Warsaw University of Technology

Faculty of Civil Engineering

Department of Building Materials Engineering

BUILDING MATERIALS

LABORATORY TASK

Composition of aggregate for ordinary concrete (iteration method)

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1. Aim of the task

Understanding two methods of selecting the composition of aggregate for ordinary concrete:

- empirical method of subsequent approximations (iterations),
- aggregate selection based on standard grain size distribution curves.

2. Theoretical background

2.1. Definitions

- **Aggregate** – granular material used in construction; aggregate can be natural, artificial or recycled.
- **Sand point** – the percentage content of sand fraction (0/2 mm) in the total mass composition of aggregates.
- **Empty voids** – volume of inter-grain voids (expressed in dm^3) in a unit of aggregate mass.
- **Water demand ratio of aggregate** – the amount of water (expressed in dm^3) added to 1 kg of aggregate required to obtain a concrete mix of a certain consistence.

2.2. Introduction

The determination of the aggregate composition for ordinary concrete by means of subsequent approximations method (also called the "iteration method") should be performed in a series of several experiments - as many as planned fractions in the aggregate mix. Within each series, the optimal proportion between subsequent (increasingly finer) aggregate fractions is determined. The optimal mix is characterized by the maximum bulk density value in the condensed state and the minimum total value of empty voids and water demand of aggregate. Bulk density in the condensed state of the aggregate is calculated according to formula (1). Aggregate's empty voids (cavity) is calculated according to formula (2). The aggregate's water demand ratio is calculated according to formula (3) using appropriate coefficients of the water demand of individual aggregate fractions for the indicated concrete mix consistence (the teacher will provide students with additional data regarding sand graining necessary to calculate the aggregate water demand in iteration 3).

$$\rho_{nu} = \frac{m}{V} \quad [\mathrm{kg/dm^3}] \tag{1}$$

where: ρ_{nu} – bulk density in condensed state of aggregate or aggregates mix $\left[\frac{\mathrm{kg}}{\mathrm{dm^3}}\right]$, m – mas of aggregate [kg], V – the volume of aggregate after condensing on the vibration table [dm^3].

$$j_k = \left[\frac{\rho - \rho_{nu}}{\rho}\right] * \frac{1}{\rho_{nu}} \quad \left[\frac{\mathrm{dm}^3}{\mathrm{kg}}\right] \tag{2}$$

where: j_k – empty voids (cavity) in aggregate $\left[\frac{\mathrm{dm}^3}{\mathrm{kg}}\right]$, ρ – density of the aggregate (of the material, namely the rock used as the aggregate) $\left[\frac{\mathrm{kg}}{\mathrm{dm}^3}\right]$, ρ_{nu} – bulk density in condensed state of aggregate or aggregates mix $\left[\frac{\mathrm{kg}}{\mathrm{dm}^3}\right]$.

Note: for calculations of gravel and sand aggregate cavity, as the density of the aggregate there should be used the quartz density, which is 2,650 kg/dm^3.

$$w_k = \frac{\Sigma n_i w_i}{100} \quad \left[\frac{\mathrm{dm}^3}{\mathrm{kg}}\right] \tag{3}$$

where: ρ_{nu} – bulk density in condensed state of aggregate or aggregates mix $\left[\frac{\mathrm{kg}}{\mathrm{dm}^3}\right]$, n_i – percentage of individual aggregate fractions [%], w_i – coefficient of the water demand of individual aggregate fraction for the indicated concrete mix consistence $\left[\frac{\mathrm{dm}^3}{\mathrm{kg}}\right]$.

The aggregate composition determined by the method of subsequent approximations should be presented in the form of a grading curve (cumulative relative frequency plot), which should be compared to the relevant (note: pay attention to the maximum aggregate size in the mixture, D_{max}) limit curves recommended in the standard PN-88/B-06250.

