TRANSPORT
CERTIFICATION SERVICES

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CHASSIS MODIFICATION GUIDELINES

The following document has been prepared by TCS to provide basic guidance to vehicle modifiers when modifying and/or reinforcing a heavy vehicle chassis, partiularly when performing wheelbase modifications, extending chassis rear overhangs or installing lazy axles.

These guidelines are supplied without prejudice and free of charge to assist modifiers. TCS will not be held liable for any problems that arise from sole reliance on, or misinterpretation of, these guidelines or from the introduction of new rules after the issue date of these guidelines. The following documents/items should be read in conjunction with these guidelines:

1. Vehicle Manufacturer (OEM) Modification Guidelines
   (takes precedence over VSB-6 and TCS guidelines)
2. VSB-6 Sections H (Chassis Frame), C (Tail Shafts) and G (Brakes).
   (VSB6 is the National Code of Practice for heavy vehicle modifications and takes precedence over TCS guidelines. At the time this document was completed, VSB6 could be accessed via the following link: https://www.nhvr.gov.au/safety-accreditation-compliance/vehicle-standards-and-modifications/vehicle-standards-bulletin-6)
3. Disclaimer on the last page of this document

All modifications must be carried out by suitably qualified tradespeople in accordance with the relevant Australian Design Rules, Australian Standards and National Codes of Practice. Any uncertainties should be discussed with TCS prior to commencing the modification. **These guidelines are not intended to be used as the sole instructional tool for vehicle modifiers; modifiers must be suitably qualified tradespeople who are experienced in modifying heavy vehicles. These guidelines do not provide all the necessary information to carry out a chassis modification and must only be used as a supplementary quick reference guide.**

The chassis is the backbone of a heavy vehicle and its main function is to carry the maximum load safely in all designed operating conditions. It absorbs engine and driveline torque, endures shock loading and accommodates twisting on uneven road surfaces. To ensure a modified heavy vehicle chassis remains safe under all operating conditions, any modification must be subject to careful design and analysis.

These guidelines provide an insight into how the chassis functions, the regions that generally experience the highest stresses and measures that should be taken to protect these highly stressed regions.

Chassis Function

Heavy vehicle chassis are usually constructed with parallel longitudinal channels connected by cross-members. The longitudinal channels are optimised to withstand vertical loading on the chassis and the cross-members provide torsional resistance to the longitudinal channels in localised areas where they experience eccentric loading and also to allow torsional flexibility along the length of the chassis. This is explained further overleaf.

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Generally, the higher the stiffness of the cross-section of a rail is, the less stress is experienced by the rail. The stiffness of a section of rail depends on the height, width and thickness of the rail, but these factors don't necessarily contribute to the stiffness evenly. The figures below give an indication of the stiffness of different cross sections when they are exposed to vertical loading.

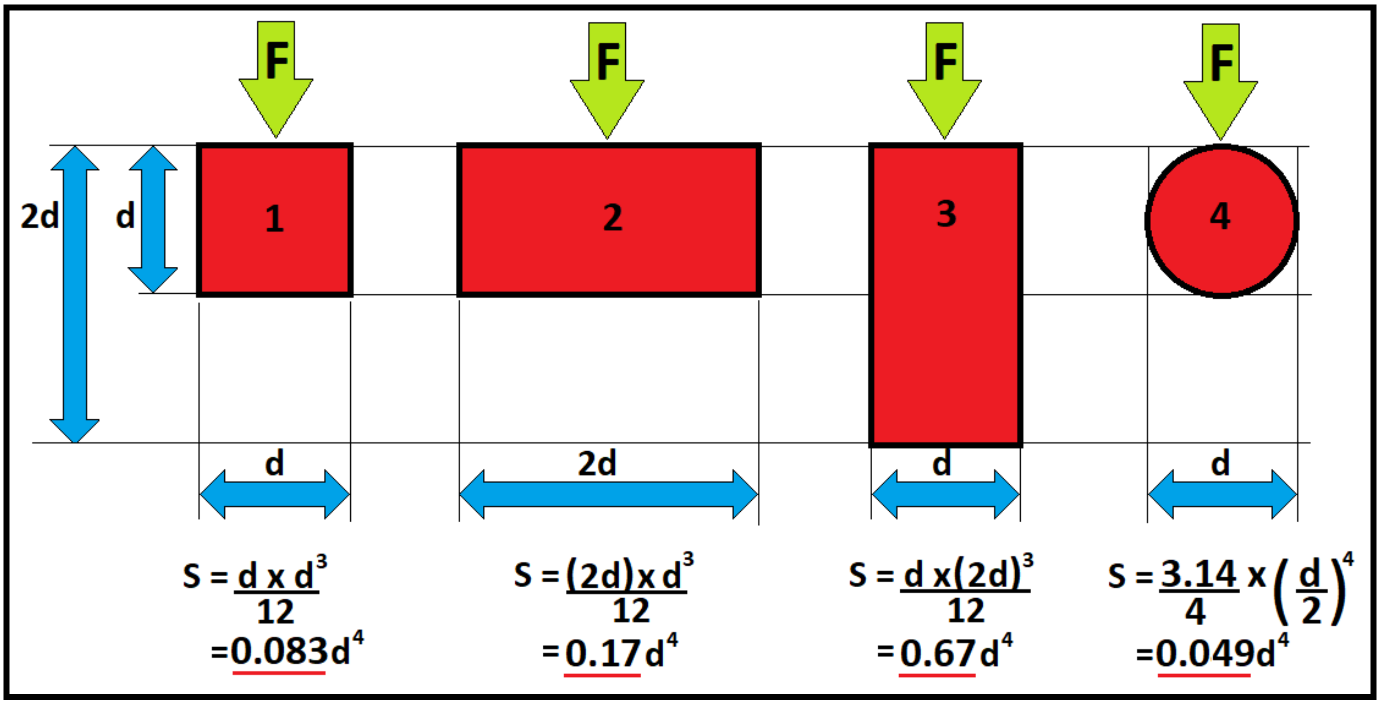

FIGURE 1: STIFFNESS COMPARISON OF DIFFERENT CROSS SECTIONS

From Figure 1, the following observations can be made:

- Shape 1 is about 1.7 times stiffer than Shape 4 (0.083 / 0.049 = 1.7) but less stiff than Shape 2 and Shape 3
- Shape 2 is the same height as Shape 1 and twice as wide. It is twice as stiff in the direction of loading (0.17 / 0.083 = 2)
- Shape 3 is twice as high as Shape 1 and the same width. It is 8 times as stif in the direction of loading (0.67 / 0.083 = 8)
- Shape 3 has the same cross-sectional area as Shape 2, but is 4 times as stiff in the direction of loading (0.67 / 0.17 = 4)

This why chassis rails are higher than they are wide.

