



Roof Strength Test

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. To determine if a vehicle roof meets the requirements of:

- (USA) National Highway Traffic Safety Administration (NHTSA)
- Federal Motor Vehicle Safety Standard (FMVSS) 216a
- Canada Motor Vehicle Safety Standard (CMVSS) 216, Revision 1
- Korea Motor Vehicle Safety Standard (KMVSS) 92
- Gulf Standards (GS) 39/2005, 40/2005, 42/2003
- GM Feature Technical Specifications (FTS) CG4754 Section 3.2.2.2.3
- (China) Roof Strength standard GB 26134
- Insurance Institute for Highway Safety (IIHS) Roof Strength Rating
- Australian New Car Assessment Program (ANCAP) Minimum Roof Strength Rating
- GM Vehicle Technical Specification (VTS)
- GB 26134-2010

1.2 Applicability. This test procedure applies to passenger cars, multipurpose passenger cars, and trucks with a Gross Vehicle Weight Rating (GVWR) $\leq$ 4536 kg (10 000 lb).

The GM requirements pertaining to this procedure are defined in the GM Vehicle Technical Specification (VTS). This procedure is used to determine compliance to the standards listed in 1.1 of this procedure.

1.3 Remarks. All values given in this test procedure were valid at the date of issue. For the actual values refer to the newest edition of the standard mentioned in 2.1. Special considerations are required by leads of validation, Design, Analysis and Test to apply this procedure to a convertible vehicle.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

CMVSS 216	GB 26134-2010	GS 40/2005	KMVSS 92
FMVSS 216a	GS 39/2005	GS 42/2003	

2.2 GM Standards/Specifications.

None

2.3 Additional References.

- ANCAP Minimum Roof Strength Rating
- CG190 (GM Evaluation Report template, available from responsible GM Engineer)
- CG4754 Rollover Occupant Protection Feature Technical Specification
- Federal Register Vol. 74 No. 90
- GM Vehicle Technical Specification (VTS)

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- IIHS Crashworthiness Evaluation Roof Strength Test Protocol

3 Resources

3.1 Facilities. Use facilities that have the test equipment as described in 3.2. Use facilities that have sufficient platen motion control to maintain the platen roll angle at $25^\circ \pm 0.5^\circ$ and the platen pitch angle at $-5^\circ \pm 0.5^\circ$ throughout platen travel.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment.

3.2.1 Electronic instrumentation and equipment to record and process the sensor data as required.

3.2.2 Computer system and software for data processing.

3.2.3 Video cameras to take film shots as required.

3.2.4 Lighting equipment to take film shots as required.

3.2.5 Hydraulic push/pull system including mounting plate and tilt adjusting mechanism. This system should be capable of 100 000 N (22 482 lb).

3.2.6 Rigid unyielding block with its lower surface formed as a flat rectangle 1829 mm by 762 mm (72 in by 30 in) and oriented as described in Sections S7.2 and S7.3 of FMVSS 216a.

3.2.7 Head Position Fixture (HPF) (if required).

3.2.8 Portable Coordinate Measuring Machine (CMM) arm and reference plate for locating head position.

3.2.9 Instrumentation to record the data described in 4.3.

3.2.10 Inclinometer.

3.2.11 "CHOCKFAST Gray" Epoxy (ITW Polymer Technologies).

3.2.12 Information. Requesting Engineer must provide the following;

For FMVSS 216a, CMVSS 216, KMVSS 92, GS 39, GS 40, GS 42:

- The Maximum Curb Mass for the heaviest vehicle to be validated by the test.
- The coordinates for the HPF(s) and at least three other points in the vehicle that are readily reachable by a portable CMM, should be provided when HPF(s) are to be used.

For IIHS/ANCAP:

- The pitch angle of the rocker-sill.
- The IIHS typically equipped vehicle mass.

3.3 Test Vehicle/Test Piece. The test vehicle should include:

- Painted, baked, fully sealed Body in White (BIW).
- Fixed glass; Windshield and Quarter glass installed per certified production standards.
- Instrument Panel (I/P) beam structure complete (all body interface locations required).
- Bodyside exterior trim (bright moldings, pillar trim, etc.)
- Roof exterior trim except for roof racks for longitudinal roof rails (ditch moldings).
- Closures; front, side and rear.
- Complete closure hardware systems (including strikers).
- Closure glass; fixed and movable.
- Closure sealing systems (closure and body mounted weatherstrips).
- Inside rearview mirror.
- Outside rearview mirrors (exclude from content for a convertibles).
- Bolt-on front end module (if applicable).

