

Review and Revision of UN-ECE Regulation No. 66.  
Consolidated Document presenting the work to date of the  
ad hoc Expert Group

This informal document is offered to the GRSG Group of WP29 of the UN-ECE as a summary of the work of the ad hoc Expert Group set up by the 73rd GRSG meeting 27-30 October 1997 to review UN-ECE Regulation No: 66 and to offer proposals for its revision.

This informal document incorporates the following documents

TRANS/WP29/GRSG/2001/5

TRANS/WP29/GRSG/2001/6

TRANS/WP29/GRSG/2001/14

TRANS/WP29/GRSG/2001/18

This document replaces the Informal Document No 5 of 82<sup>nd</sup> meeting of GRSG  
It includes the results of the meeting of the ad hoc Expert Group in Barcelona, Spain,  
13-14 May 2002.

The whole of this text remains open for discussion and improvement by GRSG.

A final meeting of the ad hoc Expert Group is scheduled for 28/29 Oct 200. It will concentrate on the following subjects

Annex 7 – Quasi-static loading test of body sections

Annex 8 – Calculation method based on quasi/static tests.

Annex 9 – Computer simulation of rollover test on complete vehicle.

The effect of fitment and use of seat-belts.

Note well:

Paragraph 10: Transitional provisions

This paragraph will be drafted following instructions from GRSG.

## Regulation No. 66

### UNIFORM PROVISIONS CONCERNING THE APPROVAL OF LARGE PASSENGER VEHICLES WITH REGARD TO THE STRENGTH OF THEIR SUPERSTRUCTURE

#### REGULATION

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#### 1. SCOPE

This Regulation applies to single-deck rigid or articulated vehicles designed and constructed for the carriage of more than 22 passengers, whether seated or standing, in addition to the driver and crew."

#### 2. DEFINITIONS

In this Regulation and its Annexes the following units of measurement shall be used.

Gravitational constant (g)	(9.81 m/s <sup>2</sup> )
Energy	kilojoules (kJ)
Mass	kilograms (kg)
Weight or Force	Newtons (N)
Dimensions	metres (m) or millimetres (mm)

For the purposes of the Regulation:

- 2.1 "Vehicle" means a bus or coach designed and equipped for transportation of passengers. The vehicle is an individual representative of a vehicle type.
- 2.2 "Vehicle type" means a category of vehicles produced with the same design technical specification, main dimensions and constructional arrangement. The vehicle type shall be defined by the vehicle manufacturer.
- 2.3 "Group of vehicle types" means those vehicle types, proposed in future as well as existing now, which are covered by the approval of the worst case, in respect of this Regulation

- 2.4 "Worst case" means the vehicle type, among a group of vehicle types, least likely to withstand the requirements of this Regulation in respect of the strength of superstructure. The three parameters which define the worst case are; structural strength, potential energy and the residual space.
- 2.5 "Approval of a vehicle type" means the whole official process in which the vehicle type is checked and tested to prove that it meets all the requirements specified in this Regulation;
- 2.6 "Articulated vehicle" means a vehicle which consists of two or more rigid sections which articulate to one another, the passenger compartments of each section intercommunicate so that passengers can move freely between them; the rigid sections are permanently connected so that they can only be separated by an operation involving facilities which are normally only found in a workshop;
- 2.7 "Passenger compartment" means the space intended for passengers' use excluding any space occupied by fixed appliances such as bars, kitchenettes or toilets;
- 2.8 "Driver's compartment" means the space intended for the driver's exclusive use and containing the driver's seat, the steering wheel, controls, instruments and other devices necessary for driving the vehicle;
- 2.9 "Unladen kerb mass" ( $M_k$ ) means the mass of the vehicle in running order, unoccupied and unladen but with the addition of 75kg for the mass of the driver, the mass of fuel corresponding to 90 per cent of the capacity of the fuel tank specified by the manufacturer, and the masses of coolant, lubricant, tools and spare wheel, if any;
- 2.10 "Total occupant mass" ( $M_o$ ) means the combined mass of any passengers, driver, crew who occupy seats fitted with occupant restraints.
- 2.11 "Total vehicle mass" ( $M_t$ ) means the unladen kerb mass of the vehicle ( $M_k$ ) combined with the portion ( $k$ ), of the total occupant mass ( $M_o$ ), considered to be rigidly attached to the vehicle ( $M_m$ ), ie,  $M_t = M_k + k.M_o$
- 2.12 "Individual occupant mass" ( $M_{mi}$ ) means the mass of an individual occupant. The value of this mass is defined in UN-ECE Reg36 as 68kg.
- 2.13 "Residual space" means a space to be preserved in the passenger's and driver's compartment to provide better survival possibility for passengers, driver and crew in case of a rollover accident;
- 2.14 "Rollover test on a complete vehicle" means a realistic rollover simulation which is defined as basic test with full scale vehicle to prove the required strength of the superstructure;
- 2.15 "Tilting bench" means a technical device, an arrangement of tilting platform, ditch and concrete ground surface together, with the help of which a rollover test on complete vehicle can be performed;
- 2.16 "Tilting platform" means a rigid plane which can be rotated around a horizontal axis in order to tilt a vehicle either to determine the height of its centre of gravity or to perform a rollover test on complete vehicle;
- 2.17 "Energy balance" means applying the principle of energy conservation during the standard rollover test as a process. The total potential energy of the vehicle - through kinetic energy - is transformed into different kinds of mechanical work;
- 2.18 "Plastic zone" (PZ) means a special geometrically limited part of the superstructure in which, as the result of dynamic, impact forces:
- large scale plastic deformations are concentrated
  - essential distortion of the original shape (cross section, length, or other geometry) occurs
  - in consequence of local buckling, loss of stability ensues

- due to deformation, a certain amount of kinetic energy is absorbed;

- 2.19 "Plastic hinge" (PH) means a simple plastic zone formed on a rod-like element (single tube, window column, etc);
- 2.20 "Reference energy" ( $E_R$ ) means the potential energy of the vehicle to be tested, measured in the starting, unstable position of the rollover process;
- 2.21 "Body work" means the complete structure of the vehicle in running order, including all the structural elements which form the passenger compartment, driver's compartment, baggage compartment and spaces for the mechanical units and components;
- 2.22 "Superstructure" means the load bearing components of the bodywork as defined by the manufacturer, containing those coherent parts and elements which contribute to the strength and energy absorbing capability of the bodywork., and preserve the residual space in the rollover test;
- 2.23 "Bay" means a structural section of the superstructure forming a closed loop between two planes which are perpendicular to the longitudinal axis of the vehicle. A bay contains one window (or door) pillar on each side of the vehicle as well as side wall elements, a section of the roof structure and a section of the floor and underfloor structure;
- 2.24 "Reinforced bay" means a bay containing additional strengthening elements; for example, stiffening ribs; partitions; wardrobe kitchen or toilet walls. These additional elements essentially change the structural behaviour of the bay. Specific examples of reinforced bays are the front and rear end structures of the vehicle body;
- 2.25 "Body section" means a structural unit, which represents one part of the superstructure for the purposes of an approval test. A body section contains at least two bays connected by representative connecting elements (side, roof, and underfloor, structures);
- 2.26 "Original body section" means a body section composed of two or more bays of exactly the same form and relative position, as they appear in the actual vehicle. All connecting elements between the bays are also arranged exactly as they appear in the actual vehicle;
- 2.27 "Artificial body section" means a body section built up from two or more bays but not in the same position, nor at the same distance from each other as in the actual vehicle. The connecting elements between these bays need not be identical with the real body work structure but shall be structurally equivalent (see Annex 6 para.3.3.2)
- 2.28 "Rigid part" means a structural part or element which does not have significant deformation and energy absorption during the rollover test;
- 2.29 "Cant-rail" means the longitudinal structural part of the bodywork above the side windows including the curved transition to the roof structures. In the rollover test the cant-rail hits the ground first;
- 2.30 "Waist-rail" means the longitudinal structural part of the bodywork below the side windows. In the rollover test the waist-rail may be the second area to contact the ground after initial deformation of the vehicle cross-section.
- 2.31 "Occupant restraint" means any device which connects a passenger, driver or crew member to his seat, during a rollover.
- 2.32 "Extension of approval" means the official process in which a new vehicle type is approved on the basis of an earlier approved vehicle type, by comparison of structure, potential energy and residual space criteria

2.33 “Vertical longitudinal central plane” means that plane which passes through the mid-points of the front axle track and the rear axle track.

### 3. APPLICATION FOR APPROVAL

3.1. The application for approval of a vehicle type with regard to the strength of its superstructure shall be submitted by the vehicle manufacturer or by his duly accredited representative.

3.2. It shall be accompanied by three copies of each of the undermentioned documents and by the following particulars:

**3.2.1 The main identifying data and parameters of the vehicle or group of vehicle types;**

3.2.1.1. general layout drawings of the vehicle, its bodywork and its interior arrangement with the main dimensions. Seats which have passenger restraints shall be clearly marked and their positions in the vehicle shall be accurately dimensioned;

3.2.1.2. the unladen kerb mass of the vehicle (kg) and the associated axle loads (kg);

3.2.1.3. the exact position of the unladen vehicle’s centre of gravity (CG) together with the measuring report. To determine the centre of gravity position the measuring and calculation methods described in Annex 3 shall be used;

3.2.1.4. the value of reference energy ( $E_R$ ) which is the product of the total vehicle mass ( $M_t$ ), the gravity constant ( $g$ ) and the height ( $h_0$ ) of centre of gravity with the vehicle in its unstable equilibrium position when starting the rollover test (see Figure 3 and para.3.2.2.1).

3.2.1.5. the total vehicle mass and resultant axle loads. For this calculation, the applicant shall use the individual occupant mass ( $M_{mi}$ ) stated in paragraph 2.29 of this regulation, and multiply it by the number of seats fitted with occupant restraints and the factor  $k$  - see 2.11 of this Regulation.

3.2.1.6. the exact position of the of the centre of gravity (CG) of the total mass of the vehicle, together with the measuring report. To determine the CG position the measuring and calculation methods described in Annex 3 shall be used.”

