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NATIONAL STANDARD OF THE
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ICS 43.020

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GB 17578-2013

Replacing GB/T 17578-1998

**Requirements and test methods of strength for the
superstructure of bus**

客车上部结构强度要求及试验方法

Issued on: September 18, 2013

Implemented on: July 01, 2014

**Issued by: General Administration of Quality Supervision, Inspection and
Quarantine of PRC;
Standardization Administration of PRC.**

Table of Contents

Foreword.....	3
1 Scope	6
2 Normative references.....	6
3 Terms and definitions.....	6
4 Technical requirements and test methods	11
5 Judgment of same type	15
6 Transition requirements for implementation of standard.....	16
Appendix A (Informative) Comparison of clause number between this standard and ECE R66.....	17
Appendix B (Informative) The technical differences between this standard and ECE R66 and their reasons	19
Appendix C (Normative) Basic test method -- Vehicle rollover test.....	24
Appendix D (Normative) Technical documents required for type approval test	31
Appendix E (Normative) Equivalent test method 1 -- Body section rollover test	33
Appendix F (Normative) Equivalent test method 2 -- Quasi-static load test of body section	37
Appendix G (Normative) Equivalent test method 3 -- Quasi-static calculation based on test components	43
Appendix H (Normative) Equivalent test method 4 -- Computer simulated vehicle rollover test	50
Appendix I (Normative) Measurement of the centroid of vehicle.....	54
Appendix J (Normative) Basic explanation about the structure of the superstructure	59
References.....	65

Requirements and test methods of strength for the superstructure of bus

1 Scope

This standard specifies the technical requirements and test methods for the strength of the superstructure of buses.

This standard is applicable to grade B, grade II, grade III buses and special school buses of categories M₂ and M₃. Other buses in categories M₂ and M₃ can be implemented with reference to this standard.

2 Normative references

The following documents are essential to the application of this document. For the dated documents, only the versions with the dates indicated are applicable to this document; for the undated documents, only the latest version (including all the amendments) is applicable to this standard.

GB 11551 The protection of the occupants in the event of a frontal collision for motor vehicle

3 Terms and definitions

The following terms and definitions apply to this document.

3.1

Group of vehicle types

A group of current or future vehicle types, that meet or exceed the worst-case test requirements, according to this standard.

3.2

Worst case

In a group of vehicle types, the vehicle that is least likely to meet the superstructure strength requirements of this standard. The three parameters to determine the worst state are structural strength, reference energy, residual space.

4.2 Residual space

The outline of the vehicle's residual space is determined, by creating a vertical cross-section in the cabin, the edges of which are shown in Figure 2a) and Figure 2b); this vertical cross-section is moved across the entire length of the vehicle as follows [see Figure 2c)]:

- a) The S_R point is located on the front surface of the backrest of each forward or rearward facing seat (or assumed seat position), on the outer side, at 500 mm from the floor below the passenger's feet (regardless of local changes in floor height, as caused by the engine compartment, etc.), AND at 150 mm from the inner surface of side panel. For side-facing seats, these dimensions are measured in the center plane of the seat.
- b) If the left and right sides of the vehicle are asymmetrical, due to the floor arrangement, THEN the height of the S_R point is also different; the height difference of the residual space, on both sides, shall be reflected in the longitudinal vertical center plane of the vehicle [see Figure 2b)].
- c) The rear end of the residual space is the vertical plane, which is 200 mm backward from the S_R point of the rearmost outer seat. If the distance between the inner surface of the rear panel of the vehicle is less than 200 mm from the S_R point, THEN, the inner surface of the rear panel of the vehicle shall be taken as the rearmost end of the residual space.

The frontmost end of the residual space is also a vertical plane, which is located 600 mm in front of its S_R point, after the frontmost seat of the vehicle (whether it is the passenger, crew or driver's seat) is adjusted forward to the maximum extent.

If the seats on both sides of the frontmost and/or rearmost rows of the vehicle are not on the same lateral plane, the length of the residual space on each side may be different.

- d) The residual space is continuous, in the areas of passengers, crew, driver. It is determined, by the scanning zone, which is formed by moving the vertical cross-section as shown in Figure 2a) and Figure 2b), along the straight line formed by each S_R point on both sides of the vehicle, from the front end face of the residual space to the rear end face. The straight line, which passes before the frontmost seat's S_R point and behind the rearmost seat's S_R point, is horizontal.
- e) In order to meet the needs of product design, it is allowed to determine a residual space, which is larger than the space required for a given seating arrangement, according to the worst state vehicle type in the planned group of vehicle types, during the test.

