# 混凝土强度和弹性模量计算技术规程

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# 目录

# 1.BSEN1992-1-1：2004

依据《BSEN1992-1-1：2004》中表 3.1，混凝土圆柱体抗压强度与其他类型强度和弹性模量的换算公式如下表所示：

**表 3.1：混凝土强度与变形特征值**

| 混凝土强度等级 | | | | | | | | | | | | | | | 分析关联/解释 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $f_{ck}$ (MPa) | 12 | 16 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 70 | 80 | 90 | |
| $f_{ck,cube}$ (MPa) | 15 | 20 | 25 | 30 | 37 | 45 | 50 | 55 | 60 | 67 | 75 | 85 | 95 | 105 | |
| $f_{cm}$ (MPa) | 20 | 24 | 28 | 33 | 38 | 43 | 48 | 53 | 58 | 63 | 68 | 78 | 88 | 98 | $f_{cm}=f_{ck}+8(MPa)$ |
| $f_{ctm}$ (MPa) | 1.6 | 1.9 | 2.2 | 2.6 | 2.9 | 3.2 | 3.5 | 3.8 | 4.1 | 4.2 | 4.4 | 4.6 | 4.8 | 5.0 | $f_{ctm}=0.30\times f_{ck}^{(2/3)}\le C50/60$<br>$f_{ctm}=2.12\cdot\ln(1+(f_{cm}/10))$<br>$>C50/60$ |
| $f_{ctk,0.05}$ (MPa) | 1.1 | 1.3 | 1.5 | 1.8 | 2.0 | 2.2 | 2.5 | 2.7 | 2.9 | 3.0 | 3.1 | 3.2 | 3.4 | 3.5 | $f_{ctk;0.05}=0.7\times f_{ctm}$<br>5%分位 |
| $f_{ctk,0.95}$ (MPa) | 2.0 | 2.5 | 2.9 | 3.3 | 3.8 | 4.2 | 4.6 | 4.9 | 5.3 | 5.5 | 5.7 | 6.0 | 6.3 | 6.6 | $f_{ctk;0.95}=1.3\times f_{ctm}$<br>95%分位 |
| $E_{cm}$ (GPa) | 27 | 29 | 30 | 31 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 41 | 42 | 44 | $E_{cm}=22[(f_{cm})/10]^{0.3}$<br>（$f_{cm}$单位：MPa） |

依据《BSEN1992-1-1：2004》中表 2.1，混凝土材料系数如下表所示：

1、材料系数

**表 2.1N：材料承载能力极限状态的分项系数**

| 设计条件 | 混凝土$\gamma_c$ | 钢筋 $\gamma_s$ | 预应力钢筋 $\gamma_s$ |
|---|---|---|---|
| 持久与瞬时 | 1.5 | 1.15 | 1.15 |
| 偶然 | 1.2 | 1.0 | 1.0 |

换算过程表如图所示：

| EN混凝土强度和弹性模量 | | | | |
|---|---|---|---|---|
| | | 参数 | 结果 | 单位 |
| 输入参数 | 圆柱体抗压强度 | $f_{ck}$ | 120 | Mpa |
| 过程参数 | 实际养护强度标准值 | $f_{cm}$ | 128 | Mpa |
| | 混凝土抗拉强度标准值（≤C50） | $f_{ctm1}$ | 7.298642395 | Mpa |
| | 混凝土抗拉强度标准值（>C50） | $f_{ctm2}$ | 5.564297415 | Mpa |
| | 混凝土抗拉强度标准值（最终） | $f_{ctm}$ | 5.564297415 | Mpa |
| | 混凝土抗拉强度标准值（5%保证率） | $f_{ctk,0.05}$ | 3.895008191 | Mpa |
| | 混凝土抗拉强度标准值（95%保证率） | $f_{ctk,0.95}$ | 7.23358664 | Mpa |
| | 灌浆/混凝土材料疲劳系数 | 混凝土材料安全系数 | 1.5 | |
| 输出结果 | 弹性模量 | $E_{cm}$ | 47.27000756 | Gpa |
| | 抗压强度设计值 | 抗压强度设计值$f_{cd}$ | 80 | Mpa |
| | 抗拉强度设计值 | 抗拉强度设计值$f_{td}$ | 2.596672127 | Mpa |

## 2.DNV-ST-0126

（1）现场抗压强度标准值

依据《DNVGL-ST-0126-2018 Support structures for wind turbines》中 6.3.2.3 节，混凝土圆柱体抗压强度与现场抗压强度标准值的换算公式如下所示：

**6.3.2.3** Additionally, the variation of results that has to be expected for in-situ conditions offshore has to be considered in the design for high strength grout by an additional including allowance. The characteristic compression strength, $f_{ck}$, shall be converted to characteristic in-situ compression strength, $f_{cn}$, by means of the following formula:

$$f_{cn} = f_{ck}\left(1 - \frac{f_{ck}}{600}\right)$$

where:

$f_{ck}$ = characteristic grout cylinder strength [MPa].