3.2.1.7. (deleted, because it repeated para 3.2.1.4 exactly).

3.2.2. All the data and information which are needed to evaluate the worst case criteria:

3.2.2.1. the value of reference energy when starting the rollover test (see Fig.3.)

$$E_R = M_k g \left[ 0,8 + \sqrt{h_0^2 + (B \pm t)^2} \right]$$

where  $M_k$  = the unladen mass of the vehicle type  
 $h_0$  = the height of the CG of the unladen vehicle  
 $t$  = perpendicular distance of the vehicle CG from its longitudinal vertical central plane.  
 $B$  = perpendicular distance of the vehicle’s longitudinal vertical central plane through its CG to the axis of rotation in the rollover test  
 $g$  = gravitational constant

3.2.2.2. drawings and detailed description of the superstructure of the vehicle type or types according to Annex 4

3.2.2.3. detailed drawings of the residual space according to para.5.2. for every vehicle type to be approved

3.2.3. Further detailed documentation, parameters, data depending on the approval test method chosen by the manufacturer, as detailed in Annex 5, Annex 6, Annex 7, Annex 8 and Annex 9.

3.2.4.. In case of an articulated vehicle, all of this information shall be given separately for the two rigid parts of the vehicle type, except for paragraph 3.2.1.1. which is related to the complete vehicle.

3.3 On request of the Technical Service a complete vehicle (or one vehicle from each vehicle type, if approval is requested for a group of vehicle types) shall be presented to check its unladen kerb mass, axle loads, position of the centre of gravity and all other data and information which are to the strength of superstructure.

3.4 According to the approval test method chosen by the manufacturer, appropriate test pieces, shall be submitted to the Technical Service upon its request. The arrangement and number of these test pieces shall be agreed with the Technical Service. In case of test pieces which have been tested earlier, the test reports shall be submitted.

#### **4. APPROVAL**

4.1. If the vehicle type or group of types submitted for approval to this Regulation meets the requirements of paragraph 5 below, approval of that vehicle type shall be granted

4.2. An approval number shall be assigned to each vehicle type (as defined in 2.2. of this Regulation) approved. Its first two digits (at present 00 for the Regulation in its original form) shall indicate the series of amendments incorporating the most recent major technical amendments made to the Regulation at the time of issue of the approval. The same Contracting Party shall not assign the same number to another vehicle type

4.3. Notice of approval or of refusal or extension of approval of a vehicle type pursuant to this Regulation shall be communicated to the 'Parties' to the Agreement which apply this Regulation, by means of a form conforming to the model in annex 1 to this Regulation and of drawings and diagrams supplied by the applicant for approval, in a format not exceeding A4 (210 x 297 mm) or folded to that format and on an appropriate scale.

4.4. There shall be affixed, conspicuously and in a readily accessible place specified on the approval form, to every vehicle conforming to a vehicle type approved under this Regulation an international approval mark consisting of :

4.4.1. a circle surrounding the letter "E" followed by the distinguishing number of the country which has granted approval;

4.4.2. the number of this Regulation, followed by the letter "R", a dash and the approval number to the right of the circle prescribed in paragraph 4.4.1.

4.5. The approval mark shall be clearly legible and be indelible.

4.6. The approval mark shall be placed close to or on the vehicle data plate affixed by the manufacturer.

4.7 Annex 2 to this Regulation gives an example of the approval mark.

#### **GENERAL SPECIFICATIONS AND REQUIREMENTS**

5.1. Requirements

The superstructure of the vehicle shall have the sufficient strength to ensure that the residual space during and after the rollover test on complete vehicle is unharmed. That means:

- 5.1.1 No part of the vehicle which is outside the residual space at the start of the test (e.g. pillars, safety rings, luggage racks) shall intrude into the residual space during the test. Any structural parts, which are originally in the residual space (e.g. vertical handholds, partitions, kitchenettes, toilets) shall be ignored when evaluating the intrusion into the residual space.
- 5.1.2. No part of the residual space shall project outside the contour of the deformed structure. The contour of the deformed structure shall be determined sequentially, between every adjacent window and/or door pillar. Between two deformed pillars the contour shall be a theoretical surface, determined by straight lines, connecting the inside contour points of the pillars which were the same height above the floor level before the rollover test. (see figure 2)

## 5.2 Residual space

The envelope of the vehicle's residual space is defined by creating a vertical transverse plane within the vehicle which has the periphery described in Figures 1(a) and 1(c), and moving this plane through the length of the vehicle (see Figure 1(b)) in the following manner:

- 5.2.1. The  $S_R$  point is located on the seat-back of each outer seat (or assumed seat position), 500 mm above the floor under the seat, 350 mm from the inside surface of the side wall. These dimensions shall also be applied in the case of rearwards facing and inward facing seats;
- 5.2.2 If the two sides of the vehicle are not symmetrical in respect of floor arrangement and, therefore, the height of the  $S_R$  points, the step between the two floor lines of the residual space shall be taken as the longitudinal vertical centre plane of the vehicle (see Figure 1(c));
- 5.2.3 The rearmost position of the residual space is a vertical plane 200 mm behind the  $S_R$  point of the rearmost outer seat, or the inner face of the rear wall of the vehicle if this is less than 200mm behind that  $S_R$  point.  
The foremost position of the residual space is a vertical plane 600 mm in front of the  $S_R$  point of the foremost seat in the vehicle set at its fully forward adjustment.  
If the rearmost and foremost seats on the two sides of the vehicle are not in the same transverse planes, the length of the residual space on each side will be different;
- 5.2.4 The residual space is continuous between its rearmost and foremost plane and is defined by moving the defined vertical transverse plane through the length of the vehicle along straight lines through the  $S_R$  points on both sides of the vehicle. Behind the rearmost and in front of the foremost seat's  $S_R$  point the straight lines are horizontal.

**5.2.5 The manufacturer may define a bigger residual space than is required for a given seat arrangement, to simulate a worst case to allow for future design development**

### 5.3 Specification of rollover test on a complete vehicle

The rollover test is a lateral tilting test, see Figure 3, specified as follows:

- 5.3.1. The full scale vehicle is standing stationary and is tilted slowly to its unstable equilibrium position. If the vehicle type is not fitted with occupant restraints it will be tested at unladen vehicle mass. If the vehicle type is fitted with occupant restraints it will be tested at total vehicle mass;
- 5.3.2. The rollover test starts in this unstable vehicle position with zero angular velocity and the axis of rotation runs through the wheel-ground contact points. At this moment the vehicle is characterised by the reference energy  $E_R$  (see paragraphs 3.2.1.4, 3.2.1.7, and Figure 3.);
- 5.3.3. The vehicle tips over into a ditch, having a horizontal, dry concrete ground surface with a nominal depth of 800 mm;
- 5.3.4. The detailed technical specification of the rollover test on a complete vehicle as an approval test is given in Annex 5

### 5.4. Specifications of equivalent approval tests

Instead of the rollover test on a complete vehicle, at the discretion of the manufacturer, one of the following equivalent approval test methods can be chosen.

- 5.4.1 Rollover test on body sections which are representative of the complete vehicle, in accordance with the specifications of Annex 6.

#### 5.4.2 Quasi-static Loading tests of body panels in accordance with the specifications of annex 7.

- 5.4.3. Calculation method based on the results of quasi-static tests in accordance with the specifications of Annex 8

- 5.4.4 Computer simulation of the standard rollover test in accordance with the specifications of Annex 9.

5.4.5 The basic principle

is that the equivalent approval test method must be carried out in such a way that it represents the rollover test specified in the appendix of annex 5. If the equivalent approval test method chosen by the manufacturer cannot take account of some special feature or construction of the vehicle (e.g. air-conditioning installation on the roof, changing height of the waist rail, changing roof height) the complete vehicle may be required by the Technical Service to undergo the rollover test specified in annex 5.

### 5.5. Test of articulated buses

In the case of an articulated vehicle, each section of the vehicle shall comply with the general requirement specified in paragraph 5.1. Each section of an articulated vehicle may be tested separately or in combination as described in Annex 5 para 2.3.

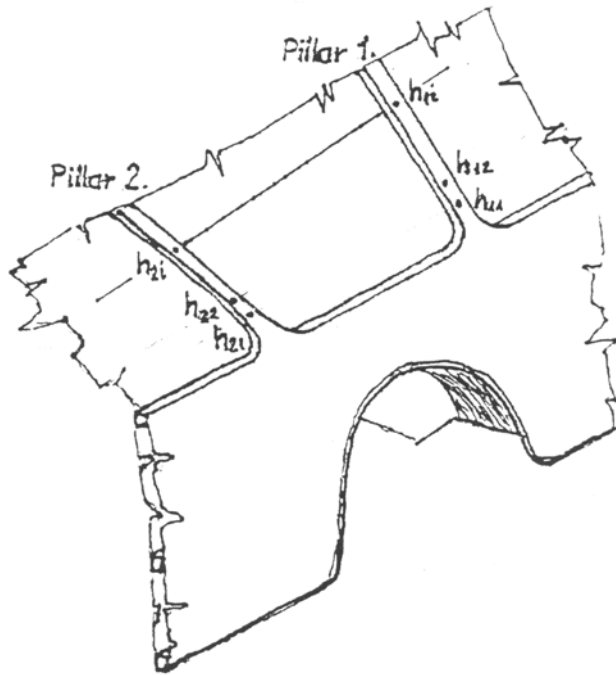
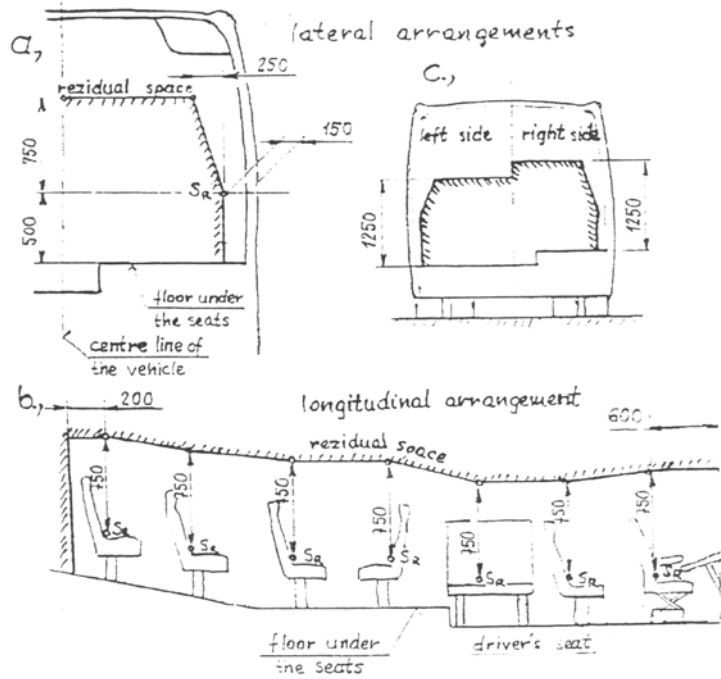
### 5.6. Direction of rollover test