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The figure to the right shows two channels which have the the same height, width and cross-sectional area, but one has flanges which are twice as thick and a web which is half as thick as the other, making it about 23% stiffer. ***This shows that reinforcement around the flanges of a chassis rail is more effective at increasing stiffness than reinforcement around the web. This also explains why the flanges in most heavy trailer chassis are usually much thicker than the webs.***

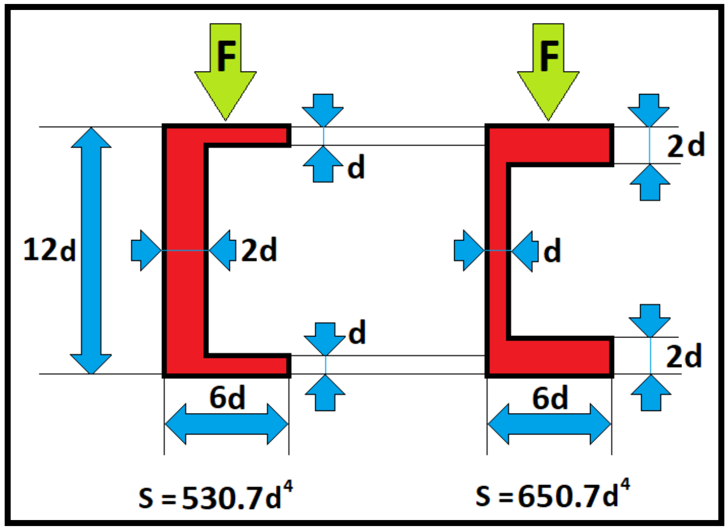

FIGURE 2: THICKNESS COMPARISON

The figure below shows that when a rail is subjected to bending, the region on one side of the neutral axis experiences compressive stress and the region on the other side of the neutral axis experiences tensile stress. The further away from the neutral axis (in the direction of loading) the higher the stress is, which means the flanges of a chassis rail experince the highest stress. ***This is why it is generally advised that all components are mounted to the web of a chassis rail and that the flanges are not drilled or welded. This also shows why it is critical to reinforce the flanges when a chassis rail is joined.***

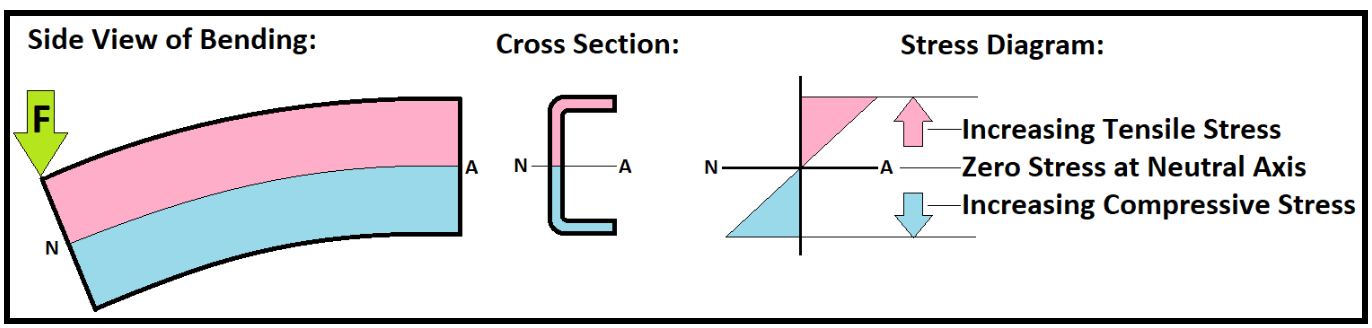

FIGURE 3: STIFFNESS STRESS DISTRIBUTION FOR A BEAM IN BENDING

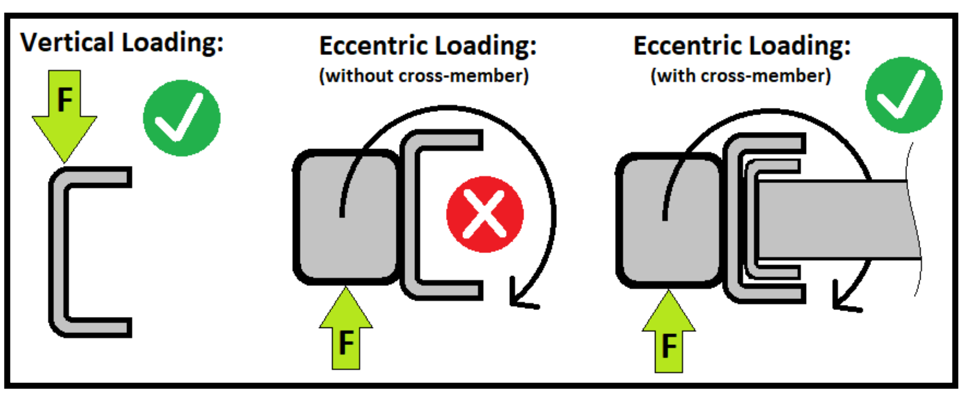

FIGURE 4: TORSIONAL RESISTANCE PROVIDED BY CROSS-MEMBERS

Chassis rails are ideal for direct vertical loading but don't provide a lot of resistance to twisitng, which can be caused by offset or eccentic loads from components such as suspension hangers and fuel tanks. For this reason, cross-members are installed between chassis rails to provide resistance to twisting. A similar situation exists for cross-members which support drive shaft centre bearings and for this reason caution must be exercised when designing centre bearing mounts. Cross-members are constructed from open (channel-style) sections to allow them to be torsionally flexible, however this provides minimal resistance to eccentric loads from centre bearing mounts and can lead to the cross-member cracking. For this reason, it is strongly recommended that centre bearing mounts are attached to cross-members in a way which minimises the eccentric load exerted on the cross-members.

