railway world although it was, and still is, very much a feature of full size railway track. Surprisingly it surfaced recently in a Gauge 1 group to which I belong where, although irrelevant in such a small scale, it provoked quite a bit of discussion but from the comments made it seemed that most people were a bit hazy on the subject. I thought it might be interesting to have a look in 5" gauge, especially since contestants in the last IMLEC were obliged to start their loads on a curve which appeared to have considerable super elevation.

Curved track is often super elevated by raising the outside rail so that the vehicles are tilted towards the inside of the curve, a bit like the banking at Brooklands but not so steep! The tilt provides an inward force that helps the vehicle to travel in a curve rather than go straight on and the amount required depends on the sharpness of the curve (radius) as well as the speed. Any massive body (most people would say lump of stuff) travelling on the circumference of a circle is in fact accelerating at a constant rate towards the centre of the circle, and as Newton figured out some time ago, mass only accelerates when a force is applied to it, so the body on the curve has to be constantly forced towards the centre: this is centripetal force. Think of the pull on the string as you whirled your conker round. The calculation of the force is very simple: the mass times the square of the velocity divided by the radius. This means that the force will have to be increased on tighter curves or when travelling faster: double for half the radius but quadruple for twice the speed so the effect of speed is more predominant.

The little diagrams show what happens: the upper figures show a body travelling at constant speed in a straight line with just an upward force W to support the weight. Next, when the body travels round a curve another force C has to be applied to make it follow the curve, the two forces can be combined as a single force R at a slight angle to the vertical. The lower figures show a train on a straight line with the rails supporting the weight of the wheels but when it corners the force C has to be provided so that it does not continue straight, the only contact with the ground is at the rail head so this force has to be supplied by the outside rail on the wheel flange. At slow speed the wheel will continue to roll with the flange against the rail but at a faster rate the increased force causes the wheel to try to rise and as the centripetal force acts through the centre of gravity above rail level the weight on the inner wheels reduces so that in an extreme case the train falls to the outside.



This was easily done with Hornby-Dublo and more recently a tragic full size demonstration was provided in Spain when a high speed train failed to reduce speed when running on to a conventional line with a sharp curve.

By raising the outer rail and thus tilting the train, the combined reaction force becomes perpendicular to the line across the rails so the forces on each wheel are equal and no sideways push at the flange is required. As a full size example imagine the Coronation Scot snaking through the Lune valley round a 60 chain curve at 70 mph. Yes, real curves were measured in "Chains", there must be someone around who chanted "22 yards make 1 chain, 10 chains make 1 furlong, etc". OK so the radius is $\frac{3}{4}$ mile. Each pound of mass will need 0.08 lbf to pull it into the curve and the combination of weight with centripetal force will lie at $4\frac{1}{2}^\circ$ to the vertical. To avoid the need for any sideways force at the wheel the track can be super elevated to this angle, so the outer rail would have to be raised about $4\frac{1}{2}$ ". This is called the "Balancing super elevation" as it provides just the right amount of centripetal force for this train on this curve, but what happens when the night goods train appears pulled by a Super D slogging along at 20 mph? This train would need only one twelfth of the centripetal force due to its low speed so the $4\frac{1}{2}$ " super elevation would push the flanges on to the inner rail by about a fifteenth of a ton for each ton weight of train. Just imagine starting 500 tons of freight with a 35 ton side force on the flanges. In practice super elevation on tracks carrying trains of widely differing speeds had to be a compromise.

Tighter curves or higher speeds would need more lift but the usual limit was about 5" or exceptionally 6" and if this was insufficient to balance the centripetal force assistance from the flanges was accepted. Some guiding effect was obtained from the coning of the wheel treads and inwards inclination of the rails, when the wheels moved towards the outer rail the effective diameter of the outer wheel was slightly greater than the inner thereby imparting a small tilt.

So, what about getting our Chief Engineer to put in a bit of SE? It would be useful for the speed merchants (whoever they may be). A model travelling at a scale 70mph (6mph) round a scale 60 chain (330ft) curve would require an inward force of less than one hundredth of its weight that could be balanced by $\frac{1}{32}$ " elevation. But in reality, we regularly run at 6mph round 60 ft radius curves so the force becomes a thirtieth of the weight, this could be balanced using $\frac{3}{16}$ " elevation. For a locomotive weighing in at 120 lb the force of 5lbf acting about 5" above the rail is scarcely noticeable but it is a bit different for a 12 stone driver for whom the pull inwards at 7lbf is only a bit bigger but the effect is more noticeable as his centre of gravity is considerably higher and the force from the flanges has to be transmitted through the trolley to the driver. What do you think, should we go for it? But please not through the station curve, with a 1000 lb train behind there would be about 35 lbf flange pressure to be overcome when getting away. Perhaps this sheds some light on the slipping at the Bournemouth IMLEC.