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(54) Benævnelse: **COMPUTERUNDERSTØTTET FREMGANGSMÅDE OG STYREANORDNING TIL BESTEMMELSE AF SICHTBETONKVALITET**

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COMPUTER-SUPPORTED METHOD AND CONTROL DEVICE FOR DETERMINING A QUALITY OF EXPOSED CONCRETE

Reference to Related Applications

The present application claims the priority of German Patent Application No. 10 2019 219 269.6, filed on 10 December, 2019.

The present invention relates to a computer-supported method and control device for producing a concrete component with one outer surface in a defined exposed concrete quality by means of a formwork arrangement installed at a construction site or in a precast plant, into which formwork arrangement a suitable fresh concrete is to be filled as starting material. Furthermore, the invention also relates to a computer program that embodies the method, in particular for a computer-supported prognosis unit of the control device.

The field of application of the invention extends to construction technology and is specifically directed to the production of exposed concrete. Exposed concrete refers to concrete components whose outer surfaces serving as visible surfaces are part of the architectural or interior design of the building. In the strict sense, the term exposed concrete is limited to component surfaces that were in contact with the formwork skin of a formwork arrangement required for production. Although outer surfaces

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of exposed concrete exist in many different forms and production techniques, for example colored, stonemasonry-finished, acidified, washed and the like, all these outer surfaces are nevertheless originally formed surfaces and show an appearance more or less co-determined by the formwork skin. Reproducible surface quality plays a decisive role in the production of exposed concrete, as the end result depends on a large number of influencing factors.

Prior art

The "Exposed Concrete Information Sheet" (Deutscher Beton- und Bautechnik-Verein e. V. and Verein Deutscher Zementwerke, 53-page edition, 2004) specifies concrete exposed concrete classes SB1 to SB4, which serve as a quality benchmark in practice. These exposed concrete classes SB1 to SB4 define technical requirements and individual design criteria with regard to the quality of the formwork skin, the concrete material and the care to be taken when working and the like. Compliance with these individual criteria should facilitate reproducible exposed concrete quality.

In practice, the specification for exposed concrete - for example for a smooth exposed concrete - generally contains the description of the required surface characteristics, such as exposed concrete class, smooth, produced with non-absorbent or slightly absorbent formwork and the like, the description of the surface structure per formwork pattern plan and some additional requirements regarding the color shade of the surfaces. Depending on the desired appearance, information on the surface treatment or optional coloring of the surfaces can be added. The planner selects the exposed concrete class from a performance description table in the "Exposed concrete information sheet". The selection and specification of the exposed concrete class SB1 to SB4 defines all the surface characteristics pertaining to this class as well as the condition of the formwork skin that must be maintained.

The surface finish of the formwork skin has a decisive influence on the subsequent appearance of exposed concrete surfaces. This applies all the more, the less the desired design should deviate from the classic characteristics of a smooth exposed concrete surface produced with a non-absorbent formwork skin. Wooden formwork made of untreated wood, rough-sawn or planed, or OSB boards give the exposed concrete surface a typical appearance, but depending on the wood or brand used, can cause very large variations in the later appearance of the surface. Therefore, the practical study of exemplary surfaces on existing buildings has so far been helpful in deciding on the formwork skin. The decision for a particular formwork skin is usually made later, after the start of construction, through extensive testing. All of this also requires a great deal of planning.

With regard to the choice of material for the fresh concrete to be used, the coloring is influenced by the choice of cement, for example limestone cements for lighter or slate cements for darker surfaces, which is specified in the respective concrete formulation. A very light, almost white surface coloring can only be achieved by using white cements. Colored concrete is also possible by adding pigments. However, the realization of colored outer surfaces requires a very high degree of care during construction. This is because a colored outer surface cannot usually be finished in exposed concrete quality SB4 if the humidity is too high. Furthermore, rainwater on the formwork skin before the formwork arrangement is filled with fresh concrete can lead to subsequent streaks on the outer surface. For these reasons, various other factors also influence the quality of exposed concrete that can be realized during construction.