4.5 Tests on hinged buses

Each rigid segment of a hinged bus shall comply with the provisions of 4.1. Each connected rigid segment of the vehicle can be tested individually, or connected for testing, see C.2.3 of Appendix C and I.2.6 g) of Appendix I.

4.6 Orientation of rollover test

When carrying out the rollover test, it shall be directed towards the more dangerous side of the vehicle's residual space, which is determined by the testing agency, on the basis of the manufacturer's recommendations, taking into account at least the following factors:

- a) The lateral eccentricity of the centroid AND its influence on the reference energy when the vehicle starts unstable, as shown in Appendix D.
- b) Asymmetric residual space, as shown in 4.2.
- c) The different and asymmetrical structural features on both sides of the vehicle, as well as the support of bays and inner compartments (such as wardrobes, toilets, small kitchens, etc.), the side with less support shall be selected as the direction of the rollover test.

If the weak structure side cannot be clearly determined, the rollover to the right is preferred.

4.7 Alternative requirements for grade-B buses

For grade-B buses, it shall meet the requirements in 4.1 ~ 4.4 and 4.6, OR it shall be proved by tests or other appropriate methods, that the vehicle structure is sufficient to withstand the uniformly distributed static load, which is equivalent to the maximum design total mass of the vehicle AND is applied on the roof.

5 Judgment of same type

5.1 Take the vehicle type, that has passed the test, as the basic model. When making the judgement of same type for other vehicle types, it shall be based on the following triple principle, in the worst case:

- a) Structural strength: Compared with the basic vehicle type, the superstructure is not changed or the new structure has better strength;
- b) Reference energy: The reference energy is the same as or smaller than that of the basic vehicle type;
- c) Residual space: Every contour line of the residual space is within the residual space of the basic vehicle type.

rollover axle, to prevent slippage, when the vehicle is tilted. The main features of the wheel baffles (see Figure C.1) are as follows:

a) Dimensions of wheel baffles:

Height: Not more than $\frac{2}{3}$ of the height, from the lowest point of the rim of the baffled wheel to the platform surface;

Thickness: Not less than 20 mm;

Edge radius: 10 mm;

Length: Not less than 500 mm;

b) The horizontal distance, between the wheel baffle at the widest axle and the center of the rollover axle, is not more than 100 mm;

c) The wheel baffles at the other axles shall be adjusted, so that the vertical longitudinal center plane (VLCP) of the vehicle is parallel to the rollover axle.

C.1.5 The tilting platform shall prevent the vehicle from moving along its longitudinal axis.

C.1.6 The impact plane shall be a horizontal, uniform, dry, smooth plane, which is composed of concrete or other hard materials.

C.2 Preparation of the test vehicle

C.2.1 Vehicles ready for testing need not be in a fully completed "runnable" state. In general, any changes to the incomplete state are acceptable provided that the essential characteristics and functions of the superstructure are not affected. The test vehicle shall be identical to all its finished vehicles in the following respects:

a) The position of the centroid, the total mass of the vehicle (the unladen kerb mass or the total effective mass of the vehicle with restraint device), as well as the distribution and location of the mass.

b) All components contributing to the strength of the superstructure shall be installed in their original positions (see Appendix J).

c) For the components that do not contribute to the strength of the superstructure or are too expensive (such as transmission systems, instrument panels, driver seats, kitchen equipment, toilet equipment, etc.), they can be replaced by other components of the same mass and installation method. These "other components" cannot contribute to the strength of the superstructure.

d) Fuel, battery acid, other flammable, explosive or corrosive materials can be replaced by other materials, BUT they shall meet the conditions specified in

height depends on whether the vehicle is unladen or loaded with total effective mass.

- c) Each door and openable window of the vehicle shall be closed but not locked.

C.2.3 Rigid segments of hinged buses can be tested individually or in connection.

C.2.3.1 If the hinged bus is tested in connection, the mutual fixation between the rigid segments of the vehicle shall ensure that:

- a) There is no relative movement during rollover;
- b) There is no significant change in mass distribution and centroid position;
- c) The strength and stiffness of the superstructure do not change significantly.

