134705

TNI	Kozmická technika Príručka o konštrukčných materiáloch Časť 3: Prenos zaťaženia a návrh spojov a návrh konštrukcií	TNI CEN/TR 17603-32-03
		31 0540

Space engineering - Structural materials handbook - Part 3: Load transfer and design of joints and design of structures

Táto technická normalizačná informácia obsahuje anglickú verziu CEN/TR 17603-32-03:2022. This Technical standard information includes the English version of CEN/TR 17603-32-03:2022.

Táto technická normalizačná informácia bola oznámená vo Vestníku ÚNMS SR č. 04/22



Úrad pre normalizáciu, metrológiu a skúšobníctvo Slovenskej republiky, 2022 Slovenská technická norma a technická normalizačná informácia je chránená zákonom č. 60/2018 Z. z. o technickej normalizácii.

TECHNICAL REPORT RAPPORT TECHNIQUE TECHNISCHER BERICHT

CEN/TR 17603-32-03

January 2022

ICS 49.140

English version

Space engineering - Structural materials handbook - Part 3: Load transfer and design of joints and design of structures

Ingénierie spatiale - Manuel des matériaux structuraux - Partie 3 : Transfert des charges, conception des jonctions et conception des structures

Raumfahrttechnik - Handbuch der Konstruktionswerkstoffe - Teil 3: Lastabtragung und Bemessung von Verbindungen und Konstruktion von Bauwerken

This Technical Report was approved by CEN on 22 November 2021. It has been drawn up by the Technical Committee CEN/CLC/JTC 5.

CEN and CENELEC members are the national standards bodies and national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.



CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

© 2022 CEN/CENELEC All rights of exploitation in any form and by any means reserved worldwide for CEN national Members and for **CENELEC** Members.

LEC

TNI CEN/TR 17603-32-03: 2022

CEN/TR 17603-32-03:2022 (E)

Table of contents

Europe	ean For	eword	20		
Introdu	iction		21		
23 Inse	erts		22		
23.1 Introduction					
23.2	Feature	s of inserts	22		
	23.2.1	Basic description	22		
	23.2.2	Types of inserts	23		
	23.2.3	Inserts for honeycomb sandwich structures	25		
	23.2.4	Sizes of inserts	27		
	23.2.5	Design parameters	28		
	23.2.6	Typical insert materials	29		
	23.2.7	Surface protection for inserts	31		
23.3	Insert d	esign for non-metallic sandwich components	31		
	23.3.1	Basic design parameters	31		
	23.3.2	Areas of concern with respect to analysis	33		
23.4	Insert a	nalysis for sandwich components	36		
	23.4.1	General	36		
	23.4.2	Inserts loaded normal to the plane of facing	36		
	23.4.3	Inserts loaded in plane of the facing	38		
23.5	Referen	nces	42		
	23.5.1	General	42		
	23.5.2	ECSS documents	42		
24 Loa	d introd	luction elements	43		
24.1	Introduc	stion	43		
	24.1.1	Composite links	43		
	24.1.2	Shear load elements	43		
24.2	Compos	site links	43		
	24.2.1	Basic description	43		
24.3	Analysis	s of composite links	45		
	24.3.1	Analytical notation	45		

	24.3.2	Stress distribution in unidirectional composite links	.45
24.4	Shear lo	oad elements	.53
	24.4.1	The 'Spider' element	.53
24.5	Referen	nces	.55
	24.5.1	General	.55
25 Des	ign of s	truts	.56
25.1	Introduc	ction	.56
	25.1.1	General	.56
	25.1.2	Design aspects	.56
25.2	Analytic	al notation for strut optimisation	.57
25.3	Theoret	ical evaluation	.57
	25.3.1	Method	.57
	25.3.2	Evaluation example	.59
25.4	Optimis	ation of compression tubes	.62
	25.4.1	General	.62
	25.4.2	Critical column buckling load	.63
	25.4.3	Local buckling stress for circular cylinders	.65
	25.4.4	Applied stress	.65
25.5	References		
	25.5.1	General	.69
	25.5.2	ECSS documents	.70
26 Des	ign of s	andwich structures	.71
26.1	Notatior	٦	.71
26.2	Introduc	ction	.73
	26.2.1	The structural sandwich concept	.73
	26.2.2	Historical background and overview	.75
	26.2.3	Applications	.77
26.3	Constitu	uent materials and manufacturing	.79
	26.3.1	General	.79
	26.3.2	Face materials and their properties	.79
	26.3.3	Core materials and their properties	.79
	26.3.4	Cores: Honeycomb materials	.80
	26.3.5	Cores: Honeycomb properties	.82
	26.3.6	Cores: Metallic honeycomb	.84
	26.3.7	Cores: Non-metallic honeycomb	.87
	26.3.8	Cores: Foams	.93
	26.3.9	Adhesives: Characteristics	.97

