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Rail Industry Guidance Note
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Rail Industry Guidance Note on Vehicle Static Testing

This document gives guidance on meeting the requirements of GMRT2141 'Permissible Track Forces and Resistance to Derailment and Roll-Over of Railway Vehicles' and BS EN 14363 'Railway applications. Testing and Simulation for the acceptance of running characteristics of railway vehicles. Running behaviour and stationary tests' in respect of vehicle static testing.

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Synopsis

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Issue Record

Issue	Date	Comments
One	01/06/2019	Recommendations in GMRC2641 issue two have been rewritten as guidance to reflect the change of status from a Code of Practice to a Guidance Note. Recommendations in GMRC2641 issue two have been updated to change the references throughout to BS EN 14363:2016 rather than GMRT2141 issue three. New guidance added for the assessment of offset loaded container wagons at section G2.5. New guidance added regarding the benefits of recording vehicle body twist within clause G2.4.20. Editorial changes throughout.
Two	01/06/2024 [proposed]	Additional guidance, incorporating worked examples, for the Delta Q/Q assessment with offset loads for vehicles carrying intermodal load units. TSI changed to NTSN where appropriate.

Revisions have been marked by a vertical black line in this issue. Definitions and References may also have been updated but these are not marked by a vertical black line.

Superseded Documents

The following Railway Group documents are superseded, either in whole or in part as indicated:

Superseded documents	Sections superseded	Date when sections are superseded
GMGN2641 issue one, Rail Industry Guidance Note on Vehicle Static Testing	All	01/06/2024 [proposed]

Supply

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Part 1 Introduction

G1.1 Purpose

G1.1.1 This document gives guidance on meeting the requirements of GMRT2141 'Permissible Track Forces and Resistance to Derailment and Roll-Over of Railway Vehicles' and BS EN 14363 'Railway applications. Testing and Simulation for the acceptance of running characteristics of railway vehicles. Running behaviour and stationary tests' in respect of vehicle static testing. It also gives guidance on vehicle simulation model validation.

G1.1.2 This document does not set out requirements.

G1.2 Structure of this document

G1.2.1 Guidance is provided as a series of sequentially numbered clauses.

G1.2.2 Specific responsibilities and compliance requirements are set out in GMRT2141 and BS EN 14363.

G1.2.3 Except where specifically identified otherwise, references to BS EN 14363 in this document are to BS EN 14363:2016+A2:2022. Technical requirements in the superseded documents BS EN 14363:2016 and BS EN 14363:2005, supplemented by ERA/TD/2012-17/INT are equivalent to those in BS EN 14363:2016+A2:2022.

G1.3 Approval and authorisation of this document

G1.3.1 The content of this document will be approved by Rolling Stock Standards Committee on 18 April 2024 [proposed].

G1.3.2 This document will be authorised by RSSB on 03 May 2024 [proposed].

Part 2 Guidance on vehicle static testing

G2.1 Background

G2.1.1 A review of previous issues of GMRT2141 highlighted the need for improved definitions of the physical tests carried out on new vehicle types. This was because certain tests were undefined in Railway Group Standards, while others were defined in a way that differs from the methods used in practice.

G2.1.2 Although most Great Britain (GB) rail vehicle test laboratories use similar methods (for historical reasons) this is not necessarily the case for all suppliers, especially companies new to the GB market. Clarifying the test conditions and requirements enables common methods to be used for the acceptance of all vehicles. It also provides consistent baseline data for the validation of models used in simulations for acceptance purposes.

G2.1.3 The appendices in GMRT2141, issue three, set out the details of a series of tests that may be carried out to satisfy and support its requirements. GMRT2141, issue four and later issues, no longer contain the requirements for the static tests as these are now included within section 6, Method 3 of BS EN 14363. The guidance in this document, GMGN2641, is based on proven methodologies for undertaking those tests.

G2.1.4 This document provides guidance on performing four generic static vehicle tests as set out below:

a) Weighbridge test, to determine nominal axle load, as required, for example, in GERT8006.
b) Wheel unloading test, required by section 6, Method 3 of BS EN 14363.
c) Bogie rotational resistance test, required by section 6, Method 3 of BS EN 14363.
d) Sway test, to determine maximum static displacements, as required, for example, in GMRT2173.

G2.1.5 The wheel unloading and bogie rotational resistance test procedures, along with the weighbridge and sway test procedures, are based on the tests that are now all defined in the European standard BS EN 14363.

G2.1.6 The guidance has been drawn from a variety of sources, including current and historical standards, and test procedures used by the major GB rail vehicle test laboratories.

G2.2 Conditions common to all tests

General

G2.2.1 It is expected that test laboratories have a standard test procedure for each of the four static tests set out in clause *G2.1.4*. The test procedure describes the operation of the test equipment and the processing and presentation of results.

G2.2.2 It is good practice for the test conditions and results to be recorded in a formal document to set out and justify in detail any alterations made to the standard test procedure. The vehicle number, orientation, modification state, suspension condition and load condition are also recorded to define the context of the results.

G2.2.3 Where possible, all tests are carried out on the same vehicle to ensure a consistent set of data.

G2.2.4 The effects of the following are included in the consideration of the range of vehicle conditions to be tested:

a) Vehicle design asymmetry
b) Loading, load distribution and so on
c) Inter-vehicle connections
d) Degraded suspension modes or component failure
e) Any novel design features.

G2.2.5 The specified tests and the associated limit values include a margin for the normal variation of vehicle parameters and it is not necessary to test all conceivable conditions. It is, however, important to consider any unique or novel features of the vehicle, or its load, which may lead to variations outside the 'historic norm' for similar vehicles, and whether it is therefore necessary to test a wider range of conditions.

G2.2.6 Vehicles with significant friction or hysteresis in the suspension can give inconsistent results caused by locked-in movement, especially after a vehicle has been stationary for several days, or weeks, as may be the case prior to a test. These effects can be reduced by running the vehicle repeatedly over a section of track with level differences that activate these aspects of the suspension system. It may be necessary to repeat this exercise when vehicles are moved or stored between tests.

G2.2.7 Vehicles are generally tested in their new condition. However, effects such as bedding-in, ageing, wear and degradation can cause significant changes to a vehicle's behaviour during its lifetime. Consideration given to any effects that can worsen the performance and lead to an unsafe condition during the life of the vehicle can result in recommendations for future testing and / or operating restrictions (for example, load or speed) for the vehicle included in the test report.

G2.2.8 The suspension springs of a vehicle, particularly those fitted with rubber springs, are generally matched to within a few percent of one another to avoid large discrepancies in stiffness across a wheelset or pair of wheelsets. If the stiffness of the springs is towards the upper or lower limits of their allowable tolerances, which for rubber springs may be significant, since their stiffness can vary by ±20 % of their nominal value, this could have a significant influence on the test results. It is therefore important to know the stiffness of the springs of the tested vehicle's suspension in relation to the nominal design values, and consider and note any effects this might have on the results.

Additional procedures for the purpose of validating a vehicle simulation model

G2.2.9 Clauses *G2.2.10* and *G2.2.11* set out targets for the matching error and matching accuracy when the test results are to be used to validate a vehicle simulation model. Further options for model validation are also set out in BS EN 14363 Annex T.

G2.2.10 Matching errors are calculated as set out in this document. They are always positive, such that they do not cancel each other out when calculating an average error:

a) Sway test validation: $absolutematchingerror = [simulation - measured]$

b) Weighbridge, wheel unloading and bogie rotational resistance tests validation:

$$percentagematchingerror = 100 \times \frac{[simulation - measured]}{0.5 \times (simulation + measured)}$$

G2.2.11 Matching accuracy limits are set out in this document for each test for both maximum and average matching errors:

a) The 'average error' limit controls the overall accuracy of the matching within tight limits
b) The 'maximum error' limit allows for individual spurious results but limits the magnitude of such errors.

G2.2.12 Any doubt about the matching accuracy of the test results or conditions can be addressed by revision of the model and recalculation.

G2.3 Weighbridge test

Scope

G2.3.1 This section gives guidance on achieving accurate and repeatable results from the weighbridge test.

G2.3.2 The purpose of the weighbridge test is to evaluate the vehicle's weight and the distribution of the static vertical wheel forces (wheel loads).

G2.3.3 The test results also facilitate validation of a vehicle model, for use in a simulation.

G2.3.4 This includes tests for each of the following parameters:

a) Total vertical vehicle load
b) Vertical load per axle
c) Vertical load per wheel.

Vehicle conditions

G2.3.5 The test vehicle is tested with the usual operating equipment and fluids installed. This might for example be with the tanks full. However, there are many variations and the most relevant condition may vary with vehicle type. It is important that the implication of variation in operating equipment and fluids is considered (for example the effect of emptying a fuel or water tank) and the most relevant 'worst' case for the test is identified. For further guidance, BS EN 15663:2017+A1:2018 'Vehicle reference masses' sets out the definitions for different load conditions.

