

DIN CEN/TR 13121-5:2020-11 (E)

GRP tanks and vessels for use above ground - Part 5: Example calculation of a GRP-vessel

Contents		Page
European foreword		5
Introduction		6
1	Scope	7
2	General	7
3	Dimensions of the tank	7
4	Building materials	9
5	Loadings (9)	9
6	Limit strain for laminate (8.2.2)	11
7	Influence factors (7.9.5.2)	11
8	Partial safety factors (Table 12)	12
9	Combination factors (Table 11)	12
10	Analysis of the cylinder	12
10.1	Influence factor A5	12
10.2	Characteristic strength values	13
10.3	Moduli of elasticity	13
10.4	Analysis of the cylinder in axial direction	13
10.4.1	Proof of strength (Ultimate limit state)	14
10.4.2	Proof of strain (Serviceability limit state)	17
10.4.3	Stability proof (Ultimate limit state)	19
10.5	Analysis of the cylinder in tangential direction	21
10.5.1	Strength analysis (Ultimate limit state)	21
10.5.2	Proof of strain (Serviceability limit state)	23
10.5.3	Stability proof for the cylindrical shell tangential (Ultimate limit state)	23
10.5.4	Critical buckling pressure for rings (Ultimate limit state)	24
10.6	Earthquake design of the cylinder	26
10.6.1	Analysis of the cylinder in axial direction	26
10.6.2	Analysis of the cylinder in tangential direction	29
11	Opening in the cylinder	30
11.1	Analysis in circumferential direction	31
11.1.1	Proof of strength	31
11.1.2	Proof of strain	31
11.2	Analysis in axial direction	32
11.2.1	Proof of strength	32
11.2.2	Proof of strain	32
12	Analysis of the skirt	33
12.1	Internal forces of the skirt	33
12.2	Proof of strength (Ultimate limit state)	34
12.2.1	Design value of actions	34

12.2.2	Design value of corresponding resistance	34
12.2.3	Verification	35
12.3	Proof of strain (Serviceability limit state)	35
12.3.1	Design value of actions	35
12.3.2	Limit design value of serviceability criterion	35
12.3.3	Verification	35
12.4	Stability proof (Ultimate limit state)	35
12.4.1	Design value of actions	35
12.4.2	Design value of corresponding resistance	36
12.4.3	Verification	36
12.5	Earthquake design of the skirt	36
12.5.1	Internal forces Earthquake	36
12.5.2	Proof of strength (Ultimate limit state)	37
12.5.3	Proof of strain (Serviceability limit state)	37
12.5.4	Stability proof (Ultimate limit state)	38
13	Overlay laminate connection skirt - vessel	39
13.1	Proof of strength (Ultimate limit state)	39
13.1.1	Design value of actions	39
13.1.2	Design value of corresponding resistance	40
13.1.3	Verification	40
13.2	Proof of strain (Serviceability limit state)	40
13.2.1	Design value of actions	40
13.2.2	Limit design value of serviceability criterion	40
13.2.3	Verification	40
13.3	Seismic design of the skirt overlay	41
13.3.1	Proof of strength (Ultimate limit state)	41
13.3.2	Proof of strain (Serviceability limit state)	41
14	Analysis of the bottom	42
14.1	Influence factor A5	42
14.2	Characteristic strength values	42
14.3	Moduli of elasticity	42
14.4	Actions, which cause internal forces for the bottom	42
14.5	Strength analysis (Ultimate limit state)	42
14.5.1	Design value of actions	42
14.5.2	Proof of strain (Serviceability limit state)	44
14.5.3	Stability proof of the bottom (Ultimate limit state)	45
15	Lower part of the cylinder (Region 1)	46
15.1	Strength analysis (Ultimate limit state)	46
15.1.1	Design value of corresponding resistance	47
15.1.2	Verification	47
15.2	Proof of strain (Serviceability limit state)	47
15.2.1	Design value of actions	47
15.2.2	Limit design value of serviceability criterion	47
15.2.3	Verification	47
15.3	Earthquake design of region 1 (Ultimate limit state)	48
15.3.1	Strength analysis (Ultimate limit state)	48
15.3.2	Proof of strain (Serviceability limit state)	48
16	Upper part of the skirt (Region 2)	49
16.1	Strength analysis (Ultimate limit state)	49
16.1.1	Design value of corresponding resistance	50
16.1.2	Verification	50
16.2	Proof of strain (Serviceability limit state)	50
16.2.1	Design value of actions	50
16.2.2	Limit design value of serviceability criterion	50
16.2.3	Verification	50
16.3	Seismic design of region 2 (Ultimate limit state)	51
16.3.1	Strength analysis (Ultimate limit state)	51
16.3.2	Design value of corresponding resistance	51

16.3.3	Verification	51
16.4	Proof of strain (Serviceability limit state)	51
16.4.1	Design value of actions	51
16.4.2	Limit design value of serviceability criterion	51
16.4.3	Verification	52
17	Flange design	52
18	Anchorage	57
18.1	Anchorage for wind loads (Permanent / Transient situation)	57
18.1.1	Uplifting anchor force	57
18.1.2	Anchor shear force	57
18.2	Anchorage for seismic loads (Seismic design situation)	57
18.2.1	Uplifting anchor force	57
18.2.2	Anchor shear force	58