27 Des	ign of tl	hin-walled structures	163
	26.10.2	ECSS documents	
	26.10.1	General	156
26.10	Referen	ces	156
		sandwich shell.	150
	26.9.3	Case study: Pre design calculation of an optimised circular	
	26.9.2	Design approach for sandwich structures	149
20.9	26 Q 1	General design of sandwich structures	149
26.0	20.0.4		140 1/10
	20.0.3 26 8 1	Geometrical and material discontinuities	144 1/16
	20.0.2	Euge closures and joints	
	20.0.1 26.8.2	Edge closures and joints	142
26.8		Considerations associated with sandwich structures	
00.0	20.7.3		
	26.7.2	vvrinkling instability	
	26.7.1		
26.7		uckling instability of sandwich structures	
	.	compression loading	
	26.6.4	Buckling of cylindrical sandwich shells subjected to axisymmetry	ic
	26.6.3	Shear "crimping"	125
	26.6.2	Buckling of sandwich panels	116
	26.6.1	General	116
26.6	Global b	puckling instability of sandwich structures	116
	26.5.7	FEA finite element analysis	115
	26.5.6	Localised effects	113
	26.5.5	High-order and advanced multi-layer models	
	26.5.4	ESL and simple multi-layer theories	
	26.5.3	Love-Kirchhoff theory	
	26.5.2	Simple theories and ESL equivalent single laver models	104
20.0	26.5.1	General	103
26 5	20.4.3 Modellin	one ranure	103 103
	20.4.2		103
	20.4.1	Face failure	103
20.4		Survey of general 'candwich failure modes'	101
26.4	20.3.11 Foilure i	Bonding sandwich elements	100
	26.3.10	Manufacturing of sandwich panels	
	00 0 40		400

27.1	Introduc	stion	163
	27.1.1	General	163
	27.1.2	Design aspects	163
27.2	Inflatabl	e structures	164
	27.2.1	Introduction	164
	27.2.2	Applications	165
	27.2.3	Overall configuration	165
	27.2.4	Materials	166
	27.2.5	Rigidisation	167
	27.2.6	Evaluation and testing	168
	27.2.7	Design aspects	169
	27.2.8	Inflatable structures: Examples	171
27.3	Referen	ices	173
	27.3.1	General	173
28 Des	ian of d	limensionally stable structures	
28.1	Introduc	tion	
	28.1.1	General	
	28.1.2	Short term	
	28.1.3	Long term	178
	28.1.4	Basic properties of materials	179
28.2	Charact	eristics for dimensional stability	
	28.2.1	Characteristics	
28.3	Design	critical areas	
	28.3.1	General	
	28.3.2	CTE control by design	
28.4	Material	options	
	28.4.1	General	183
	28.4.2	Polymer composite constructions	
	28.4.3	MMC and CMC materials	184
28.5	Effect of	f composite lay-up	185
	28.5.1	Composite anisotropy	185
	28.5.2	UHM CFRP prepregs	185
	28.5.3	Fibre and ply misalignment	
	28.5.4	Material selection	
28.6	Sandwid	ch structures	192
	28.6.1	General	192
	28.6.2	Core material	192

	28.6.3	Core thermal conductivity	193
	28.6.4	Sandwich constructions	193
28.7	Space e	nvironments	194
	28.7.1	General	194
	28.7.2	Outgassing	194
	28.7.3	Thermal cycling	195
	28.7.4	Radiation damage	196
	28.7.5	Low Earth orbit	197
	28.7.6	Surface coatings	197
28.8	Effect of	f moisture	197
	28.8.1	General	197
	28.8.2	Swelling agent	198
	28.8.3	Plasticiser	199
	28.8.4	Coefficient of moisture expansion (CME)	199
28.9	Effect of	f thermal cycling	200
	28.9.1	Material properties	200
28.10) Joints		201
	28.10.1	General	201
	28.10.2	Adhesive bonding	201
	28.10.3	Fasteners and inserts	202
28.1 <i>°</i>	IRF ante	nna structures	202
	28.11.1	Basic Characteristics	202
	28.11.2	Performance	202
	28.11.3	Selection of type of construction	204
28.12	2RF Ante	nna structures: Examples	205
	28.12.1	General	205
	28.12.2	Deployable reflectors	205
	28.12.3	Solid deployable reflectors	207
	28.12.4	Solid reflectors	209
	28.12.5	Planer arrays	215
	28.12.6	Frequency selective reflectors	217
28.13	3IR and >	K-ray telescopes	219
	28.13.1	General	219
	28.13.2	Technology demonstrators	219
	28.13.3	Soft X-ray telescope (SXT)	224
	28.13.4	X-ray multi-mirror telescope (XMM)	228
28.14	Optical s	structures and devices	228

	28.14.1	General	228
	28.14.2	Mirrors and optics	228
	28.14.3	Cameras and telescopes	229
	28.14.4	Radiometers	229
28.15	5Optical s	structures: Examples	230
	28.15.1	Mars observer camera (MOC)	230
	28.15.2	High-stability telescope structures (HSTS)	234
	28.15.3	Semiconductor laser inter-satellite link experiment (SILEX)	237
	28.15.4	Scan mirror	240
28.16	6Smart te	echnologies	242
	28.16.1	General	242
	28.16.2	Active compensation	242
	28.16.3	Microvibration damping	242
28.17	7Referen	ces	242
	28.17.1	General	242
	28.17.2	ECSS documents	248
29 Fila	ment wo	ound pressure vessels, tanks and structures	249
29.1	Introduc	tion	249
	29.1.1	General	249
	29.1.2	Uses of filament winding	249
	29.1.3	Pressure vessels	249
	29.1.4	Options with filament winding	250
29.2	Develop	oments in filament winding	250
	29.2.1	Introduction	250
	29.2.2	Manufacturing capabilities	251
	29.2.3	Materials	251
	29.2.4	Pressure vessel liner technology	253
29.3	Pressur	ant and propellant tanks	253
	29.3.1	Introduction	253
	29.3.2	All-metal tanks	254
	29.3.3	Leak-before-burst concept	255
	29.3.4	Seamless metal liners	256
	29.3.5	Design considerations	259
	29.3.6	Pressure vessel performance factor	261
	29.3.7	Intelsat VII pressurant tanks	263
	~ ~ ~ ~	A sus sus sticls, was sourcest tools	266
	29.3.8	Aerospatiale pressurant tanks	200

