Warsaw University of Technology
Faculty of Civil Engineering
Department of Building Materials Engineering

BUILDING MATERIALS

LABORATORY TASK

Modification of concrete with admixtures

Authors:
Joanna Sokołowska, Ph.D.
Kamil Załęgowski, Ph.D.

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1. Aim of the task

Assessment of the effect of the selected water reducing (plasticizing or fluidizing) admixtures on the properties of concrete mix and hardened concrete.

2. Theoretical background

2.1.Definitions

Strength class of cement – compressive strength class of cement

Concrete – a material resulting from mixing cement, coarse and fine aggregate, water and any possible admixtures and additives, which obtains its properties as a result of cement hydration.

Concrete mix – completely mixed concrete components that are able to be compacted using the chosen method.

Hardened concrete - concrete that is solid and has reached a certain level of strength.

Concrete produced at the construction site – concrete produced at the construction site by the contractor for his own use.

Commodity concrete – concrete delivered as a concrete mix by a person or entity who is not a contractor.

Precast concrete product – a concrete product formed and maturing at a location other than its final location.

Ordinary concrete – concrete with a dry density greater than 2000 kg/m^3 but not exceeding 2600 kg/m^3.

Lightweight concrete – concrete with a dry density of not less than 800 kg/m^3 and not more than 2000 kg/m^3. This concrete is produced using only or partly lightweight aggregate.

Heavy concrete – concrete with a dry density greater than 2600 kg/m^3.

High-strength concrete – concrete with a compressive strength class greater than C50/60 for ordinary and heavy concrete and concrete with a higher compressive strength class than LC50 /55 for lightweight concrete.

Designed concrete – concrete whose required properties and additional features are given to the manufacturer, who are responsible for delivering concrete in accordance with the required properties and additional features.

Formula concrete – concrete whose composition and components to be used are given to the manufacturer responsible for supplying concrete with such a specific composition.

Cubic meter of concrete – the amount of concrete mix that, when compacted in accordance with the procedure given in EN 12350-6, occupies a volume of one cubic meter.

Admixture – a component added during the mixing process of a concrete mix in small amounts in relation to the weight of cement to modify the properties of the concrete mix or hardened concrete**.**

Additive – a fine-grained component used for concrete to improve certain properties or obtain special properties; usually added in quantities above 5% of cement; the additive can significantly modify the properties of both concrete mix and hardened concrete.

Aggregate – granular material used in construction; aggregate can be natural, artificial or recycled.

Cement – finely ground inorganic material, which – when mixed with water – gives a cement paste, setting and hardening as a result of hydration reactions and processes, and after hardening remains strong and durable, also under water.

Water/cement ratio – ratio of the effective water content to the mass content of cement in the concrete mix..

Characteristic strength – the value of strength below which may be 5% of the population of all possible strength determinations for a given volume of concrete.

2.2.Introduction to concrete modifying

Admixtures are materials added to the mixing water when making the concrete mix, not exceeding the amount of 5% of the cement mass. Modifying the concrete mix with admixtures is aimed at improving/changing the properties of both the concrete mix and hardened concrete. Detailed information on admixtures, including their characteristics, impact on the properties of concrete and concrete mix and the recommended dosage method, are provided on the packaging labels by manufacturers. It should be noted that the effectiveness of admixtures directly depends on their compatibility with the other components of the concrete mix..

Depending on the effect on the properties of the concrete mix or hardened concrete, admixtures can be divided into groups:

- plasticizing and fluidizing,
- air entering,
- delaying and accelerating the cement setting process,
- sealing
- anti-frost.

Admixtures can affect the properties of concrete mix and hardened concrete as follows:

- improvement of concrete mix workability,
- change in concrete mix consistence,
- adjustment of setting and hardening conditions,

- waterproofing concrete mix and concrete, resulting in increased frost resistance,
- enabling concreting at temperatures close to 0°C,
- loosening of the concrete mix,
- change in concrete tint.

