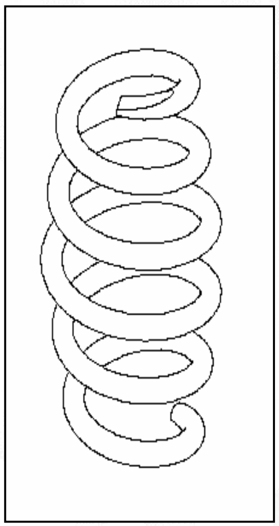
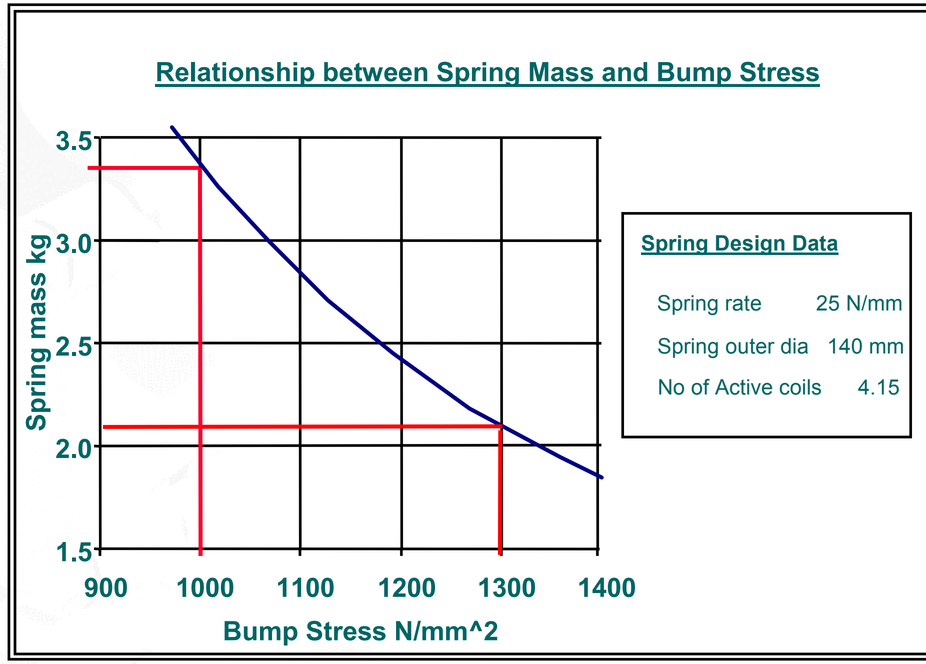
HIGH STRENGTH STEEL SPRINGS

During the creative ideas section of the program a direct relationship was identified between the yield strength of spring material and the mass of the spring.