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- Bolt-on braces (engine compartment brace, strut tower brace, etc.)
- Engine cradle if not isolated.
- Chassis frame and structure (Body on Frame (BOF)).
- B pillar-mounted assist handles.
- Seat belts, retractors, adjustable guide loops at B and C pillars.
- Roof rail airbag canister brackets.

3.3.1 When the Test Vehicle Has a Sunroof.

- Complete sunroof module assembly (including any fixed glass panels) installed in closed position with all seals and/or weatherstrips.

3.3.2 When Using a HPF.

- Headliner assembly with sun visors.
- All interior trim on the A pillar, B pillar and roof rails.
- Assist handles.

3.4 Test Time. Up to five days.

Calendar time: 5 d

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. Test technician familiar with test facilities and equipment.

4 Procedure

4.1 Preparation. Test Personnel should be familiar with all different national test setup requirements listed in 1.1.

4.1.1 Inspect Equipment. Inspect test equipment for calibration and proper operation. Note that each calibration should include a system verification which includes loading the platen near its forward, rearward, and middle points with a reference load cell and comparing the systems output to the reference. This is to ensure that the test rig is working properly as a system.

4.1.2 Inspect Test Vehicle. Visually inspect entire body and doors, with special attention to the roof structure, windshield, test side frame and front door structure. Structural damage in these areas is typically not acceptable.

Note: Structural damage incurred on a non-test side, due to previous testing, may be accepted at the judgment of the responsible engineers. Damage anywhere on the windshield is not acceptable.

Check door systems for proper operation. The movable windows should be operable without binding. The doors should open/close and lock/unlock properly. Set the door torques, noted on the test request, to the minimum specifications. This will ensure a worst case condition.

4.1.3 Prepare Test Vehicle.

4.1.3.1 Remove Test-side Longitudinal Roof Rail. Testing shall be conducted without a longitudinal roof rail unless requested by the Requesting Engineer. Figure A8 shows a vehicle that has had the test-side roof rail removed. Consult the Requesting Engineer for roof rack removal process.

4.1.3.2 Scribe a Body Alignment Reference Line. Body on frame vehicles only.

4.1.3.2.1 Drive the vehicle straight onto on a flat, level surface and park.

4.1.3.2.2 Close trunk lid, engine compartment hood, tailgate, and all doors.

4.1.3.2.3 At the vehicle centerline, lift up the front bumper approximately 30 mm (1.2 in), gently remove hands and let the vehicle settle. Repeat twice for a total of three times.

4.1.3.2.4 At the vehicle centerline, push down on the front bumper approximately 30 mm (1.2 in), gently remove hands and let the vehicle settle. Repeat twice for a total of three times.

4.1.3.2.5 At the vehicle centerline, lift up the rear bumper approximately 30 mm (1.2 in), gently remove hands and let the vehicle settle. Repeat twice for a total of three times.

4.1.3.2.6 At the vehicle centerline, push down on the rear bumper approximately 30 mm (1.2 in), gently remove hands and let the vehicle settle. Repeat twice for a total of three times.

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4.1.3.2.7 Draw a horizontal longitudinal line along each side of the vehicle from the front to the rear that transverses the cab and the cargo box, and the cab and the front fender, see Figures A15, A16, and A17 (A). If only a body on a frame is to be tested, draw the line when the test buck is supported by the frame. This line will assist in realigning the cargo box with the cab once the vehicle or test buck is no longer resting on the suspension components or frame (4.1.9).

4.1.4 Install HPF. Where required, install the HPF(s) in the vehicle. Check that potential points of HPF contact (headliner, grab handles, and other roof or side trim or components) are present in the test vehicle.

4.1.5 Fix I-beam to Test Vehicle Rockers. Two different methods for attaching the test vehicle to the I-beams are acceptable; epoxy and bolting. The epoxy method can be used for vehicles with vertical or non-vertical rocker pinch weld flanges (Figures A1 thru A6). The bolt method can only be used for vehicles with vertical rocker pinch weld flanges (Figures A7 thru A9).

4.1.5.1 Fixing I-beam to Vehicle, Epoxy Method.

4.1.5.1.1 Prepare the surfaces of the rocker panels by removing any undercoating or trim and then cleaning and roughening the surface to ensure good adhesion of the epoxy/adhesive.

4.1.5.1.2 Prepare I-beam (100 mm (4 in) minimum height) structures to support the entire length of each rocker/sill. If the rockers or sills are not straight, the I-beam structures can be broken down into multiple shorter sections to support the entire length. When local interference occurs at the front or rear of the rocker and is judged to be a structural element of the test vehicle by the Requesting Engineer, the length of the I-beam support can be reduced to eliminate the interference (Figure A20).