	29.4.1	General	.267
	29.4.2	Dimension restrictions	.267
	29.4.3	Specified load cases	.267
	29.4.4	Loads during manufacture	.268
	29.4.5	Environmental conditions	.268
29.5	Pressure	e vessels - Safety factors	.268
	29.5.1	General	.268
	29.5.2	Proposed safety factors	.269
	29.5.3	Composite material failure mode	.269
	29.5.4	Service life	.269
	29.5.5	Damage tolerance	.269
	29.5.6	Reliability	.269
29.6	Pressure	e vessels - Design concepts	.270
	29.6.1	Basic concepts	.270
	29.6.2	Isotensoid-shaped pressure vessels	.271
	29.6.3	Joint structures	274
29.7	Pressure	e vessels - Material selection	.276
	29.7.1	Basic rules	276
	29.7.2	Composite materials for pressure vessels	.276
	29.7.3	Materials for the joint structure	.278
29.8	Pressure	e vessels - Dimensioning theories	.279
	29.8.1	General	.279
	29.8.2	Analytical notation	.280
	29.8.3	Isotensoid-shaped pressure vessels	.281
	29.8.4	Joint structures	287
	29.8.5	Manufacturing	.290
29.9	Solid pro	opellant motor cases	291
	29.9.1	General	291
	29.9.2	Solid rocket motors - Mage and IRIS series	.294
	29.9.3	Design characteristics of IRIS/EBM	.296
	29.9.4	Inertial upper stage (IUS)	.300
	29.9.5	CFRP motor case designs	.302
	29.9.6	Booster motor cases	.302
29.10)Launche	ers	304
	29.10.1	General	.304
	29.10.2	Ariane 4 tanks	.304
	29.10.3	Ariane 5 pressure vessels	.305

29.11	Cryoger	nic tanks	307
	29.11.1	General	307
	29.11.2	Factors to be considered	308
	29.11.3	Single-mission conventional launchers	308
	29.11.4	Multiple-mission spaceplanes	308
	29.11.5	Possible materials	311
29.12	Satellite	e central cylinders – Filament wound	312
	29.12.1	General	312
	29.12.2	CFRP central cylinder constructions	313
	29.12.3	Attributes of filament-wound sandwich central cylinders	317
29.13	Optical :	structures	317
	29.13.1	General	317
	29.13.2	ORFEUS telescope	318
	29.13.3	Cylindrical and conical structures	319
29.14	Referen	ices	319
	29.14.1	General	319
	29.14.2	ECSS documents	325
	29.14.3	NASA standards	325
30 Exa	mples o	of developed structures	326
30 Exa 30.1	mples o Introduc	of developed structures	326
30 Exa 30.1 30.2	mples o Introduc Ariane 4	of developed structures ction 4: Interstage 2/3	326 326 326
30 Exa 30.1 30.2	mples o Introduc Ariane 4 30.2.1	of developed structures ction 4: Interstage 2/3 Contractor	326 326 326 326
30 Exa 30.1 30.2	mples o Introduc Ariane 4 30.2.1 30.2.2	of developed structures ction 4: Interstage 2/3 Contractor Characteristics	326 326 326 326 326
30 Exa 30.1 30.2	mples o Introduc Ariane 4 30.2.1 30.2.2 30.2.3	of developed structures ction 4: Interstage 2/3 Contractor Characteristics Structural configuration	
30 Exa 30.1 30.2 30.3	mples o Introduc Ariane 4 30.2.1 30.2.2 30.2.3 DFS Ko	of developed structures etion 4: Interstage 2/3 Contractor Characteristics Structural configuration pernikus: Central cylinder	326 326 326 326 326 328 329
30 Exa 30.1 30.2 30.3	mples o Introduc Ariane 4 30.2.1 30.2.2 30.2.3 DFS Ko 30.3.1	of developed structures etion 4: Interstage 2/3 Contractor Characteristics Structural configuration pernikus: Central cylinder Contractor	326 326 326 326 326 328 329 329
30 Exa 30.1 30.2 30.3	mples o Introduc Ariane 4 30.2.1 30.2.2 30.2.3 DFS Ko 30.3.1 30.3.2	of developed structures etion 4: Interstage 2/3 Contractor Characteristics Structural configuration pernikus: Central cylinder Contractor Characteristics	
30 Exa 30.1 30.2 30.3	mples o Introduc Ariane 4 30.2.1 30.2.2 30.2.3 DFS Ko 30.3.1 30.3.2 30.3.3	of developed structures etion	
30 Exa 30.1 30.2 30.3 30.3	mples o Introduc Ariane 4 30.2.1 30.2.2 30.2.3 DFS Ko 30.3.1 30.3.2 30.3.3 Olympus	of developed structures etion	
30 Exa 30.1 30.2 30.3 30.3	mples o Introduc Ariane 4 30.2.1 30.2.2 30.2.3 DFS Ko 30.3.1 30.3.2 30.3.3 Olympus 30.4.1	of developed structures etion 4: Interstage 2/3 Contractor Characteristics Structural configuration pernikus: Central cylinder Contractor Characteristics Structural configuration s C.S.E. cylinder Contractor	
30 Exa 30.1 30.2 30.3 30.3	mples o Introduc Ariane 4 30.2.1 30.2.2 30.2.3 DFS Ko 30.3.1 30.3.2 30.3.3 Olympus 30.4.1 30.4.2	of developed structures etion	
30 Exa 30.1 30.2 30.3 30.3 30.4	mples o Introduc Ariane 4 30.2.1 30.2.2 30.2.3 DFS Ko 30.3.1 30.3.2 30.3.3 Olympus 30.4.1 30.4.2 Ariane 4	of developed structures etion 4: Interstage 2/3 Contractor Characteristics Structural configuration pernikus: Central cylinder Contractor Characteristics Structural configuration s C.S.E. cylinder Contractor Characteristics Structural configuration Structural configuration Structural configuration Structural configuration Structural configuration Contractor Characteristics Characteristics	
 30 Exa 30.1 30.2 30.3 30.3 30.4 30.5 	mples o Introduc Ariane 4 30.2.1 30.2.2 30.2.3 DFS Ko 30.3.1 30.3.2 30.3.3 Olympus 30.4.1 30.4.2 Ariane 4 30.5.1	of developed structures	326
 30 Exa 30.1 30.2 30.3 30.3 30.4 30.5 	mples o Introduc Ariane 4 30.2.1 30.2.2 30.2.3 DFS Ko 30.3.1 30.3.2 30.3.3 Olympus 30.4.1 30.4.2 Ariane 4 30.5.1 30.5.2	of developed structures	326 326 326 326 328 329 329 329 330 331 331 332 332 333 333 336 336 336
 30 Exa 30.1 30.2 30.3 30.3 30.4 30.5 	mples o Introduc Ariane 4 30.2.1 30.2.2 30.2.3 DFS Ko 30.3.1 30.3.2 30.3.3 Olympus 30.4.1 30.4.2 Ariane 4 30.5.1 30.5.2 30.5.3	of developed structures	326 326 326 326 326 328 329 329 329 330 331 332 333 336 336 336 337
 30 Exa 30.1 30.2 30.3 30.3 30.4 30.5 30.6 	mples o Introduc Ariane 4 30.2.1 30.2.2 30.2.3 DFS Ko 30.3.1 30.3.2 30.3.3 Olympus 30.4.1 30.4.2 Ariane 4 30.5.1 30.5.2 30.5.3 Ariane 4	of developed structures	326