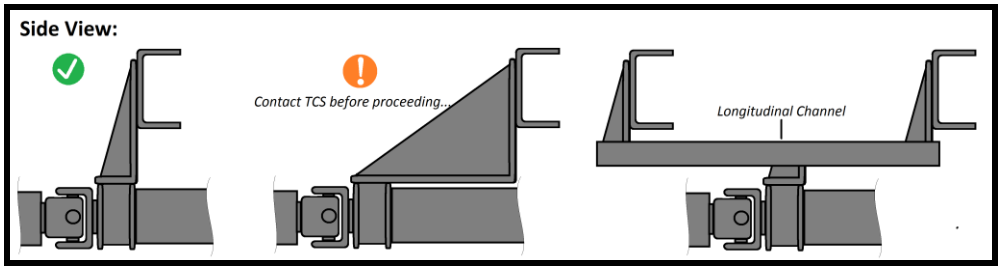

FIGURE 5: CENTRE BEARING MOUNT

When a chassis is modified, structural calculations must be conducted to ensure the predicted stress in the chassis isn't too high. Safety factors must also be used in these calculations. The safety factor for general on-road use is 3, which means the chassis must be able to withstand a stress that is at least 3 times higher than the stress predicted in the calculations. For off-road and tipper applications, this safety factor is generally increased to 5. Furthermore, if an OEM stipulates that a higher safety factor must be used (such as Kenworth who mandate a minimum safety factor of 5 for all conditions) then this requirments cannot be ignored. The highest stresses in a chassis generally occur where components such as suspension hangers, airbags, torsion bars and panard rods are mounted so it is critical to ensure chassis joins are not located in these high stress regions. Examples of chassis calculations are provided below. In these examples, the blue line on the loading diagram represents chassis delfection and red line represents bending stress. The further these lines are away from the chassis rail (in the diagram), the greater their respective values are. Nearly all chassis joins require structural reinforcement (which is discussed in detail further below) and additional reinforcement may also be needed in regions of high stress.

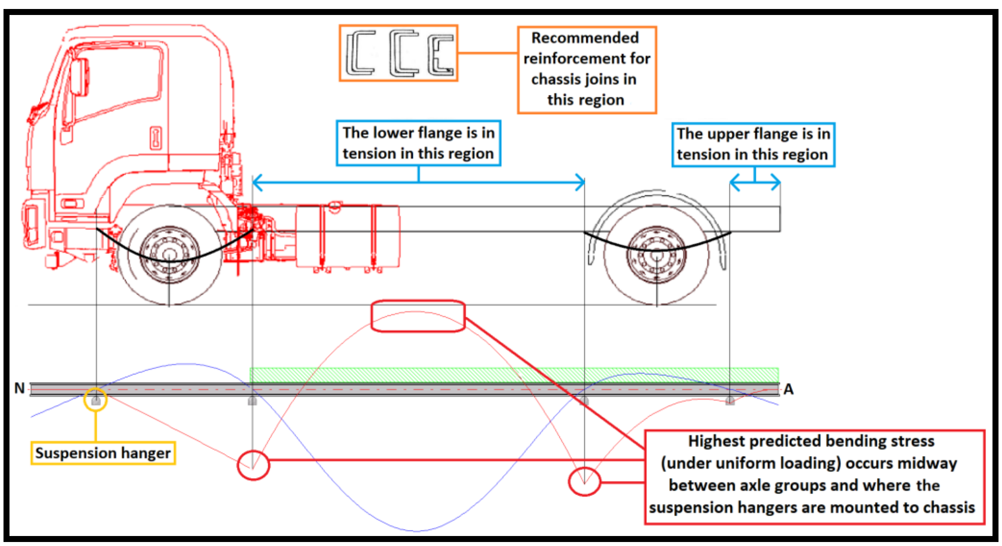

FIGURE 6: BENDING STRESS DIAGRAM FOR A 2 AXLE VEHICLE WITH A SHORT REAR OVERHANG

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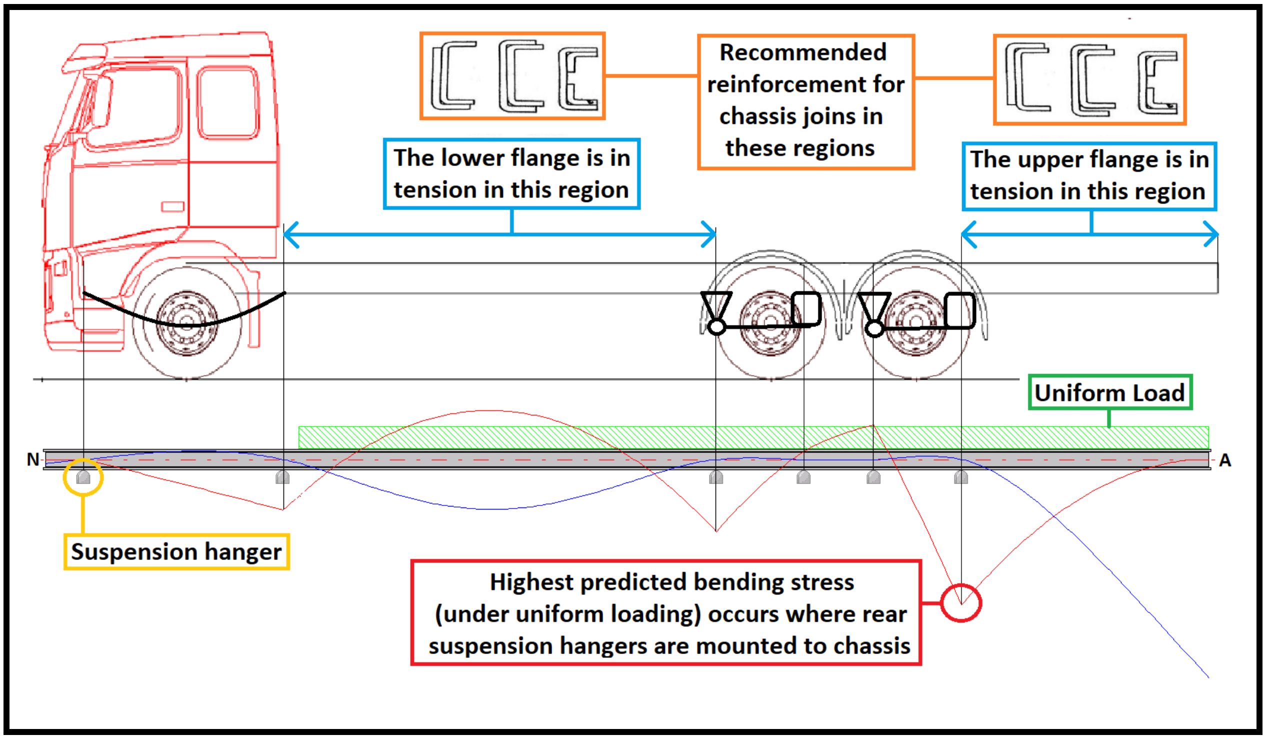