In particular, smooth surfaces produced with a non-absorbent formwork arrangement can show disturbing dark spots if they are produced at average daytime temperatures below

10°C. Depending on the temperature and sensitivity, the discoloration can reproduce the reinforcement close to the edge, appear in patches or also affect entire component areas, usually in the lower part of a wall surface and often delimited by marked installation positions. As a countermeasure, stripping the formwork as early as possible can prevent this dark spotting. Until now, the realization of a desired exposed concrete quality has been based on construction experience, which can of course vary greatly depending on the construction site and the personnel working there.

To ensure the desired exposed concrete quality, the "Exposed concrete information sheet" recommends the creation of test areas. Such test areas are used to determine the quality that can be produced under the actual constraints of the construction site and to develop and validate the technical procedure. These tests also increase the construction costs.

The prior publication KR 2012 0080795 A generally discloses a computer-supported method for producing concrete components by means of a formwork arrangement into which a fresh concrete is filled as a starting material, wherein data about the fresh concrete is provided and current physical environmental data is determined by sensors arranged on the construction site in order to compare the various types of data provided and measured with corresponding stored historical data of similar concrete components for the purpose of quality assurance. However, this does not refer to the aspect of a specifically desired exposed concrete quality and specifically relevant data for this, in particular with regard to the formwork skin class of the formwork arrangement.

EP 2 743 427 A1 describes reusable formwork elements with integrated temperature sensors, which can be used to monitor the hardening of the concrete in order to improve the quality of the exposed concrete.

It is therefore the object of the present invention to provide a technical solution for producing a concrete component in exposed concrete quality, with the aid of which it is possible to achieve a surface quality of a quality class specified in the implementation planning that is as reproducible as possible.

Disclosure of the invention

The object is achieved with regard to a computer-supported method by claim 1. Independent claim 10 specifies a control device serving to carry out this method and claim 14 contains a computer program embodying the method according to the invention, with which at least partial steps of the method can be carried out.

The invention includes the process-engineering teaching that in order to produce a concrete component with an outer surface in a defined exposed concrete quality SB1 to SB4 or another classification by means of a formwork arrangement installed on a construction site, into which a suitable fresh concrete is introduced as a starting material, the following steps must be carried out:

- Provision of data on the concrete formulation and/or concrete quality of the fresh concrete delivered or to be delivered to the construction site,
- Provision of data on the formwork skin class or information equivalent to this of the formwork arrangement installed at the construction site,
- Measurement of actual physical environmental data by sensors arranged on the construction site,
- Comparison of the provided and measured dissimilar data with corresponding stored historical data of similar concrete components of known exposed concrete quality SB1 to SB4 in order to predict via
- Data pattern recognition to predict with which exposed concrete quality SB1 to SB4 the concrete component to be produced can be realized under the given circumstances.

Thus, the solution according to the invention is based on providing the essential quality-relevant information about the material used, the tool used and the environmental conditions on the construction site in order to compare these different types of data with the data of concrete components of already known exposed concrete quality SB1 to SB4, which originate from previous construction projects. If the different types of data provided and measured in the past are identical or similar to the different types of data provided and measured for the construction project currently being carried out, it can be predicted that the same exposed concrete quality SB1 to SB4 can be achieved. The larger the data pool that can be used for prediction, the more precise this data pattern recognition becomes.

The advantage of the invention is that a consistently reproducible exposed concrete quality can be achieved with a high degree of probability, which would not be possible with a manual process based on experience alone due to the large number of influencing factors. In addition, appropriate documentation of realized exposed concrete qualities SB1 to SB4 and the underlying data can be used to counteract any unjustified complaints or, for example, to assign the damage that has occurred to the actual person responsible in the event of an incorrect concrete formulation. Furthermore, the prediction also makes it possible, for example, to determine that the planned exposed concrete quality cannot be realized under the given circumstances, for example because formwork elements have been installed that are too old and have insufficient evenness and too high absorbency. In this case, the formwork arrangement can be replaced as a result of the prediction in order to be able to produce the planned exposed concrete quality. Thus, the added value of the solution according to the invention also lies in the logistics of formwork elements for shoring formwork arrangements, which is known, for example, from transponder technology, in order to be able to replace unsuitable formwork elements with suitable formwork elements with a sufficiently flat formwork skin if necessary. This prevents damage resulting from the use of an incorrect formwork arrangement.