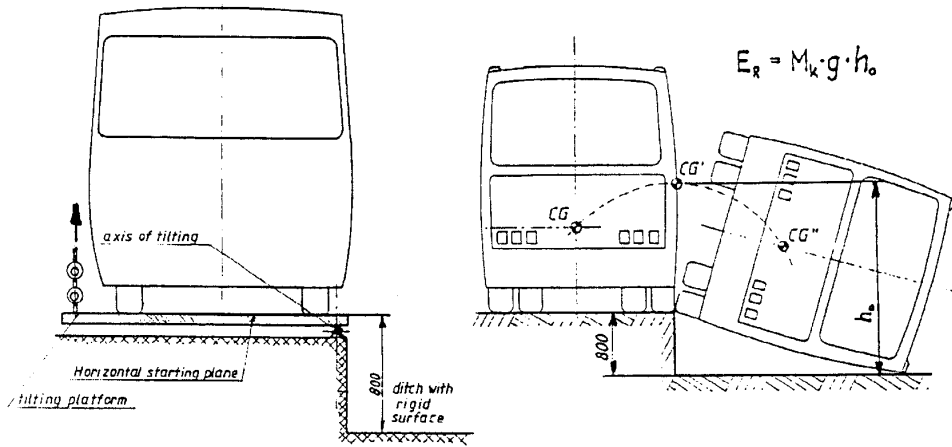
The rollover test shall be carried out on that side of the vehicle which is more dangerous with respect to the residual space. The decision is made by the competent Technical Service on the basis of the manufacturer's proposal, considering at least the following:

- 5.6.1. the lateral eccentricity of the centre of gravity and its effect on the potential energy in the unstable, starting position of the vehicle;
- 5.6.2. the asymmetry of the residual space, see paragraph 5.2.6.



5.6.3 the different, asymmetrical constructional features of the two sides of the vehicle; which side is stronger, better supported by partitions or inner boxes (e.g. wardrobe, toilet, kitchenette)





## 6 MODIFICATION AND EXTENSION OF APPROVAL OF A VEHICLE TYPE

- 6.1 Every modification of the approved vehicle type shall be advised to the administrative department which granted the type approval. The department may then either,
- 6.1.1 agree that the modifications made are unlikely to have an appreciable effect and that in any case the new vehicle type still complies with the requirements of this Regulation and constitutes part of a group of vehicle types together with the approved vehicle type; or
- 6.1.2 require a further test report from the Technical Service responsible for conducting the tests to prove that the new vehicle type complies with the requirements of this Regulation and constitutes part of a group of vehicle types together with the approved vehicle type;
- 6.1.3. refuse the extension of approval and require a new approval procedure to be carried out.**
- 6.2 The decisions of the administrative department and the Technical Service shall be based on the threefold criteria of the worst case:
- 6.2.1. the structural criterion means whether the superstructure is changed or not (see Annex 4) If no change, or the superstructure is stronger, this is favourable.
- 6.2.2. the energy criterion means whether the reference energy is changed or not. If the new vehicle type has the same or smaller reference energy than the approved one, this is favourable.
- 6.2.3. residual space criterion is based on the envelope surface of the residual space. If the residual space of the new vehicle type is everywhere within the approved case residual space, this is favourable.
- 6.3. If all three criteria described in para. 6.2. are changed favourably, the extension of the approval shall be done without further investigation. If all of three answers are unfavourable, a new approval procedure is required.  
If the answers are mixed, further investigations (tests, calculation, structural analysis, for example) will be required. These investigations shall be determined by the Technical Service cooperating with the manufacturer.
- 6.4 Confirmation or refusal of approval, specifying the alterations, shall be notified by the procedure specified in paragraph 4.3 above to the Parties to the Agreement which apply this Regulation.
- 6.5 The competent authority issuing the extension of approval shall assign a series number to each

communication form drawn up for such an extension.

## **7 CONFORMITY OF PRODUCTION**

- 7.1 Vehicles which are manufactured to an approval granted under this Regulation shall demonstrate conformity to that approval.
- 7.2. In order to verify this conformity only the superstructure shall be considered (see Annex 4). Only those structural elements which are nominated by the manufacturer as part of the superstructure shall be checked.
- 7.3. The check for conformity shall consider the material properties, the geometry and joint technology of the superstructure elements, and the mass distribution.
- 7.4. The holder of the approval shall in particular:
  - 7.4.1. ensure existence of procedures for the effective control of the quality of the superstructure.
  - 7.4.2. have access to test equipment necessary to check the conformity
  - 7.4.3. record test results and annexed documents. This data shall remain available for a period to be determined by the Administrative Service;
  - 7.4.4. analyse the results of each test, in order to verify the continued conformity of the superstructure's characteristics
  - 7.4.5. ensure that sufficient checks and tests are carried out on the dimensions, materials and joints of the components to demonstrate continued conformity
    - 7.4.5.1. ensure that any non-conformity revealed by a test is investigated through further sampling and testing and that all necessary steps are taken to re-establish the conformity of the corresponding production.
- 7.5. The competent authority which has granted type approval shall have free access at any reasonable time to check and verify the conformity;
  - 7.5.1. all test results and production survey records shall be readily available to the visiting inspector.
  - 7.5.2. the inspector may take samples at random which shall be tested in the manufacturer's laboratory. The number of samples taken will be determined according to the results of the manufacturer's own verification.
  - 7.5.3. if the competent authority is not satisfied with the quality level or when it is necessary to verify the tests carried out in the manufacturer's laboratory, the inspector may select samples to be sent to the Technical Service which has conducted the type approval tests.
  - 7.5.4. the normal frequency of inspections authorised by the competent authority shall be once every two years. If non-conformity is discovered in the course of one of these visits, the competent authority may increase the visit frequency to re-establish the conformity of production as rapidly as possible.

## **8. PENALTIES FOR NON-CONFORMITY OF PRODUCTION**

- 8.1 The approval granted in respect of a vehicle type pursuant to this Regulation may be withdrawn if the requirements laid down in paragraph 10.1 above are not complied with.

8.2 If a party to the Agreement applying this Regulation withdraws an approval it has previously granted, it shall forthwith so notify the other Contracting Parties applying this Regulation, by means of a copy of the approval form bearing at the end, in large letters, the signed and dated annotation “APPROVAL WITHDRAWN”

**9. PRODUCTION DEFINITELY DISCONTINUED**

If the holder of the approval completely ceases to manufacture a type of vehicle approved in accordance with this Regulation, he shall so inform the authority which granted the approval. Upon receiving the relevant communication, that authority shall inform thereof the other Parties to the Agreement applying this Regulation by means of a copy of the approval form bearing at the end, in large letters, the signed and dated annotation “PRODUCTION DISCONTINUED”.

**10. TRANSITIONAL PROVISIONS – *to be drafted***

**11 NAMES AND ADDRESSES OF TECHNICAL SERVICES RESPONSIBLE FOR CONDUCTING APPROVAL TESTS, AND OF ADMINISTRATIVE DEPARTMENTS**

The Parties to the Agreement which apply this Regulation shall communicate to the United Nations Secretariat the names and addresses of the Technical Services responsible for conducting approval tests and of the Administrative Departments which grant approval and to which forms certifying approval or extension or refusal or withdrawal of approval, issued in other countries, are to be sent.

Footnotes - To be formulated according to current UN-ECE WP29/GRSG requirements

**ANNEX 1**

- 1 Communication concerning:
  - approval
  - refusal of approval
  - extension of approval
  - withdrawal of approval
  - production definitely discontinued

2 of a vehicle type with regard to the strength of its superstructure pursuant to Regulation No. 66

Approval No.	Extension No.
1.	Trade name or mark of the Vehicle: .....
2.	Vehicle Type:.....
3.	Manufacturer's name and address:.....
4.	If applicable, name and address of the manufacturer's representative:.....
5.	Brief summary of description of the superstructure in respect of paragraph 3.2.2 and annex 4:.....
6.	Reference Number of Detailed drawing showing the residual space used in the approval procedure:.....
7.	The position of the centre of gravity of the unladen vehicle in the longitudinal, transverse and vertical planes:..... If the vehicle is fitted with occupant restraints then additionally, the position of the centre of gravity of the total vehicle mass shall be defined in the longitudinal, transverse and vertical planes:.....
8.	Unladen kerb mass (kg):..... If the vehicle is fitted with occupant restraints then additionally, the total vehicle mass (kg) shall be stated:.....
9.	The value of reference energy ( $E_R$ ) as specified in paragraph 3.2.1.4. of this Regulation:.....
10.	Vehicle submitted for approval on:...../...../.....
11.	Method of test or calculation employed for approval:.....
12.	Direction of the rollover test used or assumed during the approval procedure:.....
13.	Technical service responsible for conducting approval tests:.....
14.	Date of test report issued by that service:...../...../.....
15.	Number of report issued by that service:...../...../.....
16.	Approval granted/refused/extended/withdrawn
17.	Reason(s) for extension (if applicable):.....
18.	Position of approval mark on the Vehicle:.....

List of documents containing data specified, in para. 3.2. of the Main Text, and in the Annex referring to the approval test method which was used.

.....  
.....  
.....  
.....  
.....

The listed documents are held by the competent authority and are available on request .....