	30.6.2	Characte	eristics	
	30.6.3	Structura	al configuration	
30.7	SPAS: S	Strut elem	nents	
	30.7.1	Contract	or	
	30.7.2	Characte	eristics	
	30.7.3	Structura	al configuration	
30.8	Ariane 4	: SPELD	Α	
	30.8.1	Contract	or	
	30.8.2	Characte	eristics	
	30.8.3	Structura	al configuration	
30.9	Ariane 5	: SYLDA	5	
	30.9.1	Contract	tor	
	30.9.2	Characte	eristics	
	30.9.3	Structura	al configuration	
	30.9.4	Material	s	
	30.9.5	Analysis		
	30.9.6	Testing.		
	30.9.7	Inspectio	on	
	30.9.8	Conclus	ions	
30.10	DALADIN	structure	9	
	30.10.1	Contract	tor	
	30.10.2	Applicati	ion	
	30.10.3	Objectiv	e of project	
	30.10.4	Concept		
	30.10.5	Design p	parameters	
	30.10.6	Analysis		
	30.10.7	Material	s	
	30.10.8	Special	features	
	30.10.9	Manufac	sture	
	30.10.10)	Test	
	30.10.11	I	Inspection	
	30.10.12	2	Conclusions	
30.1 ⁻	1ROSET1	TA lande	r structure	
	30.11.1	Contract	or	
	30.11.2	Function	1	
	30.11.3	Mass		
	30.11.4	Structura	al configuration	

	30.11.5	Construction details	
	30.11.6	Loads	370
	30.11.7	Eigenfrequencies	370
30.12	2Mecabu	s central cylinder	
	30.12.1	Contractor	
	30.12.2	Design	370
	30.12.3	Manufacturing	371
30.13	3Triax-fal	bric deployable antenna reflectors	372
	30.13.1	Contractor	372
	30.13.2	Introduction	372
	30.13.3	Design	372
	30.13.4	Materials	375
	30.13.5	Testing and Inspection	376
	30.13.6	Comments	376
	30.13.7	Conclusions	376
30.14	Ariane 5	5: DIAS	377
	30.14.1	Introduction	377
	30.14.2	Need	377
	30.14.3	Definition	379
	30.14.4	Development logic	
30.15	Referen	ces	
	30.15.1	General	
	30.15.2	ECSS documents	
31 Inte	grity co	ntrol of composite structures	
31.1	Introduc	tion	
31.2	Integrity	control guidelines	
	31.2.1	Objective	
	31.2.2	Materials	
	31.2.3	Special criteria for composites	
31.3	Integrity	control programme	
31.4			
	Material	s and design	
	Material 31.4.1	s and design Materials	389 389
	Material 31.4.1 31.4.2	s and design Materials Design	389 389 389
31.5	Material 31.4.1 31.4.2 Design	s and design Materials Design procedure	
31.5	Material 31.4.1 31.4.2 Design 31.5.1	s and design Materials Design procedure General	
31.5	Material 31.4.1 31.4.2 Design 31.5.1 31.5.2	s and design Materials Design procedure General Test programme	