The physical environmental data to be measured as part of the solution according to the invention are preferably selected from a data group comprising outside temperature T, humidity F, precipitation N and also the wind speed on the construction site, which influences the setting process. This is because these environmental data have a decisive influence on the exposed concrete quality. Of course, other environmental data to be measured can also be included in the evaluation if it proves to be relevant to quality.

The same applies to the data that determines the concrete quality, which results from the concrete formulation, for example the grain size K of the gravel and sand used, the water content W of the water added for mixing and the material temperature MT of the fresh concrete to be used, which significantly determines the pot life. The material temperature MT is largely dependent on the outside temperature during transportation of the fresh concrete from the concrete mixing plant to the construction site.

Formwork data, which can either be determined by sensors or are known from the characteristics of the formwork element used, are also taken into account as further influencing factors relating to the formwork arrangement. For example, the flatness E of the formwork skin can be determined using sensor technology, for example by laser scanning. The age-related water absorption capacity S of the formwork skin can be determined by the number of uses and the age of the formwork element, and the characteristics of the formwork element determine how large the formwork joint between adjacent formwork panels is. These formwork data are also decisive for achieving the planned exposed concrete quality.

All of the above data relates to the phase before installation of the fresh concrete supplied. In addition, data for the exposed concrete quality that can be achieved, which is generated during the installation of the supplied fresh concrete in the formwork arrangement, such as process parameters selected from a parameter group comprising the degree of compaction V of the fresh concrete, concrete maturity R and/or the forming

time Z, is also decisive. All of these process parameters, most of which are determined with the execution planning, can also be compared with previously stored process parameters of concrete components with known exposed concrete quality in order to increase the predictive reliability of the realizable exposed concrete quality SB1 to SB4.
In accordance with a further measure to improve the invention, it is proposed that, after demolding, the actually realized exposed concrete quality SB1 to SB4 is determined by optical measuring means for analyzing the outer surface in order to compare it with the planned and/or predicted exposed concrete quality SB1 to SB4. This allows a reliable and precise quality check to be carried out, which is easy to perform and document thanks to the data processing technology. The outer surface is analyzed by evaluating images and comparing color gradients, structural features and the like with the criteria defined in the "Exposed Concrete Information Sheet" or other regulations. The prerequisite for this is that the textual description of the properties of the various exposed concrete classes is translated into image information that can be used for comparison purposes.
Apart from the quality check the various data associated with the actually realized exposed concrete quality SB1 to SB4 can also be included in the data stock of the historical data as a training data set for machine learning. As a result, the database is enriched, which enables a more precise prediction reliability for future forecasts.
The method according to the invention can especially be carried out on a computer-supported control device, whose core comprises a prognosis unit to compare the provided and measured dissimilar data with corresponding historical data of similar concrete components of known exposed concrete quality SB1 to SB4 stored in a documentation database. A material database for providing data on the concrete formulation and/or concrete quality of the fresh concrete delivered or to be delivered to the construction site and a formwork logistics database for providing data on at least the formwork skin class of the formwork arrangement installed on the construction site are also connected to the prognosis unit. In addition, the measured values from the various sensors for measuring current physical environmental data are sent to the prognosis unit, which uses data pattern recognition to output a stochastic prognosis based on the input data to determine the exposed concrete quality SB1 to SB4 with which the concrete component to be produced can be realized under the given circumstances.
In accordance with a further measure to improve the solution according to the invention, an analysis unit connected downstream of the prognosis unit is provided in order to compare the exposed concrete quality SB1 to SB4 that can actually be realized with the planned and/or predicted exposed concrete quality for testing purposes on the basis of

the measured outer surface. This quality inspection takes place after the concrete component has been demolded.