Place:  
Date:  
Signature:

## **ANNEX 2 ARRANGEMENT OF THE APPROVAL MARK**

### **Application**

See paragraph 4.4 of this Regulation.

*Figure 2.1 (Unchanged from existing UN-ECE Reg 66)*

### **Example**

The above approval mark affixed to a vehicle shows that the vehicle type concerned has, with regard to the strength of the superstructure, been approved in the United Kingdom (E11) pursuant to Regulation No. 66 under approval number 002431. The first two digits of the approval number indicate that the approval was granted in accordance with the requirements of Regulation No. 66 in its original form.

## **ANNEX 3 DETERMINATION OF THE CENTRE OF GRAVITY OF THE VEHICLE**

### **1 General principles**

- 1.1 The energy levels in the rollover test depend directly on the position of the vehicle's centre of gravity position: Therefore, its determination should be as accurate as practicable. The method of measurement of dimensions, angles and load values, and the accuracy of measurement shall be recorded for assessment by the Technical Service.

The following accuracy is required.

For dimensions less than 2000 mm,	accuracy of	$\pm 1$ mm
For dimensions greater than 2000 mm,	accuracy of	$\pm 0.05$ per cent
For angles,	accuracy of	$\pm 1$ per cent
For load values	accuracy of	$\pm 0.2$ per cent

- 1.2 Blocked suspension is specified as the condition for determining centre of gravity and for carrying out the actual roll-over test.
- 1.3 The position of the centre of gravity is defined by three parameters:
- 1.3.1. longitudinal distance ( $l_f$ ) from the centre line of front axle
- 1.3.2. transverse distance ( $t$ ) from the vertical longitudinal central plane of the vehicle.
- 1.3.3. vertical height ( $h$ ) above the flat horizontal ground level when the tyres are inflated as specified for the vehicle
- 1.4 A method for determining  $l_f$ ,  $t$ ,  $h$ , using load cells is described here. Alternative methods using lifting equipment and/or tilt tables for example may be proposed by the manufacturer to the Technical Service who will decide whether the method is acceptable based on its degree of accuracy.

### **2. Measurement:**

- 2.1. The position of the vehicle's CG shall be determined in the unladen kerb mass condition and the total vehicle mass condition as defined in paras 2.9 and 2.11 of this Regulation. It is acceptable to measure the position of the CG in the unladen vehicle mass condition and to use this to calculate the position of the CG in the total vehicle mass condition. For the determination of the position of the CG in the total vehicle mass condition, the individual occupant mass (factored by the constant,  $k$ ) shall be positioned and rigidly held 200mm above and 100mm forward of the R point of the seat which is defined in UN-ECE Reg21 Annex 5
- 2.2. The longitudinal ( $l_f$ ) and transverse ( $t$ ) co-ordinates of the centre of gravity shall be determined with the vehicle on flat, horizontal ground (see Figure A3.1)
- 2.3 The height of the centre of gravity ( $h$ ) shall be determined by tilting the vehicle longitudinally with the suspension blocked in the normal operating position as defined by the manufacturer.
- 2.4 **Determination of the longitudinal and transverse position of CG in the horizontal plane.**  
The total weight [ $W$ ] of the vehicle shall be determined by the test station: the vehicle shall be placed with each wheel, or twinned wheel, on a load cell set in a common horizontal plane. Each steered wheel shall be set to its zero straight-ahead steer position. The individual load-cell readings shall be noted simultaneously. The wheel-base(s) and track(s) of the vehicle shall be accurately measured.

The individual load-cell readings are used to calculate the total vehicle weight and the moment of the CG.

- 2.4.1. The longitudinal position of the CG relative to the centre of the contact point of the front wheels(see Figure A3.1) is given by,

$$l_1 = \frac{(P_3 + P_4).L_1 + (P_5 + P_6).L_2}{(M_K)} \quad \dots \text{Equ. 1}$$

where

$P_1$  = reaction load on the load cell under the left-hand wheel of the front (1<sup>st</sup> axle) of the vehicle

$P_2$  = reaction load on the load cell under the right-hand wheel of the 1<sup>st</sup> axle of the vehicle

$P_3$  = reaction load on the load cell under the left-hand wheel(s) of the 2<sup>nd</sup> axle of the vehicle

$P_4$  = reaction load on the load cell under the right-hand wheel(s) of the 2<sup>nd</sup> axle of the vehicle

$P_5$  = reaction load on the load cell under the left-hand wheel(s) of the 3<sup>rd</sup> axle of the vehicle

$P_6$  = reaction load on the load cell under the right-hand wheel(s) of the 3<sup>rd</sup> axle of the vehicle

$$M_k = (P_1 + P_2 + P_3 + P_4 + P_5 + P_6)$$

$L_1$  = wheel base of the vehicle, centre of wheel on 1<sup>st</sup> axle to centre of wheel on 2<sup>nd</sup> axle

$L_2$  = wheel base of the vehicle, centre of wheel on 1<sup>st</sup> axle to centre of wheel on 3<sup>rd</sup> axle, if fitted

2.4.2. 'The transverse position of the vehicle's CG relative to its longitudinal vertical centre plane (see Figure A3.2) is given by,

$$t = \left( (P_1 - P_2) \frac{T_1}{2} + (P_3 - P_4) \frac{T_2}{2} + (P_5 - P_6) \frac{T_3}{2} \right) \cdot \frac{1}{M_K} \quad \dots \text{Equ. 2}$$

where

$T_1$  = distance between the centres of the footprint of the wheel(s) at each end of the 1<sup>st</sup> axle of the vehicle

$T_2$  = distance between the centres of the footprint of the wheel(s) at each end of the 2<sup>nd</sup> axle of the vehicle

$T_3$  = distance between the centres of the footprint of the wheel(s) at each end of the 3<sup>rd</sup> axle of the vehicle

- Note Well:
1. This equation assumes that a straight line can be drawn through the centre points of  $T_1$ ,  $T_2$ ,  $T_3$ . If this is not the case then a specialised formula will be required.
  2. If the value of ( $t$ ) is negative, then the CG of the vehicle is situated to the right of the centreline of the vehicle

## 2.5 Determination of the vertical height of the CG

The suspension shall be blocked in the normal operating position as defined by the manufacturer, to fix the CG of the unsprung masses with respect to the CG of the sprung mass.

- 2.5.1 Two load-cells shall be positioned on a common horizontal plane, to receive the front wheels. The horizontal plane shall be at sufficient height above the surrounding surfaces that the vehicle can be tilted forward to the required angle (see para.2.5.2 below) without its nose touching that surface.
- 2.5.2 A second pair of load-cells shall be placed in a common horizontal plane on top of support structures, ready to receive the wheels of the 2<sup>nd</sup> axle of the vehicle. The support structures shall be sufficiently tall to generate a significant angle of inclination  $\alpha$  ( $> 25^\circ$ ) for the vehicle. The greater the angle, the more accurate will be the calculation – see Figure A3.3.

The vehicle is repositioned on the four load-cells, with the front wheels chocked to prevent the vehicle rolling forward.

The loads in the load cells shall be noted and the inclination (centre of front wheel disc to centre of rear wheel disc) shall be measured.

The height of the vehicle CG is given by,

$$h = \left( \frac{1}{\tan \alpha} \right) \left( L_1 - \left( \frac{L_a}{\cos \alpha} \right) \right) \quad \dots \text{Equ. 3}$$

where  $h$  = height above the horizontal ground level when the vehicle tyres are inflated as specified.

$\alpha$  = angle of inclination of the longitudinal axis of the vehicle

$L_a$  = horizontal distance between the centre of the contact point of the left front wheel and the line of action of the CG of the vehicle.

$L_a$  is given by,



$$L_a = \frac{L_t(F_3+F_4)}{M_k} \quad \dots\text{Equ. 4}$$

where

$F_3$  = reaction load on the load cell under the left-hand wheel(s) of the 2<sup>nd</sup> axle of the vehicle

$F_4$  = reaction load on the load cell under the right-hand wheel(s) of the 2<sup>nd</sup> axle of the vehicle

$L_t$  = horizontal distance between the centre of the contact point of the left front wheel and the left -hand wheel(s) of the 2<sup>nd</sup> axle of the vehicle

## **ANNEX 4 VIEW-POINTS TO THE STRUCTURAL DESCRIPTION OF THE SUPERSTRUCTURE**

### **1. General principles**

- 1.1. The manufacturer shall define unambiguously the superstructure of the body-work (see Figure A4.1, for example) and shall state:
  - 1.1.1. which bays contribute to the strength and energy absorption of the superstructure
  - 1.1.2. which connecting elements between the bays contribute to the torsional stiffness of the superstructure.
  - 1.1.3. the mass distribution among the nominated bays
  - 1.1.4. which elements of the superstructure are assumed as rigid parts
- 1.2. The manufacturer shall supply the following information about the elements of the superstructure:
  - 1.2.1. drawings, with all the significant geometrical measurements necessary to produce the elements and to evaluate any change or alteration of the element,
  - 1.2.2. the material of the elements referred to national, or international standards
  - 1.2.3. the joint technology between the structural elements (riveted, bolted, glued, welded, type of welding, etc.)
- 1.3. Every superstructure shall have at least two bays: one in front of the CG and one behind the CG.
- 1.4. No information is required about any elements of the body-work, which are not parts of the superstructure.
- 1.5. When a new variant is developed from an approved vehicle type, but no changes are made in the superstructure, its elements and their joints, the body-work of the new variant is assumed to have the same strength as the approved vehicle type.

