BS ISO 4000-1:2021

BSI Standards Publication

Passenger car tyres and rims

Part 1: Tyres (metric series)

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National foreword

This British Standard is the UK implementation of ISO 4000-1:2021. It supersedes BS ISO 4000-1:2015, which is withdrawn.

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Twelveth edition
2021-08

Passenger car tyres and rims —

Part 1: Tyres (metric series)

Pneumatiques et jantes pour voitures particulières —
Partie 1: Pneumatiques (série millimétrique)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC ISO/TC 31, *Tyres, rims and valves*, Subcommittee SC 3, *Passenger car tyres and rims*.

This twelfth edition of ISO 4000-1 cancels and replaces the eleventh edition (ISO 4000-1:2015), which has been technically revised.

The main changes compared to the previous edition are as follows:

— some definitions have been aligned with ISO 4223-1;

— the text on inflation pressures in Clause 8 has been reworded;

— new internationally harmonized load indices has been added in Annex B.

A list of all parts in the ISO 4000 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Passenger car tyres and rims —

Part 1: Tyres (metric series)

1 Scope

This document specifies the designation, dimensions, and load ratings of metric-series tyres primarily intended for passenger cars.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3877-1, *Tyres, valves and tubes — List of equivalent terms — Part 1: Tyres*

ISO 4223-1, *Definitions of some terms used in the tyre industry — Part 1: Pneumatic tyres*

ISO 16992, *Passenger car tyres — Spare unit substitutive equipment (SUSE)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3877-1, ISO 4223-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
rim protector
feature incorporated into the lower sidewall area of the tyre which is intended to protect the rim flange from damage

EXAMPLE Protruding circumferential rubber rib.

4 Designation

4.1 Size and construction

4.1.1 Characteristics

The tyre characteristics shall be designated:

Nominal section width / Nominal aspect ratio Tyre construction code Nominal rim diameter code

EXAMPLE 235/45 R 17.

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4.1.2 Nominal section width

The nominal section width of the tyre shall be indicated in millimetres, and this part of the designation shall end in either the numeral of zero or five, so that in any single series of tyres with the same nominal aspect ratio, the values shall all end in 0 or all end in 5.

For sizes mounted on 5° tapered (code-designated) rims, the nominal section width shall end in 5.

4.1.3 Nominal aspect ratio

The nominal aspect ratio (H/S, where H is the design tyre section height and S is the design tyre section width) shall be expressed as a percentage and shall be a multiple of 5.

4.1.4 Tyre construction code

The tyre construction code shall be:

— B for bias-belted construction;

— D for diagonal construction;

— R for radial construction;

— RF for radial run-flat construction (only applicable to run-flat or self-supporting tyres as defined in ISO 16992; radial extended mobility tyres as defined in ISO 16992 shall have the construction code R).

In the case of tyres having a maximum speed capability exceeding 240 km/h, the tyre construction code R can be replaced by ZR and the tyre construction code RF can be replaced by ZRF.

In the case of tyres having a maximum speed capability exceeding 300 km/h, the tyre construction code R shall be replaced by ZR and the tyre construction code RF shall be replaced by ZRF.

Use of any other code-letter (e.g. in the case of a new construction type) should first be submitted to ISO for acceptance.

4.1.5 Nominal rim diameter code

For tyres mounted on 5° tapered (code-designated) rims, the code shall be as given in Table 1.

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Table 1 — Nominal rim diameter code

Nominal rim diameter code	Nominal rim diameter D_r mm
10	254
12	305
13	330
14	356
15	381
16	406
17	432
18	457
19	483
20	508
21	533
22	559
23	584
24	610
25	635
26	660
28	711
30	762

In the case of tyres requiring new-concept rims, for safety reasons, especially concerning mounting, the code-number shall be equal to the nominal rim diameter (D_r) expressed as a whole number in millimetres.

4.2 Service description

4.2.1 General

The service description shall be:

Load index Speed symbol

In the case of tyres having a maximum speed capability exceeding 300 km/h, the speed symbol Y and the load index shall be both placed within parentheses, to identify performance up to 300 km/h.