3. Practical tasks

3.1. Composition of aggregate using subsequent approximations method (iteration method)

3.1.1. Materials and equipment

- Gravel in 3 fractions (2/4 mm, 4/8 mm and 8/16 mm fractions),
- sand (fraction 0/2 mm),
- scale with an accuracy of 0.01 kg,
- metal container with a capacity of 10 dm^3,
- vibration table.

3.1.2. Task completion

The assay consists in performing 4 iterations of experiments – procedures at the stage of each iteration are given as following.

ITERATION 1 – determining the optimal ratio between gravel fractions: 4/8 mm and 8/16 mm fractions

For the measurement, take a constant mass of 8/16 mm gravel in the amount of 5.00 kg. Gravel of 4/8 mm fraction should be added to the mix in increasing amounts (the amounts are given in Table 1). The volume of the mix should be determined experimentally in a metal container with a capacity of 10 dm^3 after compacting the aggregate mix on a vibrating table for 10 seconds. The bulk density in the condensed state of the mix should be calculated on the basis of formula (1).

Table 1. The results obtained in the iteration 1 – determining the optimal composition of gravels of fraction 4/8 mm and 8/16 mm

Mix No	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Fraction 8/16 mm – percentage content in aggregate mix [%]	70	65	60	55	50	45	40
Fraction 4/8 mm – percentage content in aggregate mix [%]	30	35	40	45	50	55	60
Fraction 8/16 mm – mas [kg]	5,00	5,00	5,00	5,00	5,00	5,00	5,00
Fraction4/8 mm – mas [kg]	2,14	2,69	3,35	4,09	5,00	6,10	7,50
Mas of the mix [kg]							
Volume of the mix [dm^3]							
Bulk density in the condensed state of the mix, ρ_{nu} $\left[\frac{kg}{dm^3}\right]$							

Conclusion: The maximal bulk density in condensed state was obtained in case of a mix containing (by mass):

...........% of 4/8 mm fraction and ....% 8/16 mm fraction.

The density was ....

This mix was considered optimal in this iteration.

ITERATION 2 – determining the optimal ratio between gravel fractions:
2/4 mm and 4/16 mm (4/8 mm + 8/16 mm)

At this stage, the mix of the 4/8 mm and 8/16 mm fractions in the proportion set in iteration 1 is treated virtually as one component – the optimized 4/16 mm fraction. For the measurement, take a constant mass of gravel of optimized fraction 4/16 mm in the amount of 5.00 kg, consisting of:

- 4/8 mm fraction gravel in the amount of .... kg,
- 8/16 mm fraction gravel in the amount of .... kg.

Then 2/4 mm fraction gravel should be added to the above mix in the amounts given in Table 2. The volume of the mix should be determined experimentally in a container with a capacity of 10 dm^3 after compacting the aggregate mix on a vibrating table for 10 seconds. The bulk density in the concentrated state of the mix should be calculated on the basis of formula (1).

Table 2. The results obtained in the iteration 2 – determining the optimal composition of gravels of fraction 2/4 mm and 4/16 mm

Mix No	**1**	**2**	**3**	**4**	**5**	**6**
Fraction 4/16 mm – percentage content in aggregate mix [%]	90	85	80	75	70	65
Fraction 2/4 mm – percentage content in aggregate mix [%]	10	15	20	25	30	35
Fraction 4/16 mm – mas [kg]	5,00	5,00	5,00	5,00	5,00	5,00
Fraction 2/4 mm – mas [kg]	0,55	0,88	1,25	1,67	2,14	2,69
Mas of the mix [kg]						
Volume of the mix [dm^3]						
Bulk density in the condensed state of the mix, ρ_{nu} $\left[\frac{kg}{dm^3}\right]$						

<u>Conclusion:</u> The maximal bulk density in condensed state was obtained in the case of a mixture containing (by mass):

............% of 2/4 mm fraction, ...% of 4/8 mm fraction and ....% of 8/16 mm fraction.

The density was ....

This mix was considered optimal in this iteration.