	31.5.4	Stiffness charachteristics	
	31.5.5	Potentially fracture critical items	
31.6	Referen	ces	
	31.6.1	General	
	31.6.2	ECSS documents	
32 Veri	fication	of composite structures	
32.1	Introduc	tion	
32.2	Building	block approach	
	32.2.1	General	
	32.2.2	Testing aspects	
	32.2.3	Damage tolerance	
32.3	Global a	nd local structural analysis	
	32.3.1	Design philosophy	
	32.3.2	Design steps	
	32.3.3	Preliminary design	
	32.3.4	Durability design	
	32.3.5	Damage tolerance design	
	32.3.6	Structural analysis	
32.4	Develop	ment tests	400
	32.4.1	General	400
	32.4.2	Behaviour with defects	401
	32.4.3	Modelling of the lay-up behaviour	402
	32.4.4	Areas with a hole	402
	32.4.5	Modelling of bonded areas	402
	32.4.6	Local loadings	402
	32.4.7	Load gradients	402
	32.4.8	Buckling and post-buckling behaviour	403
	32.4.9	Design allowable	403
	32.4.10	Detection and repair of defects	404
32.5	Qualifica	ation tests	405
	32.5.1	General	405
	32.5.2	Validation of global behaviour, weak areas and modes of failure .	405
	32.5.3	Margins of safety	406
	32.5.4	Updating of the models used for calculations	406
	32.5.5	Documentation	407
32.6	Referen	ces	407
	32.6.1	General	407

32.6.2	ECSS documents	408
--------	----------------	-----

Figures

Figure 23.2-1 - Inserts for honeycomb sandwich structures	.26
Figure 23.2-2 - Determining the preferred insert height	.29
Figure 23.3-1 - Basic aspects of insert design, analysis and testing	.32
Figure 23.3-2 - Insert design: Decrease of the residual strength with life	.35
Figure 23.4-1 - Fully potted insert: Shear stress distribution in the core depending upon radius r	.36
Figure 23.4-2 - Design plot from ECSS-E-HB-32-22: The relevance of failure modes	.37
Figure 23.4-3 - Insert under in plane loading	.38
Figure 23.4-4 - Insert analysis: Predictions of the failure criteria	.40
Figure 23.4-5 - Insert analysis: Predictions of the failure criteria for samples with fibre orientations +45°/-45°	.41
Figure 24.2-1 - Composite link: Tensile or compression loaded	.44
Figure 24.3-1 - Composite links: Tangential stress distribution of tensile loaded GFRP and CFRP HM	.47
Figure 24.3-2 - Composite links: Tangential stress distribution of compression loaded GFRP and CFRP HM	.48
Figure 24.3-3 - Composite links: Tangential stress distribution of tensile and compression loaded links	.49
Figure 24.3-4 - Hybrid composite links: Optimal thickness relation under tensile loading	.50
Figure 24.3-5 - Composite links: Ultimate strength ratios of tensile loaded links with optimal thickness relation compared with homogeneous (single material) links	.51
Figure 24.3-6 - Composite links: Stress concentration factors for tensile loading	.52
Figure 24.3-7 - Composite links: Stress concentration factors for compression loading	.53
Figure 24.4-1 - Shear load 'Spider' element: Structural components and assembly into a sandwich panel	.54
Figure 25.3-1 - Notation: Compression loaded strut	.57
Figure 25.3-2 - Strut optimisation: Maximum compressive strength	.60
Figure 25.3-3 - Strut optimisation: Minimum specific weight	.61
Figure 25.3-4 - Strut optimisation: Optimum radius	.61
Figure 25.3-5 - Strut optimisation: Optimum thickness	.62
Figure 25.4-1 - Notation: Beam column configuration and loading conditions	.63
Figure 26.2-1 – Schematic illustration of sandwich panel	.74
Figure 26.2-2 - The components of a honeycomb-cored sandwich panel	.74
Figure 26.2-3 – Comparison between beams with monolithic and sandwich cross sections	.75

Figure 26.2-4 – World War II, De Havilland "Mosquito" fighter-bomber aircraft	76
Figure 26.2-5 – ASAS reflector: Example of lightweight sandwich structure	76
Figure 26.3-1 – Honeycomb cores: Common cell configurations	80
Figure 26.3-2 – Honeycomb cores: Typical stabilised compression strength (T-	
direction)	
Figure 26.3-3 - Honeycomb cores: Typical 'L' shear strength	83
Figure 26.3-4 - Honeycomb cores: Typical plate shear v density for 5052 aluminium core	83
Figure 26.3-5 – Metal foam: Example of aluminium foam	95
Figure 26.4-1 – Sandwich panels: Common failure modes	102
Figure 26.5-1 – Geometry of deformation for sandwich plate in x-z plane	105
Figure 26.5-2 – Deformed sandwich element	107
Figure 26.5-3 – Bending and shear stresses in sandwich element for different levels of approximations	108
Figure 26.5-4 – Boundary conditions imposed on a sandwich panel	109
Figure 26.5-5 – Non-linear displacements through sandwich cross-section	112
Figure 26.5-6 – Sandwich panel: Local bending effects	113
Figure 26.5-7 – Approximate modelling of local bending effects in sandwich panel loaded in 3-point bending	114
Figure 26.6-1 – Sandwich plate subjected to biaxial compression	117
Figure 26.6-2 – Buckling coefficients for a simply supported isotropic sandwich plate subjected to uniaxial compression	119
Figure 26.6-3 – Buckling coefficients K versus a/b orthotropic sandwich plates loaded in uniaxial compression	124
Figure 26.6-4 - Sandwich cylinder: Loads and dimensions for calculations	127
Figure 26.6-5 - Buckling coefficient	132
Figure 26.6-6 - Knock down factor	132
Figure 26.7-1 – Wrinkling modes	134
Figure 26.7-2 - Sandwich plate with load and dimensions	135
Figure 26.7-3 - Sandwich plates: Wrinkling test results	137
Figure 26.7-4 - Dimpling stress under uniaxial compression	138
Figure 26.7-5 - Measurement of sandwich core cell size	139
Figure 26.7-6 - Characteristic intra-cell buckling pattern observed experimentally	140
Figure 26.7-7 - Development of intra-cell buckling for sandwich test specimen (CFRP/AI-honeycomb core)	141
Figure 26.7-8 – Improved intra-cell face plate model	142
Figure 26.8-1 - Sandwich panel edge closure	143
Figure 26.8-2 – Design details in sandwich structures: Examples of edges, joints and corners	144
Figure 26.8-3 – Types of potted inserts for sandwich structures (ECSS-E-HB-32-22)	145

