**Warsaw University of Technology**

Faculty of Civil Engineering

Department of Building Materials Engineering

**BUILDING MATERIALS**

LABORATORY

**Concrete conformity assessment
(PN-EN 206)**

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1. **Aim of the task**

The purpose of the task is to perform compressive strength tests of specimens formed from concrete mixes that were designed during laboratory classes and to assess the compressive strength compliance with PN-EN 206.

1. **Theoretical background**
	1. **Definitions according to PN-EN 206**

**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/m3 but not exceeding 2600 kg/m3.

**Lightweight concrete** – concrete with a dry density of not less than 800 kg/m3 and not more than 2000 kg/m3. This concrete is produced using only or partly lightweight aggregate.

**Heavy concrete** – concrete with a dry density greater than 2600 kg/m3.

**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.

**Concrete family** – a group of concrete for which the relationship between the respective properties is determined and documented.

**Specification** – the final set of documented technical requirements for the execution or composition of concrete, given to the manufacturer.

**Specifier** – a person or entity setting the specification of a concrete mix and hardened concrete.

**Manufacturer** – a person or entity producing a concrete mix.

**Contractor** – a person or entity using a concrete mix to make a structure or element.

**Service life** – the period during which the condition of concrete in the structure meets the exploratory requirements related to this structure, provided that it is properly used.

**Preliminary testing** – tests or tests to check before starting production what the composition of the new concrete or concrete family should be so that it meets all the specified requirements for concrete mix and hardened concrete.

**Identity test** - a study to determine if the earnings or charges selected are from the appropriate population.

**Compliance test** - a test performed by the manufacturer to assess the compliance of concrete.

**Conformity assessment** - systematic testing of the degree to which the product meets the specified requirements.

**Verification** - confirmation or verification of objective evidence that the specified requirements have been met.

* 1. **Introduction**

Compliance control is an integral part of production control and, as defined in the PN-EN 206 standard, covers all actions and decisions taken in accordance with compliance rules adopted before checking compliance of concrete with the specification. Therefore, it is one of the activities included in the production control, which covers all aspects necessary to ensure concrete properties in accordance with the requirements, i.e.:

* selection of materials,
* concrete design,
* concrete production,
* checking and testing,
* use of test results for components, concrete mix and concrete, and equipment,
* inspection of the equipment used to transport the concrete mix (in cases concerned),
* compliance check,
* and in particular control activities in relation to:
* determining the composition of concrete, including preliminary tests,
* personnel,
* equipment and devices (storage of materials, dosing devices, concrete mixers, testing equipment),
* dosing ingredients,
* mixing the concrete mix,
* production control procedures (control of components, equipment, production procedures and concrete properties, for which detailed guidelines are given in the standard).

According to PN-EN 206, each concrete should be subject to a production control process for which the producer is responsible. Production control is one of the basic obligations of a concrete producer. The confirmation of conducting production control should be the implementation and maintenance of a documented production control system in the form of a production control book containing appropriate procedures and instructions.

In the compliance check of concrete, a distinction is made between compliance checking (1) compressive strength and (2) tensile strength and (3) checking properties other than strength. The most important, because concerning the basic property of hardened concrete is the control of compliance of compressive strength, which certifies the strength class of concrete. This assessment is carried out for individual concrete compositions (individual recipes) or for concrete families (a concrete family is a group of concrete for which the relationship between relevant properties has been established and documented). A distinction is made between initial or continuous production, where continuous production is achieved when at least 35 test results are obtained within a period not exceeding 12 months. The frequency of sampling varies depending on the type of production and should be in accordance with Table 1.

*Table1. Minimum frequency of sampling up to the price of compliance*

|  |  |
| --- | --- |
| Production | Minimum frequency of sampling |
| First 50 m3 of production | After first 50 m3 of production |
| Concrete with control certificate | Concrete without control certificate |
| Start | 3 specimens | 1 specimen / 200 m3 or2 specimens/week | 1 specimen / 150 m3 or1 specimen / week |
| Continuous\* |  | 1 specimen / 400 m3 or1 specimen / week |
| \* When the standard deviation of the last 15 test results exceeds 1.37σ, the sampling frequency shall be increased to the frequency required for initial production until the next 35 test results are obtained |

If the production of concrete with an individual composition or a concrete family is suspended for more than 12 months, the manufacturer is forced to adopt a sampling plan and compliance criteria as for initial production.