It is also proposed that the analysis unit generates training data sets for classifying exposed concrete qualities SB1 to SB4 from the image data of the outer surfaces, in order to enrich the data stock of the documentation database for future forecasts therewith.

Detailed description based on the drawing

Further measures improving the invention are described in more detail below together with the description of a preferred exemplary embodiment of the invention with reference to the figures. In the figures:

Fig. 1 shows a schematic representation of a control device for producing a concrete component in an exposed concrete quality based on a prognosis in interaction with planning data as well as the construction site facilities, and

Fig. 2 shows a flow chart of the method for producing the concrete component performed with the control device.

In accordance with Fig. 1, a control device for producing a concrete component 1 with one outer surface 2 in a defined exposed concrete quality, here SB3, by means of a formwork arrangement 4 installed at the construction site 3, into which formwork arrangement a fresh concrete 5 is filled, essentially comprises a material database 6 for providing data about the concrete formulation 7 of the fresh concrete 5 delivered to construction site 3 for installation. In addition, there is a formwork logistics database 8, which supplies data on at least the formwork class H of the formwork arrangement 4 installed on the construction site 3 via a formwork data record 9 assigned to the formwork arrangement 4.

In addition, several sensors 10 to 12 measure current physical environmental data at the construction site 3. The sensor 10 measures current precipitation N, for example drizzle, heavy rain and the like. The sensor 11 measures the current humidity F at the construction site 3 and sensor 12 serves to measure the current outside temperature T at the construction site 3. All this measured data, together with the data provided via the databases, is fed to a prognosis unit 13 on the input side. The prognosis unit 13 compares the various data provided and measured with corresponding historical data of similar components 1' of known exposed concrete quality stored in a documentation database 14, in order to prognosticate by data pattern recognition with which exposed concrete the component 1 to be produced can be realized under the given circumstances. The given

circumstances are defined by the various types of data provided and measured as mentioned above.
After demolding the concrete component 1, the outer surface 2 of the manufactured concrete component 1 is tested with regard to the predicted exposed concrete quality SB3. This is done via a 3D camera unit 15, whose measured image information is transmitted to an analysis unit 16. The analysis unit 16 uses the image data of the measured outer surface 2 to compare the actually realized exposed concrete quality with the predicted exposed concrete quality SB3, which regularly also corresponds to the planned exposed concrete quality SB3. Otherwise, environmental conditions are changed first, for example by switching to a different concrete formulation.
In addition, the analysis unit 16 generates a training data set for classifying exposed concrete qualities from the image data of the outer surface 2. Once the exposed concrete quality SB3 has been confirmed, the associated data provided from the material database 6, the formwork database 8 and the data measured by the sensors 10 to 12 can be added to the documentation database 14 as a training data set in order to enrich its database. This allows future forecasts to be made more precisely.
Fig. 2 illustrates the sequence of steps in the computer-supported process for manufacturing a concrete component 1 using the control device described above.
In a first step I, data on the concrete formulation 7 of the fresh concrete to be used is provided for the prediction to be made regarding a realizable exposed concrete quality SB1 to SB4 in accordance with the "Exposed Concrete Information Sheet". This data includes the grain size K, the water content W and the material temperature M of the fresh concrete to be used, which is selected here from the formulation specifications.
In a parallel step II, data about the formwork arrangement installed on the construction site is provided, which originates from the type description stored for this purpose and the lifecycle data of the formwork data set 9. This mainly concerns the formwork skin class H to be assigned to the formwork arrangement, which significantly influences the exposed concrete surface, but also the evenness E of the formwork skin and the age-related water absorption capacity S.
In addition to this data provided from planning or documentation data, current physical environmental data is also measured on the construction site in a step III. For this purpose, a sensor 10 is used to measure precipitation N. A sensor 11 measures the current humidity F and a sensor 12 measures the current outside temperature T on the construction site.