Figure 26.8-4 – Novel insert designs	146
Figure 26.8-5 – Sandwich panels: Bonding different densities of core	146
Figure 26.8-6 - Sandwich panels: Core thickness transition	147
Figure 26.8-7 – Sandwich panels: External and internal doublers	148
Figure 26.9-1 - Determination of minimum mass of an optimised sandwich	151
Figure 26.9-2 - Optimum sandwich core thickness	153
Figure 26.9-3 - Optimum sandwich facing thickness	154
Figure 26.9-4 - Optimum sandwich core density	155
Figure 27.2-1 – Inflatable technologies: European perspective	164
Figure 27.2-2 – Inflatable technologies: ESA advanced solar array (breadboard)	173
Figure 28.5-1 - Coefficient of thermal expansion αx for $[\pm \theta]$ s angle ply laminate	188
Figure 28.5-2 - Moisture: Typical swelling of several different cured resins	189
Figure 28.5-3 - Typical moisture absorption of different composites at 66°C and 100% RH	190
Figure 28.5-4 - Calculated Thermal expansion coefficient for various lay ups of carbon/epoxy: GY 70/Code 69	191
Figure 28.8-1 - Moisture: Shrinkage during desorption	199
Figure 28.9-1 - Influence of thermal cycling on the CTE	201
Figure 28.11-1 - Antenna surface precision and usable frequency versus size	203
Figure 28.12-1 - Antenna examples: MBB double-hinged rib reflector	206
Figure 28.12-2 - Antenna examples: Deployment scheme for CONTRAVES inflatable space rigidised reflector	207
Figure 28.12-3 - Antenna examples: SELENIA 20/30 GHz reflector	208
Figure 28.12-4 - Antenna examples: Dornier DAISY	209
Figure 28.12-5 - Antenna examples: Mathematical model of CASA 11/14 GHz reflector	210
Figure 28.12-6 - Antenna examples: MBB polarisation sensitive reflector	211
Figure 28.12-7 - Antenna examples: ERA dichroic sub-reflector	211
Figure 28.12-8 - Antenna examples: CSELT/SELENIA dichroic sub-reflector	212
Figure 28.12-9 - Antenna examples: CASA radiometer geometry	213
Figure 28.12-10 - Antenna examples: BAe gridded reflector (stowed and deployed configuration)	214
Figure 28.12-11 - Antenna examples: BAe gridded reflector - general sunshield construction	214
Figure 28.12-12 - Antenna examples: DORNIER CFRP SAR antenna	216
Figure 28.12-13 - Antenna examples: Design approaches for frequency selective surface (FSS) sub-reflector	218
Figure 28.12-14 - Antenna examples: Design approaches for frequency selective surface (FSS) sub-reflector: Flat panel design cross-sections	218

Figure 28.12-15 - Antenna examples: Design approaches for frequency selective surface (FSS) sub-reflector: Add-on design on Kevlar/epoxy face sheet: Representative double square loop FSS periodic array	219
Figure 28.13-1 - IR and X-ray telescopes: Schematics of LDR and typical PSR panel	220
Figure 28.13-2 - IR and X-ray telescopes: 4.5m FIRST reflector	222
Figure 28.13-3 - IR and X-ray telescopes: FIRST reflector -construction of core and sandwich reflector	223
Figure 28.13-4 - IR and X-ray telescopes: SXT telescope assembly	225
Figure 28.13-5 - IR and X-ray telescopes: Schematic of SXT telescope metering tube	227
Figure 28.15-1 - Optical structures examples: Basic construction of Mars observer camera - engineering model and flight model	231
Figure 28.15-2 - Optical structures examples: HSTS demonstrator	235
Figure 28.15-3 - Optical structures examples: HSTS ring-to-tube joint	236
Figure 28.15-4 - Optical structures examples: HSTS test specimen joint	237
Figure 28.15-5 - Optical structures examples: SILEX architecture	238
Figure 28.15-6 - Optical structures examples: SILEX OHB lay-out	239
Figure 28.15-7 - Optical structures examples: SILEX OHB core assembly in CFRP	240
Figure 28.15-8 - Optical structures examples: Ultra-lightweight scanning mirror (ULSM)	241
Figure 29.2-1 - 50 percentile fibre life	252
Figure 29.3-1 - Leak/burst threshold	255
Figure 29.3-2 - Manufacture of seamless aluminium liners	257
Figure 29.3-3 - Typical cyclic life of aluminium liners	258
Figure 29.3-4 - Stress-strain curve for prestressed composite vessel	260
Figure 29.3-5 - Strain distributions within INTELSAT VII pressurant tanks	265
Figure 29.6-1 - Pressure vessels: Typical components of a solid propellant motor case as represented by MAGE	271
Figure 29.6-2 - Pressure vessels: Geodetic winding	272
Figure 29.6-3 - Pressure vessels: Configurations of skirt structures	274
Figure 29.6-4 - Pressure vessels: Typical lay-up of a skirt, as represented by MAGE	275
Figure 29.7-1 - Pressure vessels: Some typical values for fibres	277
Figure 29.8-1 - Pressure vessel dimensioning, from MAGE: Definition of design variables	281
Figure 29.8-2 - Pressure vessel dimensioning: Definition of fitting variables	286
Figure 29.8-3 - Pressure vessels: Definition of joint structure variables	288
Figure 29.9-1 - MAGE 1 configuration	295
Figure 29.9-2 - Skirt lay-up with integrated flange for the EBM case	297
Figure 29.9-3 - Theoretical and practical winding angles over radius for the two IRIS/EBM domes	298
Figure 29.9-4 - Stage configuration for IUS	301