### **2. Bays**

- 2.1. A bay is defined as a transverse section of superstructure containing at least one window pillar from each side-wall. Every bay has a transverse centre plane (CP) perpendicular to the longitudinal vertical centre plane of the vehicle and passing through the centre points ( $C_p$ ) of the window-pillars (see Figure A4.2)
  - 2.2. The  $C_p$  is defined as a point at half window height and halfway across the pillar width. If the  $C_p$  of the left-side and right-side pillars of a bay are not in the same transverse plane, the CP of the bay is set halfway between the transverse planes of the two  $C_p$ -s
  - 2.3. The length of a bay is measured in the direction of the longitudinal axis of the vehicle, and is determined by the distance between two planes perpendicular to the longitudinal axis of the vehicle. There are two limits which define the length of a bay; the window (door) arrangement, and the shape and construction of the window (door) pillars (see Figure A4.2)
- 2.3.1. The maximum length of a bay is defined by the length of the two neighbouring window (door) frames (see Figure A4.2)

$$(W_j)_{\max} = \frac{1}{2}(a + b) \quad \dots \text{Equ.1}$$

where  $a$  = the length of the window (door) frame behind the  $j^{\text{th}}$  pillar, and  
 $b$  = the length of the window (door) frame in front of the  $j^{\text{th}}$  pillar

Note Well: If the pillars on opposite sides of the bay are not in one transverse plane, or the window frames on each side of the vehicle have different lengths (see Figure A4.3), the overall length,  $W_j$  of the bay is defined by,

$$(W_j)_{\max} = \frac{1}{2}(a_{\min} + b_{\min} - 2l) \quad \dots \text{Equ.2}$$

where  $a_{\min}$  = the smaller value of  $a_{\text{right side}}$  or  $a_{\text{left side}}$   
 $b_{\min}$  = the smaller value of  $b_{\text{right side}}$  or  $b_{\text{left side}}$   
 $l$  = the longitudinal offset between the centrelines of the pillars  
on the left and right sides of the vehicle

- 2.3.2 The minimum length of a bay shall include the whole window pillar (including its inclination, corner radii, etc.). If the inclination and corner radii exceed half the length of the adjacent window then the next pillar shall be included in the bay.
- 2.4 The distance between two bays shall be defined as the distance between their CP-s .
- 2.5 The distance of a bay from the CG of the vehicle shall be defined as the perpendicular distance from its CP to the vehicle CG

**3. Connecting structures between the bays.**

- 3.1. The connecting structures between bays shall be clearly defined in the superstructure. These structural elements fall into two distinct categories:
  - 3.1.1. the connecting structures which form part of the superstructure. These elements shall be identified by the manufacturer, in this design submission: they include
    - 3.1.1.1 side-wall structure, roof structure, floor structure, which connect several bays,
    - 3.1.1.2 structural elements which reinforce one or more bays; for example, boxes under seats, wheel arches, seat structures connecting side-wall to floor, kitchen, wardrobe and toilet structures
  - 3.1.2. the additional elements which do not contribute to the structural strength of the vehicle, for example: ventilation ducts, hand luggage boxes, heating ducts. Information about these elements required.

**4. Mass distribution**

- 4.1. The manufacturer shall clearly define the portion of the mass of the vehicle attributed to each of the bays of the superstructure. This mass distribution shall express the energy absorbing capability and load bearing capacity of each bay. The following requirements shall be met when defining the distribution of mass:
  - 4.1.1. the sum of the masses attributed to each bay shall be related to the unladen mass:

$$\sum_{j=1}^n (m_j) \geq M \quad \dots \text{Equ.3}$$

where  $m_j$  = the mass attributed to the  $j^{\text{th}}$  bay  
 $n$  = the number of bays in the superstructure  
 $M$  =  $M_k$ , unladen mass; or  $M_t$ , total vehicle mass, as appropriate

- 4.1.2. the CG of the distributed masses shall be in the same position as the CG of the vehicle:

$$\sum_{j=1}^n (m_j l_j) = 0 \quad \dots \text{Equ.4}$$

where  $l_j$  = the distance of the  $j^{\text{th}}$  bay from the CG of the vehicle (see para, 2.3.).  
 $l_j$  is positive, if the bay is in front of the CG and negative if it is behind it.

- 4.2. The mass „ $m_j$ ” of each bay of the superstructure shall be defined by the manufacturer, as follows,
  - 4.2.1. the masses of the components of the „ $j^{\text{th}}$ ” bay shall be related to its mass „ $m_j$ ” by:

$$\sum_{k=1}^s m_{jk} \geq m_j \quad \dots \text{Equ.5}$$

where  $m_{jk}$  = the mass of each component of the bay  
 $s$  = number of individual masses on the bay

4.2.2. the CG of the component masses of a bay shall have the same transverse position inside the bay as the bay's CG (see Fig.3.):

$$\sum_{k=1}^s m_{jk} y_k \equiv \sum_{k=1}^s m_{jk} z_k \equiv 0 \quad \dots \text{Equ.6}$$

where  $y_k$  = the distance of the  $k^{\text{th}}$  mass component of the bay from the axis „Z” (see Figure A4.4).  $y_k$  will have a positive value on one side of the axis and a negative value on the other side.

$z_k$  = the distance of the  $k^{\text{th}}$  mass component of the bay from the axis “Y”,  $z_k$  will have a positive value on one side of the axis and a negative value on the other side.

4.2.3 In the case where occupant restraints are part of the vehicle specification, the occupant mass attributed to a bay shall be attached to that part of the superstructure which is designed to absorb seat and occupant loadings.

## **ANNEX 5 ROLLOVER OF FULL- SCALE VEHICLE AS THE BASIC APPROVAL TEST METHOD**

### **1 The tilting test bench**

- 1.1 The tilting platform shall be rigid enough and rotated so that the simultaneous lifting of the axles of the vehicle shall be ensured. No bigger difference than 1° is allowed between the tilting angle of the platform below each axle.
- 1.3 The height difference between the horizontal lower plane of the ditch (see Figure.A5.1) and the plane of the tilting platform on which the bus is standing, shall be 800±20 mm
- 1.4 The tilting platform, related to the ditch, shall be placed as follows (see Figure A5.1) :
- 1.4.1 the axis of its rotation is max 100 mm from the vertical wall of the ditch;
- 1.3.2. the axis of the rotation is max 100 mm below the plane of the horizontal tilting platform.
- 1.5 Wheel supports shall be applied at the wheels being close to the axis of rotation against sliding of the vehicle sideways when tilting it.  
The main characteristics of the wheel supports shall be (see figure A5.1)
- 1.4.1 dimensions of one wheel support:
- |             |                 |
|-------------|-----------------|
| Height      | 80 mm           |
| Width       | 20 mm           |
| Edge radius | 10 mm           |
| Length      | 500 mm minimum; |
- 1.4.2 the wheel supports at the widest axle shall be placed on the tilting platform so that the side of the tyre is 20 mm from the axis of rotation;
- 1.4.3 the wheel supports at the other axles shall be adjusted so that the longitudinal vertical centre plane of the vehicle shall be parallel to the axis of rotation.
- 1.5 The tilting platform shall be constructed to prevent the vehicle moving along its longitudinal axis.
- 1.6 The impact area of the ditch shall have a horizontal, uniform concrete surface.

### **2 Preparation of tested vehicle**

- 2.1 The vehicle to be tested need not be in a fully finished, “ready for operation” condition. Generally: any alteration from the fully finished condition is acceptable if the basic features and behaviour of the superstructure are not influenced by it. The test vehicle shall be the same as its fully finished version in respect of the following:
- 2.1.1 the position of the CG, the value of unladen kerb mass and the distribution and location of masses as declared by the manufacturer
- 2.1.2 all of those elements which – according to the manufacturer - contribute to the strength of the superstructure shall be installed in their original position ( see Annex 4 to this Regulation).
- 2.1.2 elements, which do not contribute to the strength of the superstructure and are too valuable to risk damage (e.g. drive chain, dashboard instrumentation, driver’s seat, kitchen equipment, toilet equipment, etc.) can be replaced by additional elements equivalent in mass and method of installation. These additional elements must not have a reinforcing effect on the strength of superstructure.
- 2.1.4 fuel, battery acid and other combustible, explosive or corrosive materials may be substituted with other materials provided that the conditions of para 2.1.1. are met.
- 2.1.5 In the case where occupant restraints are part of the vehicle type, a mass shall be attached to each seat fitted with an occupant restraint. That mass shall be,
- 2.1.5.1 a portion  $k$  ( see 2.11 of this Regulation ) of the occupant mass ( $M_{mi}$ ).

- 2.1.5.2 placed 200mm above and 100mm forward of the R point of the seat which is defined in UN-ECE Reg 21 Annex 5
- 2.1.5.3 fixed securely so that it does not break away during the test.
- 2.2 The test vehicle shall be prepared as follows:
  - 2.2.1 tyres shall be inflated to the pressure prescribed by the manufacturer.
  - 2.2.2 The suspension system of the vehicle shall be blocked, i.e. the axles, the springs and the suspension elements of the vehicle shall be fixed in relation to the bodywork. The floor of the vehicle shall be horizontal on the horizontal tilting platform, the floor height shall be according to the manufacturer's specification for the unladen vehicle.
  - 2.2.3 every door and opening window of the vehicle shall be closed but not locked.
- 2.3 The rigid sections of an articulated vehicle may be tested separately or in combination.
  - 2.3.1 For testing the articulated sections as a combination, the sections of the vehicle shall be fixed to each other in such a way that,
    - 2.3.1.1 there is no relative movement between them during the roll-over process.
    - 2.3.1.2 there is no significant change in mass distribution and CG positions
    - 2.3.1.3 there is no significant change in the strength and deformation capability of the superstructure.
  - 2.3.2, For testing the articulated sections separately, the single-axle sections shall be attached to an artificial support which keeps them in fixed relation to the tilting platform during its movement from the horizontal to the point of roll-over. This support shall meet the following requirements:
    - 2.3.2.1 it shall be fixed to the structure in such a way that it does not cause either reinforcement or extra additional load to the superstructure.
    - 2.3.2.2 it shall be constructed so that it does not suffer any deformation which could change the direction of the rollover of the vehicle.
    - 2.3.2.3 its mass shall be equal to the mass of those elements, parts of the articulated joint, which nominally belong to the section being tested, but which are not placed on it (e.g. turntable and its floor, handholds, rubber sealing curtains, etc.).
    - 2.3.2.4 its CG shall have the same height as the common CG of those parts which are mentioned in para 2.3.2.3.
    - 2.3.2.5 it shall have an axis of rotation parallel to the longitudinal axis of the multi-axle section of the vehicle, and passing through the points of contact of the tyres of that section.