FIGURE 7: BENDING STRESS DIAGRAM FOR A 3 AXLE VEHICLE WITH A LONG REAR OVERHANG

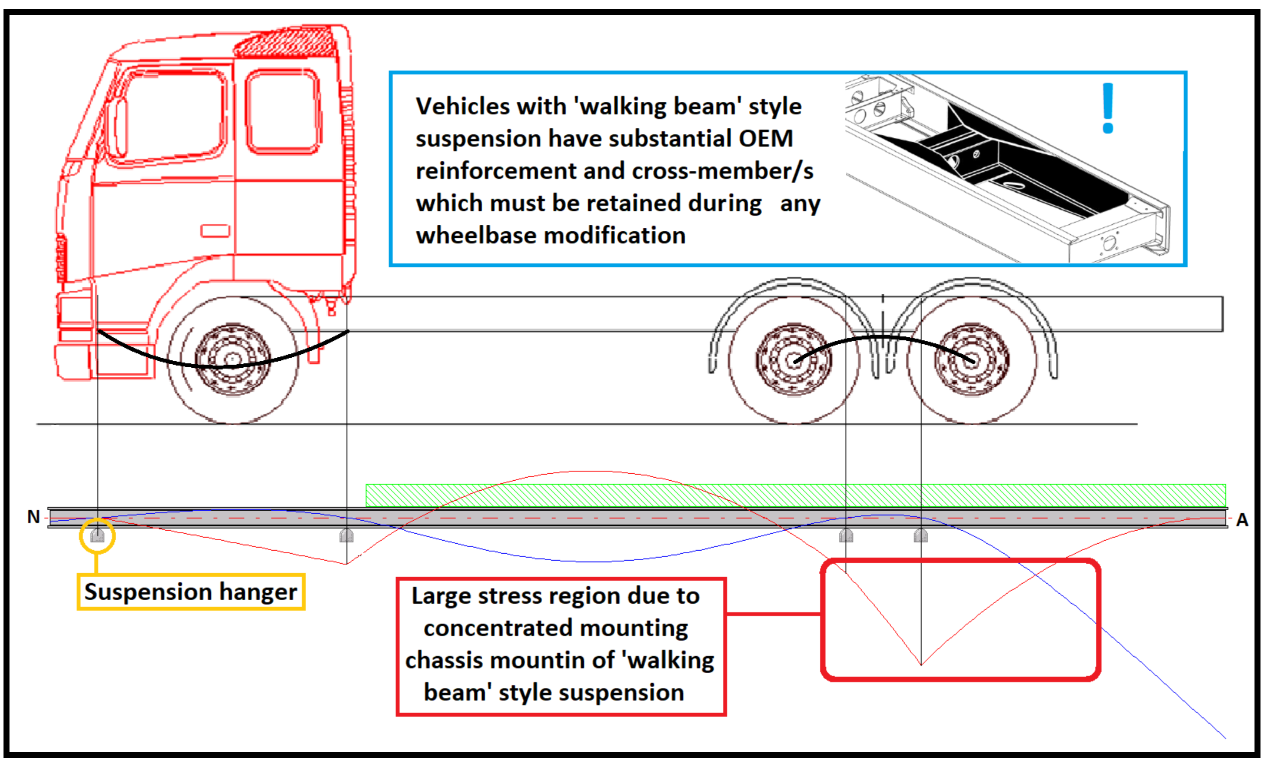

FIGURE 8: BENDING STRESS DIAGRAM FOR A 3 AXLE VEHICLE WITH A WALKING BEAM REAR SUSPENSION SETUP

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If the specific vehicle application is known when the chassis modification is being planned, structural calculations should consider the actual loading scenarios the vehicle will be subjected to. For the specific application shown below, the chassis is also reinforced with the crane sub-frame and the fifth wheel angles.