Figure 29.11-1 - Cryogenic tank concepts from the FESTIP programme	312
Figure 29.13-1 - ASTRO-SPAS with integrated ORFEUS	318
Figure 30.2-1 - Ariane 4: Interstage 2/3	327
Figure 30.2-2 - Ariane 4 Interstage 2/3: Blade stiffened dimensions	328
Figure 30.2-3 - Ariane 4 Interstage 2/3: Special feature	329
Figure 30.3-1 - DFS: Central cylinder	
Figure 30.3-2 - DFS Kopernikus central cylinder: Geometry	331
Figure 30.3-3 - DFS Kopernikus central cylinder: Special features	
Figure 30.4-1 - Olympus: C.S.E cylinder	
Figure 30.4-2 - Olympus C.S.E. cylinder: Geometry and materials	
Figure 30.4-3 - Olympus C.S.E. cylinder: Special feature	
Figure 30.5-1 - Ariane 4: Adapter 937-B	
Figure 30.5-2 - Ariane 4 937-B adapter: Special features	
Figure 30.6-1 - Ariane 4: Vehicle equipment bay	340
Figure 30.6-2 - Ariane 4: Vehicle equipment bay: Structural detail	341
Figure 30.7-1 - SPAS: Strut elements	343
Figure 30.7-2 - SPAS strut element: Conical transition and stretch bolt	
Figure 30.7-3 - SPAS strut element: Assembly detail	345
Figure 30.7-4 - SPAS strut elements: Optimised bonded section	345
Figure 30.8-1 - Ariane 4: SPELDA	347
Figure 30.8-2 - Ariane 4 SPELDA: Assembly	348
Figure 30.8-3 - Ariane 4 SPELDA: Joint detail	351
Figure 30.9-1 - Ariane 5: SYLDA	352
Figure 30.9-2 – Ariane 5: SYLDA launch configuration	353
Figure 30.9-3 – Ariane 5: SYLDA structural configuration	354
Figure 30.9-4 – Ariane 5: SYLDA joint detail	355
Figure 30.10-1 - ALADIN: Design concept	358
Figure 30.10-2 – ALADIN: Star tracker support	359
Figure 30.10-3 - ALADIN: Structure, proto-flight model (PFM)	
Figure 30.10-4 – ALADIN: Primary structure, proto-flight model (PFM)	
Figure 30.10-5 – ALADIN: IEB middle cylinder (left), CFRP IEB strut end fitting (centre) and typical IEB node (right)	
Figure 30.11-1 – Rosetta: Basic configuration of the lander structure (without the landing gear)	
Figure 30.11-2 – Rosetta: View of the instrument carrier	
Figure 30.11-3 – Rosetta: View of base plate and support truss	
Figure 30.11-4 – Rosetta: Solar hood inner side (view from bottom to top)	
Figure 30.12-1 - Mecabus central cylinder: Overview	

Figure 30.13-1 – STENTOR: Triax fabric membrane reflector	372
Figure 30.13-2 – ASAS: Reflector under inspection	373
Figure 30.13-3 – Ultra-light reflector design	374
Figure 30.13-4 – Triaxial woven fabric	375
Figure 30.13-5 – Reflector backing structure (2.2 m diameter URL)	375
Figure 30.14-1 – Ariane 5: Position of DIAS and LEC	378
Figure 30.14-2 – Ariane 5: Detail of DIAS construction	380
Figure 31.3-1 - Logic of a structural integrity control programme applied during development, manufacturing and operation	388
Figure 31.5-1 - Verification logic of potential fracture critical items (PFCI) with respect to integrity control	391
Figure 32.3-1 - The global and local design philosophy	396
Figure 32.4-1 - Justification philosophy of design allowables	403