### **3 Test procedure, test process**

- 3.1 The rollover test is a very rapid, dynamic process having distinguishable stages, should be taken into consideration when a rollover test, its instrumentation and measurement are planned.
- 3.2 The vehicle shall be tilted without rocking and without dynamic effects until it rolls over. The angular velocity shall not exceed 5 degrees per second (0,087 radians/sec).
- 3.3 For inside observation high-speed photography, video, deformable templates, electrical contact sensors or other suitable means shall be used to determine that the requirements of para 5.1 in the main text of this Regulation has been met. This shall be verified at any places of the passenger compartment where the residual

space seems to be endangered, the exact positions being at the direction of the technical service. At least two positions, nominally at the front and rear of the passenger compartment shall be used.

- 3.4. Outside observation and recording of the rollover and deformation process is recommended, which means the following:
  - 3.4.2. two high-speed cameras - one at the front and another at the rear . They should be located far enough from the front and rear wall of the vehicle to produce a measurable picture, by avoiding wide-angle distortion, in the shaded area shown in Figure A5.2a
  - 3.4.3. the position of the CG and the contour of the superstructure (see Figure A5.2b), is marked by stripes and bands to ensure correct measurements on the pictures.

#### **4 Documentation of the rollover test**

- 4.1 Detailed description of the tested vehicle shall be given by the manufacturer in which:
  - 4.1.1 all the deviations between the fully finished, ready-for-operation vehicle type and the tested vehicle are listed.
  - 4.1.2 the equivalent substitution (in respect of mass, mass distribution and installation) shall be proved in every case, when structural parts, units are substituted by other units or masses.
  - 4.1.3 there is a clear statement of the position of CG in the tested vehicle which may be based on measurements carried out on the test vehicle when it is ready for test, or a combination of measurement (carried out on the fully finished vehicle type) and calculation based on the mass substitutions.
- 4.2 The test report shall contain all the data (pictures, records, drawings, measured values, etc.) which show:
  - 4.2.1. that test was carried out according to this Annex;
  - 4.2.2. that the requirements given in para 5.1.1. and 5.1.2. in the main text of this Regulation are met (or not);
  - 4.2.3 the individual evaluation of inside observations;
  - 4.2.4. all the data and information needed for the identification of the vehicle type, the test vehicle, the test itself, and the personnel responsible for the test and its evaluation.
- 4.3. It is recommended to document in the test report the CG's highest and lowest position related to the ground level of the ditch.

## **ANNEX 6 ROLLOVER TEST WITH BODY SECTIONS**

### **1. Additional data and information**

If the manufacturer chooses this method of testing, the following additional information shall be given to the Technical Service in addition to: beyond the data, information and drawings listed in para.3. of this Regulation:

- 1.2 drawings of the body sections to be tested;
- 1.3 verification of the validity of Equations 3, 4, 5 and 6, given in Annex 4 para. 4 .1, upon successful completion of the body section rollover tests.
- 1.3. The measured masses of the body sections to be tested, and verification that their CG positions are the same as that of the unladen vehicle. (Presentation of measuring reports)

### **2. The tilting bench**

The tilting bench shall meet the requirements given in Annex 5, para. 1.

### **3. Preparation of body sections**

- 3.1 The number of the body sections to be tested shall be determined by the following rules:
  - 3.1.1 all the different bay configurations which are part of the superstructure shall be tested in at least one body section;
  - 3.1.2 every body section shall have at least two bays;
  - 3.1.3 in an artificial body section (see para. 2.27 of the main text of this Regulation) the ratio of the mass of any one bay to any other bay shall not exceed 2;
  - 3.1.4. the residual space of the whole vehicle shall be well represented in the body sections, including any peculiar combinations arising from the vehicles bodywork configuration;
  - 3.1.5. the whole roof structure shall be well represented in the body sections if there are local specialities, like changing height, air condition installation, gas tanks, luggage carrier, etc.
- 3.2. The bays of the body section shall be exactly the same structurally as they are represented in the superstructure, as regards shape, geometry, material, joints.
- 3.3. The connecting structures between the bays shall represent the manufacturer's description of the superstructure (see Annex 4 para.3.) and the following rules shall be considered:
  - 3.3.1 in the case of a body section taken directly from the actual vehicle layout, the basic and the additional connecting structures (see para. 3.1. in Annex 4 ) shall be the same as that of the vehicle superstructure;
  - 3.3.2 in the case of an artificial body section, the connecting structures shall be equivalent in terms of strength, stiffness and behaviour to that of the vehicle superstructure;
  - 3.3.3 those rigid elements which are not part of the superstructure but which can encroach on the residual space during deformation, shall be installed into the body sections;
  - 3.3.4 the mass of the connecting structures shall be included in the mass distribution, in terms of attribution to a particular bay and distribution within that bay.
- 3.4. The body sections shall be equipped with artificial supports, to provide the same CG positions and axis of rotation for them on the tilting platform as that of the complete vehicle. The supports shall meet the following requirements:
  - 3.4.1 they shall be fixed to the body section in such a way that they do not provide either reinforcement or extra additional load on the body section;
  - 3.4.2 they shall be sufficiently strong and rigid to resist any deformation which could change the direction of the body section motion during the tilting and rollover process;



3.4.3 their mass shall be included in the mass distribution and CG position of the body section.

3.5. The distribution of mass in the body section shall be arranged with the following considerations:

3.5.1. the whole body section (bays, connecting structures, additional structural elements, supports) shall be considered when checking the validity of Equations 5 and 6, in Annex 4 para. 4.2.;

3.5.2. any masses attached to the bays (see para 4.2.2. and Fig.4. in Annex 4]) shall be placed and fixed to the body section in such a way that they do not cause reinforcement or additional load or limitation of the deformation.

3.5.3 In the case where occupant restraints are part of the vehicle type, the occupant masses shall be considered as described in Annex 4 and Annex 5.

#### **4. Test procedure.**

The test procedure shall be the same as described in para.3. of Annex 5 for a complete vehicle.

#### **5. Evaluation of the tests.**

5.1. The vehicle type shall be approved if all the body sections pass the rollover test and the Equations 2 and 3 in para. 4 of Annex 4, are fulfilled.

5.2. If one of the body sections fails the test, the vehicle type shall not be approved.

5.4. If a body section passes the rollover test, each of the bays which form that body section are considered to have passed the rollover test, and the result can be quoted used in future applications for approval, provided that the ratio of their masses remains the same in the subsequent superstructure .

5.5. If a body section fails the rollover test, all the bays within that body section shall be considered to have failed the test even if the residual space is invaded in only one of the rings.

#### **6. Documentation of body section rollover tests**

The test report shall contain all the data necessary to demonstrate,

6.1. that the tests were carried out according to this Annex

6.3. whether, or not, the requirements - given in para 5.1 of the main text of this Regulation - are met

6.4. the individual evaluation of the body sections and their bays.

6.5. the identity of the vehicle type, its superstructure, the tested body sections, the tests themselves and the personnel responsible for the tests and their evaluation.

## **ANNEX 7 QUASI- STATIC LOADING TEST OF BODY SECTIONS**

### **1. Additional data and information**

This method of testing uses structural test units, each one built up from at least two bays of the vehicle under appraisal, connected together with representative structural elements. In place of a roll-over test, loads are applied to the static structure.

If the manufacturer chooses this method of testing the following additional information shall be supplied to the Technical Service, in addition to the data, and drawings listed in para.3.2 of the main text of this Regulation:

- 1.1. Drawings of the body sections to be tested.
- 1.2. Energy values to be absorbed by the individual bays of the superstructure, as well as the energy values belonging to the body sections to be tested.
- 1.3. Verification of the energy requirement , see para. 4.2 below, upon completion of successful quasi-static loading tests of body sections.

### **2. Preparation of body sections.**

- 2.1. The manufacturer shall consider the requirements given in Annex 6 paragraphs 3.1, 3.2, and 3.3., when designing and producing the body section for test,
- 2.2. The body section shall be equipped with the residual space profile, at positions where it is considered that the pillars or other structural elements are likely to intrude as a result of the expected deformation.

### **3. Test procedure**

- 3.1. The body section to be tested shall be firmly and securely attached to the test bench through a rigid underframe structure in such a way that:
  - 3.1.1. local plastic deformation shall not occur around the attachment points;
  - 3.1.2. the location and method of attachment shall not inhibit the formation and working of expected plastic zones and hinges.
- 3.2. For application of the load to the body section, the following rules shall be considered:
  - 3.2.1. the load be evenly distributed on the cantrail, through a rigid beam, which is longer than the cantrail to simulate the ground in rollover test, and shall follow this geometry of the cantrail.
  - 3.2.2. the direction of the applied load (see Figure A7.1.) shall be related to the vertical centre plane (VCP) of the vehicle and its inclination ( $\alpha$ ) shall be determined as follows:

$$\alpha = 90^\circ - \arcsin(800/H_c) \quad \dots \text{Equ.1}$$

where  $H_c$  [mm] is the cantrail height of the vehicle measured from the ground when it is standing on a horizontal plane.

- 3.2.3. the load shall be applied to the beam at the CG of the body section derived from the masses of its bays and the structural elements connecting them.. Using the symbols of Fig.A.7.1. the position of the CG can be determined by the following formula:

$$l_{CG} = \frac{\sum_{i=1}^s m_i l_i}{\sum_{i=1}^s m_i} \quad \dots \text{Equ.2}$$

where  $s$  is the number of the bays in the body section  
 $m_i$  is the mass of the  $i^{\text{th}}$  bay

- $l_i$  is the distance of the CG of the  $i^{\text{th}}$  bay from a selected pivot point.
- $l_{CG}$  is the distance of the CG of the body section from the same selected pivot point.