C.2.3.2 If the body section of hinged bus is to be tested individually, the single-axle body section shall be attached to a support; meanwhile hold the body section-support roll over simultaneously with the tilting platform, in the rotation process of the tilting platform from the horizontal position to the critical rollover point. The bracket shall meet the following requirements:

- a) It shall be fixed to the body section, in a way that neither reinforces the superstructure nor adds additional loads;
- b) It shall not cause any deformation, to change the overturning direction of the vehicle;
- c) Its mass shall be equal to the mass of those hinged parts (such as turntable and its floor, handle, rubber sealing curtain, etc.), that are nominally tested in the rigid segment but not placed;
- d) Its centroid shall be the same height, as the common centroid of those components, which are listed in C.2.3.2c);
- e) There shall be a rollover axle, which is parallel to the longitudinal axis of the multi-axle body section of the vehicle, AND passes through the tire contact point of the body section.

C.3 Test procedure, test process

C.3.1 The rollover test is a high-speed and dynamic process with obvious stages. It shall consider using the necessary instruments and equipment, in the rollover test.

C.3.2 The bus rolls over until it is overturned, without shaking or being affected by other external forces. The angular velocity of the tilting platform shall not exceed 5°/s (0.087 rad/s).

Appendix D

(Normative)

Technical documents required for type approval test

D.1 Main identification data and parameters of vehicle types or group of vehicle types

D.1.1 The general floor plan of the vehicle type, including the body and interior layout and main dimensions. The seats, which are equipped with occupant restraint devices, shall be clearly marked; their positions in the vehicle shall be marked with accurate dimensions.

D.1.2 The unladen kerb mass of the vehicle and the corresponding axle load.

D.1.3 The exact position of the centroid of the unladen vehicle and its measurement report; the measurement and calculation methods, which are described in Appendix I, shall be used to determine the position of the centroid of the vehicle.

D.1.4 Total effective vehicle mass and corresponding axle load.

D.1.5 The exact position of the centroid of the vehicle with the total effective mass and its measurement report; the measurement and calculation methods, which are described in Appendix I, shall be used to determine the position of the centroid of the vehicle.

D.2 All data and information required to evaluate the worst case in the group of vehicle types

D.2.1 Reference energy value (E_R), which is the product -- of the vehicle mass (M), the gravitational acceleration (g), the height of the centroid (h_1) when the vehicle is in an unstable equilibrium at the beginning of the rollover test (see Figure 3).

$$E_R = M \times g \times h_1 = M \times g \left[0.8 + \sqrt{h_0^2 + (B \pm t)^2} \right] \quad \dots\dots\dots (D.1)$$

Where:

M - The unladen kerb mass M_k (if no occupant restraint device), OR the total effective mass M_t (if occupant restraint device is installed), in kilograms (kg);

M_t - $M_k + kM_m$, where $k = 0.5$, M_m is the total restrained occupant mass, in kilogram (kg);

h_0 - The height of the centroid of the vehicle, under the selected mass value (M), in meters (m);

Appendix E

(Normative)

Equivalent test method 1 -- Body section rollover test

E.1 Additional data and information

If this test method is selected, in addition to the data, information, drawings required in Appendix D, the following information shall be provided to the testing organization:

- a) Drawings of the body section to be tested;
- b) After the successful completion of the body section rollover test, according to the requirements of J.4, the proof of the validity of the mass distribution;
- c) The measured masses of the body sections to be tested, as well as the proof that the centroid position is the same as the centroid position of the vehicle of unladen kerb mass without occupant restraint device, OR the same as the centroid position of the total effective mass of the vehicle as equipped with occupant restraint device (A measurement report is required).

E.2 Tilting bench

The tilting bench shall meet the requirements of C.1.

E.3 Preparation of body sections

E.3.1 The number, geometric characteristics, rollover axle, position of the centroid of the body section to be tested shall be representative of the entire vehicle, which are specifically determined by the following provisions:

- a) All different bay configurations, which are part of the superstructure, shall be tested in at least one body section;
- b) Each body section shall have at least two bays;
- c) The mass ratio of any one bay to another, in the simulated body section, shall not be greater than 2;
- d) The residual space of the entire vehicle shall be fully reflected in the body section, including any special combination formed in the body structure;
- e) If there are local particularities, such as the height change of the roof, the installation of air conditioners, gas tanks, luggage racks, etc., the entire superstructure shall be fully reflected in the body section;

- f) There shall be at least two body sections: One in front of the centroid in the longitudinal direction of the vehicle, the other behind the centroid in the longitudinal direction of the vehicle;
- g) In order to evaluate the worst case criteria of the vehicle, the body section shall at least contain the bay, which has the weakest structural strength, the bay which has the heaviest mass, the bay which has the most severe residual space.