G2.3.6 With respect to vehicles carrying loads or passengers, the test vehicle is weighed in the tare and the fully laden state. The simulated load status corresponds to the planned maximum permissible occupancy (typically the crush laden weight) or freight load. Where the effects of the maximum permissible occupancy or freight load, on the individual wheel loads, are understood and documented from previous test results, it may only be necessary to test the vehicle in its tare state.

G2.3.7 The test(s) is carried out with the suspension in its normal operating condition(s) and in any foreseeable active system failure condition(s) which could affect the vertical wheel load distribution.

Test rig

G2.3.8 The test rig and the adjacent track are plain and nominally straight and level. During the test the vertical misalignment measured at each wheelset location is generally within the limits 0 mm ± 2 mm in order to minimise the effects of cross-level and twist. Inaccuracy is reduced when the test track is on foundations that minimise rail deflection.

G2.3.9 It is preferable that the vertical wheel forces under all wheels of the vehicle or one bogie are measured at the same time. However, equipment that is capable of measuring the vertical wheel forces of one wheelset at a time could be used, with each wheelset being positioned sequentially on the test rig.

Test conditions

G2.3.10 Tests can be preceded by adjustment of the suspension where this forms part of the normal manufacturing or maintenance procedures in accordance with the specified vehicle maintenance instructions. Any adjustments prior to the tests are, in principle, carried out by means that do not require the measurement of forces but only require checks of a dimensional character.

G2.3.11 The influence of friction can be minimised by using the following procedure:

a) The vehicle is run at reduced speed on to the test rig after it has been run over a section of track with level differences that activate the suspension system
b) After passing over this section of track and during weighing, no alteration or adjustment is made to the vehicle.

G2.3.12 At the moment of measurement, it is normal to isolate or eliminate external forces acting on the vehicle due to such conditions as:

a) Braking reactions (including static, parking brakes);
b) Externally restrained wheelsets; and
c) Non-permanent inter-vehicle connections.

G2.3.13 Four successive and complete weighing operations are carried out with the vehicle being run onto the rig for each test and twice from each direction. This can be achieved by turning the vehicle between weighing operations, or by approaching the weighbridge from the opposite direction, with a record of the method used.

Measured values and evaluation

G2.3.14 The vertical wheel forces (Q) of all wheels are measured for each of the four weighing operations, using the calculated average for each wheel.

Assessment of test accuracy

G2.3.15 The following values are then calculated from the average calculated wheel loads from each set of measured values:

a) Wheelset loads – the vertical load in kN on each wheelset
b) Side loads – the total load in kN on each rail (that is, all left-hand side and all right-hand side wheel loads)

c) End loads – the total load in kN on each bogie or on each axle (for two-axle vehicles)
d) Total load – the total load in kN of all bogies or all wheelsets of a vehicle.

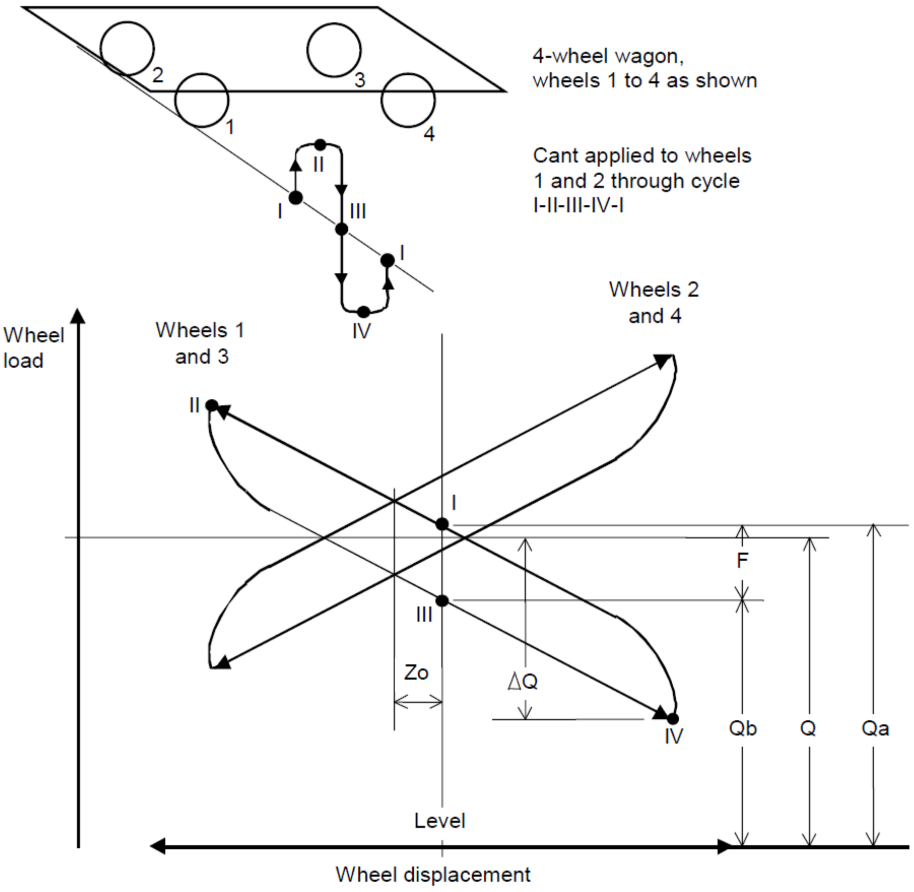
G2.3.16 The values for b), c) and d) in clause *G2.3.15* are nominally constant regardless of frictional effects or twist. Hence, variation in these values gives an indication of the accuracy of the measurements and defines any significant inconsistencies to be investigated and reported.

G2.3.17 The variation of individual wheel loads gives an indication of the hysteresis in the suspension. If the wheel load results from the four tests are highly inconsistent, an alternative weighing method may be appropriate such as that described in clauses *G2.3.18* and *G2.3.19*.

Alternative weighing method where results are dominated by hysteresis

G2.3.18 Certain types of suspension that are dominated by friction or hysteresis could give such variable results that the calculated average values from tests on level track are not meaningful. In this case, a torsion diagram can be plotted by taking the wheelset through a twist cycle (as in the wheel unloading test). This process gives nominal, minimum and maximum wheel loads on level track, and can also quantify built-in centre of gravity offset and twist.

G2.3.19 The nominal wheel load is considered to be the representative value. An example of a two-axle wagon is shown in Figure *1*. These principles could be extended to a bogie vehicle, if required.



Q - Nominal wheel load
Qa - Maximum wheel load on level
Qb - Minimum wheel load on level
F - Overall friction, Qa-Qb
ΔQ - Reduction in wheel load
Zo - Adjustment required to correct out-of-level

Figure 1: Example torsion diagram for a two-axle wagon

Limit values

G2.3.20 Limit values (for example maximum and minimum) are usually set out in the contract between user and manufacturer, subject to the requirements of section 6, Method 3 of BS EN 14363.

Additional test for tilting vehicles

G2.3.21 To characterise the behaviour of tilting vehicles, a complete additional weighbridge test is performed with the vehicle body tilted to the maximum angle in both extreme tilt positions. This gives an indication of any lateral shift of the centre of gravity when tilt is applied and also any torsional imbalance in the tilt system. These factors could affect the wheel unloading or sway performance of the tilted vehicle.

Additional procedure for the purpose of validating a vehicle simulation model

G2.3.22 The vehicle simulation model outputs the average static load value for each of the following:

a) Wheel loads – the vertical load in kN on each individual wheel
b) Wheelset loads – the vertical load in kN on each wheelset
c) Side loads – the total load in kN on each rail (that is, all left-hand side and all right-hand side wheel loads).

G2.3.23 The percentage matching error, between the simulation and measured results, is calculated, as described in clause *G2.2.10 b)* for the load on each wheel of the vehicle. The maximum error for any one wheel is then identified with subsequent calculation of the average error (over the whole vehicle).

G2.3.24 Where the maximum errors and average errors are no greater than the limits in Table *1*, the validation is considered to be acceptable and the model matched for this test.

Criterion	Limit of maximum error	Limit of average error
Wheel loads	15 %	7 %
Wheelset loads	6 %	3 %
Side loads	3 %	3 %

Table 1: Matching accuracy limits for weighbridge test model

G2.4 Wheel unloading test

Scope

G2.4.1 This section gives guidance for the wheel unloading test procedure, and supports the requirements in BS EN 14363 section 6.1. Additional guidance is included to improve the reliability and consistency of test results.

G2.4.2 The purpose of the wheel unloading test is to measure the changes in wheel load when a vehicle is subjected to a short wavelength irregularity, for example a track twist or dipped joint. The results of the wheel unloading test can be used to demonstrate conformance with the requirements in BS EN 14363 section 6.1 (and GMRT2141 section 3.3, for vehicles carrying intermodal load units only, for the assessment with offset loads).

G2.4.3 The test results are also used to validate a vehicle model for use in a simulation.

Track twist condition

G2.4.4 Severe track twist conditions encountered by vehicles are most likely to be associated with a short wavelength irregularity (dipped joint). However, in the laboratory it is not usually practical to lower wheels below rail level, so this test is carried out by raising the wheels of a stationary vehicle to an equivalent geometry.