Tables

Table 23.2-1 - Types of inserts	24
Table 23.2-2 - Summary list of standcrds for inserts	28
Table 23.2-3 - Insert material: Aluminium alloys specifications	29
Table 23.2-4 - Typical insert materials	30
Table 23.3-1 - Summary of the basic insert design parameters	34
Table 23.3-2 - Contribution of sandwich elements to insert load carrying capability	35
Table 24.3-1 - Composite link analysis: Unidirectional properties of fibre reinforced plastics	46
Table 25.3-1 - Strut optimisation: Material properties	60
Table 25.3-2 - Comparison of optimised values for a CFRP and aluminium strut	60
Table 26.3-1 – Honeycomb cores: Properties of 5056, 2024 and 5052 hexagonal aluminium cores	85
Table 26.3-2 - Properties of commonly used glass reinforced plastic honeycombs	88
Table 26.3-3 - Properties of special purpose glass reinforced plastic honeycombs	89
Table 26.3-4 – Properties of Nomex honeycombs	91
Table 26.3-5 – Selected properties of Ultracor carbon honeycombs	93
Table 26.3-6 – Mechanical properties of Rohacell© PMI foam cores	94
Table 26.3-7 – Selected properties Duocel SiC foam (8% nominal density)	95
Table 26.3-8 – Example of properties of various metallic foams	96
Table 26.3-9 – Adhesive material systems for sandwich structures	98
Table 26.6-1 - Comparison of sandwich shell failure load predictions	126
Table 26.7-1 – Sandwich plates: Wrinkling test samples	136
Table 28.8-1 - Typical moisture exposure schedule	198

Table 28.8-2 - Basic comparison of moisture absorbing properties of a cyanate ester and epoxy matrix resin	200
Table 28.11-1 - Antenna structures: Advantages and limitations of sandwich structures	204
Table 28.13-1 - IR and X-ray telescopes: Candidate CFRP materials for PSR	220
Table 29.2-1 - High strength carbon fibres for potentially mass efficient pressure vessels	252
Table 29.3-1 - Typical space system pressure vessel specification	254
Table 29.3-2 - Data on liner materials (material state in prestressed vessel)	259
Table 29.3-3 - Performance of pressure vessels made by SCI, (USA), for satellite use	262
Table 29.3-4 - Stress-rupture lifetime probabilities for various fibres	263
Table 29.3-5 - Performance requirements for INTELSAT VII pressurant tank	264
Table 29.3-6 - Tank mass summary	264
Table 29.3-7 - Characteristics of Aerospatiale CFRP/Ti spherical pressurant vessels	266
Table 29.5-1 - Pressure vessels: Proposed safety factors for space applications	269
Table 29.6-1 - Isotensoid pressure vessels: Example layout factors	273
Table 29.6-2 - Pressure vessels: Function of the different layers, as on MAGE construction	275
Table 29.7-1 - Pressure vessels: Typical elastomer property data, at RT	279
Table 29.9-1 - Worldwide list of solid propellant motors with composite cases	292
Table 29.9-2 - Characteristics of MAGE and IRIS rocket motors	294
Table 29.9-3 - Safety factors applied to IRIS/EBM cases for unmanned operation	296
Table 29.9-4 - Design values for the EBM case	296
Table 29.9-5 - IRIS/EBM winding angles	298
Table 29.9-6 - Booster motor case details for Ariane 4 and 5	303
Table 29.10-1 - Technical characteristics for HPV GAT and GAM	305
Table 29.12-1 - Olympus central cylinder characteristics	313
Table 29.12-2 - British Aerospace EUROSTAR central cylinder	315
Table 30.6-1 - Ariane 4 vehicle equipment bay: Geometry, materials and mass of major component parts	342
Table 30.8-1 - Ariane 4 SPELDA: Geometry	349
Table 30.8-2 - Ariane 4 SPELDA: Strength and stiffness charachteristics	350
Table 30.8-3 - Ariane 4 SPELDA: Final mass	350
Table 30.13-1 – Triax ULR: Qualification status of 2.2 m, 2nd generation reflector	376

European Foreword

This document (CEN/TR 17603-32-03:2022) has been prepared by Technical Committee CEN/CLC/JTC 5 "Space", the secretariat of which is held by DIN.

It is highlighted that this technical report does not contain any requirement but only collection of data or descriptions and guidelines about how to organize and perform the work in support of EN 16603-32.

This Technical report (CEN/TR 17603-32-03:2022) originates from ECSS-E-HB-32-20 Part 3A.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

This document has been developed to cover specifically space systems and has therefore precedence over any TR covering the same scope but with a wider domain of applicability (e.g.: aerospace).

Introduction

The Structural materials handbook is published in 8 Parts.

A glossary of terms, definitions and abbreviated terms for these handbooks is contained in Part 8.

The parts are as follows:			
TR 17603-32-01	Part 1	Overview and material properties and applications	Clauses 1 - 9
TR 17603-32-02	Part 2	Design calculation methods and general design aspects	Clauses 10 - 22
TR 17603-32-03	Part 3	Load transfer and design of joints and design of structures	Clauses 23 - 32
TR 17603-32-04	Part 4	Integrity control, verification guidelines and manufacturing	Clauses 33 - 45
TR 17603-32-05	Part 5	New advanced materials, advanced metallic materials, general design aspects and load transfer and design of joints	Clauses 46 - 63
TR 17603-32-06	Part 6	Fracture and material modelling, case studies and design and integrity control and inspection	Clauses 64 - 81
TR 17603-32-07	Part 7	Thermal and environmental integrity, manufacturing aspects, in-orbit and health monitoring, soft materials, hybrid materials and nanotechnoligies	Clauses 82 - 107
TR 17603-32-08	Part 8	Glossary	

koniec náhľadu – text ďalej pokračuje v platenej verzii STN