- 3.2.4. the load shall be increased gradually, taking measurements of the associated deformation at discrete intervals until the ultimate deformation „ $d_u$ ” when the residual space is invaded by one of the elements of the body section.
- 3.3. When plotting the load-deflection curve:
  - 3.3.1. the frequency of measurement shall be such as to produce a continuous curve (see Figure A.7.2.)
  - 3.3.3. the values of load and deformation shall be measured simultaneously
  - 3.3.4. the deformation of the loaded cantrail shall be measured in the direction of the applied load
  - 3.3.5. both load and deformation shall be measured to an accuracy of  $[\pm 1\%]$

**4. Evaluation of test results**

- 4.1. From the plotted load-deflection curve the actual energy absorbed by the body section ( $E_{BS}$ ) shall be expressed as the area below the curve (see Figure A.7.2.)
- 4.2. The minimum energy required to be absorbed by the body section ( $E_{min}$ ) shall be determined as follows:
  - 4.2.1. the total energy ( $E_T$ ) to be absorbed by the superstructure, when the vehicle type does not include occupant restraints, is;

$$E_T = 0.75 M g \Delta h \quad \dots \text{Equ.3}$$

where  $M = M_k$ , unladen mass; or  $M_t$ , total vehicle mass when occupant restraints are fitted,  
 $g$  = gravitational constant,  
 $\Delta h$  = the distance which the CG of the vehicle falls during a rollover test, as determined in Appendix 1 to this Annex.

- 4.2.2. the total energy „ $E_T$ ” shall be distributed among the bays of the superstructure in the proportions of their masses:

$$E_j = E_T \frac{m_j}{M_k} \quad \dots \text{Equ.4}$$

where  $E_j$  = the absorbed energy by the „ $j^{\text{th}}$ ” bay  
 $m_j$  = mass of the „ $j^{\text{th}}$ ” bay, as determined in Annex 4 para.4.1

- 4.2.3. the minimum energy required to be absorbed by the body section ( $E_{min}$ ) is the sum of the energy of the bays comprising the body section:

$$E_{min} = \sum_{j=1}^S E_j \quad \dots \text{Equ.5}$$

- 4.3. The body section passes the loading test , if:

$$E_{BS} > E_{min} \quad \dots \text{Equ.6}$$

In this case, all the bays which form that body section are considered to have passed the quasi-static loading test and these results can be quoted in future requests for approval provided that the component bays are not expected to carry a greater mass in the subsequent superstructure.

4.4. The body section fails the loading test if:

$$E_{BS} < E_{min} \quad \dots \text{Equ.7}$$

In this case all the bays which form that body section are considered to have failed the test even if the residual space is invaded in only one of the bays.

4.5. The vehicle type shall be approved if all the required body sections pass the loading test.

**5. Documentation of body section quasi-static loading tests**

The test report shall follow the format of Annex 6 para.6.

## ANNEX 7 APPENDIX 1

### **DETERMINATION OF THE VERTICAL MOVEMENT OF CG DURING ROLLOVER - FOR QUASI-STATIC LOADING TEST**

The vertical movement ( $\Delta h$ ) of CG related to the rollover test may be determined by the graphical method shown below.

1. Using scaled drawings of the cross-section of the vehicle, the starting position ( position 1 ) of the CG relative to the pivot axis of the tilt table is determined for the vehicle standing at its point of balance on the tilting platform (see Figure A7.A1.1)
2. From the result of the quasi-static load test, the final deformed shape of the body cross-section containing the vehicle CG, shall be drawn to the same scale as in para.1.
3. Using the assumption that the cross-section rotates around the edge of the wheel supports, the deformed vehicle cross-section is drawn with its cant-rail touching the bottom of the ditch (see Figure A7.A1.2). In this position the height of the CG (position 2) relative to the pivot point of the tilt table is determined.
4. The vertical movement of the CG ( $\Delta h$ ) is represented by the height difference between position 1 and position 2 of the CG.
5. If more than one body section is tested and each body section has a different final deformed shape, the vertical movement of CG ( $\Delta h_i$ ) shall be determined for each body section and the combined mean value ( $\Delta h$ ) is taken as,

$$\Delta h = \frac{1}{k} \sum_{i=1}^k \Delta h_i$$

where ( $\Delta h_i$ ) is the vertical movement of the CG of the  $i^{\text{th}}$  body section,  
k is the number of body sections tested.

**ANNEX 8 - CALCULATION METHOD BASED ON QUASI/STATIC TESTS**

*(The ad hoc Expert Group is discussing whether this subject should be included)*

## **ANNEX 9 COMPUTER SIMULATION OF ROLLOVER TEST ON COMPLETE VEHICLE**

### **1. Additional data and information**

The superstructure, or sections of the superstructure, may be shown to meet the requirements specified in para.

5.1.1. And 5.1.2 of the main text of this Regulation by a calculation method approved by the Technical Service.

If the manufacturer chooses this testing method, the following information shall be supplied to the Technical Service in addition to the data, and drawings listed in para. 3.2 of the main text of this Regulation;

- 1.1 A description of the applied calculation method which has been utilised, and clear precise identification of the analysis software, including at least, its producer, its commercial name, the version used and contact details of the developer.
- 1.2 The material models and the input data utilised.
- 1.3 The values for total mass, centre of gravity (CG), and the moments of inertia used in the mathematical model

### **2. The mathematical model**

The model shall be capable of describing the real physical behaviour of the rollover process, in accordance with Annex 5 and Annex 6. The mathematical model shall be constructed, and assumption made, in such a way that the calculation gives conservative results. The model shall be built up with the following specifications;

- 2.1 The Technical Service may require tests to be carried out on the actual vehicle structure to prove the validity of the mathematical model and to verify the assumptions made in the model.
- 2.2 The total mass and the CG position used in the mathematical model shall be identical to those of the vehicle, or sections as appropriate, to be approved.
- 2.3 The mass distribution in the mathematical model shall correspond to the vehicle, or sections, to be approved. Moments of inertia used in the mathematical model shall be calculated on the basis of this mass distribution.

### **3. Requirements for the algorithm and simulation program, and for computing equipment**

- 3.1 The position of the vehicle in unstable equilibrium at point of rollover, and the position at first contact with the ground shall be specified. The simulation program may start at the unstable equilibrium position, but shall start, at the latest, at the point of first contact with the ground.
- 3.2 The initial conditions at the point of first contact with the ground shall be defined using the change of potential energy from the unstable equilibrium position.
- 3.3 The simulation program shall run, at least, until the maximum deformation is reached.
- 3.4 The simulation program shall produce a stable solution, in which the result is independent of the incremental time step.
- 3.5 The simulation program shall be able to calculate the energy components for the energy balance at every incremental time step. The total energy - as the sum of all energy components - shall not deviate from the initial energy value by more than [XX] %.
- 3.6 Non-physical energy components such as “hourglass” and internal damping shall not exceed [YY] % of the total energy at any time.
- 3.7 The friction coefficient used at the ground contact shall be validated with physical test results, or the calculation shall be prove that the friction coefficient chosen produces conservative results.
- 3.8 All the possible physical contacts between parts of the vehicle shall be taken into account in the mathematical model.

### **4. Evaluation of the simulation**

- 4.1. When the stated requirements for the simulation program are met, the simulation of the changes in geometry of the interior structure and comparison with the geometrical shape of the residual space can be evaluated as defined in the para 5.1 and 5.2 of the main text of this Regulation.

- 4.2 If the residual space is not infringed during the rollover simulation, the approval shall be granted.
- 4.3 If the residual space is infringed during the rollover simulation, the approval shall be refused.

## **5 Documentation**

- 5.1 The report on the calculation shall contain the following information:
  - 5.1.1 All the data and information stated in Section 1 of this Annex;
  - 5.1.2 A drawing showing the mathematical model of the vehicle structure;
  - 5.1.3 A statement of the values of critical parameters (angle, velocity, and angular velocity) at the unstable equilibrium position of the vehicle and at the position of first contact with the ground;
  - 5.1.4 A table of the value of the total energy and the values of all its components (kinetic energy, internal energy, hourglass energy), at time increments of 1 ms covering, at least, the period from first contact with the ground until the maximum deformation is reached;
  - 5.1.5 The assumed ground friction coefficient;
  - 5.1.6 Plots or data which show in an appropriate way that the requirements specified in paragraph 5.1.1 and 5.1.2 of the main text of this regulation are met. This requirement can be satisfied by the provision of a plot, against time, of the distance between the inside contour of the deformed structure and the periphery of the residual space.
  - 5.1.7 A statement of whether, or not, the requirements specified in paragraph 5.1.1 and 5.1.2 of the main text of this Regulation have been met;
  - 5.1.8 All the data and information necessary for the clear identification of the vehicle type, its superstructure, the mathematical model of the superstructure, and the calculation itself.
- 5.2 It is recommended that the report also contains plots of the deformed structure at the moment when maximum deformation occurs, giving an overview of complete structure and regions of large plastic deformation.
- 5.3 At the request of the Technical Service, further information shall be provided and included in the report.