G2.4.5 The test represents a dipped joint in a track cant gradient at its permissible limit before intervention is required.

G2.4.6 A dip of 20 mm over a span of 6 m is used to represent a typical dipped joint and results in a track twist of 1:300. Track in GB may be installed with a gradient of up to 1:400 but which is allowed to deteriorate to 1:300 before maintenance is required to restore the track geometry. If the dipped joint is superimposed on a track cant gradient at its permissible limit before intervention is required, the resultant twist is 1:150.

G2.4.7 The track twist case is shown in Figure *2* and is equivalent to the case shown in BS EN 14363, Figure 1, with the requirements from Method 3, but showing a wheel lift rather than a wheel fall position to achieve the track twist. The length of the 1:150 track twist is always 6 m but the length of the 1:300 track twist depends on the geometry of the vehicle being tested.

G2.4.8 This arrangement is consistent with the findings of Committee B55 of the Office for Research and Experiments (ORE) of the International Union of Railways (UIC), who determined that a 1:150 twist was the worst twist that short wheelbase wagons (or bogies) are likely to encounter and, therefore, to which they are expected to be tested.

G2.4.9 It is good practice for the lift at each wheel to be within ±1 mm of the defined value.

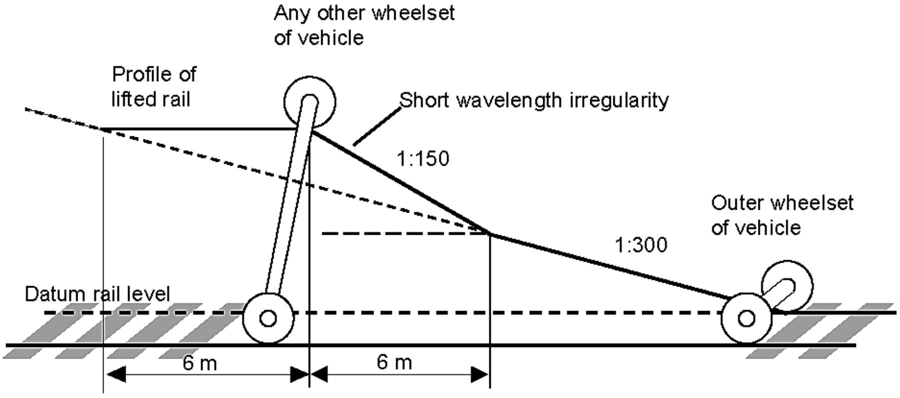


Figure 2: Track twist case to be applied in wheel unloading test

G2.4.10 The worst case for conventional vehicles is usually with one end wheelset of the vehicle on the level, and the opposite end wheelset in the dip, as this gives the maximum twist over the vehicle. The test can also be carried out by lifting the relevant wheels by the same amount. This case is shown in Figure *3* for a typical bogie passenger vehicle.

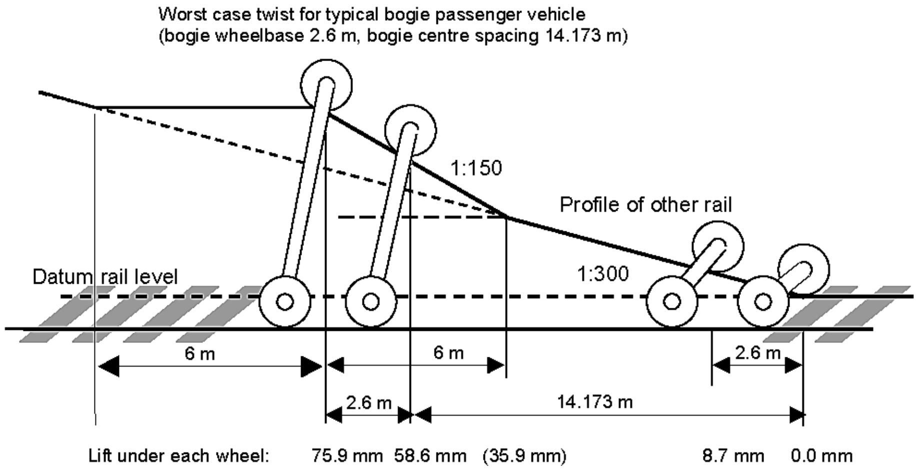


Figure 3: Typical bogie passenger vehicle on track twist case

Vehicle condition

G2.4.11 BS EN 14363, section 6.1.4 defines the required vehicle condition.

G2.4.12 Except as defined in clause *G2.5.1*, it is good practice for the wheel loads measured at the commencement of the test to be within ±5 % of their value as measured by the weighbridge tests. If this is not the case, running the vehicle over uneven track may break out stiction prior to re-weighing, although further investigation and definition of the cause may be necessary. The nominal wheel loads can be taken as the calculated average values of the four weighbridge test results.

G2.4.13 The test(s) is carried out with the suspension in its normal operating condition(s) except where the vehicle is fitted with air suspension. In the latter case the test is carried out with the air suspension in both the inflated and deflated conditions (normally all the airsprings are in the deflated condition for the deflated test).

G2.4.14 The test(s) with the airsprings in the inflated condition is carried out with the levelling valves, and any cross feed between airsprings isolated, to check that the airsprings remain fully inflated for the duration of the tests. An air pressure ‘stand-up’ test carried out beforehand will give confidence that no significant pressure drop occurs over the time period that the test is expected to take (typically no more than 0.1 bar drop over the test duration).

G2.4.15 When the air suspension is deflated prior to testing the deflated condition, the deflation is carried out on straight and level track.

G2.4.16 If the inflated condition with levelling valves active is considered to give a credible derailment risk, this condition is also tested or the effects calculated. This may be significant on vehicles where the secondary roll suspension is derived from the airsprings alone; that is, where there is no anti-roll bar fitted.

G2.4.17 Except as defined in clause *G2.5.1*, vehicles are tested in a range of load conditions to identify the worst case wheel unloading. The worst case is typically the tare condition, but for vehicles with non-linear suspensions the worst case can occur in other conditions. For a typical freight vehicle with high-rate springs that contact only when laden, the worst case can be when the vehicle is partially laden, just sufficient or at a slightly higher load than that required to contact the high-rate springs.

Measurements

G2.4.18 The vertical loads on individual wheels that are to be measured for wheel unloading due to twist are measured at each stage of the test and the results plotted as hysteresis loops.

G2.4.19 The method in BS EN 14363, section 6.1 only requires wheel load measurements at the maximum twists, and only for the wheelsets seeing greatest unloading. However, to gain a good understanding of vehicle behaviour it is useful to measure wheel loads at intermediate values of twist, and to measure all wheel loads throughout the test. Measuring at intermediate values of twist is particularly important for vehicles with non-linear or frictional suspension.

G2.4.20 It is considered good practice to fit inclinometers above the bogie pivot centres (or suspension mountings for 2-axle vehicles) to measure the body roll angle during the test. The results can be used to determine the amount of body twist, which is important for vehicle model validation purposes, as described in clause *G2.4.31*c).

Effect of over-jacking

G2.4.21 The wheel unloading test requires the wheels of the vehicle to be raised by specified amounts (see clause *G2.7.21*) and the individual wheel forces measured. The normal process is for the wheels to be jacked under the axlebox and then lowered onto packings placed between the wheel and rail.

G2.4.22 For vehicles with friction damping, slight over-jacking during the test process can have a significant influence on the test results, as indicated below. The results for some test simulations are shown in Figure 4 for the right wheel of wheelset 1 (R1):

a) Test 1 was a standard prediction of the wheel unloading process with three stages of twist applied, but with no over-jacking. The outputs from the test were plotted for all wheels in the normal format, Test 1 R1 (fine blue);
b) Test 2 included small amounts of over-jacking at the different measuring heights – 3 mm at the lowest, 4 mm at the second and 5 mm at the highest. The outputs from the test were plotted in two ways:
    i) The full time history of the ‘lift and lower’, Test2F R1 (dotted red); and
    ii) A summary, where only the forces after lowering onto the packing are plotted, Test2S R1 (broad green).