In step IV, all these different types of data provided and measured are then compared by a prognosis unit with the corresponding stored historical data of similar concrete parts of known exposed concrete qualities. This is done with a computer-supported prognosis unit 13 using data pattern recognition. The historical data used for the pattern comparison is taken from a documentation history of past construction projects and, in this way, it is possible to predict the exposed concrete quality with which the concrete component to be produced can be realized under the given circumstances.

In an additional step V, after demolding the concrete component, it is analyzed whether the realized outer surface 2 corresponds to the predicted and thus planned exposed concrete quality SB3. This is done using the optical measuring means described above.

The invention is not limited to the preferred embodiment described above. Rather, other variations thereof are also conceivable, which are also covered by the scope of protection of the following claims. It is also possible, for example, for the prediction of the exposed concrete quality to be realized to be based on other data provided or measured, such as process parameters during the installation of the fresh concrete 5. For example, its layer-by-layer degree of compaction V, the concrete maturity R and the forming time Z can be used to expand the data set for data pattern recognition. On the other hand, the data set on which the data pattern recognition is based does not need to include all of the above-mentioned and various types of data; a partial selection of this is sufficient, provided that it can be used to make an accurate prediction about the realizable exposed concrete quality SB1 to SB4.

List of reference signs

1	Concrete component
2	Outer surface
3	Construction site
4	Formwork arrangement
5	Fresh concrete
6	Material database
7	Concrete formulation
8	Formwork logistics database
9	Formwork database
10	First sensor
11	Second sensor
12	Third sensor

13	Prognosis unit
14	Documentation database
15	3D camera unit
16	Analysis unit
SB1 ... SB4	Exposed concrete qualities
T	Outside temperature
F	Humidity
N	Precipitation
K	Grain size
W	Water content
M	Material temperature
H	Formwork skin class
E	Evenness
S	Water absorption capacity
V	Degree of compaction
R	Concrete maturity
Z	Forming time

COMPUTERUNDERSTØTTET FREMGANGSMÅDE OG STYREANORDNING TIL BESTEMMELSE AF SICHTBETONKVALITET

PATENTKRAV

1. Computerunderstøttet fremgangsmåde til fremstilling af et betonelement (1) med mindst en ydre overflade (2) i en defineret sichtbetonkvalitet (SB1 – SB4) ved hjælp af en forskallingsanordning (4), der er installeret på en byggeplads (3) eller på en byggeelementfabrik, hvor en færdigblandet beton (5) påfyldes som udgangsmateriale, og som omfatter følgende trin:

- Forsyning (I) af data om betonformlen (7) og/eller betonkvaliteten på den færdigblandede beton (5), der er eleveret eller skal leveres til byggepladsen (3),
- Forsyning (II) af data om forskallingsklassen (H) på den installerede forskallingsanordning (4) på byggepladsen (3),
- Måling (III) af aktuelle fysiske miljødata ved hjælp af sensorer (10, 11, 12), der er anbragt på byggepladsen (3),
- Sammenligning (IV) af de forsynede og målte forskelligartede data med tilsvarende gemte historiske data for lignende betonelementer (1‘) af en kendt sichtbetonkvalitet (SB1 – SB4), for via
- Identifikation af datamodeller at prognosticere, med hvilken sichtbetonkvalitet (SB1 – SB4) det betonelement (1), der skal fremstilles, kan realiseres under de givne omstændigheder.

2. Fremgangsmåde ifølge krav 1,
kendetegnet ved, at den prognosticerede sichtbetonkvalitet (SB1 – SB4) sammenlignes med den planlagte sichtbetonkvalitet (SB1 – SB4) for at identificere eventuelle afvigelser før realiseringen.

3. Fremgangsmåde ifølge krav 1,
kendetegnet ved, at de fysiske miljødata udvælges fra en datagruppe, som omfatter: Udendørs temperatur (T), luftfugtighed (F), nedbør (N), vindhastighed.

4. Fremgangsmåde ifølge krav 1,

kendetegnet ved, at korntheden (K), vandindholdet (W) og/eller materialetemperaturen (M) på den færdigblandede beton (5), der skal anvendes, medregnes som de data, der er bestemmende for betonkvaliteten.