4.1.5.1.3 If the local interference is judged to be a non-structural element of the test vehicle by the Requesting Engineer (ELPO drain flutes, bolt-on parking brake cable brackets, etc.), the test vehicle may be modified locally to eliminate the interference (flatten ELPO drain flutes, remove bolt-on parking brake cable brackets, etc.) (Figure A21).

4.1.5.1.4 If the rockers/sills have vertical (or nearly vertical) pinch weld flanges on their lower surfaces, configure the I-beam structures similar to Figures A1 thru A3 to form a trough (to be filled with epoxy or other suitable adhesive) for the pinch weld flanges to sit in.

4.1.5.1.5 If the rockers/sills have pinch weld flanges on their lower surfaces that are closer to horizontal configure the I-beam structures similar to Figures A4 thru A6 to form a trough (to be filled with epoxy or other suitable adhesive) for the pinch weld flange and portion of the rocker/sill to sit in.

4.1.5.1.6 Using a hoist capable of supporting the entire vehicle, bring the I-beam structures in contact with the rockers/sills until they are completely supporting the vehicle. Check that the rockers/sills are supported evenly by the I-beam structures.

4.1.5.1.7 Lower the I-beam structures away from the rockers/sills so that they can be filled with epoxy or other suitable adhesive. Fill the ends of the troughs with clay or putty in order to retain the epoxy/adhesive while it hardens. Fill the troughs with the epoxy/adhesive and bring the I-beam structures into contact with the rockers/sills until they are completely supporting the vehicle. Verify that the rockers/sills are supported evenly by the I-beam structures. Check for leaks of epoxy/adhesive and plug them as required. Add epoxy/adhesive as required to obtain as complete a bond as possible.

4.1.5.1.8 Allow the vehicle to sit undisturbed while the epoxy/adhesive cures.

4.1.5.2 Fixing I-beam to Vehicle, Bolt Method.

4.1.5.2.1 Prepare the test vehicle by removing any rocker trim that may interfere with the I-beam.

4.1.5.2.2 Prepare I-beam (100 mm (4 in) minimum height) structures to support the entire length of each rocker/sill. When local interference occurs at the front or rear of the rocker and is judged to be a structural element of the test vehicle by the Requesting Engineer, the length of the I-beam support can be reduced to eliminate the interference, see Figure A20.

4.1.5.2.3 If the local interference is judged to be a non-structural element of the test vehicle by the Requesting Engineer (ELPO drain flutes, bolt-on parking brake cable brackets, etc.) the test vehicle may be modified locally to eliminate the interference (flatten ELPO drain flutes, remove bolt-on parking brake cable brackets, etc.) See Figure A21.

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4.1.5.2.4 If the local interference is judged to be a structural element of the test vehicle by the Requesting Engineer, the I-beam angle iron may be cut locally to eliminate the interference. Supplemental supporting structure can be added if necessary, see Figures A18 and A19.

4.1.5.2.5 Using a hoist capable of supporting the entire vehicle, bring the I-beam structures in contact with the rockers/sills until they are completely supporting the vehicle. Check that the rockers/sills are supported evenly by the I-beam structures. Tighten the bolts at this time. Move the test vehicle onto the support system of the test fixture.

4.1.6 Adjust to Pitch Angle. If requested, position the test vehicle to the rocker sill pitch angle provided in 3.2.12. With the Requesting Engineer, locate a stable and suitable location for rocker sill angle measurement, see Figures A10 and A11. Mark these locations. Install rigid, metal shims between the I-beam and the test fixture such that the measured vehicle pitch angle (measured at the rocker sill) is within 0.1° of the rocker sill pitch angle provided in 3.2.12, see Figure A14. Record the measured pitch angles. Ensure that the proper sign convention is used, see Figure A12.

4.1.7 Secure the Test Vehicle to the Test Fixture. Secure the test vehicle by anchoring the I-beam structures to the bed plate or load frame below the platen. Confirm that the test vehicle is positioned in the test fixture with regards to the criteria listed in 4.1.6. If the pitch angle has been adjusted per 4.1.7, confirm that the rocker sill angles are within tolerance.

4.1.8 Position Test Vehicle in Fixture. Position the vehicle so that:

- The yaw angle of the vehicle relative to longitudinal axis of the platen is $0^\circ \pm 0.5^\circ$. See Figure A13 (A).
- The longitudinal centerline of the platen is within 10 mm of the initial roof contact point. See Figure A13 (B).
- The platen's forward edge is $254 \text{ mm} \pm 10 \text{ mm}$ forward of the forward-most point on the roof exterior surface, including windshield trim, at centerline. See Figure A13 (C).