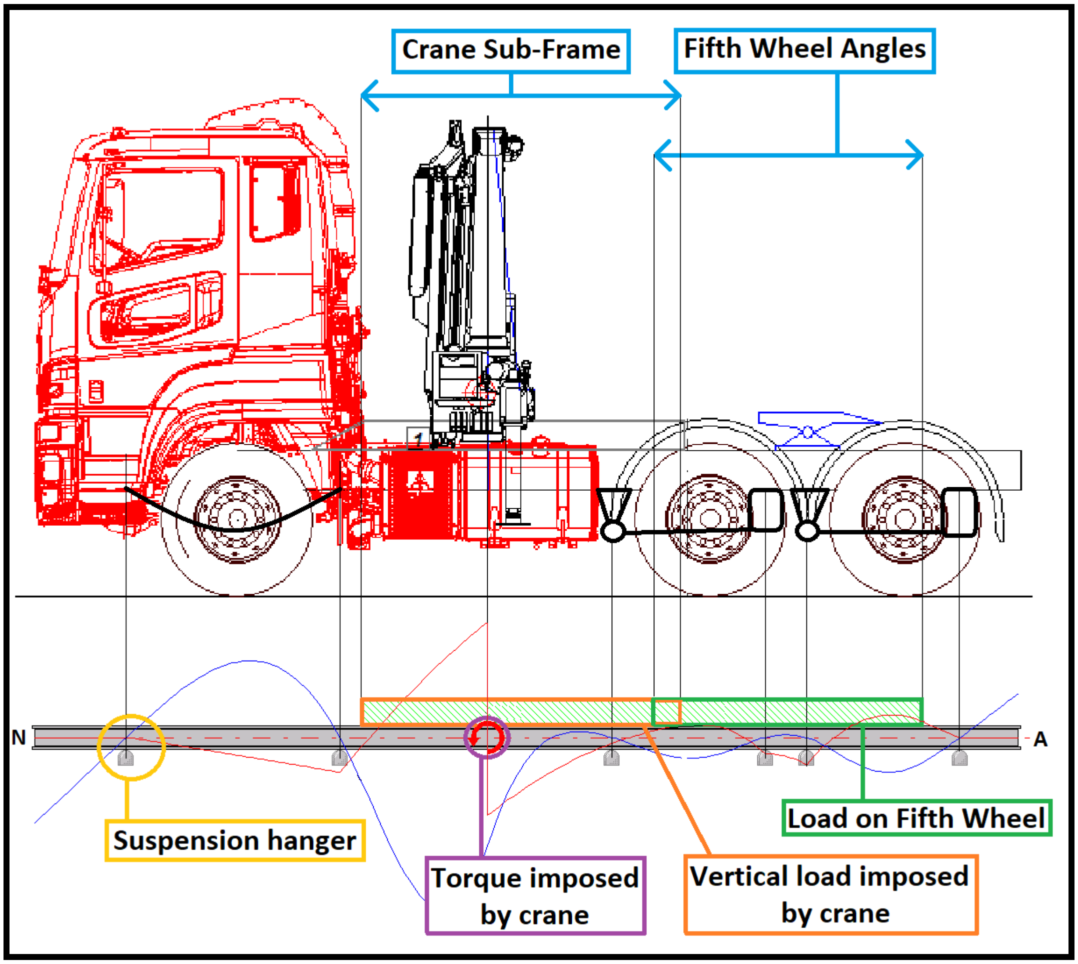

FIGURE 9: BENDING STRESS DIAGRAM FOR A 3 AXLE VEHICLE WITH A WALKING BEAM REAR SUSPENSION SETUP

<u>General Guidance from Section H of Revision 3 of VSB6</u>

Summarised and/or paraphrased in some instances for quick reference, *italic* sections are TCS comments:

- Vehicle specifications should remain within the options offered by the original manufacturer. If they differ, then the chassis must meet at least the requirements outlined in VSB6.
- It is better to shorten a longer wheelbase than to extend a shorter one.

REQUIRED

- If possible, achieve an increase in wheelbase by moving the complete rear axle assembly along the frame (*roll the axle group*) rather than cutting the chassis *(unless the manufacturer states otherwise*).
- If additional chassis length is required, (*depending on the length* required) achieve this by extending the rear overhang rather than inserting any extension between the front and rear axle groups.
- If original manufacturer's instructions are unavailable, the following requirements apply:

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- Where chassis alterations result in a modifications to wiring harnesses, where possible, replacement harnesses of the required length should be used to prevent cutting/splicing.
- As far as possible, keep all additional materials used to modifiy the chassis rails to the same dimensions and material specifications.

RECOMMENDED

- Use the manufacturer's chassis rail material if available. *Some examples of common chassis materials are provided further on in Table 1*.

Bolts and fasteners

REQUIRED

- Ensure all bolts for structural purposes are high tensile bolts in at least ISO Grade 8.8 (or SAE Class 5) and all bolts used for attaching suspension components to the chassis are at least ISO Grade 10.9 (or SAE Class 8).
- Observe the manufacturer's re-usability limitations on fasteners (bolts, nuts, locknuts, huck bolts, etc.).
- Ensure bolts have sufficient unthreaded under headed length to prevent thread being in contact with the inside of the hole and use a hardened washers between the chassis and the nut so that the nut has enough thread on the bolt to be fastened tightly.
- Ensure the shank of a filler bolt is a tight fit within the chassis hole and extends throughout th depth of the hole.
- Ensure all nuts are self-locking.

RECOMMENDED

- In regard to reusability of fasteners, if the vehile is modified before entering service it may only be necessary to replace locknuts.
- When attaching cross-members to the chassis (*and in general unless flange nuts and/or bolts are used*) flat washers or load distribution plates should be used under all nuts and bolts.

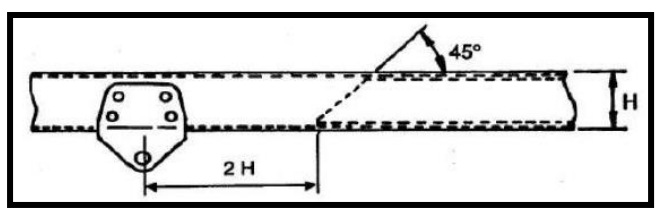
Advanced braking systems (such as ESC, ESP, VSC, DSC, VSA, RSC, RCS, EBS, TEBS)

- These systems are programmed by the vehicle manufacturer and are specific to the vehicle. Altering aspects such as tyre size, suspension characterisitcs, vehicle mass and it's distribution, wheelbase and axle configuration may require re-programming, if it is possible.
- These systems can be sensitive and can be damaged by rattle guns being used to close to sensors.

Chassis Reinforcement

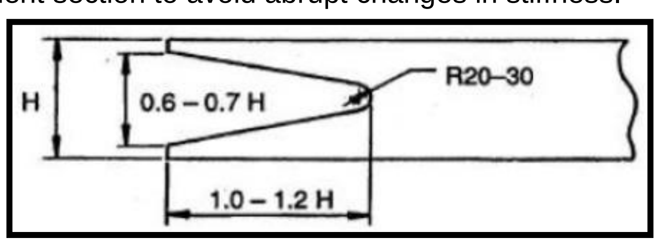
REQUIRED

- Where multiples reinforcement sections are used, attach reinforcements securely to each other, either by overlapping and bolting or by butt welding.



RECOMMENDED

- Aim to avoid terminating reinforcements within a distance of 2H from the centre of a spring hanger (H = chassis rail depth). *Many OEM's allow reinforcement to terminate closer to springs hangers than this recommendation*.
- Taper or frog mouth the ends of any reinforcement section to avoid abrupt changes in stiffness.
- Extend the chassis reinforcement at least 2H fore and aft of a join.