5. Fremgangsmåde ifølge krav 1,
kendetegnet ved, at ud over den sensorteknisk målte jævnhed (E) medregnes forskallingen på forskallingsanordningen (4), dennes aldersbetingede vandsugningsevne (S) og/eller forskallingsfugen mellem tilstødende formplader på forskallingsanordningen (4) som de data, der er bestemmende for forskallingsanordningen (4).

6. Fremgangsmåde ifølge krav 1,
kendetegnet ved, at der til anvendelse af den leverede, færdigblandede beton (5) i forskallingsanordningen (4) som sammenligningsgrundlag benyttes gemte, lagrede procesparametre for de medregnede betonelementer (1‘) af en kendt sichtbetonkvalitet (SB1 – SB4).

7. Fremgangsmåde ifølge krav 5,
kendetegnet ved, at procesparametrene udvælges fra en parametergruppe, som omfatter: Kompakteringsgrad (V) på den færdigblandede beton (5), betonens modenhed (R) og/eller dennes forskallingstid (Z).

8. Fremgangsmåde ifølge krav 1,
kendetegnet ved, at den reelt realiserede sichtbetonkvalitet (SB1 – SB4) fastsættes efter afskallingen via optiske måleinstrumenter til analysen (V) af den ydre overflade (2), for at sammenligne denne med den planlagte og/eller prognosticerede sichtbetonkvalitet (SB1 – SB4).

9. Fremgangsmåde ifølge krav 1,
kendetegnet ved, at de forskelligartede data, der er i sammenhæng med den reelt realiserede sichtbetonkvalitet (SB1 – SB4) medtages som træningsdatasæt til maskinel indlæring i databestanden over historiske data.

10. Styreanordning til fremstilling af et betonelement (1) med en ydre overflade (2) i en defineret sichtbetonkvalitet (SB1 – SB4) ved hjælp af en på en byggeplads (3) eller på

en byggeelementfabrik installeret forskallingsanordning (4) til påfyldning af færdigblandet beton (5) heri, hvor styreanordningen til gennemførsel af fremgangsmåden ifølge et af de ovenstående krav omfatter de følgende komponenter:

- en materialedatabase (6) til forsyning af data om betonformlen (7) og/eller betonkvaliteten på den færdigblandede beton (5), der er leveret eller skal leveres til byggepladsen (3),
- en database over forskallingslogistik (8) til forsyning af data om i det mindste forskallingsklassen (H) på den installerede forskallingsanordning (4) på byggepladsen (3),
- flere sensorer (10, 11, 12) til måling af aktuelle fysiske miljødata på byggepladsen (3),
- en prognoseenhed (13) til sammenligning af de forsynede og målte forskelligartede data med tilsvarende, lagrede historiske data for lignende betonelementer (1‘) af en kendt sichtbetonkvalitet (SB1 – SB4) i en dokumentationsdatabase (14), for via identifikation af datamodeller at prognosticere, med hvilken sichtbetonkvalitet (SB1 – SB4) det betonelement (1), der skal fremstilles, kan realiseres under de givne omstændigheder.

11. Styreanordning ifølge krav 10,
kendetegnet ved, at en 3D-kameraenhed (15) eller en overflade-laserscanner registrerer den reelt realiserede sichtbetonkvalitet (SB1 – SB4) som optisk måleinstrument for den ydre overflade (2).

12. Styreanordning ifølge krav 10,
kendetegnet ved, at en analyseenhed (16) ved hjælp af den måleteknisk registrerede, ydre overflade (2) sammenligner den reelt realiserede sichtbetonkvalitet (SB1 – SB4) med den planlagte og/eller prognosticerede sichtbetonkvalitet (SB1 – SB4).

13. Styreanordning ifølge krav 12,
kendetegnet ved, at analyseenheden (16) ud fra billeddata for de ydre overflader (2) genererer træningsdatasæt til klassificering af sichtbetonkvaliteter (SB1 – SB4), for dermed at udvide databestanden i dokumentationsdatabasen (14) til fremtidige prognoser.