ITERATION 3 – determining the optimal ratio between sand fraction 0/2 mm and gravel fraction 2/16 mm (2/4 mm + 4/8 mm + 8/16 mm)

At this stage the optimal sand point for the concrete aggregate mix is determined. For the measurement, take a constant mass of gravel of optimized fraction 2/16 mm in the amount of 5.00 kg, consisting of:

- 2/4 mm fraction gravel in the amount of .... kg,
- 4/8 mm fraction gravel in the amount of .... kg,
- 8/16 mm fraction gravel in the amount of .... kg.

Add the sand fraction (0/2 mm) to the gravel mix in the amounts given in Table 3. The mix volume should be determined experimentally in a container with a capacity of 10 dm^3 after compacting the aggregate mix on a vibrating table for 10 seconds. The bulk density in the concentrated state of the mix should be calculated on the basis of formula (1).

Table 3. The results obtained in the iteration 3 – determining the optimal composition of sand fraction 0/2 mm and gravel fraction 2/16 mm

Mix No	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Fraction 2/16 mm – percentage content in aggregate mix [%]	70	67	64	61	58	55	52
Fraction 0/2 mm – percentage content in aggregate mix [%]	30	33	36	39	42	45	48
Fraction 2/16 mm – mas [kg]	5,00	5,00	5,00	5,00	5,00	5,00	5,00
Fraction 0/2 mm – mas [kg]	2,14	2,46	2,81	3,20	3,62	4,09	4,62
Mas of the mix [kg]							
Volume of the mix [dm^3]							
Bulk density in the condensed state of the mix, ρ_{nu} $\left[\frac{kg}{dm^3}\right]$							
Empty voids, j_k $\left[\frac{dm^3}{kg}\right]$							
Water demand*, w_k $\left[\frac{dm^3}{kg}\right]$							
Empty voids + water demand, $j_k + w_k$ $\left[\frac{dm^3}{kg}\right]$							

*) The teacher provides students with additional data on sand grain size necessary to calculate the water content of the aggregate mix.

<u>Conclusion:</u> The maximal bulk density in condensed state was obtained in the case of a mixture containing (by mass): **............% of 0/2 mm fraction (sand point)**, ...% of 2/4 mm fraction,

...........% of 4/8 mm fraction and ....% of 8/16 mm fraction. The density was .... This mix of aggregates was considered optimal.

3.1.3. Elaboration of results

The results should be presented in tables analogous to Table 1-3. The values of bulk density in condensed state (ρ_{nu} $\left[\frac{kg}{dm^3}\right]$) and the aggregate values of empty voids content (cavity) and water content of aggregate mixes ($j_k + w_k$, $\left[\frac{dm^3}{kg}\right]$]) calculated in 3 iteration (Table 3) should be additionally present in the form of two graphs depending on the value of the sand point, which are to confirm the fulfillment of the conditions of maximum density and minimum total empty voids (cavity) and water demand ratio of the optimal aggregate mix. An examples of presenting the results in the form of graphs are shown in Fig. 1. and fig. 2.

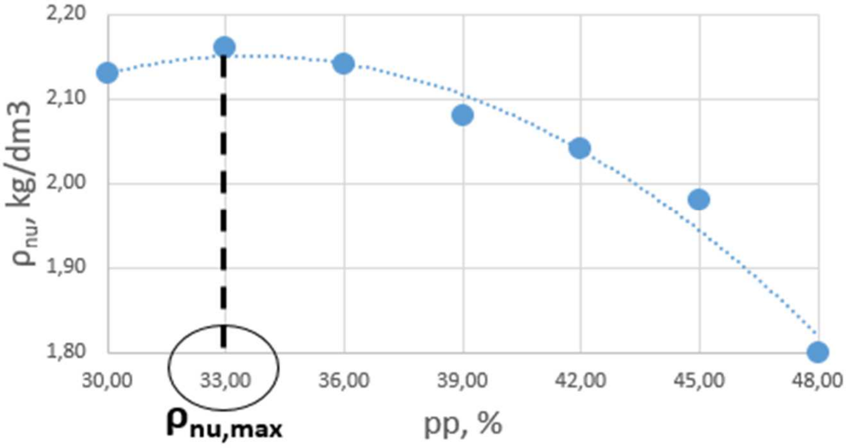

Fig.1. Relation between the bulk density in a condensed state of a mix of four aggregate fractions: 0/2 mm, 2/4 mm, 4/8 mm and 8/16 mm and the sand point value of the mix