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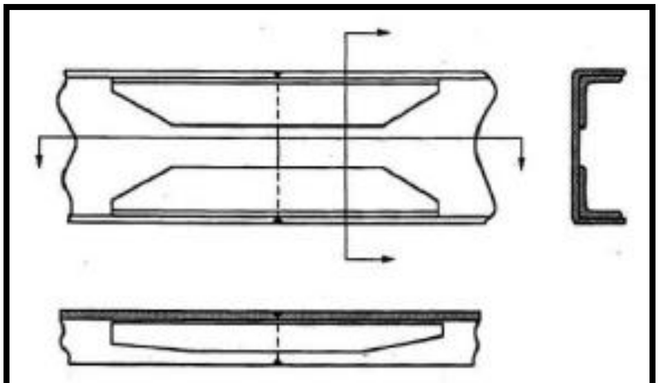
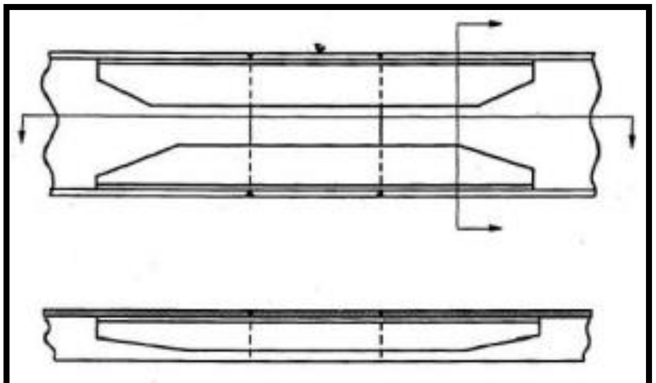
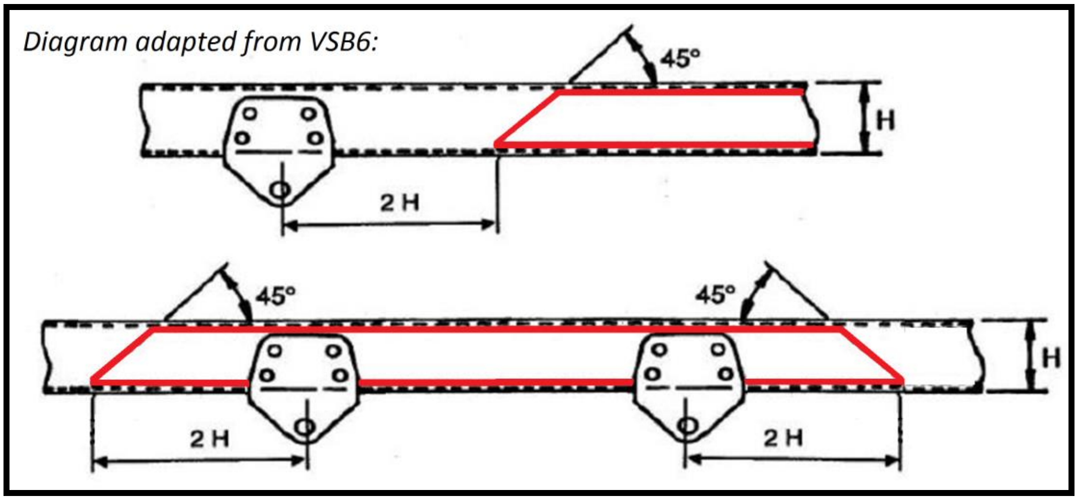
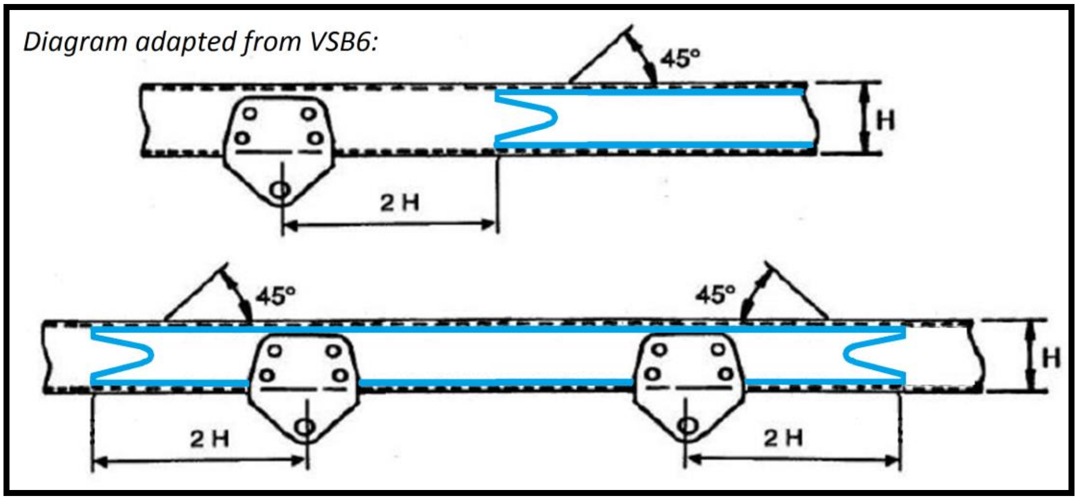

Typical Shortening Method


Typical Lengthening Method

The diagrams below have been adapted from VSB6 and are recommended minimum requirements for reinforcement but not necessarily mandatory. Contact TCS anytime if clarification is required:





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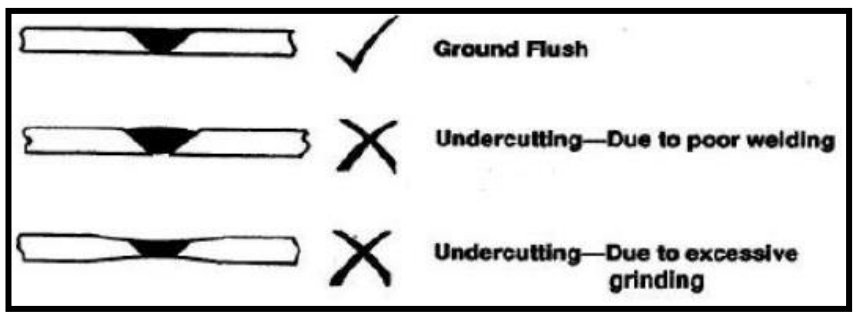
Welding of chassis rails

