Supplementary Material

Quantification of anthropogenic metabolism using spatially differentiated continuous MFA

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Additional information to section 2.7

<u>DAfStb (Deutscher Ausschuss für Stahlbeton) = German Committee for Reinforced Concrete:</u>

The German committee for reinforced concrete (DAfStb) is a nationally and internationally recognized and respected technical-scientific panel for the promotion of concrete construction for more than 100 years. The DAfStb forms the platform on which the main activities of concrete and reinforced concrete construction in the field of research and control converge. The DAfStb acts as the publisher of a series of publications with technical scientific content for the documentation and updating of developments in concrete construction. The publication of guidelines as a further pillar of the DAfStb serves to transfer the research results achieved as soon as possible into practical application. The DAfStb guideline "Concrete acc. to DIN EN 206-1 and DIN 1045-2 with RA acc. to DIN EN 12620, Part 1: Requirements for the concrete for dimensioning in accordance with DIN EN 1992-1-1" is one of these guidelines having the character of a technical code.

<u>Exposure classes under EN 206:2013:</u>

Exposure conditions are chemical and physical conditions to which the concrete structure is exposed and are classified in exposure classes (EN 206:2013).

Table 1: Exposure classes related to environmental conditions (EN 206:2013):

Class designation	**Description of the environment**	**Informative examples where exposure classes may occur**
1 No risk of corrosion or attack		
X0	For concrete without reinforcement or embedded metal: all exposures except where there is freeze/thaw, abrasion or chemical attack For concrete with reinforcement or embedded metal: very dry	Concrete inside buildings with very low air humidity
2 Corrosion induced by carbonation		
XC1	Dry or permanently wet	Concrete inside buildings with low air humidity Concrete permanently submerged in water
XC2	Wet, rarely dry	Concrete surfaces subject to long-term water contact Many foundations
XC3	Moderate humidity	Concrete inside buildings with moderate or high air humidity External concrete sheltered from rain
XC4	Cyclic wet and dry	Concrete surfaces subject to water contact, not within exposure class XC2

3 Corrosion induced by chlorides		
XD1	Moderate humidity	Concrete surfaces exposed to airborne chlorides
XD2	Wet, rarely dry	Swimming pools Concrete components exposed to industrial waters containing chlorides
XD3	Cyclic wet and dry	Parts of bridges exposed to spray containing chlorides Pavements Car park slabs
4 Corrosion induced by chlorides from sea water		
XS1	Exposed to airborne salt but not in direct contact with sea water	Structures near to or on the coast
XS2	Permanently submerged	Parts of marine structures
XS3	Tidal, splash and spray zones	Parts of marine structures
5. Freeze/Thaw Attack		
XF1	Moderate water saturation, without de-icing agent	Vertical concrete surfaces exposed to rain and freezing
XF2	Moderate water saturation, with de-icing agent	Vertical concrete surfaces of road structures exposed to freezing and airborne de-icing agents
XF3	High water saturation, without de-icing agents	Horizontal concrete surfaces exposed to rain and freezing
XF4	High water saturation with de-icing agents or sea water	Road and bridge decks exposed to de-icing agents Concrete surfaces exposed to direct spray containing de-icing agents and freezing Splash zone of marine structures exposed to freezing
6. Chemical attack		
XA1	Slightly aggressive chemical environment according to EN 206-1, Table 2	Natural soils and ground water
XA2	Moderately aggressive chemical environment according to EN 206-1, Table 2	Natural soils and ground water
XA3	Highly aggressive chemical environment according to EN 206-1, Table 2	Natural soils and ground water

Additional information to section 3.4

The assumption of 72% by volume forms an average value for the fraction of concrete aggregates in concrete, which was calculated by a mixture calculation. The amount of cement, aggregates, water, additives and fibers required for 1 m³ of concrete are to be determined by a mixture calculation. The individual quantities are determined in each case including the surface moisture of the aggregates with a material-volume-calculation, whereby 1 m³ of concrete is composed of the volume fractions of the individual substances and the pore content. The volume fraction for each substance has to be calculated by $V = M / \rho$ (volume = mass / bulk density). The following equation defines the composition of 1 m³ of concrete and form the basis of a mixture calculation:

$$1\ m^3 = c / \rho_c + w / \rho_w + g / \rho_g + p + a / \rho_a$$

With
c: cement content [kg]
w: water content [kg]
g: aggregate content (grains) [kg]
p: pore volume [m³]

f: content of additives [kg]
ρ_c: gross density of cement [kg / m³]
ρ_w: gross density of water [kg / m³]
ρ_g: gross density of the individual grains of the aggregate [kg / m³]
ρ_a: gross density of additives [kg / m³]

Given some typical input values of the individual substances for a normal (standard) concrete:

- Mass of cement: c = 300 kg
- Gross density of cement: ρ_c = 3,000 kg / m³
- Volume of water: w / ρ_w = 160 l = 0.16 m³ (total, including surface moisture of aggregates)
- Volume of pores: p = 0.02 m³ (2% pore volume fraction)
- no additives (neglected)

we can calculate:

- Volume of cement: c / ρ_c = 300 kg / (3,000 kg / m³) = 0.10 m³
- Volume of aggregates:
  g / ρ_g= 1 m³ - c / ρ_c - w / ρ_w – p = 1 m³ - 0.10 m³ - 0.16 m³ - 0.02 m³ = 0.72 m³
- Volume fraction of aggregates: 0.72 m³ / 1 m³ = 0.72 = 72% by volume

It has to be mentioned here, that the volume fraction for the individual substances (e.g. cement and water) varies depending on the boundary conditions, such as exposure or strength class of the concrete or pouring requirements (e.g. requirement of additives).