Lastrada - process capability KPIs for the quality assurance of aggregates and asphalt

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ABSTRACT

How to efficiently manage the quality of a natural product under the assumption of changing properties, changing sources, a complex production process, environmental influences and a high throughput of bulk production? Is it possible to predict the next non-conformity event?

In this paper we describe how to run a QC system in an effective and (at the same time) understandable and easy way. We show how to make use of Key Performance Indicator (KPIs) on the basis of process capability indices in aggregate and asphalt quality control. Hence, given a tool for the management to pinpoint where resources are needed and action has to be taken in order to secure QC according to requirement/EN-standards. In doing so, we describe several aspects of the LASTRADA approach: the definition of meaningful Key Performance Indices, the advantages of a central database solution and standardised workflows when it comes to maintaining a suitable data basis and finally, the challenge to simplify the complexity in the presentation of data.

We will provide a number of up to date, practice-proven examples on how process-related issues can be detected. The paper ends with some illustrative examples from a company using this system. The examples clearly show how processes can be improved using KPIs on responsibility levels closer to the production process, i.e. on site manager level.

Keywords: Aggregate, Asphalt, KPI, Quality assurance, Software

1 Monitoring the Production of Construction Materials with KPIs

The top management requires up-to-date information from all sites to monitor the production both according to EN standards, national or local requirements and contract specifications. With a large number of asphalt and aggregate production sites at Veidekke, the number of test results is huge and one integrated quality control system based has been searched.

1.1 What is a KPI?

A Key Performance Indicator, hereafter KPI, is intended to provide a single value that can be used to quickly assess the performance of a process. Having a defined single number, processes can be easily monitored, compared and managed. Examples for KPIs are:

- Finance: Sales per person, profit per unit, new sales this year / last year
- Production: Run time / total time, good parts / total parts produced on a machine.
- IT: Availability / uptime, mean time between failure
- Projects: Estimated completion, labour costs per month, total costs per month, planned costs per total costs

1.2 How to Measure the Quality of Construction Materials

In this paper we are proposing Process Capability Indices, which have been successfully used in many other industries, similar to the 'SixSigma' approach. The core assumptions are: A production with a good and constant quality should have many conforming samples, a small spread of test results and should be centred between the Min/Max limits. Whereas more non-conforming samples or a larger spread of test results indicate changes in the quality level. In mathematical terms, this means that the smaller the standard deviation of the test results and the more the process is centred, the better.

The later presented KPIs provide a single value that quickly assess the

- Overall quality performance of a plant,
- Quality a single product,
- Quality of a single parameter of a product.

2 Technological Prerequisites

To deploy the statistical approach of Process Capability Indices on quality data, there are several requirements on the used systems regarding database, software and quality control workflow.

2.1 Central Database

Only a central database fulfils the requirements on the quality control of construction materials with KPIs. These are:

- All quality data can be analysed at any time: All samples, all products, all test results can be evaluated for all plants at the push of a button.
- All the quality data can be accessed at the same time from any location.
- Higher data quality: Data integrity is maximised and data redundancy is minimised, as the single storing place of all the data also implies that a given set of data only has one primary record. Quality data is not entered on several systems, manual typing of data is reduced to the minimum.

2.2 Professional Laboratory Software / Standardised Workflows

Manual errors caused by repeated work by different persons should be reduced to the minimum. Only a professional laboratory software, such as LASTRADA, fulfils the following requirements:

- All calculations are done by the software, the end user cannot change the calculation.
- All requirements of the (product and test) standard are the same throughout the company.
- The workflows in the quality control are standardised: In every location the quality control is performed in the same way. Manual errors are reduced to the minimum.
- Data is completely traceable.

The best way to fulfil these requirements is to implement a central database system where all quality control and all laboratory processes are integrated and standardised. A practical example of such a system is implemented by Veidekke Industri AS, the largest aggregate and asphalt producer in Norway who implemented LASTRADA, the standard laboratory software for quality control of construction materials.

3 Selection of Indicators

In the following we describe which statistical indicators are used and how the indicators are developed.