As a result of the use of admixtures, one can obtain benefits such as:

- reducing the amount of water in the concrete mix,
- change in consistence of the concrete mix,
- reduction in the amount of cement,
- increase of concrete strength,
- increase of concrete durability,

The listed benefits cannot be obtained simultaneously.

3. Practical tasks

3.1. Coefficient of activity of mineral additive

3.1.1. Materials and equipment

- Cement,
- Admixture
- Tap water,
- Natural aggregate of fractions: 0/2 mm, 2/4 mm, 4/8 mm and 8/16 mm,
- Scale,
- Plastic bowls,
- Metal spoons,
- Proper set for testing the concrete mix consistence (e.g. for Vebe test, slump test),
- Concrete cube molds of dimensions 15 x 15 x15 cm,
- Antiadhesive agent,
- Brush,
- Vibrator.

3.1.2. Task completion

Modifying of concrete mix with the admixture should be done according to the following stages:

I. Preliminary assumptions for the concrete mix and concrete

- Assumptions regarding the components for making concrete mixes - type and class of cement, type of aggregate, water.

- Assuming the composition of the initial standard concrete mix per 1 m^3 without admixture (M1) - composition from the previous exercises (Table 1).

Table 1. Starting (reference) composition of concrete mix per 1 m^3 (*M1*)

Component		Mass [kg]
cement		
water		
Aggregate	0/2 mm	
	2/4 mm	
	4/8 mm	
	8/16 mm	

- Assuming the type and amount of admixture *D* (mass according to the cement mass).

II. Preparation and verification of concrete mix without admixture (*M1*)

Please follow the steps below:

- Prepare a test mix of ordinary concrete without any admixture (*M1*) of the theoretical volume (*Vt*) sufficient to carry out the assumed tests of the concrete mix and hardened concrete. Dose the ingredients in the following order: aggregate from the coarsest to the finest fraction, cement and water;
- Examine the consistence of the concrete mix using the slump test method and determine the consistence class;
- Examine the actual volume of the test mix (*Vr*);
- Calculate the density of the concrete mixer: $\rho_{mb} = \frac{m}{V_r}$ [kg/m^3]

  where: *m* – total mass of all used components [kg],

  V_r – volume of the test mix [m^3].
- Calculate the masses of the components of the concrete mix per 1 m^3 (only if $V_r \neq V_t$):

$$C_2 = \frac{C}{V_r} * 1000 \ \text{[kg]} \qquad W_2 = \frac{W}{V_r} * 1000 \ \text{[kg]} \qquad A_2 = \frac{A}{V_r} * 1000 \ \text{[kg]}$$

where: C_2 – cement mass per 1 m^3 of concrete mix [kg], *C* – cement mass in trial concrete mix [kg], W_2 – water mass per 1 m^3 of concrete mix [kg], *W* – water mass in trial concrete mix [kg], A_2 – aggregate mass per 1 m^3 of concrete mix [kg], *A* – aggregate mass in trial concrete mix.

- Check the equation of absolute volume:

$$\frac{C}{\varrho_C} + \frac{A}{\varrho_A} + W = 1000 \pm 2\%$$

where: C – cement mass per 1 m^3 of concrete mix [kg], ρ_C – cement density ($\rho_C = 3{,}100\ \mathrm{kg/dm^3}$), A – aggregate mass per 1 m^3 of concrete mix [kg], ρ_A – aggregate density ($\rho_A = 2{,}65\ \mathrm{kg/dm^3}$), W – water mass per 1 m^3 of concrete mix [kg].

If the condition is not met, the contents of components should be corrected.