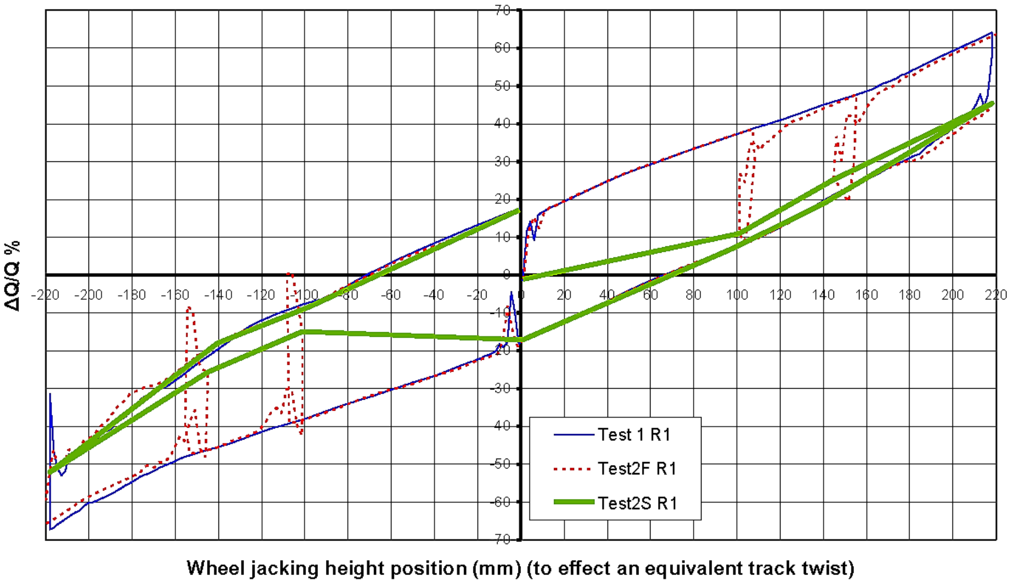


Figure 4: Example of the effect of over-jacking on ΔQ/Q results

G2.4.23 It can be seen that the effect of over-jacking on the ΔQ/Q results is significant. Taking the right wheel of wheelset 1 (see Figure 4), the Test2S R1 (broad green) results suggest a peak ΔQ/Q value of around 50 %, which is well within the allowable limit, whilst the 'correct' results, Test 1 R1 (fine blue) where the results had been recorded continuously, indicate that the 60 % limit would have been exceeded.

G2.4.24 The form of the Test2S R1 (broad green) results also gives an indication of a potential problem as the hysteresis loop is not of a conventional shape, showing the expected width at the level track point (jacking height 0 mm) but with very small or no width at the higher equivalent track twist positions. This is as a result of the reversal of the friction.

G2.4.25 This effect can be avoided by minimising over-jacking and careful examination of the shape of the hysteresis loop. If the loop is unconventional in shape, the test may need to be repeated, or an appropriate safety allowance used to determine acceptability of the vehicle. The magnitude of this allowance depends on the vehicle characteristics but relating to the width of the hysteresis loop as observed in the 'no twist' condition (jacking height 0 mm).

Additional procedure for the purpose of validating a vehicle simulation model

G2.4.26 The effect of airspring levelling valves can be significant, and for validation purposes it may be desirable to isolate them.

G2.4.27 Lifting one rail, as opposed to dropping the other, does not give the exact equivalent geometry. The twist across the vehicle is equivalent, but the position of the centre of gravity of the vehicle is not. In general, lifting one rail will give slightly better ΔQ/Q results, because the wheel (on the low rail) which sees maximum unloading due to track twist, will see some increased loading due to the shift of the centre of gravity. It is good practice to consider this effect when the ΔQ/Q results are to be used for computer model validation.

G2.4.28 The percentage matching error, between the simulation and measured results, is calculated as described in clause *G2.2.10*b) for the load on each wheel of the vehicle. The maximum error for any one wheel is then identified and the average error (over the whole vehicle) calculated.

G2.4.29 The loop shape (representing the wheel loads measured during complete cycles of unloading and reloading) is examined to establish that the simulation model accurately reflects the behaviour of the vehicle. Pay attention to matching the gradient of the loop (which represents the torsional stiffness) and to any unusual or non-linear behaviour represented in the loop shape.

G2.4.30 The torsional stiffness over the body and the bogies is calculated from the applied moments and angles for both the tests and simulations. The results are compared to establish that the simulation model is a good representation of the test results.

G2.4.31 The validation is considered acceptable and the model matched for this test where all the following apply:

a) The maximum errors and average errors, between the simulation and measured results (see clause *G2.4.28*), are no greater than the limits set out in Table *2*
b) The simulated loop shape is consistent with the tests
c) The torsional stiffnesses are determined to be an accurate representation.

Criterion	**Limit of maximum error**	**Limit of average error**
All wheel loads at maximum track twist	15 %	5 %

Table 2: Matching accuracy limits for the wheel unloading test model

G2.4.32 It may be possible to check the model using modest track twist inputs that encompass all the non-linear behaviours but which produce considerably less wheel unloading than the maximum allowable limit of 60 %. This could inadvertently allow percentage error to residual wheel loads well above the 40 % that represents the nominal limit for the maximum allowable limit of 60 % wheel unloading. Care taken when designing the wheel unloading test, particularly for vehicles with good wheel unloading performance, may avoid allowing larger than intended absolute modelling errors. These modelling errors are those that are larger than would be the case if the vehicle has poor wheel unloading performance on the standard track twist input, and where the standard input is used for the test on which static matching is based.

Applicability to more complex vehicles

G2.4.33 BS EN 14363 section 6.1.4 defines the considerations for complex vehicles, such as articulated or multi-bogie vehicles.

G2.4.34 For validating a vehicle simulation model, to be used for the low speed Y/Q simulations, the results from the wheel unloading test are used. The torsional stiffness of the vehicle and of the bogies have particular importance for the low-speed Y/Q simulations.

G2.4.35 This information can be more readily determined for a complex vehicle by carrying out separate tests with track twist applied over the body or over the bogie. The track twist conditions for each vehicle are chosen to maximise the useful information for model validation.

Tilting vehicles

G2.4.36 Tilting vehicles are tested with the tilt system locked, with no tilt applied (to give the maximum blocking of the tilt system and hence the highest suspension stiffness) to reflect the worst unloading conditions.

G2.4.37 It may be necessary to consider cases which the vehicle might experience with the tilt system active or failed, as applicable to the vehicle design, to be used when applying the process of model validation. Where the following cases are credible and could offer a worse wheel unloading performance, additional tests are carried out:

a) Change in lateral position of the body centre of gravity (CoG)
b) Uneven set-up or action of the tilt system (between bogies) that could apply a twist moment over the vehicle body.

G2.5 Offset loaded wagons carrying intermodal load units

Scope

G2.5.1 GMRT2141, issue five, clause 3.3.1, requires the wheel unloading test to be carried out for wagons carrying intermodal load units with lateral and/or longitudinal offset load. Three offset loaded conditions, cases a), b) and c), are specified in GMRT2141, issue five, clause 3.3.2.

G2.5.2 The intermodal load unit(s) on the wagon is (are) loaded and the wheel loads verified using the procedure set out in section *G2.3* prior to conducting the wheel unloading test. It is good practice to conduct four wheel weighing tests prior to the wheel unloading test in each load condition; between each wheel weighing test the loaded wagon is run over uneven track to break out any suspension friction that may be present. The resulting loads for each wheel are averaged over the four tests.

Determining required additional load and offset

G2.5.3 The following worked example provides guidance on the factors to consider in determining the appropriate additional loads and offsets to meet the requirements in GMRT2141, issue five. The particular example used relates to a wagon carrying intermodal containers but other types of load units are also relevant.

Realistic values for load offset

G2.5.4 The requirement in GMRT2141, issue five, section 3.3, is for the specified offset loads to be achieved with the minimum amount of additional load within the vehicle load arrangements. A minimum load will, in many cases, be the most onerous test. To determine the required additional load for each case, a representative load offset is also determined.

G2.5.5 If particular loading conditions or types of traffic apply further restrictions, then other load offsets may be appropriate.

G2.5.6 Further information on offset container loading is set out in Appendix *A*.

Case study wagon

G2.5.7 The example used is a bogie wagon with 7.4m bogie spacing, with a 40ft deck capable of carrying one or two 20ft containers (at the end, not in the middle), or one 40ft container. The tare mass of the wagon is 22.7 tonnes.

G2.5.8 It is assumed that a 20ft container has a tare mass of 2.3 tonnes and a 40ft container has a tare mass of 4 tonnes. The internal width of the container is taken as 2.33m. Alternative values will be appropriate for different load units but the principles are the same. The spacing of the wheel-rail contact patches is taken as 1.52m.

Offset load case a)

G2.5.9 To minimise the additional loading, reasonable CoG offsets for the load are considered. To achieve end-to-end balance for this wagon for this load case requires a 40ft container.

G2.5.10 If the additional load were fully at one edge of the container, then the load CoG offset would be 1.165m. As an extreme, but unrealistic, case assume a load of P tonnes with a CoG offset of 1.165m.

The load on the heavy side of the wagon will be:

$$\frac{(22.7+4.0)}{2}+\frac{P\times\left(\frac{1.52}{2}+1.165\right)}{1.52}=13.35+1.226P$$

The load on the light side of the wagon will be:

$$\frac{(22.7+4.0)}{2}+\frac{P\times\left(\frac{1.52}{2}-1.165\right)}{1.52}=13.35-0.266P$$

To achieve the 1.38 ratio specified for case a):

$13.35+1.266P=1.38\times(13.35-0.266P)$ so P = 3.105 tonnes.

G2.5.11 Clearly the load depends on the chosen CoG offset, with some examples in the table below for this wagon and container load.