3.1 Number of non-conforming Samples

Non-conforming samples are defined as the quantity of samples that deviate against the specification/declaration limits. A large quantity of non-conforming samples indicates problems in the production process. The comparison of the amount of non-conforming samples from product to product and plant to plant widely used in the QC of construction materials.

3.2 Distribution Curve

To visualise the distribution of the test results for each parameter we show the following elements:

- Blue bar chart = real distribution of test results
- Dark green curve = Calculated distribution curve
- Green limits = 2 x Standard Deviation
- Red limits = Limits from the Specification/Declaration

The distribution is evaluated by the KPI. A large standard deviation, a large range of test results and a bad position of the mean will lead to a bad KPI.

3.3 Control Charts

KPIs rely on the assumption that the mean and spread of a process is stable throughout the analysed time frame. Control chards provide a means to control the stability of a process because their limits are calculated on the assumption of a specific spread and are plotted relative to a mean. In the following 3 control charts are presented: Xbar, MR and CUSUM. A deviation in the control charts is an indicator that the assumptions regarding mean and spread are wrong, i.e. that the process is not under control.

General used variables and notations in the control chart formulas:

Variable	Remark / Definition
d2 = 1.128	Control chart constant
D3 = 0	Control chart constant
D4 = 3.267	Control chart constant
X[i]	Individual value of the time series
X_	Mean of all values (μ)
MR_	Mean of MR values
$\tilde{\sigma}$ = MR_/d2	Estimated Sigma from MR_

3.3.1 Xbar Control Chart

The Xbar control chart draws a time series of the actual test value, mean value, the upper control limit (UCL) and lower control limit (LCL). The control limits are plotted as +/- 3 times the standard deviation around the mean.

Variable	Remark / Definition
UCL = X_ + 3 * Sig	Upper Control Limit
CL = X_	Centre Line
LCL = X_ - 3 * Sig	Lower Control Limit
Xbar1[i] = X[i]	Individual value of the Xbar1 time series

3.3.2 Moving Range Control Chart

The Moving Range (MR) control chart draws a time series of the difference of the actual test result to the mean. Also, the mean and the upper control limit (UCL) and lower control limit (LCL) are drawn. The control limits depend on the mean of deviations and the standard deviation.

Variable	Remark / Definition
UCL = D4 * MR_	Upper Control Limit
CL = MR_	Centre Line
LCL = D3 * MR_	Lower Control Limit
MR[i] = |X[i] - X[i-1]|	Individual value of the MR time series

3.3.3 CUSUM Control Chart

The Cumulated Sum (CUSUM) control chart draws a time series of the cumulative deviations from the mean (two curves for positive sums and negative sums). Also, the upper control limit (UCL) and lower control limit (LCL) are plotted as +/- 5 times the estimated standard deviation.

Multiple deviations into one direction quickly lead to a crossing of the limits, indicating a change in the underlying process.

Variable	Remark / Definition
UCL = 5 * $\tilde{\sigma}$	Upper Control Limit
LCL = - 5 * $\tilde{\sigma}$	Lower Control Limit
CuU[i] = max(0; X[i] - (X_ + $\tilde{\sigma}$/2) + CuU[i-1])	Individual value of the CuU time series (upper CUSUM)
CuL[i] = - max(0; - X[i] + (X_ - $\tilde{\sigma}$/2) + CuL[i-1])	Individual value of the CuL time series (lower CUSUM)

3.4 Key Performance Indicator (KPI)

The KPI is intended to provide a single value that can be used to quickly assess quality from the parameter level to the company level. It is the primary goal to indicate the risk regarding conformance to specifications.

$0 \leq KPI \leq 1$. The closer to 1, the better.