EXAMPLE 235/45 ZR 17 (97Y).

For maximum speed capability and load carrying capacity of the tyre over 300 km/h, consult the manufacturer.

4.2.2 Load index

The maximum tyre load-carrying capacity corresponding to the service conditions specified by the tyre manufacturer shall be indicated by a load index taken from Table 2, per tyre for a single mounting.

4.2.3 Speed symbol

Alpha or alpha-numeric code which indicates the speed category (4.2.4) of the tyre.

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4.2.4 Speed category

A speed category is assigned to a tyre according to the maximum speed which the tyre can sustain. It is expressed by the speed symbol, in accordance with Table 3.

4.3 Other service characteristics

4.3.1 The word “TUBELESS” shall appear on the sidewalls of tyres without tubes.

4.3.2 The letters “XL”, close to the tyre size designation, or the words “REINFORCED” or “EXTRA LOAD” shall appear on the sidewalls of tyres designed for loads and inflation pressures higher than the standard version.

4.3.3 The letters “LL”, close to the tyre size designation, or the words “LIGHT LOAD” shall appear on the sidewalls of tyres designed for loads lower than the standard version.

4.3.4 The letter “T”, immediately preceding the tyre size designation, shall be used to identify T-type temporary-use spare tyres.

4.3.5 Specific indications, if required, can be added to indicate:

— the type of vehicle for which the tyre is primarily designed, using the symbol “P” for passenger cars (see 4.3.6);

— temporary use of certain spare tyres, using indications such as “TEMPORARY USE ONLY”;

— bias-belted construction, with the words “BIAS-BELTED”;

— radial construction, with the word “RADIAL”;

— direction of mounting;

— direction of rotation;

— type of tread pattern;

— other characteristics.

4.3.6 The optional marking “P” can be used where there could be ambiguity regarding the tyre type. It should be positioned such that confusion cannot result from its proximity to any other service condition marking.

EXAMPLE P295/45 R 17.

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Table 2 — Equivalence between load index (LI) and tyre load-carrying capacity (TLCC)

LI	TLCC kg	LI	TLCC kg	LI	TLCC kg	LI	TLCC kg
50	190	70	335	90	600	110	1 060
51	195	71	345	91	615	111	1 090
52	200	72	355	92	630	112	1 120
53	206	73	365	93	650	113	1 150
54	212	74	375	94	670	114	1 180
55	218	75	387	95	690	115	1 215
56	224	76	400	96	710	116	1 250
57	230	77	412	97	730	117[a]	1 285
58	236	78	425	98	750	118[a]	1 320
59	243	79	437	99	775	119[a]	1 360
60	250	80	450	100	800	120[a]	1 400
61	257	81	462	101	825	—	—
62	265	82	475	102	850	—	—
63	272	83	487	103	875	—	—
64	280	84	500	104	900	—	—
65	290	85	515	105	925	—	—
66	300	86	530	106	950	—	—
67	307	87	545	107	975	—	—
68	315	88	560	108	1 000	—	—
69	325	89	580	109	1 030	—	—

[a] ISO tyre loads according to this document have a 116 load index maximum: some existing tyres can have a higher load index number.

The maximum tyre load carrying capacity corresponding to the load index shall apply for speeds up to and including 210 km/h.

For tyres with the speed symbol V (between 210 km/h and 240 km/h), the maximum load carrying capacity per tyre shall be reduced to 100 % at 210 km/h, 97 % at 220 km/h, 94 % at 230 km/h and 91 % at 240 km/h; linear interpolation is permitted.

In the case of speed symbols W and Y, the maximum load carrying capacity per tyre corresponding to the load index shall apply for speeds up to and including 240 km/h for W and 270 km/h for Y.

For tyres with the speed symbol W (between 240 km/h and 270 km/h), the maximum load carrying capacity per tyre shall be reduced to 100 % at 240 km/h, 95 % at 250 km/h, 90 % at 260 km/h and 85 % at 270 km/h; linear interpolation is permitted.