14. Computerprogram, som omfatter kommandoer, der bevirker at styreanordningen i krav 10 udfører trinnene i fremgangsmåden ifølge krav 1.

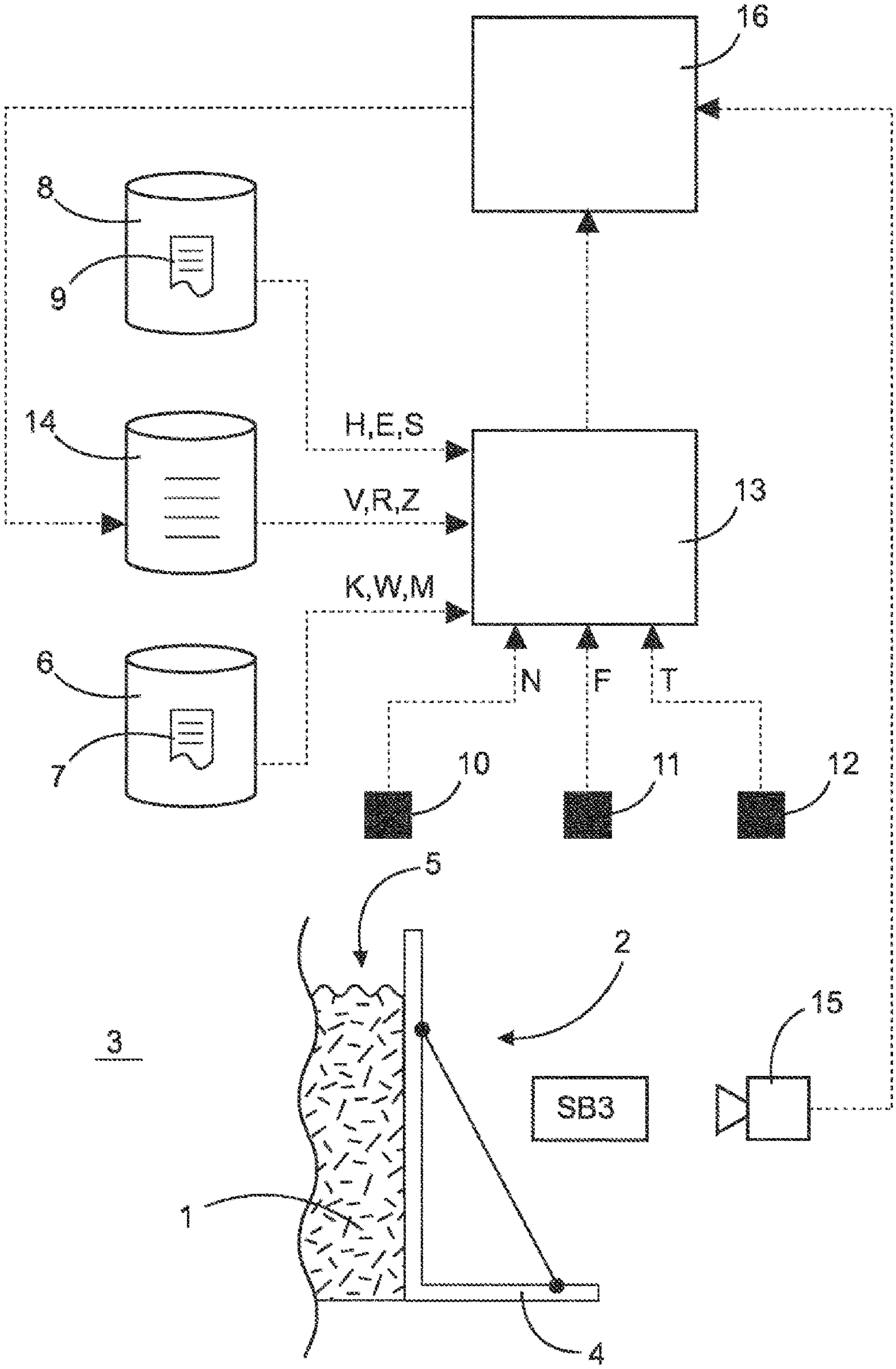

Fig. 1

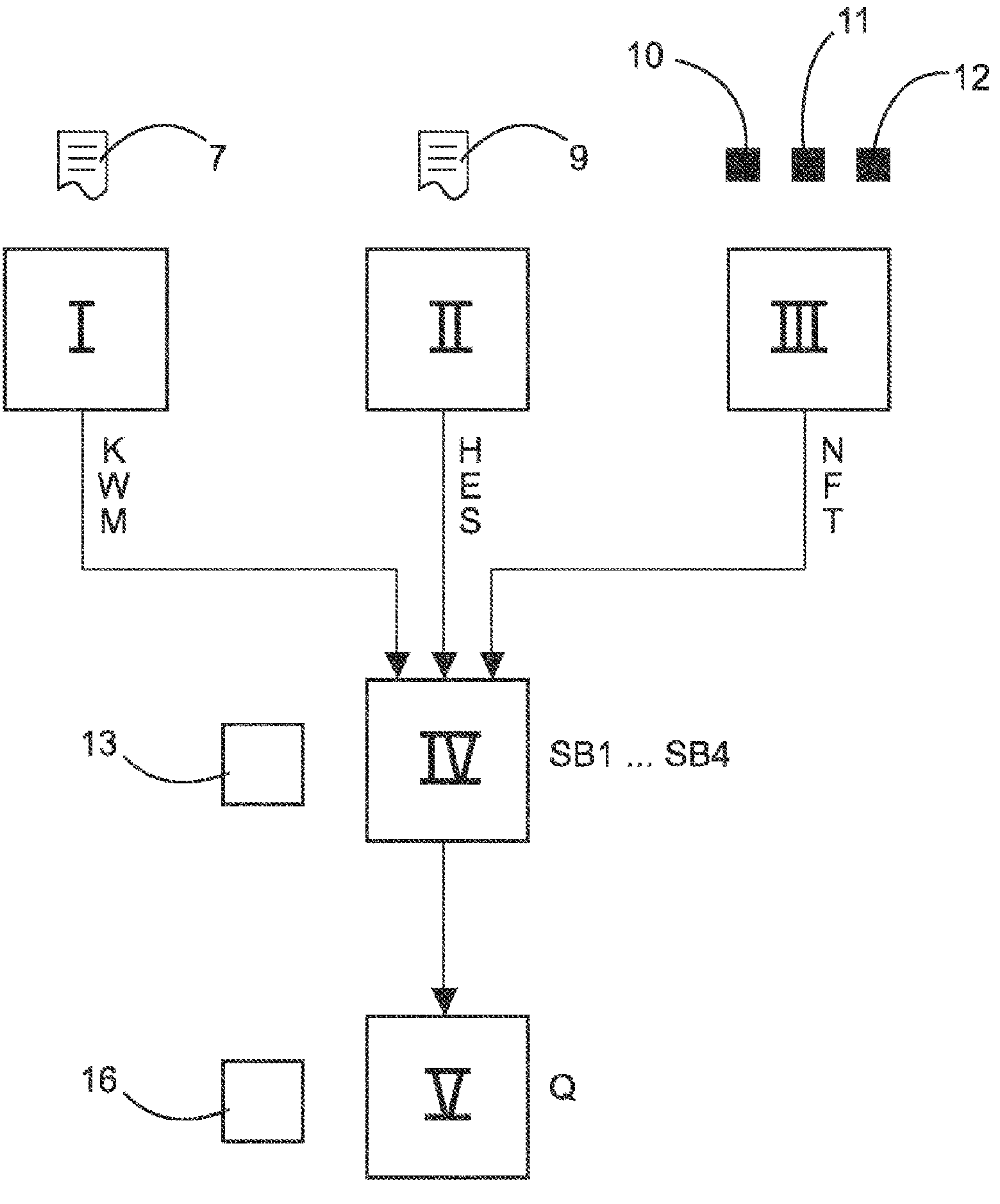

Fig. 2