REQUIRED

- Where heat-treated chassis rails are fitted, ensure advice from the chassis manufacturer is obtained about the suitability of welding these rails. Where the manufacturer does not endorse or recommend welding of heat treated rails, you cannot override that requirement.
- Follow the manufacturer's recommendation for welding preparation (i.e. pre-heating).
- Before performing any welding, obtain the material specifications so that the correct welding procedures and consumables are used.
- Always attach the welding cable terminal as close to the join as possible and never attach to components such as axles, springs, engine, driveline, ECU, etc.
- Perform all welding in accordance with AS 1554 Strucutral Steel Welding Category SP, and ensure this welding is done by a qualified tradesman.
- Leaf spring fracture can be caused by even momentary exposure to welding splatter.
- Where feasible, perform welds from both sides to ensue full penetration.
- Grind all welds flush (up to 10% increase in chassis thickness is permissable but not recommended. Undercut welds are not acceptable.



- Fill unused holes in critical areas with filler bolts wherever possible and ensure the shank of the filler bolt is a tight fit within the chassis hole and extends throughout th depth of the hole. If it is not possible to use filler bolts, plug weld holes only when it is necessary to drill a new hole nearby (*refer to TCS' Hole Drilling Guidelines for further information*).

RECOMMENDED

- Do not plug holes in heat treatd rails unless absolutely necessary. The reduction in strength caused by plug welding holes in heat treated rails can outweigh any advantage that may be gained from plugging the holes.
- In low ambient temperatures or if there is dew or other moisture present, slightly warm the area to be welded i.e with an oxy-fuel torch.

Cutting of chassis rails

REQUIRED

- For multi-section rails, ensure inner and outer rail joins have a minimum spacing of 300mm.

RECOMMENDED

- Cut and bevel chassis member with metal cutting wheels or by using plasma cutting. Heat from oxyacetylene cutting or excessive grinding will reduce the strenth of heat treated rail.
- Ensure all joins are clear of highly stressed regions of the chassis. *These regions include anywhere that suspension components are attached to the chassis*.
- For heat treated rails, use a cut angle of 45 ± 15 degrees, also favour this recommendation for vehiles that will be used in highly stressed and heavy duty applications.
- For cold-rolled rails, perpendicular (*vertical*) cuts may be used.

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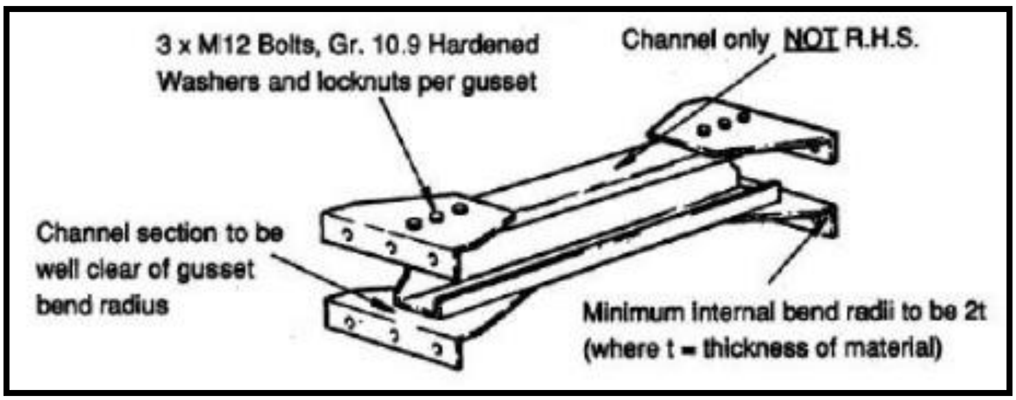
Cross-members

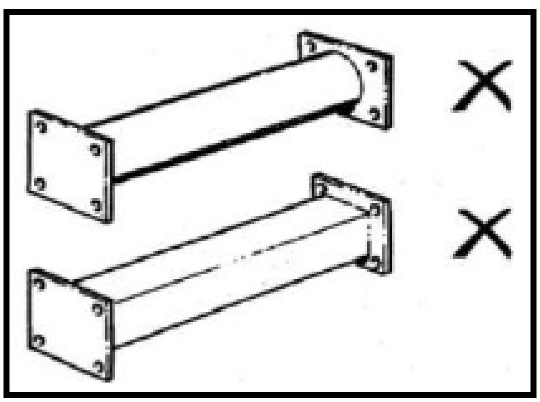
REQUIRED

- When an axle group is rolled forward or backward, ensure the suspension cross members are also rolled forward or back by the same amount so they are in the same location (relative to the axle group) after the modification as they were before the modification.
- Intermediate cross-members often have a lighter structure than suspension cross-members and therefore should not be used as suspension cross-members, especially when fitting a lazy axle. Suspension cross-members (and surrounding chassis reinforcement) should be identical, or closely replicate, the equivalent OEM suspension cross members.
- Unless allowed by the manufacturer, cross-members should be fabricated from channel or other appropriate ‘open’ sections to allow them to be torsionally flexible. They should not be made from ‘closed’ sections such as RHS or pipe.
- Cross-member spacing should be approximately even between the steer and drive axle groups to provide uniform torsional chassis stiffness in the region. Regions where cross-members are spaced closer are more torsionally stiff along the length of the chassis.

RECOMMENDED

- The thickness of the steel plate used to fabricate the cross-member should not be thicker than the web of the chassis rail that it is mounted to.