For tyres with the speed symbol Y (between 270 km/h and 300 km/h), the maximum load carrying capacity per tyre shall be reduced to 100 % at 270 km/h, 95 % at 280 km/h, 90 % at 290 km/h and 85 % at 300 km/h; linear interpolation is permitted.

See 4.2.3, 4.2.4 and Table 3 for speed categories and their symbols.

For speeds of over 300 km/h or ZR-marked tyres or both, consult the tyre manufacturer for the maximum tyre load carrying capacity permitted in relation to the maximum speed allowed for the tyre.

For vehicles with a design maximum speed capability of up to 60 km/h, the maximum load carrying capacity corresponding to the load index can be exceeded, as shown below. However, an increase in the reference inflation pressure is necessary and should be determined in consultation with the tyre manufacturer. In the absence of such agreement, the following pressure increases are recommended:

— for 60 km/h, a 10 % load increase with a 10 kPa inflation pressure increase;

— for 50 km/h, a 15 % load increase with a 20 kPa inflation pressure increase;

— for 40 km/h, a 25 % load increase with a 30 kPa inflation pressure increase;

— for 30 km/h, a 35 % load increase with a 40 kPa inflation pressure increase;

— for 25 km/h, a 42 % load increase with a 50 kPa inflation pressure increase.

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Table 3 — Speed symbols and corresponding speed

Speed symbol	Speed km/h
J	100
K	110
L	120
M	130
N	140
P	150
Q	160
R	170
S	180
T	190
U	200
H	210
V	240
W	270
Y[a]	300

NOTE This list is not exhaustive, and other categories and symbols can be added later.

[a] For tyres designed for speeds exceeding 300 km/h, see 4.2.1.

5 Marking

The marking shall include designations of the following:

a) size and construction;

b) service description (see 4.2.1);

c) any other service characteristics.

The location of the marking of the load index and speed category shall be distinct, but near the marking of the size and construction.

No location is specified for the markings related to other service characteristics (see 4.3).

EXAMPLE A tubeless tyre having a nominal section width of 165 mm, a nominal aspect ratio of 80, a radial construction and a nominal rim diameter code of 15, whose service description consists of a load index of 87 corresponding to a tyre load-carrying capacity of 545 kg, and which falls into the speed symbol H (210 km/h), is marked:

165/80 R 15 87 H TUBELESS

NOTE See Annex D for other existing size markings.

6 Tyre dimensions

6.1 Rounding values

Except in the cases given in 6.2.1 and 6.2.2, round the formula-derived values for tyre dimensions to the nearest millimetre (see ISO 80000-1:2009, B.3, rule B).

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6.2 Calculation of design tyre dimensions

6.2.1 Theoretical rim width, R_{th}

See Formula (1):

$$R_{th} = K_1 \times S_N \quad (1)$$

where

R_{th} is the theoretical rim width, expressed in millimetres;

K_1 is the theoretical rim/section width ratio coefficient;

S_N is the nominal section width.

For tyres mounted on 5° rims (code-designated) with nominal rim diameter expressed by a two-figure code:

— K_1 = 0,7 where the tyres have a nominal aspect ratio of 50 to 95;

— K_1 = 0,85 where this ratio is 20 to 45.

NOTE K_1 values for other tyre and rim types will be defined in a future revision.

6.2.2 Measuring rim width code, R_{mc}

See Formula (2), where R_{mc} is rounded to the nearest 0.5 rim width code:

$$R_{mc} = \frac{K_2 \times S_N}{25,4} \quad (2)$$

where K_2 is the measuring rim/section width ratio coefficient.

For tyres mounted on 5° drop-centre rims with a nominal diameter expressed by a two-figure code:

— K_2 = 0,7 for nominal aspect ratios 95 to 75;

— K_2 = 0,75 for nominal aspect ratios 70 to 60;

— K_2 = 0,8 for nominal aspect ratios 55 and 50;

— K_2 = 0,85 for nominal aspect ratio 45;

— K_2 = 0,9 for nominal aspect ratios 40 to 30;

— K_2 = 0,92 for nominal aspect ratios 20 and 25.