The KPI formula is designed to integrate P_{PK}, P_P, PWS and CTS.

a) $KPI = 0{,}2\, P_{pk}' + 0{,}2\, \frac{P_{pk}'}{P_p} + x\, PWS + y\, CTS$

b) $P_{pk}' = min\left(1; \frac{P_{pk}}{0{,}67}\right)$

c) $\frac{P_{pk}'}{P_p} = \min\left(1; \frac{\frac{P_{pk}}{P_P}}{0{,}5}\right)$

d) $x + y = 0{,}6$

e) $x = \max\left(0{,}5; min\left(1; 0{,}8\frac{CTS}{PWS}\right)\right)$

Variable	Share in KPI
P_{PK}	0,2
P_{PK}/P_P	0,2
PWS & CTS	0,6

P_{pk}' *and* $\frac{P_{pk}'}{P_p}$ both have a share of 20% in the KPI. *PWS* and *CTS* together have a share of 60% in the KPI.

PWS and *CTS* together have a share of 60% in the KPI. The exact share is dynamically calculated depending on the $\frac{CTS}{PWS}$ ratio. PWS will be included with at least 50%. The larger the ratio $\frac{CTS}{PWS}$ the stronger PWS will be. At $\frac{CTS}{PWS} = 1{,}25$ *PWS* will completely replace *CTS*.

The KPI uses a P_{PK} value of 0,67. This corresponds to the process mean being two standard deviations away from the closest specification limit. Statistically this is nearly equivalent to 95% compliance.

P_{PK} values greater than or equal to 0,67 contribute with 100% to the KPI. P_{PK} values below 0,67 contribute less than 100 % to the KPI. Remembering these key P_{PK} values can provide important information regarding how your process is performing relative to specifications. Values less than 0,67 indicate your closest specification is less than 2x standard deviation away from the mean, which indicates that your risk of producing nonconforming material or defects is greater than 5% and therefore your KPI is lower.

The KPI uses a P_{PK}/P_P value of 0,5. As a $P_{PK}/P_P = 1$ indicates the optimum, $P_{PK}/P_P = 0{,}5$ is already the half way between the optimum and the limits. Hence we weight $P_{PK}/P_P \geq 0{,}5$ with 100% in the KPI. If P_{PK}/P_P is below 0,5, it will lower the KPI.

P_{PK}/P_P is not a critical measure of quality on its own - it was included because it indicates where the mean is relative to the specification. P_{PK}/P_P is different than just P_{PK} because although P_{PK} may indicate that you are less than two standard deviations away from the closest specification, it doesn't indicate whether you are near the centre of the specification (indicating that your process isn't capable of producing material at 95% conformance due to a large standard deviation or too tight specifications); or if the mean is too far off-centre to produce conforming material.

3.4.1 Process Performance Index (P_{PK})

P_{PK} is a calculated process capability ratio. This ratio gives the indication where the process mean is located relative to the specifications/declaration limits.

Formula:

$P_{pk} = \min(P_{pl}, P_{pu})$
with $P_{pl} = \frac{(UCL-\mu)}{(3\,\sigma)}$ and $P_{pu} = \frac{(\mu-LCL)}{(3\,\sigma)}$

Interpretation:

$P_{PK} < 0$: the mean is outside of specifications;

$P_{PK} = 0$: the mean is on a specification;

$P_{PK} = 0{,}33$: the mean is 1x standard deviation away from the closest specification;

$P_{PK} = 0{,}67$: the mean is 2x standard deviation away from the closest specification;

$P_{PK} = 1$: the mean is 3x standard deviation away from the closest specification;

$P_{PK} > 1$: the mean is more than 3x standard deviation away from the closest specification.

3.4.2 Process Performance (P_P)

P_P is a calculated measure of the spread relative to the specification limits. It represents the variability of the process within a brief period. P_P used by itself it does not indicate where the process mean is located relative to specifications. Therefore, P_{PK}/P_P is used.

Formula:

$$P_p = \frac{Specification\ range}{Process\ Range} = \frac{UCL - LCL}{6\ \sigma}$$

3.4.3 P_{PK}/P_P

P_{PK}/P_P is a ratio of P_{PK} and P_P. P_{PK}/P_P is calculated to normalise P_{PK} to make products with different specification limits comparable.

P_{pk}/P_p is used to give an indication of how off-centre the process mean is located relative to the specifications. In general, the more off-centre the process mean, the higher the risk of non-conformance.