（2）现场抗拉强度标准值

依据《DNV-ST-C502Standard_for_Offshore_Concrete_Structures》中 4.3.3.4 节，混凝土圆柱体抗压强度与现场抗拉强度标准值的换算公式如下所示：（注意这里使用C502，是由于0126中抗拉强度标准值与圆柱体抗压强度的关系未给出，DNV-ST-0126 对应 6.3.2.5 节）

**4.3.3.4** The normalized in-situ tensile strength, $f_{tn}$, of normal weight concrete shall be determined from the following formula for concrete with concrete grade between C35 and C90:

$$f_{tn} = f_{tk} \cdot (1-(f_{tk}/25)^{0.6})$$

where:

$f_{tk} = 0.48\ (f_{cck})^{0.5}$

$f_{tk}$ may alternatively be determined in accordance with the provisions in [4.3.3.12] or [4.3.3.13].

For $f_{cck,}$ larger than 65 MPa, testing is required to determine $f_{tk}$.

依据《DNV-ST-C502Standard_for_Offshore_Concrete_Structures》中 4.3.3.6

节，C90 以下标准强度混凝土各强度关系换算如下：

**4.3.3.6** Normal weight concrete has grades identified by [4.3] and lightweight aggregate concrete grades are identified by the symbol LC. The grades are defined in Table 4-2 and Table 4-3 as a function of the characteristic compression cylinder strength of concrete, $f_{cck}$.

**Table 4-2 Properties for normal weight (NW) concrete grades**

| *Concrete grade* | *C30* | *C35* | *C40* | *C45* | *C50* | *C55* | *C60* | *C65* | *C70* | *C80* | *C90* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $f_{cck}$ [MPa] 1) | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 80 | 90 |
| $f_{cn}$ [MPa] 2) | 28.5 | 33.0 | 37.3 | 41.6 | 45.8 | 50.0 | 54.0 | 58 | 61.8 | 69.3 | 76.5 |
| $f_{tk}$ [MPa] 3) | 2.63 | 2.84 | 3.04 | 3.22 | 3.39 | 3.56 | 3.72 | 3.87 | 4.02 | 4.29 | 4.55 |
| $f_{tn}$ [MPa] 4) | 1.95 | 2.07 | 2.18 | 2.28 | 2.37 | 2.45 | 2.53 | 2.61 | 2.68 | 2.80 | 2.91 |

1) $f_{cck}$ = characteristic cylinder compressive strength
2) $f_{cn}$ = normalized in-situ compression strength
3) $f_{tk}$ = characteristic mean tensile strength
4) $f_{tn}$ = normalized in-situ tensile strength

（3）弹性模量

依据《DNVGL-ST-0126-2018 Support structures for wind turbines》中 4.3.3.15 节，混凝土圆柱体抗压强度与弹性模量的换算公式如下所示：

**4.3.3.15** The normalized Young's modulus of concrete is controlled by the Young's modulus of its components. Approximate values for the Young's modulus $E_{cn}$, is taken as the secant value between $\sigma_c = 0$ and 0.4 $f_{cck}$. Approximate values for quartzite aggregates may be determined from the following equation:

$$E_{cn} = 22\,000 \cdot (f_{cck}/10)^{0.3} \text{ MPa for } f_{cck} \le 70\text{MPa}$$
$$E_{cn} = 4800 \cdot (f_{cck})^{0.5} \text{ MPa for } f_{cck} > 70 \text{ MPa}$$

（4）抗压强度设计值和抗拉强度设计值

依据《DNVGL-ST-0126-2018 Support structures for wind turbines》中 6.3.2.6 节，混凝土圆柱体抗压强度与弹性模量的换算公式如下所示：

**6.3.2.6** The design strengths of the grout material in compression and tension are found by dividing the characteristic in-situ strengths $f_{cn}$ and $f_{tn}$ by a material factor:

$$f_{cd} = f_{cn}/\gamma_m$$
$$f_{td} = f_{tn}/\gamma_m$$

Requirements for the material factor $\gamma_m$ are specified with each individual application in [6.4.1].

依据《DNVGL-ST-0126-2018 Support structures for wind turbines》中表 6.1，材料系数如下所示：

**Table 6-1 Requirements for material factor $\gamma_m$ for grout depending on type and load case**

| *Type of grouted connection* | *Load case* | *Material factor $\gamma_m$* |
|---|---|---|
| Cylindrical grouted connections with shear keys | ULS | 2.0 |
| Conical grouted connections | ULS | 1.5 |
| Cylindrical grouted connections with shear keys | FLS | 1.5 |
| Cylindrical grouted connections with shear keys | ALS | 1.7 |
| Conical grouted connections | ALS | See Table 5-2 in [5.4.1] |
| All | SLS | 1.0 |



依据《DNV-ST-C502Standard_for_Offshore_Concrete_Structures》中表 6.1，材料安全系数如下表所示：

**Table 6-1 Material coefficients for concrete and reinforcement**

| *Material* | *Symbol* | *Ultimate ULS* | *Fatigue FLS* | *Accidental ALS* | *Serviceability SLS* |
|---|---|---|---|---|---|
| Reinforced concrete/grout[3)] (steel) | $\gamma_c$ | 1.50[1)] (1.35)[2)] | 1.50[1)] (1.35)[2)] | 1.30[1)] (1.20)[2)] | 1.00 |
| Steel reinforcement | $\gamma_s$ | 1.25[1)] (1.15)[2)] | 1.10[1)] (1.00)[2)] | 1.10[1)] (1.00)[2)] | 1.00 |