NOTE Other values of K_2 for other tyre and rim types will be defined in a future revision.

6.2.3 Design tyre section width, S

The design tyre section width, S, is the nominal section width, S_N, transferred from the theoretical rim, R_{th}, to the measuring rim width code, R_{mc}, as shown in Formula (3):

$$S = S_N + 0,4 \times (25,4 \times R_{mc} - R_{th}) \quad (3)$$

EXAMPLE 265/40 R17.

K_1 = 0,85 (see 6.2.1) and K_2 = 0,9 (see 6.2.2).

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$R_{th} = K_1 \times S_N = 265 \times 0{,}85 = 225{,}25$ mm.

$R_{mc} = K_2 \times S_N/25{,}4 = 0{,}9 \times 265/25{,}4 = 9{,}39$, rounded to 9,5.

$25{,}4 \times R_{mc} = 25{,}4 \times 9{,}5 = 241{,}3$ mm.

$S = S_N + 0{,}4\ (25{,}4\ R_{mc} - R_{th}) = 265 + 0{,}4\ (241{,}3 - 225{,}25) = 271{,}42$, rounded to 271 mm.

6.2.4 Design tyre section height, H

The design tyre section height, H, is calculated using Formula (4):

$$H = S_N \times \frac{H/S}{100} \tag{4}$$

where H/S is the nominal aspect ratio.

6.2.5 Design tyre overall diameter, D_0

The design tyre overall diameter, D_0, is calculated using Formula (5):

$$D_0 = D_r + 2 \times H \tag{5}$$

Use the corresponding value of D_r given in Table 1.

6.2.6 Guidelines

See Annex A for general guidelines on the tyre design dimensions for the metric series of passenger car tyres mounted on 5° rims (code-designated).

6.3 Calculation of maximum overall (grown) tyre dimensions in service tyre mounted on their measuring rims

6.3.1 General

The calculation of maximum overall (grown) tyre dimensions in service for tyres mounted on their measuring rims is for use by vehicle manufacturers in designing for tyre clearance.

Calculate these dimensions with the coefficient appropriate to the design tyre section width and design tyre section height (see Table 4).

Table 4 — Coefficients for calculation of tyre dimensions

Construction	Construction code	Coefficient			
		a	*b*	*c*	*d*
Diagonal	D	1,1	1,08	—	—
Bias-belted	B			—	—
Radial	R	1,04	1,04	0,96	0,97
Radial run-flat	RF				

6.3.2 Maximum overall (grown) width in service, W_{max}

The maximum overall (grown) width in service, W_{max}, includes elevation due to labelling, decorations, protective ribs or bands and rim protectors and is equal to the greater of the following values:

— the product of the design tyre section width, S, and the appropriate coefficient, a (see Table 4), see Formula (6):

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$$W_{max} = S \times a \quad (6)$$

— the addition of 8 mm to the design tyre section width, S, see Formula (7):

$$W_{max} = S + 8 \quad (7)$$

If the overall (grown) width is measured at the rim protectors, an additional 8 mm is allowed. In this case, W_{max} equals to the greater of the following values ($S \times a + 8$) or ($S + 16$).

6.3.3 Maximum overall (grown) diameter in service, $D_{0,max}$

See Formula (8):

$$D_{0,max} = D_r + 2 \times H \times b \quad (8)$$

See Table 4 for the value of coefficient b. $H \times b$ shall be first rounded to the nearest integer before calculating the maximum overall diameter in service.

6.4 Calculation of minimum tyre dimensions for radial tyres mounted on their measuring rims

6.4.1 Minimum tyre section width, S_{min}

See Formula (9):

$$S_{min} = S \times c \quad (9)$$

See Table 4 for the value of coefficient c.