E.3.2 The bay of the body section shall be completely consistent with the structure, which is represented in the superstructure, in terms of shape, geometric dimension, material, connection.

E.3.3 The connection structure between bays shall represent the manufacturer's description of the superstructure (see J.3). Meanwhile, it shall take into account the following provisions:

- a) For the original body section, which is directly cut from the actual vehicle design drawing, its basic and additional connecting structures [see J.3a)] shall be consistent with those in the vehicle's superstructure;
- b) When a simulated body section is used, the connecting structure shall be equivalent to that in the vehicle's superstructure, in terms of strength, stiffness, characteristics;
- c) For those rigid elements, that may encroach on the residual space when deformed, BUT are not part of the superstructure, they shall be installed in the body section;
- d) According to the properties of a particular bay and its distribution in that bay, the mass of the connecting structure shall be included in the mass distribution.

E.3.4 The body section shall be equipped with artificial supports, to provide the centroid position and rollover axle, which are same as the vehicle on the tilting bench. The support shall meet the following requirements:

- a) It shall be in a manner, that neither reinforces nor adds additional loads to the energy-absorbing components, in the body section;
- b) It shall have sufficient strength and rigidity, to prevent any deformation, that would change the direction of movement of the body section, during tilting and rollover;
- c) The mass of the support shall be included in the mass distribution of the body section and the position of the centroid.

E.3.5 The mass distribution in the body section shall be arranged, according to the following requirements:

Appendix F

(Normative)

Equivalent test method 2 -- Quasi-static load test of body section

F.1 Data and information to be provided

This test method uses body sections as test units. Each unit consists of at least two bays on the vehicle to be evaluated, which are connected together with typical structural elements. If this test method is selected, in addition to the data and drawings required in Appendix D, the following information shall be provided to the testing organization:

- a) Drawings of the body section to be tested;
- b) The energy value to be absorbed by the separate compartment of the superstructure AND the energy value to be absorbed by the body section to be tested, as shown in F.4.2.

F.2 Preparation of body sections

F.2.1 When designing and producing body sections for testing, they shall meet the requirements of E.3.1 ~ E.3.3.

F.2.2 The body section shall be equipped with a device, which shows the outline of the residual space. The device shall be located at the column or other structural component, that may produce the expected deformation and lead to the invasion into the residual space.

F.3 Test procedure

F.3.1 Each body section to be tested shall be securely and safety fixed on the test bench, by a rigid base structure, and:

- a) Local plastic deformation shall not occur, around the fixed point;
- b) The location and method of fixation shall not affect the expected plastic area and the formation and operation of the hinge.

F.3.2 The load shall be applied to the body section, according to the following provisions:

- a) The load shall be evenly distributed on the cantrail through a rigid plate, the size of which shall be able to simulate the ground contacted in the rollover test, AND can adapt to the geometry of the cantrail.

Appendix H

(Normative)

Equivalent test method 4 -- Computer simulated vehicle rollover test

H.1 Additional data and information

Approved by the technical authority, it may use the computer simulations, to demonstrate that the superstructure is in compliance with 4.1.2 and 4.1.3. In addition to the data and drawings specified in Appendix D, the following information shall be provided:

- a) Description of the simulation software and calculation method used, such as which simulation calculation method is used and the accuracy of the analysis software;
- b) The material model used and the input data, as well as the description of the source of the input data;
- c) The determined values of mass, centroid, moment of inertia, which is used in the mathematical model.

H.2 Mathematical model

The model shall be able to describe the actual physical behavior of the rollover test, which is conducted in accordance with Appendix C. Model construction and assumptions shall ensure that conservative results are calculated. The following factors shall be considered, when building the model:

- a) Tests are carried out, on actual vehicle structures, to demonstrate the validity of the mathematical model and validate the assumptions in the model. The parts selected for testing are mainly the joint parts, on both sides of the body frame, including welding, riveting, bolting and other joints. The test method is to intercept the joint part, to apply static or dynamic load to it, to make the component bend or break and other damage, thereby testing the deformation or failure mode of the joint part. The mathematical model uses the same working conditions for comparison, to verify the validity of the component model or assumptions in the model.
- b) The total mass and the position of the centroid, which are used in the mathematical model, shall be consistent with those on the test vehicle.
- c) The mass distribution in the mathematical model shall match that on the test vehicle. The moment of inertia, which is used in the mathematical model, shall be calculated based on this mass distribution.

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