The conformity assessment is to be carried out on the results of tests obtained during the assessment period, which should not exceed the last 12 months of production.

During continuous production, the manufacturer may adopt a sampling and testing plan, and criteria as for initial production.

The sampling location for compliance testing must be chosen so that the respective concrete properties and composition do not change significantly between the sampling place and the place of delivery.

The compliance of concrete compressive strength is assessed on samples tested on day 28 of maturing. If strength has been specified for a different age, compliance shall be assessed on test specimens at the age specified in the specification. Two conformity criteria are used in assessing compliance: (1) for n consecutive test results represented by the average strength fcm (Table 2, criterion 1) and for each individual test result fci (Table 2, criterion 2). Compliance of compressive strength is confirmed if both criteria given in Table 2 for initial or continuous production are met.

*Table 2. Compliance criteria for compressive strength*

|  |  |  |  |
| --- | --- | --- | --- |
| Production | Number *n* of results in population (number of tested specimens)  | Criterion 1 | Criterion 2 |
| Mean of *n* results*fcm* [N/mm2] | Single test result*fci* [N/mm2] |
| Start | 3 | ≥ *fck* + 4,0 | ≥ *fck* – 4,0 |
| Continuous | ≥ 15 | ≥ *fck* +1,48σ |

The value of the standard deviation *sn* of at least 15 compressive strength test results, which are subject to conformity assessment, is also monitored. This standard deviation value is compared with the initial standard deviation value *σ*, which is calculated from at least 35 consecutive test results performed over a period longer than 3 months immediately preceding the production period during which compliance is to be checked. The initial value of the standard deviation *σ* can be used in a later production period, in which compliance is checked, if the standard deviation of the last n results meets the relevant condition from Table 3. When the *sn* value is outside the indicated range, a new σ estimate should be determined based on the last 35 test results.

*Table 3. Criteria for verifying the standard deviation*

|  |  |
| --- | --- |
| Number *n* of results | Limit for *sn* |
| 15 ÷ 19 | 0,63 *σ* ≤ *sn* ≤ 1,37 *σ* |
| 20 ÷ 24 | 0,68 *σ* ≤ *sn* ≤ 1,31 *σ* |
| 25 ÷ 29 | 0,72 *σ* ≤ *sn* ≤ 1,28 *σ* |
| 30 ÷ 34 | 0,74 *σ* ≤ *sn* ≤ 1,26 *σ* |
| 35 | 0,76 *σ* ≤ *sn* ≤ 1,24 *σ* |

In case of non-compliance of compressive strength, PN-EN 206 requires the manufacturer to take the following actions:

* verify the test results and, if they are incorrect, take actions to eliminate errors,
* when non-compliance is confirmed (e.g. by repeated testing), take corrective action, including management reviews of the relevant production control procedures,
* if non-compliance with the specification is confirmed, which was not known at the time of delivery, notify the specifier and the contractor to avoid harmful consequences.

If the incompatibility of concrete is caused by the addition of water or admixtures, the manufacturer should only take action if he has decided to add it.

1. **Practical task:**
	1. **Testing of specimens of concrete prepared during the course of Building Materials 2 - laboratory**
		1. **Materials and equipment**
* hydraulic press (or other machine enabling the mechanical strength tests of concrete),
* laboratory scale,
* caliper,
* Concrete specimens (cubes of 15 x 15 x 15 cm) prepared during the laboratory classes.
	+ 1. **Task completion**

Compressive strength tests of designed concrete should be carried out using the destructive method, using a hydraulic press. Before carrying out strength tests, check the mass and dimensions of the specimens and then calculate the bulk density of the concrete.

* + 1. **Results and evaluation**

The tested concretes should be assessed in terms of belonging to the assumed exposure classes.

To this end, it should be checked whether the individual results of the fci compression strength tests meet criterion 2:

*fci* ≥ *fck* – 4

where: *fck* – characteristic compressive strength of concrete.

* + 1. **Elaboration of results**

The results should be presented in the form of a table (table 4).