6.4.2 Minimum tyre overall diameter, $D_{0,min}$

See Formula (10):

$$D_{0,min} = D_r + 2 \times H \times d \quad (10)$$

See Table 4 for the value of coefficient d. $H \times d$ shall be first rounded to the nearest integer before calculating the minimum overall diameter.

6.5 Range of approved rims

The range of approved rim width codes for the nominal aspect ratio of 35 and above is calculated as the product of the nominal section width, SN, and the coefficients shown in Table 5, divided by 25,4. Round the values obtained to the nearest 0,5 rim width code. For tyre sizes with a nominal aspect ratio of 30 and below, the range of approved rim width codes is the measuring rim width code ±0,5.

The maximum overall (grown) width in service, W_{max}, and the minimum tyre section width, S_{min}, will change by 40 % of the change in rim width code multiplied by 25,4, rounded to the nearest millimetre. However, this is not applicable to tyres which overall width is measured at the rim protectors, in which case, the change will be greater than 40 %.

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Table 5 — Approved rim width codes for passenger car tyres as a function of nominal aspect ratio

Nominal aspect ratio H/S	Coefficients for calculation of approved rim width	
	min.	max.
$70 \leq H / S \leq 95$	0,65	0,85
$50 \leq H / S \leq 65$	0,7	0,9
$H / S = 45$	0,8	0,95
$35 \leq H / S \leq 40$	0,85	1
$H / S \leq 30$	measuring rim width code −0,5	measuring rim width code +0,5

7 Tyre dimension measurement procedure

The tyre dimension measurement procedure shall be as described below:

a) prior to measurement, mount the tyre on an approved rim, inflated to the recommended pressure given in Table 6, and allow it to stand for a minimum of 24 h at normal room temperature;

b) readjust the inflation pressure to the original value;

c) calliper the section width and the overall width of the tyre at six points approximately equally spaced around the tyre circumference. Record the average of these measurements as section width and overall width;

d) determine the tyre overall diameter by measuring its maximum circumference and dividing this by π (where π = 3,141 6).

Table 6 — Recommended pressures for measurement of tyre dimensions

Tyre	Pressure kPa
Standard load and P-type light load (LL) version	180
Extra load/reinforced version	220
T-type temporary-use spare type	420

8 Inflation pressures

Correct inflation pressures are of the highest importance for driving safety.

Over-inflation causes the tyre to be more susceptible to impact damage.

Under-inflation causes over-heating and can greatly shorten the life of a tyre. It affects vehicle stability and can cause irregular wear, internal damage and, ultimately, even tyre disablement.

The effects of under-inflation are not necessarily immediate. It may be a considerable time before they occur. The pressures (cold) recommended by the tyre manufacturers in their technical documents should be regarded as a minima.

The recommended cold tyre inflation pressure for each tyre position specified by the vehicle and/or the tyre manufacturer for the intended service condition of the given vehicle shall be equal or higher than the minimum cold tyre inflation pressure, given by the tyre manufacturer or the tyre standardization body for the given service conditions.

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The recommended cold tyre inflation pressure should take into account not only the tyre load-carrying capacity (see Annex C) and the high speed capability, but also the operating conditions such as maximum speed capability of the vehicle, camber angle, as well as the construction and characteristics of the vehicle.

Unless otherwise specified by the tyre manufacturer, it is recommended that the cold inflation pressure of radial tyres be limited in normal application to 350 kPa for all standard load, extra load or light load version sizes on code designated rims, irrespective of the speed symbol (see Table 3).

For normal road applications, the specified inflation pressure cannot be less than:

— 140 kPa for vehicle operating speeds ≤160 km/h, and

— 180 kPa for vehicle operating speeds >160 km/h.

For special applications, consult the tyre manufacturer.

NOTE Cold inflation pressure is the pressure of the tyre at ambient temperature, and does not include pressure build-up due to tyre usage.

9 Load carrying-capacities

Use the load indices for passenger car tyres given in Annex B.

For sizes not included in Annex B, consult the National Standardization Organization.