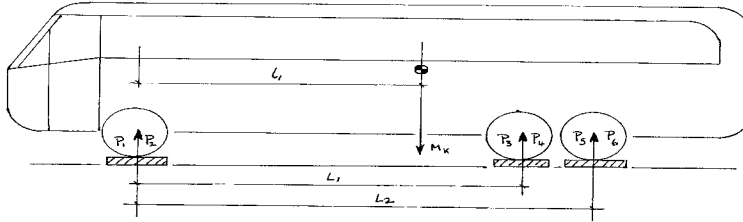


Figure A3.1

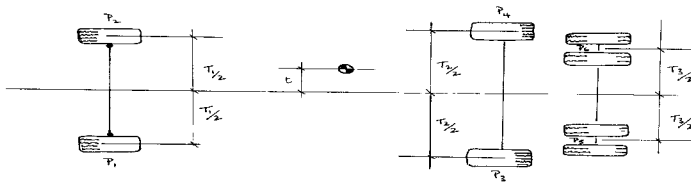


Figure A3.2

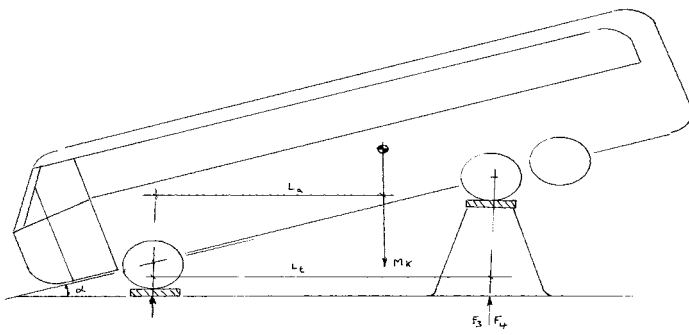


Figure A3.3

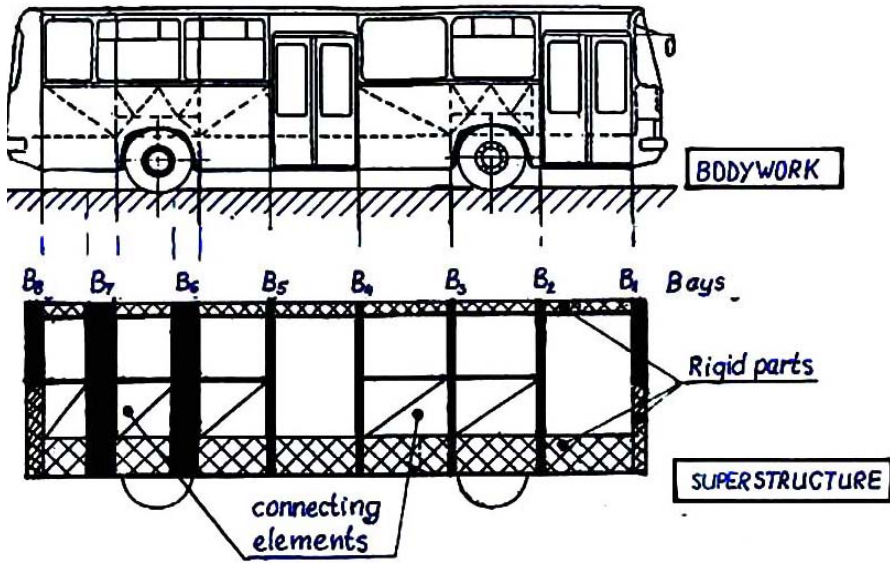


Figure A4.1

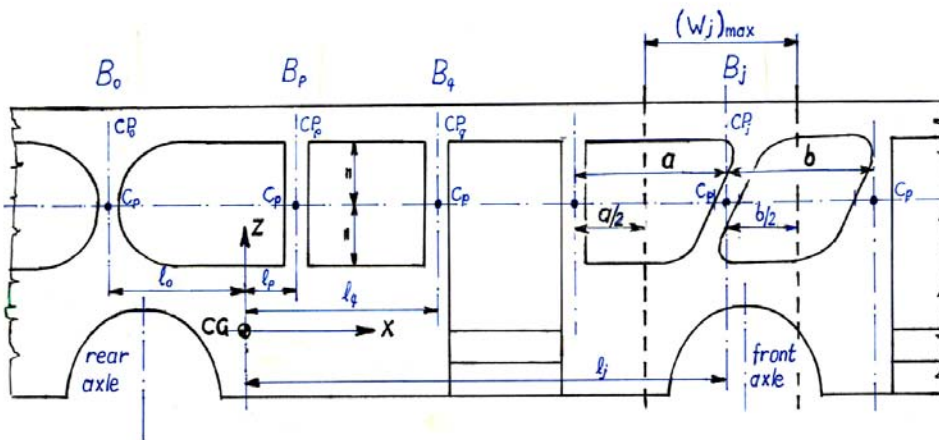


Figure A4.2

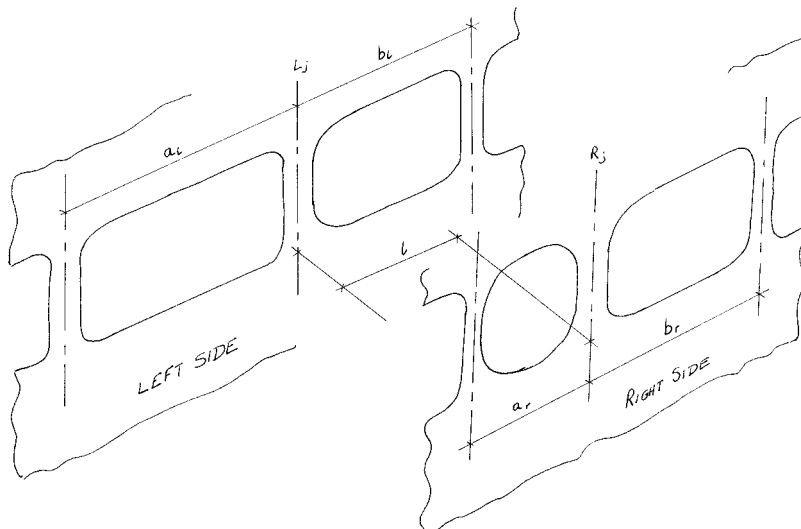
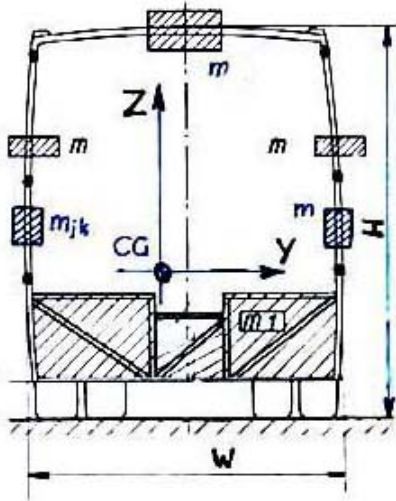


Figure A4.3



[Figure A4.4](#)

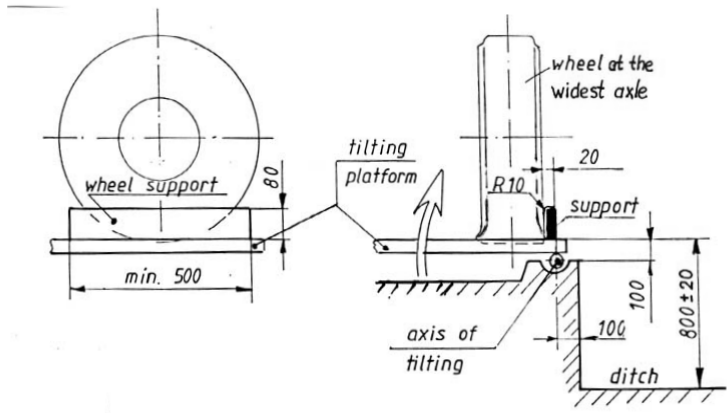


Figure A5.1

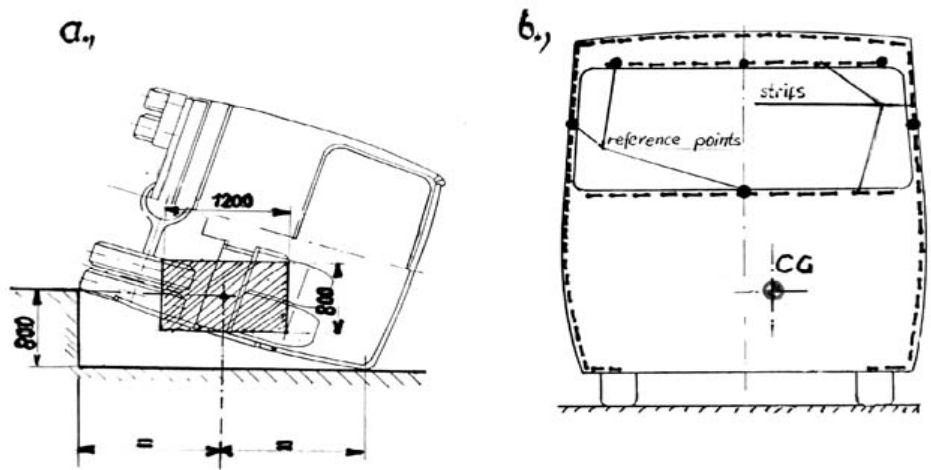


Figure A5.2a  
Figure A5.2b

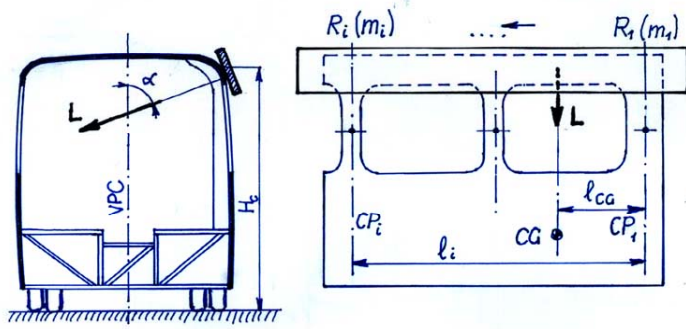


Figure A7.1

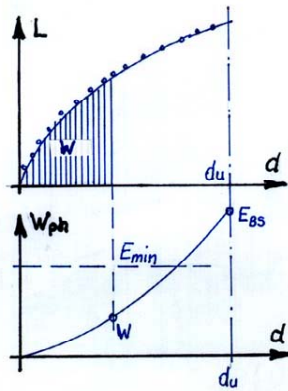


Figure A7.2

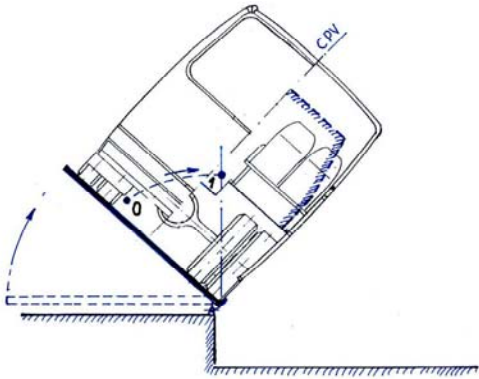


Figure A7.A1.1

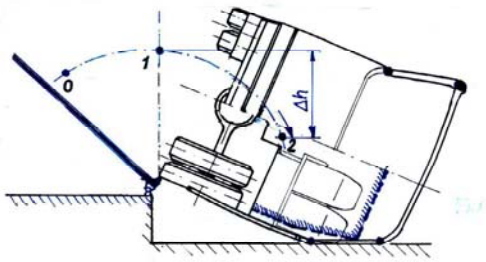


Figure A7.A1.2