	Load offset (m)	**Container + load offset (m)**	**Additional load (tonnes)**
Extreme case	1.165	0.509	3.105
	1.0	0.480	3.687
	0.5	0.341	8.556

Table 3: Possible combinations of load and offset to achieve 1:1.38 ratio

G2.5.12 Practicality suggests that an offset of >1.0m, with all the load in a very narrow strip along one edge of the container, is unrealistic. Depending on the type of cargo for which the wagon is designed, then load offsets between 0.5m and 1.0m may be realistic, with an additional load, for this example, of between 3.5 and 8.5 tonnes.

Achievable load offsets

G2.5.13 Assuming that the density of the load is 7.85 tonnes / m^3, typical for steel, and the load is distributed evenly along the length of the container, with a height no more than the width, then the following lateral offset-load combinations are achievable.

Lateral CoG offset (m)	Width of load (m)	Load in 20ft (tonnes)	Load in 40ft (tonnes)
1.0	0.33	5.1	10.2
0.9	0.53	13.2	26.4
0.8	0.73	25.1	50.2 (excessive)

Table 4: Possible lateral offset-load combinations

G2.5.14 The density of concrete is generally between one third and one quarter of steel so using concrete blocks as the load leads to a reduction in the load achieved for a given offset, under these assumptions. Other types and dimensions of load units are also relevant, depending on the application.

G2.5.15 Iterative analysis of wheel loads will allow the correct loading condition to be determined.

Offset load case b)

G2.5.16 Using a 10 % offset limit then case b) cannot be achieved with a single 20ft container at one end but can be achieved with a 40ft container with a payload of 9.64 tonnes, offset 1.725m longitudinally and 0.26m laterally. This is also achievable with two 20ft containers but the load positions cannot be determined analytically, an iterative solution is used.

G2.5.17 Offfset load case b) can be achieved with one 20ft container with a payload of 1.58 tonnes and offsets of 2.682m longitudinally and 1.162m laterally. This is an extreme lateral offset, unlikely to be realistic. A larger payload and more realistic lateral offset could also be considered as both will create the offset load requirements of the test.

Offset load case c)

G2.5.18 Using a 10 % guideline, this case can be achieved with a single 20ft container with a payload of 18.613 tonnes, offset by 3.771 longitudinally (from the vehicle centre line) and 0.085m laterally.

G2.5.19 The payload can be reduced to 11.807 tonnes, offset by 4.878m longitudinally and 0.113m laterally.

Worked example where specified ratio is not achievable

G2.5.20 The example used is a bogie wagon with 15m bogie spacing, with a 45ft deck capable of carrying one 40ft or one 45ft container, but not 20ft containers. The tare mass of the wagon is 21.3 tonnes.

G2.5.21 Case a) can be achieved with a 40ft container, payload 2.94 tonnes, offset by 2.046m longitudinally and 1.165m laterally.

G2.5.22 Case b) can be achieved with a 40ft container, payload 7.018 tonnes, offset by 5.999m longitudinally and 0.318m laterally.

G2.5.23 For case c) this wagon cannot achieve the 1:3.0 end-to-end ratio without using an unrealistically high payload of 43 tonnes and an unrealistic longitudinal offset for a 40ft container. Normal payload limits for a 40ft container would be around 30 tonnes to give a gross weight of 34 tonnes. Taking such a load and an extreme payload offset of 5.99m in a 40ft container, then the maximum end-to-end ratio that can be achieved is 1:2.45. With a 45ft container and a payload of 29.6 tonnes (to maintain the loaded container weight of 34 tonnes), an extreme offset of 6.761m gives a ratio of 1:2.76. These load offsets are not realistic and would exceed the permitted axle loading of the wagon.

G2.5.24 It is important that the loading conditions selected are consistent with the permitted loads for the particular application. Consider a 30 tonne pile of steel sheets, with a length of 8.6m, width of 2.2m and height of 0.202m, placed in one corner of the 40ft container. This would give the required side-to-side ratio of 1:1.1 and an end-to-end ratio of 1:1.24. A more extreme positioning of the load with a length of 2.0m, width of 2.2m and height of 0.869m would increase the end-to-end ratio to 1:2.06, still less than the specified 1:3.0.

G2.5.25 In accordance with GMRT2141 issue five, clause 3.3.4, the tested imbalanced wheel loads and the loading pattern used to create it are documented in the vehicle technical file.

G2.6 Bogie rotational resistance test

Scope

G2.6.1 This section provides guidance for the bogie rotational resistance test procedure, and supports the requirements in section 6, Method 3 of BS EN 14363. Additional guidance is included to improve the reliability and consistency of test results.

G2.6.2 The purpose of the bogie rotational resistance test is to measure the torque required to rotate a bogie relative to the vehicle body, and assess how this varies with angle and rotation rate. The bogie rotational resistance test can be used to demonstrate conformance with the requirements in Method 3 of BS EN 14363.

G2.6.3 The test results are also used to validate a vehicle model, for use in a simulation.

Test conditions

G2.6.4 The test conditions are defined in 'Measurement of bogie yaw resistance' of BS EN 14363, Method 3.

G2.6.5 The test rig generally consists of a short turntable mounted on a bearing arrangement with low yaw friction. The turntable is usually rotated by a linear actuator acting at a certain moment arm of known effective length. The actuator position and force are recorded continuously throughout the test and these measurements are used to derive the yaw angle and yaw torque data.

G2.6.6 The rotational resistance of the rig alone is measured and subtracted from the results. The rotational resistance of the rig is measured with the rig empty and loaded, for example with a short wheelbase shunting locomotive, to determine the variation of rig rotational resistance with vertical load.

G2.6.7 The representative maximum yaw angular velocity at curve entry and exit conditions for most vehicles is in the range 3.0 °/s to 4.0 °/s, for track conditions that are set out in GCRT5021. As an example, consider a 150 m radius curve, with no cant, no transition and a speed limit of 20 mph. The cant gradient is zero within the allowable limit of 1:400. The cant deficiency is 82 mm within the allowable limit of 110 mm. The rate of change of cant deficiency is 60 mm/s (using the virtual transition length of 12.2 m defined in GCRT5021) which is within the limit of 70 mm/s. For a typical passenger vehicle with 16 m bogie centres and 2.6 m bogie wheelbase, the time elapsed between being fully on the straight and fully on the curve is 2 s, and the bogie yaw angle on the curve is 3˚, giving an average rotation rate of 1.5 °/s. This example is not for the worst case and bogie rotation rate is not constant through a transition, and therefore peaks will be considerably higher, such as up to 4.0 °/s.

G2.6.8 It is therefore important to characterise the yaw behaviour up to these higher velocities. Experience indicates that yaw behaviour of a vehicle at speeds up to 4.0 °/s can generally be characterised by carrying out a series of tests at lower velocities and applying extrapolation, as the resistive torque is usually fairly constant at the higher velocities. This approach achieves the required output using a pragmatic and realistic method for test equipment. The highest yaw velocities are coincident with the largest yaw angles. Yaw velocities of 3.0 ˚/s to 4.0 ˚/s are beyond the 'blow-off' point of most yaw dampers, and therefore the damper forces will not be significantly more than at 1.0 ˚/s. The risk of damage and excessive forces is therefore minimal.

G2.6.9 For a vehicle expected to demonstrate constant yaw restraint (such as a freight vehicle with frictional side-bearers) the test is carried out at 0.2 °/s and 1.0 °/s. For vehicles with more complex yaw restraint, intermediate and / or higher test velocities could also be necessary to characterise the behaviour across the full range of resistive torque. The angular velocity for the test is increased until the yaw torque stabilises (that is, until the yaw stops increasing). However, where it is possible to demonstrate linearity for these higher velocities, then testing at lower velocities and extrapolation, as above, may be appropriate and applicable.

G2.6.10 Suitable test velocities can be determined based on the force / velocity characteristics of the fitted yaw dampers and, where the desired test velocity is unachievable owing to limitations of the rig, it is possible to extrapolate the test data. This extrapolation is based on the rotational resistance for the range of speeds achieved, together with the measured force / velocity characteristics derived from laboratory tests on the yaw dampers.

Vehicle condition

G2.6.11 The test(s) is carried out with the suspension in its normal operating condition(s) except where the vehicle is fitted with air suspension. In the latter case the test is carried out with the air suspension in both the inflated and deflated conditions (normally all the airsprings are in the deflated condition for the deflated test).

G2.6.12 The test(s) with the airsprings in the inflated condition is carried out with the levelling valves and any cross feed between airsprings isolated, ensuring that the airsprings remain fully inflated for the duration of the test. An air pressure 'stand-up' test is carried out beforehand to give confidence that no significant pressure drop occurs over the time period that the test is expected to take (typically no more than 0.1 bar drop over the test duration).

G2.6.13 All bogies on a vehicle are tested.

Measurements

G2.6.14 For each test, the bogie yaw angle and the yaw torque required to rotate the bogie are measured continuously and recorded in a diagram that relates these two parameters.

G2.6.15 At least two rotational speeds are tested and recorded. The bogie rotation angle and torque applied are measured, and the output plotted as a torque / angle loop for each speed. The peak X - factor is calculated from this plot.

G2.6.16 The bogie X - factor calculation is defined in section 6.1, Method 3 of BS EN 14363.