*Table 4. The results of density and compressive strength tests of concretes designed for laboratory classes*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Type of concrete | Concrete density [kg/m3] | Assumed class of concrete | Compressive strength results*fci* [MPa] | Assumed characteristic compressive strength*fck* [MPa] | Criterion 2 fulfilled?[Yes/No] |
| Lightweight |  |  |  |  |  |
| Ordinary |  |  |  |  |  |
| Ordinary |  |  |  |  |  |
| … |  |  |  |  |  |
| … |  |  |  |  |  |
| … |  |  |  |  |  |

* 1. **Assessment of the results compliance (PN-EN 206)**
		1. **Materials and equipment**
* Calculator.
	+ 1. **Task completion**

The determination consists in performing a statistical analysis of the results and assessing their belonging to the declared strength class according to PN-EN 206. For the strength tests given by the teacher n (recommended n ≤ 15) and possibly the values of the initial standard deviation σ of 35 results (in the case of strength assessment concrete in continuous production), the actual strength characteristics should be determined: average compressive strength *fcm*, characteristic compressive strength *fck*, the lowest single test result *fci* and standard deviation *sn*.

* + 1. **Results and evaluation**

The assessment of the results consists in checking whether the average (mean) compressive strength *fcm* and the individual results of the compressive strength tests *fci* meet the criteria 1 and 2 respectively (see Table 2), taking into account the type of production – initial or continuous. If the assessment of compliance of concrete compressive strength concerns continuous production, the condition of compliance of the standard deviation *sn* with n results of compressive strength tests should also be checked (see Table 3). If criteria 1 and 2 are not met, the controlled batch of concrete should be classified in a correspondingly lower strength class. If the assumed deviation σ is not compatible with the standard deviation *sn*, a new standard deviation estimate based on the last 35 test results should be used.

* + 1. **Elaboration of results**

The results should be presented in the form of a table (table 5).

*Table 5. Concrete Compressive Strength Assessment Assessment Sheet*

|  |  |  |
| --- | --- | --- |
| **1. Concrete type** | **2. test:** | **3. number of specimens:** |
|  |  |  |
| **4. declared calss of concrete** | C …. / ….  |
| **5. Compressive strength results *fci* [MPa]** | **No** | ***fci*** | **No** | ***fci*** |
| **1** |  | **12** |  |
| **2** |  | **13** |  |
| **3** |  | **14** |  |
| **4** |  | **15** |  |
| **5** |  | **16** |  |
| **6** |  | **17** |  |
| **7** |  | **18** |  |
| **8** |  | **19** |  |
| **9** |  | **20** |  |
| **10** |  | **21** |  |
| **11** |  | **22** |  |
| **6. Real compressive strength parameters** |
| Average (mean) strength *fcm* [MPa] |  |
| Characteristic strength *fck* [MPa] |  |
| Minimal strength *fci min* [MPa] |  |
| Standard deviation of population *sn* [MPa] |  |
| **7. Assessment of the results compliance**Criteria according to PN-EN 206 |
| **A. Number of specimens n < 15** |
| Criterion 1 check: *fcm* ≥ *fck* + 4,0 | Result: |
| ≥ |
| Criterion 2 check: *fci min* ≥ *fck* – 4,0 | Result: |
| ≥ |
| **B. Number of specimens n ≥ 15** |
| Criterion 1 check: *fcm* ≥ *fck* + 1,48*σ* | Result: |
| ≥ |
| Criterion 2 check: *fci min* ≥ *fck* – 4,0 | Result: |
| ≥ |
| **C. Assessment of standard deviation *sn*** |
| …….. *σ*  ≤ *sn* ≤…….. *σ* | Result: |
| ≤….......≤ |
| **8. Klasyfikacja betonu według PN-EN 206** |
| **Criterion 1** | Fulfilled / not fulfilled\* |
| **Criterion 2** | Fulfilled / not fulfilled\* |
| **Condition of σ** | Fulfilled / not fulfilled\* |
| **Real concrete compressive class** | C …. / …. |
| **New estimation of standard deviation *σ*** |  |
| **\*** Cross out if not applicable |

1. **Laboratory report**

The laboratory report should include:

1. Subject, aim and scope of research (containing basic information about tested materials/products, test methods, requirements),
2. Tests results with proper units (results obtained in the laboratory prepared in the indicated manner, e.g. put in the proper tables),
3. Conclusions (bulleted statements formulated based on the results obtained),
4. Bibliography (list of references to the literature or www used to prepare the report).