- Calculate the predicted average (mean) strength f_{cm} and concrete compressive strength class of the concrete C X/Y using the Bolomey equation and the relation between the characteristic and mean compressive strength:

$$f_{cm} = A_{1,2} * \left(\frac{C}{W} \mp 0{,}5\right)$$

$$f_{cm} = f_{ck} + 2\sigma$$

where: f_{cm} – average (mean) compressive strength [MPa], A_1 and A_2 – coefficients depending on the cement class and type of aggregate, C - mass of cement, W - water mass, f_{ck} - characteristic compressive strength [MPa], 2σ - compressive strength reserve (adopts equal to standard deviation if known, and if it is not known according to the standard, the value of $2\sigma = 3 \div 6$ MPa is assumed);

- Give the final concrete composition per 1 m^3 and fill the data in Tab.2.

III. Preparation and verification of concrete mix with an admixture (*M2*)

Please follow the steps below:

- Modify the composition of the *M1* concrete mix of the volume *Vt* with an admixture in the assumed amount. Make a trial mix, dosing the components in the following order: aggregate from the coarsest to the finest fraction, cement and water with admixture.
- Examine the consistence of the concrete mix using the slump test method and determine the consistence class;
- Examine the actual volume of the trial mix (*Vr*);
- Calculate the density of the concrete mixer: $\rho_{mb} = \frac{m}{V_r}$ [kg/m^3]

  where: m – total mass of all used components [kg],

  V_r – volume of the test mix [m^3].
- Calculate the masses of the components of the concrete mix per 1 m^3 (only if $V_r \neq V_t$):

$$C_2 = \frac{C}{V_r} * 1000\ \text{[kg]} \qquad W_2 = \frac{W}{V_r} * 1000\ \text{[kg]} \qquad A_2 = \frac{A}{V_r} * 1000\ \text{[kg]}$$

where: C_2 – cement mass per 1 m^3 of concrete mix [kg], C – cement mass in trial concrete mix [kg], W_2 – water mass per 1 m^3 of concrete mix [kg], W – water mass in trial concrete mix [kg], A_2 – aggregate mass per 1 m^3 of concrete mix [kg], A – aggregate mass in trial concrete mix.

- Check the equation of absolute volume:

$$\frac{C}{\varrho_c} + \frac{A}{\varrho_A} + W = 1000 \pm 2\%$$

where: C – cement mass per 1 m^3 of concrete mix [kg], ρ_C – cement density ($\rho_C = 3{,}100\ \mathrm{kg/dm^3}$), A – aggregate mass per 1 m^3 of concrete mix [kg], ρ_A – aggregate density ($\rho_A = 2{,}65\ \mathrm{kg/dm^3}$), W – water mass per 1 m^3 of concrete mix [kg].

If the condition is not met, the contents of components should be corrected.

- Calculate the predicted average (mean) strength f_{cm} and concrete compressive strength class of the concrete C X/Y using the Bolomey equation and the relation between the characteristic and mean compressive strength:

$$f_{cm} = A_{1,2} * \left(\frac{C}{W} \mp 0{,}5\right)$$

$$f_{cm} = f_{ck} + 2\sigma$$

where: f_{cm} – average (mean) compressive strength [MPa], A_1 and A_2 – coefficients depending on the cement class and type of aggregate, C - mass of cement, W - water mass, f_{ck} - characteristic compressive strength [MPa], 2σ - compressive strength reserve (adopts equal to standard deviation if known, and if it is not known according to the standard, the value of 2σ = 3 ÷ 6 MPa is assumed);

- Give the final concrete composition per 1 m^3 and fill the data in Tab.2.

IV. Preparation and verification of concrete mix with an admixture and reduced amount of water (*M3*)

Please follow the steps below:

- The preparation of a trial mix with the theoretical volume *Vt*, should be carried out when dosing the components in the following order: aggregate from the coarsest to the finest fraction, cement, part of the mixing water with admixture, and then the rest of the water in the amount necessary to maintain the consistency of the concrete mix *M1*;
- Examine the consistence of the concrete mix using the slump test method and determine the consistence class;
- Examine the actual volume of the trial mix (*Vr*);
- Calculate the density of the concrete mixer: $\rho_{mb} = \frac{m}{V_r}$ [kg/m^3]

  where: m – total mass of all used components [kg],

  V_r – volume of the test mix [m^3].
- Calculate the masses of the components of the concrete mix per 1 m^3 (only if $V_r \neq V_t$):

$$C_2 = \frac{C}{V_r} * 1000 \ \text{[kg]} \qquad W_2 = \frac{W}{V_r} * 1000 \ \text{[kg]} \qquad A_2 = \frac{A}{V_r} * 1000 \ \text{[kg]}$$

where: C_2 – cement mass per 1 m^3 of concrete mix [kg], C – cement mass in trial concrete mix [kg], W_2 – water mass per 1 m^3 of concrete mix [kg], W – water mass in trial concrete mix [kg], A_2 – aggregate mass per 1 m^3 of concrete mix [kg], A – aggregate mass in trial concrete mix.

- Check the equation of absolute volume:

$$\frac{C}{\varrho_c} + \frac{A}{\varrho_A} + W = 1000 \pm 2\%$$

where: C – cement mass per 1 m^3 of concrete mix [kg], ρ_C – cement density ($\rho_C = 3{,}100 \text{ kg/dm}^3$), A – aggregate mass per 1 m^3 of concrete mix [kg], ρ_A – aggregate density ($\rho_A = 2{,}65 \text{ kg/dm}^3$), W – water mass per 1 m^3 of concrete mix [kg].

If the condition is not met, the contents of components should be corrected.

- Calculate the predicted average (mean) strength f_{cm} and concrete compressive strength class of the concrete C X/Y using the Bolomey equation and the relation between the characteristic and mean compressive strength:

$$f_{cm} = A_{1,2} * \left(\frac{C}{W} \mp 0{,}5\right)$$

$$f_{cm} = f_{ck} + 2\sigma$$

where: f_{cm} – average (mean) compressive strength [MPa], A_1 and A_2 – coefficients depending on the cement class and type of aggregate, C - mass of cement, W - water mass, f_{ck} - characteristic compressive strength [MPa], 2σ - compressive strength reserve (adopts equal to standard deviation if known, and if it is not known according to the standard, the value of 2σ = 3 ÷ 6 MPa is assumed);

- Give the final concrete composition per 1 m^3 and fill the data in Tab.2.

3.1.3. Results

Assessment of the influence of the admixture on the properties of the concrete mix and hardened concrete – the direct and indirect effects of using the admixture.

3.1.4. Elaboration of results

The results of the tests should be given in the Table

Table 2. Effects of the modification of the concrete mix with a fluidizing admixture (superplasticizer)

Lp.	Specification				Unit	Concrete mix		
						Reference (no admixture)	**With admixture *M2***	**With admixture and reduced water**
1.	Composition per $1m^3$	*C*	Cement		[kg]			
		K	Sand	0/2 mm	[kg]			
			Gravel	2/4 mm	[kg]			
				4/8 mm	[kg]			
				8/16 mm	[kg]			
		W	Water		[kg]			
		D	Admixture		[%]			
					[kg]			
2.	Coefficient *C/W*							
3.	Consistence	Vebe test			[s]			
		Slump test			[mm]			
4.	Concrete mix volume	V_b			[dm^3]			
5.	Concrete mix density	ρ_b			[kg/m^3]			
6.	Expected concrete compressive strength, f_{cm}				[MPa]			
7.	Change in comparison to *M1*	Water mass	ΔW		[dm^3]	-		
					[%]	-		
		Cement mass	ΔC		[kg]	-		
					[%]	-		
		Compressive strength	Δf_{cm}		[MPa]	-		
					[%]	-		

4. Laboratory report

The laboratory report should include:

I. Subject, aim and scope of research (containing basic information about tested materials/products, test methods, requirements),

II. Tests results with proper units (results obtained in the laboratory prepared in the indicated manner, e.g. put in the proper tables),

III. Conclusions (bulleted statements formulated based on the results obtained),

IV. Bibliography (list of references to the literature or www used to prepare the report).