Additional procedure for the purpose of validating a vehicle simulation model

G2.6.17 If the purpose of the test is to validate a vehicle simulation model, it is instructive to carry out tests with certain components disconnected, for example, yaw dampers, anti-roll bar or centre pivot.

G2.6.18 The magnitude of the percentage matching error, between the simulation and measured results, is calculated as described in clause *G2.2.10*b) for each bogie and each test speed. The maximum error and the average error (over the range of bogies and speeds) is then calculated.

G2.6.19 Examination of the loop shape(s) will establish that the simulation model accurately reflects the behaviour of the vehicle, with attention paid to matching the gradient of the loop (which represents the rotational stiffness) and to any unusual or non-linear behaviour represented by any abnormal shape of the loop.

G2.6.20 Where the maximum errors and average errors are no greater than the limits set out in Table *5*, and the simulated loop shape is determined to be an accurate representation, then the validation may be considered acceptable and the model matched for this test.

Criterion	Limit of maximum error	Limit of average error
Peak values of X - factor	15 %	7 %

Table 5: Matching accuracy limits for bogie rotational resistance test model

G2.7 Sway test

Scope

G2.7.1 This section provides guidance on achieving accurate and repeatable results from the sway test.

G2.7.2 The purpose of the sway test is to evaluate the vehicle body's displacement in the transverse and roll direction caused by a lateral acceleration (acting in track plane).

G2.7.3 The sway test:

a) Validates the data used for determination of the vehicle’s swept envelope (see GMRT2173); and
b) Determines the transverse movement of the vehicle’s pantograph, where applicable (see GMRT2173).

G2.7.4 Applying the sway test is useful to validate that the displacements of the vehicle in roll and the characteristics for the installed suspension components are within the design limits.

G2.7.5 The sway test is normally carried out during the acceptance process for passenger vehicles, because an understanding of vehicle sway behaviour is necessary for compliance with the requirements of both BS EN 14363 and GMRT2173. It is also a valuable part of the validation process for a vehicle model that might be used for simulation of any dynamic predictions, being especially relevant for gauging and roll-over due to overspeed on curves calculations.

Test conditions

G2.7.6 The test conditions are set out in clauses *G2.7.7* to *G2.7.17*.

General vehicle conditions

G2.7.7 The test is normally done for a single vehicle.

G2.7.8 In the case of articulated vehicles where adjacent car bodies are suspended on a common bogie, the influence of inter-vehicle constraints are analysed in order to determine their significance. Test conditions can then be determined as a result of this analysis and it may be necessary to test more than one vehicle simultaneously. If it is not possible to test multiple articulated vehicles simultaneously on a test rig (as set out in clauses *G2.7.18* to *G2.7.23* an alternative on-track test method is described in BS EN 14363, Appendix D.2.1 Method 2.

G2.7.9 The test(s) is carried out with the suspension in its normal operating condition(s) and where air suspension is fitted in the deflated (normally all airsprings deflated) condition.

Load condition

G2.7.10 The test vehicle is tested with the usual operating equipment and fluids installed (see clause *G2.3.5*).

G2.7.11 The occupancy of vehicles with passengers or freight loads is investigated to include planned maximum permissible occupancy (typically crush laden occupancy) or freight load in the simulated load status (see clause *G2.3.6*).

G2.7.12 Worst-case sway is identified by testing a range of load conditions. This is typically the fully laden condition, but for vehicles with non-linear suspensions the worst case can occur in other conditions. For a typical freight vehicle with high-rate springs that contact only when laden, the worst case can be when the vehicle is partially laden but not yet in contact with the high-rate springs. If the effects of load are understood and documented from previous test results, then testing in only the tare state is acceptable.

G2.7.13 Where vehicles are tested in a laden condition, the characteristics of the load are expected to match those expected in service running. It is not practical to sway test passenger vehicles with a human load, but it is important that the substitute load’s centre of gravity position is correct to represent the mass distribution of the passengers.

Conditions for vehicles with airsprings

G2.7.14 The test(s) is carried out with the air suspension in both the inflated and deflated conditions (normally all the airsprings are in the deflated condition for the deflated test).

G2.7.15 The test(s) with the airsprings in the inflated condition is carried out with the levelling valves, and any cross feed between airsprings isolated, ensuring that the airsprings remain fully inflated for the duration of the test. An air pressure ‘stand-up’ test carried out beforehand will give confidence that no significant pressure drop occurs over the time period that the sway test is expected to take (typically no more than 0.1 bar drop over the test duration).

Conditions for vehicles with active systems in the suspension

G2.7.16 Several additional effects to be considered in planning the tests, include, but are not limited to:

a) System response time
b) Measurement tolerances on positions and forces
c) Credible failure modes.

Tilting vehicles

G2.7.17 As a minimum, tilting vehicles are tested with the tilt system locked, with no tilt applied, and also with the vehicle body locked at the maximum angle in each direction for the duration of the test. Other cases could be considered necessary depending on the design and response of the vehicle.

Test rig

G2.7.18 The test is carried out on a site consisting of initially straight and level track.

G2.7.19 The plane of the rails is normally able to be canted in both directions under all wheelsets of the vehicle. Alternatively, the wheels or axleboxes on each side of the vehicle could be jacked to achieve the same effect.

G2.7.20 All wheelsets are canted in the same direction and at the same angle for the duration of the test.

G2.7.21 Cant is applied in steps of maximum size 50 mm, up to an appropriate maximum value of cant deficiency / excess. A maximum of 300 mm of applied cant is typical.

G2.7.22 Care needs to be taken to avoid the effects of over-jacking, although the problems are less significant in the sway test than for the wheel unloading test (see clause *G2.4.25*).

G2.7.23 Tests are carried out for both directions of track cant, to achieve a closed hysteresis loop by reapplying a small amount of cant (for example 50 mm) in the initial cant direction at the end of the test.

Measured values

G2.7.24 Figure 5 shows a simplified sketch of the situation on the test rig indicating the parameters required. At each value of cant – from maximum negative to maximum positive value – the measured and derived values are recorded and evaluated as set out in the following sections.

G2.7.25 The lateral and vertical positions of each of the following points (targets) are measured relative to the level ground datum (that is, the horizontal plane) and recorded during the test:

a) Axleboxes or wheels on end wheelset (left / right sides)
b) If applicable, bogie frame (left / right sides)
c) Solebar (left / right sides)
d) If applicable, bodyside at cantrail position (left / right sides).

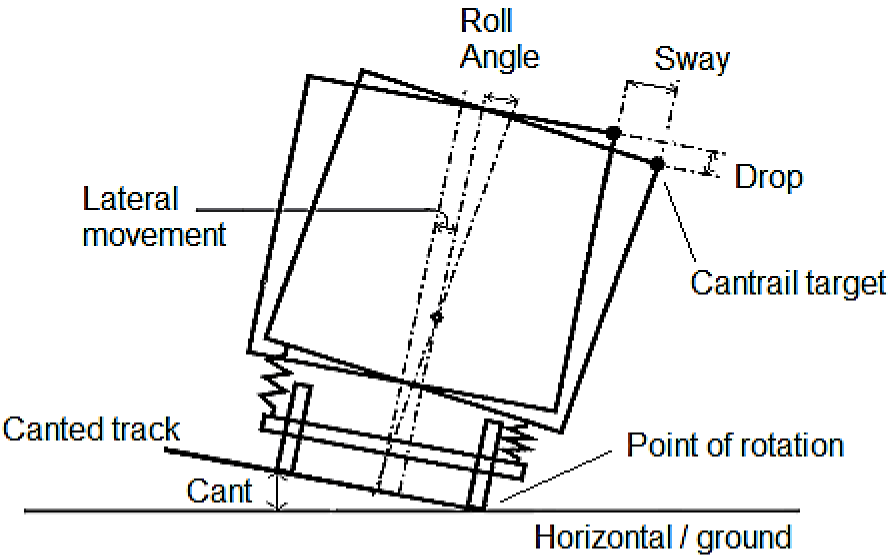


Figure 5: Sketch of standing vehicle on canted track showing parameters required

G2.7.26 The location of reference points on the horizontal ground is confirmed at intervals during the test to ensure that the test datum conditions have not changed.

G2.7.27 It may be necessary to take measures to prevent and monitor any longitudinal and / or yaw movement of the vehicle during the test.

G2.7.28 The measurements are most readily made using a theodolite positioned between the rails about 10 m from one end of the vehicle. Reflective theodolite crosshair targets are mounted on the vehicle end at all the points set out in clause *G2.7.25*. If necessary, and to assist sighting from the theodolite, the targets can be affixed to temporary jigs which are rigidly fixed to the vehicle.

G2.7.29 It is helpful to plot these results as the test is carried out, as this highlights any discontinuities that might indicate an error of measurement or a problem with the test conditions.

G2.7.30 If the vehicle is asymmetrical from end to end, the measurement of movements at one end only might be insufficient to fully characterise the vehicle movements. In this case, full measurements are made at both ends. However, it is usually sufficient to measure one end fully and to make simpler measurements, for example of suspension displacements, to characterise the differences between the two ends. The orientation of the vehicle with respect to the measuring position is recorded for each set of measurements.