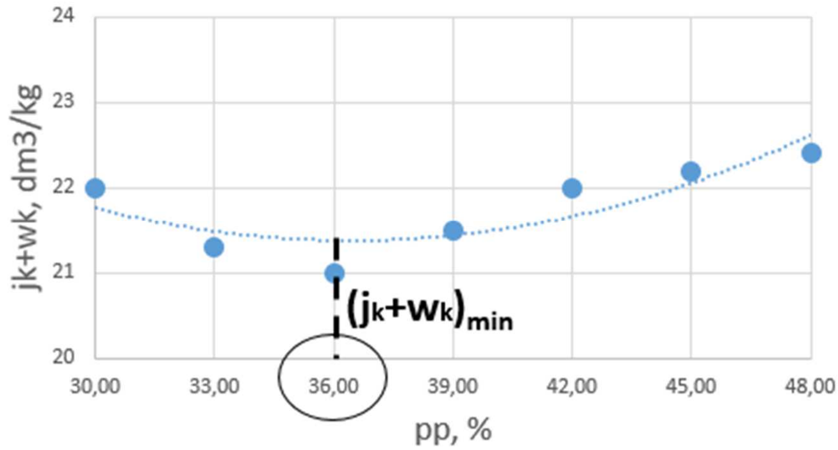

Fig.2. Relation between the value of sum of empty voids content (cavity) and water demand ratio of a mix of four aggregate fractions: 0/2 mm, 2/4 mm, 4/8 mm and 8/16 mm and the sand point value of the mix

3.1.4. Assessment of the results

The results obtained by means of the subsequent approximations method (iteration method), i.e. the grain composition of the optimized aggregate mix, should be presented in graphic form - a graph showing the mix granulation curve (cumulative plot), which should then be compared with the limiting curves of aggregate grading for concrete, exactly for aggregate with a maximum grain size of 16 mm recommended in the standard PN-88/B-06250 (Fig. 3).

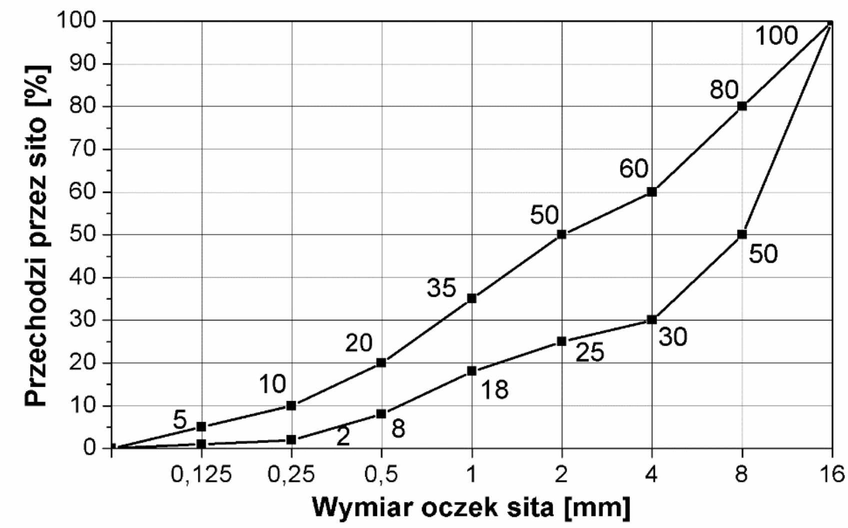

Fig.3. Limiting curves of aggregate grading for concrete with a maximum grain size of 16 mm recommended in the standard PN-88/B-06250

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).