Creative Ideas

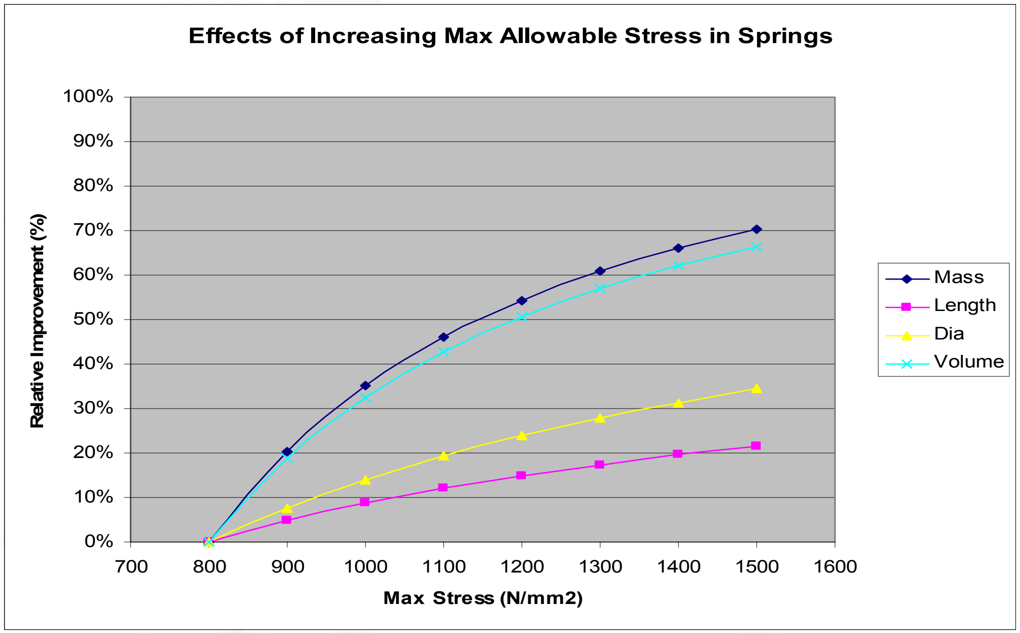




- ULSAS estimated mass, 1000 MPa 3.303 kg
- ULSAS estimated mass, 1300 MPa 2.079 kg
- Benchmark mass 2.61 kg
- 20 % mass reduction over benchmark
- 37 % mass reduction from high strength steel

COIL SPRING DESIGN

During the Concept Design section of the program the advantages of high strength spring steel were further explored. By use of standard spring design calculations and iterative optimisation techniques a more detailed understanding of the effects of utilising high strength steel on both mass and package was established.



Up to 70% Reduction

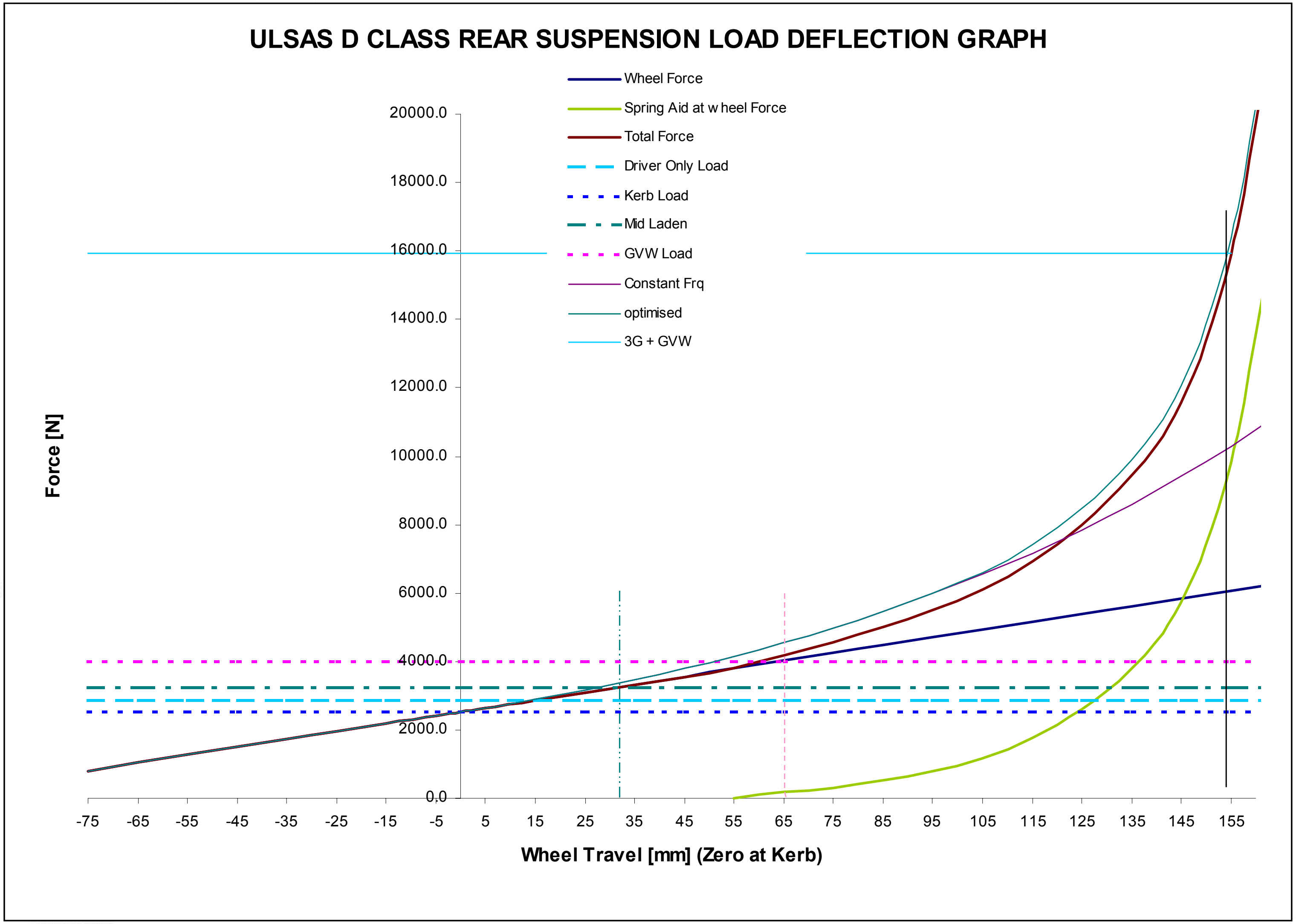
A Typical test exercise was carried out to determine the effects on mass and size of a spring as max allowable stress was increased.