Data post-processing - conversion of movements relative to track axes

G2.7.31 Post-processing starts by converting the recorded theodolite measurements (that are relative to the horizontal ground) onto axes that rotate with the wheelset (or track), that is in the plane of the rail. This conversion takes into account the cant angle of the wheelset / track and its point of rotation, which is normally the centre of the head of the 'low rail'. This conversion can be readily carried out using a spreadsheet calculation based on simple geometry.

G2.7.32 For each measured point (target) on the vehicle, the sway and drop values are the lateral and vertical movements from its initial position on the level track, when expressed relative to the track, that is, to the plane of the rail. Figure *5* shows these measurements for the cantrail target.

G2.7.33 Additionally, the roll angles at each suspension level (primary and secondary) relative to the track are calculated.

Data post-processing - required outputs

G2.7.34 The outputs consist of a complete hysteresis loop for each of the following data channels, defined relative to the track axes:

a) If applicable, bogie sideframe sway (left / right sides) (lateral movement)
b) If applicable, bogie sideframe drop (left / right sides) (vertical movement)
c) Solebar sway (left / right sides)
d) Solebar drop (left / right sides)
e) If applicable, cantrail sway (left / right sides)
f) If applicable, cantrail drop (left / right sides)
g) Primary suspension roll angle

h) Secondary suspension roll angle
i) Body roll angle
j) If applicable, pantograph head sway at its working height.

G2.7.35 Examples of typical hysteresis loops are shown in Figures 6 and 7.

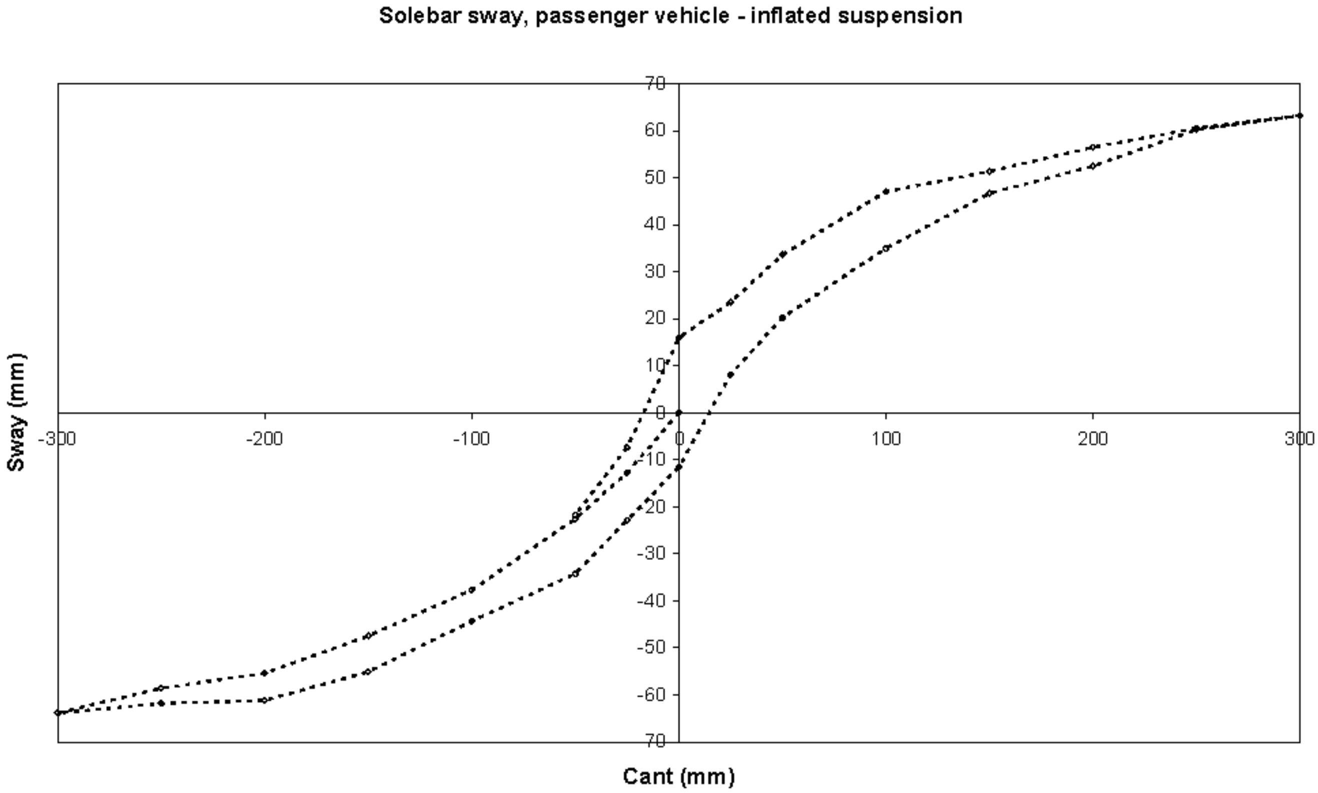


Figure 6: Typical hysteresis loop for passenger vehicle with inflated suspension

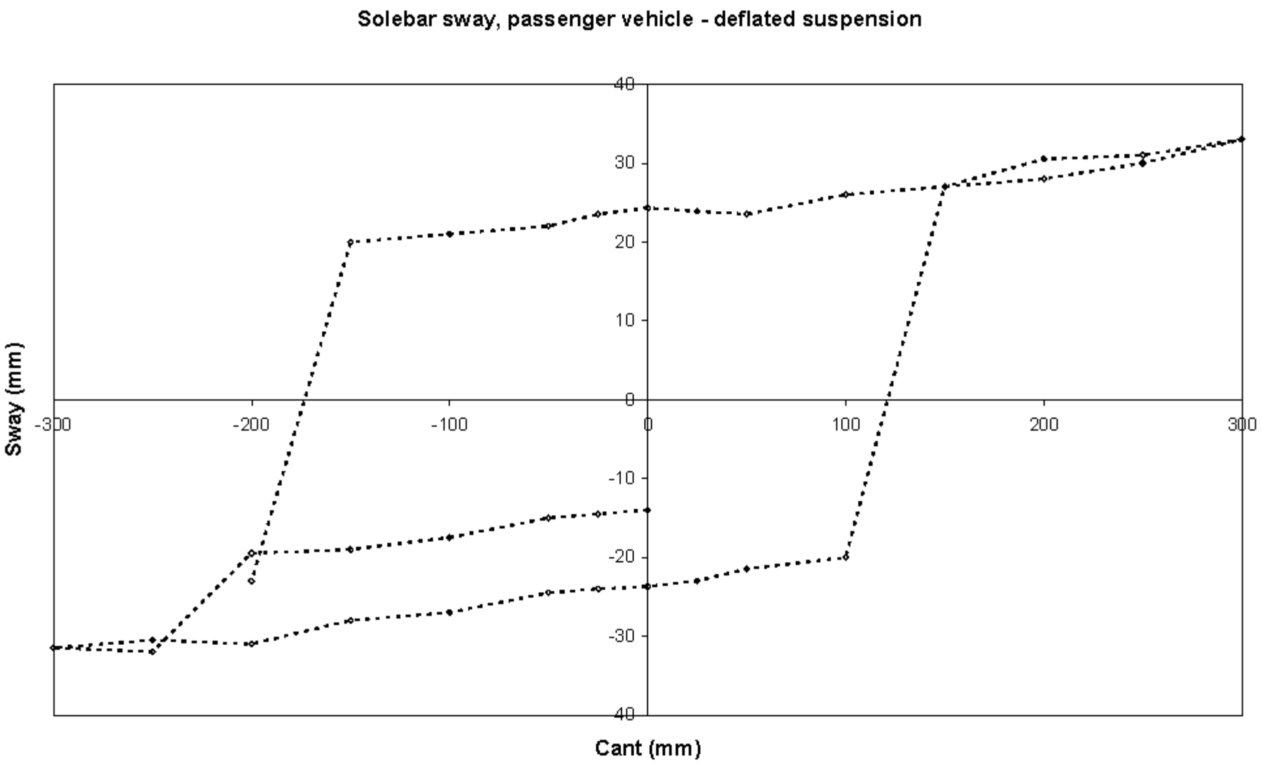


Figure 7: Typical hysteresis loop for passenger vehicle with deflated suspension

Data post-processing - consistency checking

G2.7.36 The four targets at solebar and cantrail are fixed to a rigid body (using temporary jigs if necessary), so that they remain a constant distance apart throughout the measurements. This allows a consistency check of the measuring method carried out to give confidence in the results. Large variations in the distance between the points indicate an error in the measurements, the data processing or the geometrical calculations to be investigated and corrected. Small variations give an indication of the accuracy of measurement for noting.

Data post-processing - calculation of four-part averages

G2.7.37 A sway test hysteresis loop includes four values of roll or sway for each value of cant input (two for positive and two for negative cant). The process of four-part averaging reduces the loop to a single characteristic by averaging these four values. This process is shown in Figure *8*.