4.1.9 Unweight the Test Vehicle Chassis. This procedure is intended to support the chassis such that it no longer applies load to the body of the test vehicle in compliance with Federal Register Vol. 74 No. 90 (page 22 385 Section S7.1).

4.1.9.1 Remove the road wheels.

4.1.9.2 Align the test vehicle body. (Body on frame vehicles only.)

Place a floor jack at the front and rear of each frame rail, see Figure A17 (B). Raise each jack until it contacts the frame rail.

If the test vehicle has a rear structure that is isolated from the cab (a pick-up box), jack each rear jack until the lines drawn in 4.1.3.2 are aligned at the cab/rear structure location. If the vehicle does not have an isolated rear structure (SUV), jack each rear jack an additional 5 mm, see Figure A17 (C).

At the front, jack each jack until the lines drawn in 4.1.3.2 are aligned at the cab/front fender location, see Figure A17 (D).

Verify that the doors open and close normally, without the need for excessive force.

4.1.10 Prepare Closures. Completely close and lock all window(s), door(s) front closures and rear closures.

4.2 Conditions. All windows and all doors shall be closed. Refer to Vehicle Technical Specification for instructions on testing of convertible tops or removable roof structures.

4.2.1 Environmental Conditions. The test must be run between -9°C and 38°C (15°F and 100°F), however, test should be run at room temperature (20°C to 22°C or 68°F to 72°F).

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.3 Instructions. A platen speed of 5 mm/s (0.2 in/s) is recommended. The maximum allowable speed of the platen is 12.7 mm/s (0.5 in/s). The test shall be completed within 120 s.

The following data shall be measured:

Travel of load cylinders; displacement as a function of time (t): Displacement(t)

Load applied by the test device as a function of time: F(t)

Travel of the test device as a function of time: Displacement(t)

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HPF contact load as a function of time (when used): $F_{HPF}(t)$

Deformed shape and glass performance; video

4.3.1 If only one side is to be tested: the platen shall be traveled a minimum of 127 mm (5.0 in).

4.3.2 If both sides of the vehicle are to be tested: for the first side the platen travel is to be stopped within 3 mm of reaching the required load or 127 mm, whichever comes first. The vehicle will then be positioned to test the second side. For the second side the platen travel shall be traveled a minimum of 127 mm (5.0 in).

5 Data

5.1 Calculations. The measured data listed in 4.3 shall be evaluated and saved. Calculations shall be made from load cylinder travel data to confirm that the platen motion met the criteria described in 3.1.

Diagrams for:

Platen Travel vs. Time

Cylinder Travel (each) vs. Time

Platen Force vs. Platen Travel

HPF Force vs. Platen Travel (when used)

Further evaluation shall be performed visually and by film shots, if available.

5.2 Interpretation of Results. The data presentation shall be in accordance with the appropriate standards. With reference to this test method the results shall be presented in a test report.

5.3 Test Documentation.

5.3.1 Provide the load(s) versus deflection curve(s). Provide video tape and test photographs. The test performance is documented with respect to the current applicable legal requirements stated in 1.1. The final test report shall be presented in a format consistent with the CG190 GM Evaluation Report template.

5.3.2 Provide photos of any local interference between the test vehicle and the I-beams. Describe the method used to resolve these interferences and provide photos.

5.3.3 Provide measured rocker sill pitch angles using the sign convention; "nose-down" is negative, "nose-up" is positive (Figure A12).

6 Safety

This Engineering Standard may involve safety requirements for hazardous materials, the method of operations and equipment. This standard does not propose to address all the safety issues associated with its use. It is the responsibility of the user of this standard to ensure compliance with all appropriate safety and health practices. This would include any specific training that may be required. The safety and health standards include site specific rules and procedures, company rules and procedures, and Government Standards. Contact shall be made with the appropriate site Safety and Health personnel for further direction and guidance in these matters.

7 Notes

7.1 Glossary.

H Beams and W Beams: I-beams with wider flanges.

7.2 Acronyms, Abbreviations, and Symbols.

ANCAP	Australian New Car Assessment Program
ATD	Anthropomorphic Test Device
BIW	Body in White
BOF	Body on Frame
CMM	Coordinate Measuring Machine
CMVSS	Canada Motor Vehicle Safety Standard
FMVSS	Federal Motor Vehicle Safety Standard
FTS	Feature Technical Specification

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