- **Substantial Mass & Size Reductions**

Max Stress	Mass	Length	Dia	Volume
800	5.15	283.5	127.50	3620
900	4.10	270.0	117.80	2943
1000	3.35	258.9	109.72	2448
1100	2.78	249.4	102.94	2075
1200	2.35	241.3	97.10	1786
1300	2.02	234.2	92.01	1557
1400	1.75	228.1	87.54	1373
1500	1.53	222.6	83.56	1221

COIL SPRING DESIGN

The Design process examines first the ride frequency and suspension travel requirements as highlighted during the Targets Setting process.



ULTRALIGHT STEEL AUTO SUSPENSION

COIL SPRING DESIGN

The data is then used in the Spring Design Calculation sheet. This analysis is able to vary the design parameters and variables within defined limits to achieve the lightest spring within the allowable stress limits imposed for the material.

COIL SPRING DESIGN

Prepared in accordance with 'A Guide to the design and specification of Helical Springs'
Published in conjunction with the Spring Research and Manufacturers Association May 1985.
Applies to parallel springs with constant circular section wire only.

Vehicle Data			
Wheel travel about design			
Design to bump (metal to metal)	125 mm		
Design to rebound (metal to metal)	105 mm		
DOUBLE WISHBONE		**D Class**	
Rear Suspension system axle load at design		733.5	kg
Assumes unsprung mass		35	kg
Sprung mass per side		331.75	kg
Spring ratio - spring travel/wheel travel		0.8	
Spring load at design		4068.084	N
wheel Rate		22.9	

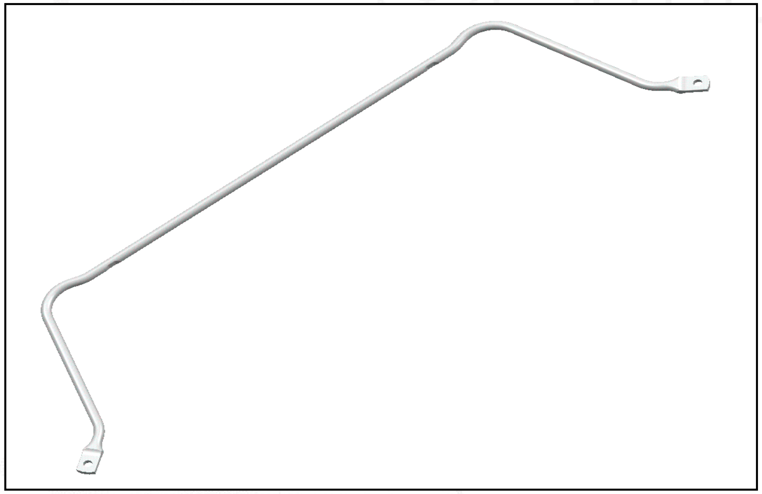
Input Data			
Modulus of rigidity of material	G	78500	N/mm^2
Wheel rate (target)	kw	22.9	N/mm
Parasitc Rate		4.9	N/mm
Ride Frequency		1.32	Hz
Spring rate (target)	**ks**	**28.13**	**N/mm**

Spring Design Parameters & Variables			
Outer Diameter	Do	92.01	mm
Inner diameter	Di	70.20	mm
Design length	Ld	234.23	mm
Bump length	Lb	134.23	mm
Rebound length	Lr	318.23	mm
Load at Design length	Pd	4068.08	N
Number of working coils	n	9.25	-
Total number of coils	N	10.75	