G2.7.38 The four-part average is useful for several gauging techniques and particularly for validation of vehicle simulation models. However, it is also important to represent the hysteresis effects in any simulation.

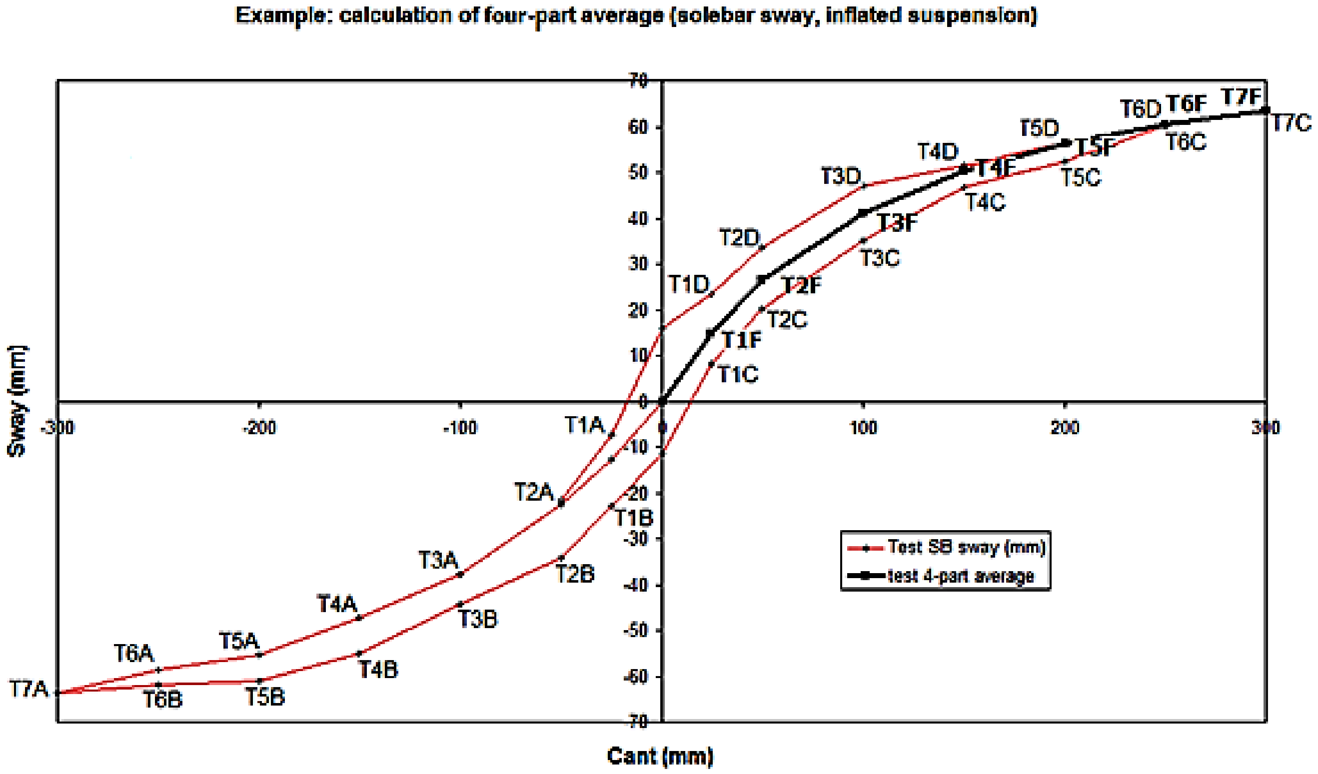


Figure 8: Example calculation of four-part average

G2.7.39 Calculation method of the four-part average for each position is set out below (where 'Tn' represents the measurement point, 1, 2, 3, and so on, and 'A' represents the first quarter of the loop, 'B' the second, and so on, and 'F' represents the final calculated average value):

T1F = average (-T1A,-T1B,T1C,T1D)

T2F = average (-T2A,-T2B,T2C,T2D)

↓ ↓

T6F = average (-T6A,-T6B,T6C,T6D)

T7F = average (-T7A,T7C)

G2.7.40 If a vehicle has an asymmetric sway performance that could lead to an underestimation of the true sway of the vehicle, then each side is assessed separately using a two-part average technique for left and right sides respectively.

Additional procedure for the purpose of validating a vehicle simulation model

G2.7.41 For the purpose of validating a vehicle simulation model, the levelling valves, and any cross feed between airsprings are isolated with no other suspension elements adjusted or disconnected.

G2.7.42 The outputs required for each value of cant are at least:

a) Primary suspension roll angle
b) Secondary suspension roll angle
c) Solebar sway and
d) Solebar drop.

G2.7.43 The magnitude of the absolute matching error (in mrad or mm) between the simulation and measured results is calculated as set out in clause *G2.2.10*a), for the outputs at each value of cant applied in the test.

G2.7.44 The maximum error between the measured and simulation four-part average points is then calculated (or two-part average points, where applicable) for the outputs at each cant applied in the test. The average error between the measured and simulation hysteresis loops is also calculated.

G2.7.45 If the four-part average maximum errors (or two-part average maximum errors, where applicable) and the hysteresis loop average errors are no greater than the limits set out in Table *6*, then the validation is considered acceptable and the model matched for this test.

Criterion	Limit of maximum error on four-part average (or two-part average)	Limit of average error on hysteresis loop
Primary roll angle	4 mrad	2 mrad
Secondary roll angle	4 mrad	2 mrad
Solebar sway	10 mm	15 mm
Solebar drop	10 mm	10 mm

Table 6: Matching accuracy limits for sway test model

Appendices

Appendix A Information on Offset Container Loading

A.1 Offset container loading

Guidance

G A.1.1 This appendix contains additional information for offset container loading with references to T1112 'Quantifying Offset Loading of Container Wagons' and the IMO/ILO/UNECE code of practice.

G A.1.2 Research project T1112 'Quantifying Offset Loading of Container Wagons' undertook a survey of the weights, and load distributions, of containers passing through two rail-connected GB ports. For reasons of commercial confidentiality, it was not possible to determine which containers were carried on rail vehicles, but the data gives an indication of typical load eccentricities for different sizes of containers. This data is useful to assist in determining what is a representative load offset when determining the relevant offset loading conditions.

G A.1.3 The International Maritime Organisation (IMO) document 'Informative material related to the IMO/ILO/UNECE code of practice for packing of cargo transport units (CTU code)' published in 2014, suggests that once the centre of gravity (CoG) longitudinal offset reaches 10 % of the length, a reduced load is appropriate. The T1112 data indicates that a significant proportion of both 20ft and 40ft containers have a load offset greater than the IMO 10 % so this is unlikely to be a suitable limit for such loads.

G A.1.4 T1112 describes a Maritime Safe Zone (MSZ) of load offset which can be safely handled by typical port loading and unloading equipment. This is taken as 1.5m longitudinal and 0.75m lateral offset, independent of the size of the container. A much smaller proportion of the measured containers were outside this value, so the MSZ values are likely to be suitable as limits for offset loads in containers. This is the CoG offset for the container + load and therefore the CoG offset for the load will be greater.

Definitions

Derailment quotient Y/Q	The ratio between the lateral force Y and the vertical force Q acting on a wheel.
Intermodal load unit	Goods container used in intermodal transport. Typically either shipping containers or swap bodies.
Level track	Track with no discernible twist or cant.
Matching accuracy	A value set to determine an allowable matching error.
Matching error	A value based on the difference between a measured value and a value calculated by a simulation model.
Wheel unloading quotient ΔQ/Q	The ratio between the instantaneous reduction in a wheel load ΔQ and the average static wheel load Q (that is, 'wheelset load'/2) for its wheelset.
Yaw	Rotational movement in nominally the horizontal plane (Cartesian X-Y plane).
Yaw restraint	The resistance of a vehicle suspension to rotational yaw movement.
Yaw torque	The resisting force of a vehicle suspension to rotational yaw movement.

References

The Standards catalogue gives the current issue number and status of documents published by RSSB: http://www.rssb.co.uk/railway-group-standards.co.uk.

RGSC 01	Railway Standards Code
RGSC 02	Standards Manual

Documents referenced in the text

Railway Group Standards

GCRT5021	Track System Requirements
GERT8006	Route Availability Number for Assessment of Compatibility between Rail Vehicles and Underline Bridges
GMRT2141	Permissible Track Forces and Resistance to Derailment and Roll-Over of Railway Vehicles
GMRT2173	Size of Vehicles and Position of Equipment

Other References

BS EN 14363:2016+A2:2022	Railway applications. Testing and Simulation for the acceptance of running characteristics of railway vehicles. Running behaviour and stationary tests
BS EN 15663:2017+A1:2028	Vehicle reference masses
IMO document	International Maritime Organisation document 'Informative material related to the IMO/ILO/UNECE code of practice for packing of cargo transport units (CTU code)', Published 2014
T1112	Quantify the distribution of unevenly loaded container wagons