The tyre load-carrying capacity at various inflation pressures given in Annex C shall be used.

10 Choice of tyre sizes

In selecting tyres for a vehicle, the vehicle maximum load on the tyre shall not be greater than the applicable maximum load-carrying capacity of the tyre. Vehicle maximum load on the tyre is the load on an individual tyre that is determined by distributing to each axle its share of the maximum loaded vehicle mass and dividing by the number of tyres on the axle.

The vehicle normal load on the tyre shall not be greater than 88 % of the maximum load-carrying capacity of the tyre. Vehicle normal load on the tyre is the load on an individual tyre that is determined by distributing (in accordance with Table 7) to each axle its share of the curb mass, accessory mass and normal occupant mass and dividing by the number of tyres on the axle. These, and other relevant masses, are defined below.

In specific local regulations, the vehicle normal load on the tyre shall not be greater than 94 % of the load rating at the vehicle manufacturer's recommended cold inflation pressure for the tyre.

The vehicle manufacturer can specify an inflation pressure less than that corresponding to the maximum tyre load. In this case, the load on the tyre (at the corresponding vehicle loading condition) shall not exceed the tyre load carrying capacity at the specified inflation pressure.

Maximum loaded vehicle mass is the sum of the following:

a) curb mass;

b) accessory mass;

c) vehicle capacity mass;

d) production option mass.

Curb mass is the mass of a motor vehicle with standard equipment, including the maximum capacity of fuel, oil and coolant, and, if so equipped, of air conditioning and the additional mass of an optional engine.

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Accessory mass is the combined mass (in excess of those standard items that can be replaced) of automatic transmission, power steering, power brakes, power windows, power seats, radio and heater, to the extent that these items are available as factory-installed equipment (whether installed or not).

Normal occupant mass is equivalent to 68 kg multiplied by the number of occupants, as specified in Table 7. When local regulation includes a luggage mass, a mass of 7 kg per occupant, located in the luggage compartment, shall be used. Occupant distribution is the distribution of occupants in a vehicle as specified in Table 7.

Table 7 — Occupant loading and distribution for vehicle normal load for various designated seating capacities

Designated seating capacity, number of occupants	Vehicle normal load, number of occupants	Occupant distribution in a normally loaded vehicle
2 to 4	2	2 in front
5 and above	3	2 in front, 1 in second seat

Vehicle capacity mass is the rated cargo and luggage load plus 68 kg multiplied by the vehicle designated seating capacity.

Production option mass is the combined mass of those installed regular production options, weighing over 2,3 kg in excess of those standard items they replace, not previously considered in curb mass or accessory mass, and including heavy duty brakes, ride levellers, roof rack, heavy duty battery, and special trim.

11 Camber angle

Vehicle camber angles, especially under severe driving conditions, have an influence on tyre performance. For low aspect ratio tyres, increasing the camber angle above 2° makes constraints on the tyre performance, e.g. mileage, uneven wear, and other criteria. Consult the tyre manufacturer for more information.

Generally, it is recommended that the camber angles of vehicles should not be greater than 4° including any tolerance.

On vehicles with speeds in excess of 270 km/h, it is recommended that the camber angle should not be greater than 3° including any tolerance.

Vehicle camber angles on a passenger car should not exceed the values for different aspect ratios in Table 8.

Table 8 — Maximum camber angle for different aspect ratios

Aspect ratio *H/S*	Maximum camber angle	
	up to 270 km/h	above 270 km/h
80 to 25	4°	3°
20	3°	3°

The only way to compensate for camber angle is by increasing the inflation pressure by multiplying it with the camber factor as shown in Table 9. This shall be applied to tyres for all speeds.

The maximum inflation pressure of 350 kPa shall be observed. For a given size, if the calculated pressure exceeds the maximum, then this size is not suitable for this application.

For static camber angle, γ, between 2° and 4°, the camber factor, K_S, is calculated as follows:

— for aspect ratio 50 and above, see Formula (11):

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