Calculations			
Mean coil diameter	D	81.11	mm
Wire diameter	d	10.91	mm
Spring index	c=D/d	7.437	target4<c<10
Stress correction factor	K	1.186	
Spring rate	**S**	**28.13**	**N/mm**
Wire length	Lw	2752.26	mm
Spring mass	m	2.018	kg
Bump Load	Pb	6880.58	N
Rebound Load	Pr	1705.58	N
Free Length	Lo	378.9	mm
Solid Length (open ends)	Lc	111.8	mm
Solid Length (Ground ends)		122.7	mm
Solid Length (Closed ends)		133.6	mm
Stress rebound		322.25	N/mm^2
Stress design		768.61	N/mm^2
Stress bump (Limit =1300Mpa)		1300.00	N/mm^2
Stress solid (open ends)		1419.38	N/mm^2
Stress soild (ground ends)		1361.43	N/mm^2
Stress solid (closed ends)		1303.48	N/mm^2
Stress range (working)		977.75	N/mm^2
Maximum working deflection per coil		28.88	mm
(Lo-Lb)/Lo		0.646	
Spring aspect ratio	Lo/D	4.671	
Limit		0.171258364	
Residual deflection per coil		1.58	

STEEL AUTO SUSPENSION

ANTI-ROLL BARS



Generic Anti-Roll Bar Design

A basic design of Anti-roll bar was developed that would be suitable for the Multi-Link system to allow comparisons to be made between alternative designs.

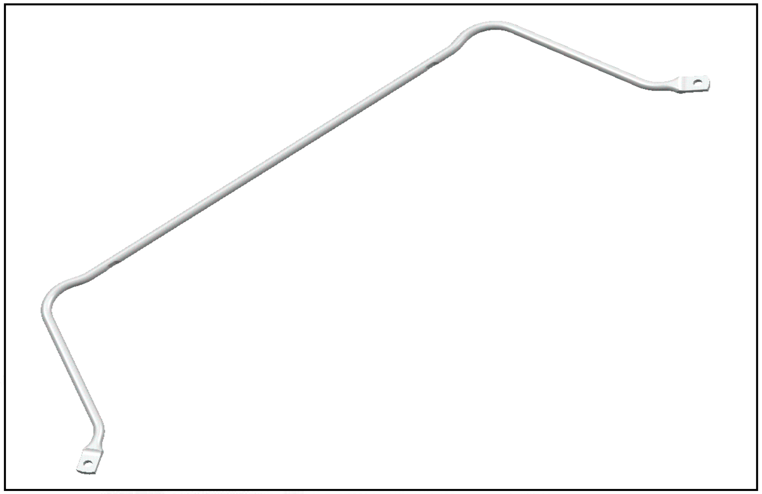
The tuning of the roll stiffness of the suspension systems is undertaken using anti-roll bars. The design arrangement i.e. routing, of an anti-roll bar is dominated by system packaging and vehicle integration. With the absence of these constraints, the development of designs and their comparison with the benchmark data is not credible. To overcome this difficulty a generic design of anti-roll bar has been derived to demonstrate the material requirements and mass reduction potential associated with adopting tubular and high strength product in place of bar product.

For reference the range of the additional roll stiffness requirements of the ULSAS Solutions is very low in the range 0 - 50 Nm/deg. To cover a wider range of requirements that may be required for sports models etc a range of 1-200 Nm/deg should be considered.

A basic form of anti-roll bar was developed with the operating parameters suitable for the Multi-Link system:

The bar was initially assumed to be solid with diameters typical of such parts in volume production and sizes to cover the required range of stiffnesses. Following the analysis, further part designs were subsequently generated using tubular product to achieve similar stiffness properties. The results of these studies are presented below and the mass reduction potential of adopting high strength tubular product is shown.

ANTI-ROLL BARS



Generic Anti-Roll Bar Design

A basic design of Anti-roll bar was developed that would be suitable for the Multi-Link system to allow comparisons to be made between alternative designs.

BAR TYPE	DIAMETER	MASS	WHEEL RATE	ROLL STIFFNESS
	Od x Id mm	kg	N/mm	Nm/Deg
Solid	10	0.894	2.24	45.7
	12	1.287	4.6	94.6
	14	1.752	8.6	174.6
Tube	11x 8.3	0.466	2.22	45.2
	12.9x9.1	0.747	4.6	95
	14.7x9.55	1.116	8.6	174.5

36 - 48 % Lighter

Requires 5 - 10 % stronger material grade in Tube