Type	Yield Strength (Mpa)	Tensile Strength (Mpa)	Manufacturer	Reference	Models
Hino SPH440	310	440	Hino	Hino body mounting manuals 2017	616 IFS Narrow Cab
Hino HSAPH540	390	540			616 Wide Cab, 617, 716, 717, 816, 916, 917, 920, 921, FC1022, FD1124, FD1126, GT1322, FE1426, GH1728 FS2844, FS2848, FD1124, FG1628 (old model), FM2628 (old model), FL2628 (old model), FM2632 (old model)
Hino HSAPH620	500	620			FG1628 (MY2017), GH1828, GH1832, GH1835, SH2045, FL2628 (MY2017), FM2628 (MY2017), FM2632 (MY2017), FM2635, SS2848 , FY3248
SAPH440	303	440	Isuzu	Isuzu Body builders guide 2014 Section 7.1/8.1/9.1	NLR 45-150, NLS 45-150, NNR 45-150, NNR 55-150, NNR 65-150, NPR 45-155, NPR 55-155, NPR 45-190, NPR 65-190, NPS 45-155, NPS 75-155, NQR 80-190, NQR 87 190, FSS 110-210, FVM 230-300, FVL 240-300, FVZ 260-300 (SOME - check spec sheet), FVY 240-300 (SOME - check spec sheet)
HT540A	390	540		Isuzu Body Builders guide (F Series) 2011 Page 364	FRR 107-210, FRD 107-210, FRR 110-240, FRR 110-260, FRD 110-260, FSR 120-240, FSR 140-240, FSR 120-260, FSR 140-260, FSD 120-260, FSD 140-260, FTR 150-260, FTS 139-260, FXL 1500, FXR 1000, FXD 1000, FXZ 1500, FXY 1500, GXD, FYH 2000, FYJ2000, FYX 2500, Giga CXZ 415, Giga CXY 415, Giga CXZ 455, Giga CXY 455, Giga EXY 455, Gigamax EXY 510 FVZ 260-300 (SOME - check spec sheet), FVY 240-300 (SOME - check spec sheet)
DAF KF375	375	See standards for BSEN S460MC	DAF	DAF Body Builders guide 2011 page 29	FTM, FA, FN, FAR, FAS, FAT (SOME - check specs), FAX, FAD (SOME - check specs), FAG, FAK, FAQ
DAF KF460	460				FT (LF55), FA(LF45), FA(LF55), FACF65, FAN (LF55)
DAF KF500	500				FT (SOME - check specs), FTG, FTR, FTS, FTT, FAT (SOME - check specs)
DAF KF600	600				FT (SOME - check specs), FTP, FAT (SOME - check specs), FAD (SOME - check specs)
Kenworth	758	834	Kenworth	Kenworth Body mounting guide 2008 Page 31	All
Fuso SAPH440	See standards for S355MC	440	Fuso	Canter Body Builder Guide 2015 Page 163	Canter 413, Canter 515 Narrow Cab, Canter 615, Canter Eco Hybrid, Canter 815 Wide (3850mm wheelbase only), Canter FG 4x4
Fuso HTP540	See standards for S500MC	540			Canter 515 Wide Cab, Canter 815 Wide (3400mm wheelbase only), Canter 918, Fighter FK1024, Fighter FK1224, Fighter 1227, Fighter 1424, Fighter 1427, Fighter 1627, Fighter 2427, Heavy FP54, Heavy FS52, Heavy FV51, Heavy FV54
MB S380MC	Min 380	450-530	Mercedes-Benz	material data sheets	Atego - Euro WB from 4.8m
MB S500MC	Min 500	550-650			Atego - Euro WB up to 4.2m, Actros (old model V6, V8), Axor, Econic
MB S600MC	Min 600	670-790			Actros (MY16 Inline 6)
Volvo 445	445		Volvo	Volvo Body Builder Instructions (Frame Reinforcement) 2007 Pages 2-3 Volvo standards Issue 7 page 4	FL (variant FMAT-BAS)
Volvo 560	560				FL (variant FMAT-HT)
Volvo VSHR590	590	min 650			FE,FM,FH
Iveco 420	420	530	Iveco	Bodybuilder Instructions 2016 ch 2.1	Eurocargo, Daily
Iveco 760	760	860-1140		Acco bodybuilder guide 2015 page 17	Acco, Powerstar, Stralis (8x4)
Iveco FeE490	490	610		Stralis bodymaking manual 2008 ch. 2-13	Stralis
Scania F700	500-600	Max 730	Scania	Scania Body Builder Guide Chassis Frames 2014 page 2	
Scania F800					
Scania F950					G440(8x4), G440-480(6x4), G440-480(6x2), P250-310(4x2), P250-310(6x2), P310(8x2), P360-400(4x2), P360-400(8x4), P280-320(4x2), P280-320(8x4), P360-400-440(6x2), P400-440(8x4), P400-440(6x4), R480, R500-560-620(6x4)
Scania F957					R730(6x4)
Scania F958					
SAE Q9110A	760	795-930	Mack	Material property table for Macks	All Macks after 2007 use SAE Q9110A, available in: 300*90*7mm, 300*90*8mm, 300*90*9.5mm, 300*90*11.1mm
UD 45/30	294	441	UD	Specification sheets	MK5, MK6, PK9, PK10, MKB35A, MKB37A, PKC37A
UD 55/38	372	539			MK, PK, PW, PD
UD 55/40.8	400	539			CK, GW, GK
UD 55/48	471	539			GKB, CWB, GWB

TABLE 1: COMMON HEAVY VEHICLE CHASSIS MATERIALS

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ABOUT THESE GUIDELINES:

These guidelines are published by Transport Certification Services (TCS) to assist vehicle modifiers to conduct modifications in accordance with the OEM Requirements, Australian Design Rules, Vehicle Standards Bulletins and good engineering practice. These guidelines are not, nor are intended to be, complete or without exceptions. The guidelines are a guide only and their use is entirely voluntary. Recommendations may not be suitable for, or applicable to, all modifications. Modifiers should consider their own circumstances, practices and procedures when using these guidelines. Modifiers must comply with the Australian Design Rules (ADRs), the Australian Vehicle Standards Regulations, Vehicle Standards Bulletins (VSBs), the Roadworthiness Guidelines and any specific information and instructions provided by OEMs in relation to vehicle's systems and components. No endorsement of products or services is made or intended. Diagrams, where used in these Guidelines, are for illustrative purposes only.
Suggestions or comments about these guidelines are welcome. Please write to the Manager, Transport Certification Services, 14/69 Acacia Road, Ferntree Gully, VIC 3156.

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Transport Certification Services makes no representations and provides no warranty that the information and recommendations contained in these guidelines are suitable for use by or applicable to all modifiers, up to date, complete or without exception. Reliance upon or use of the information or recommendations is voluntary and the user accepts all risks and responsibility for any such reliance or use and to the maximum extent permitted by law Transport Certification Services excludes all liability to any person arising directly or indirectly out of any such reliance or use.