Interpretation:

P_{pk}/P_p = 0,25: The mean is a quarter way from the closest specification relative to the centre of the specification;

P_{pk}/P_p = 0,5: The mean is half way between the centre of the specification and the closest specification;

P_{pk}/P_p = 1: The mean is centred within the specifications;

P_{pk}/P_p > 1: Indicated that the process is off-centre but is not a concern when the boundary specification on percent values is 0 or 100.

3.4.4 Percentage within Specification (PWS)

PWS estimates the percentage of conforming samples. Conforming means within specification/declaration limits.

Formula:

a) $PWS = \int_{min}^{max} \varphi_{\mu,\sigma}(x)\, dx$

b) $\varphi_{\mu,\sigma}(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$ $(Probability\ density\ function\ according\ to\ N_{\mu,\sigma})$

Interpretation:

$0 \leq PWS \leq 1$. The closer to 1, the better.

PWS is preferred to CTS because it is an estimate based on a sub-sample of the total population is taken (and the probability of conformance estimated) than measuring the entire production.

3.4.5 Conformance to Specification (CTS)

CTS calculates the quantity of conforming samples relative to the total number of samples. Conforming means within specification/declaration limits.

Formula:

$$CTS = 100 \times \frac{(all\ samles -\ nonconform\ samples)}{all\ samples}$$

Interpretation:

$0 \leq CTS \leq 1$. The closer to 1, the better.

4 Data Presentation and Daily Work with KPIs

As all data is available in a central database, they can be evaluated at push of a button. In the following, we present different views on the data: comparison of asphalt plants, comparison of aggregate plants, comparison of asphalt products, and comparison of aggregate products.

4.1.1 Comparison of Plants

Plant View: OCL, KPI und non-conforming Samples

Per plant and per product category the following is shown:

- OCL
- Quantity of non-conforming samples
- Percentage of non-conforming samples
- KPI

The product categories follow the European standard for the Operating Compliance Level. For simplicity reasons we here only use Small Asphalt Mix and Large Asphalt Mix. Other product categories can be blinded-in at any time.

Samples from 01.07.2012 to 01.12.2012

Max No.

Min. no of samples OCL 32

Min. no of samples KPI/CC 15

Plant	Mixture category	OCL	# Non-conforming	% Non-conforming	Total KPI	KPI	# Total numbe... samples
	Small AM	B				0,95	49
10_Helsinki	Large AM	B	5	4,7	0,97	1,00	58
	Small AM	A				0,98	53
11_Tokio	Large AM	A	5	1,6	0,99	1,00	261
	Small AM	B				0,95	31
12_London	Large AM	C	11	10,8	0,94	0,93	71
	Small AM	A				0,99	97
13_Paris	Large AM	A	2	1,3	0,99	1,00	62
	Small AM	C				0,93	71
14_Rome	Large AM	C	14	8,9	0,96	0,98	87
	Small AM	A				0,98	40
15_Athens	Large AM	A	1	1,2	0,99	1,00	44

Figure A: Plant Overview of OCL, Non-conforming Samples and KPI

Interpretation:

The non-conforming samples and the KPI give a clear top-down indication, which plant is underperforming. For instance, the plant "12_London" has the worst KPI. Here, a more detailed analysis should be performed.

Plant View: Indicators per Parameter

Additionally, for each product category and per test category (Binder; Filler; Sand; characteristic fine/coarse sieve; D; 1,4D) the following indicators are presented:

- Ratio: Number of non-conforming samples / total samples (also shown as #NC/#)
- Quantity of Xbar deviations
- Quantity of MR deviations
- Quantity of CUSUM deviations
- PWS, P_{PK} and P_{PK}/P_P

Samples from 01.07.2012 to 01.12.2012 | Max No. | Min. no of samples OCL 32 | Min. no of samples KPI/CC 15 | Region 10_Berlin

Plant	OCL	# Non-conforming	% Non-conforming	Total KPI	KPI	Binder #NC /#	XBar	MR	CUSUM	PWS	PPK	PPK /PP		# Total number of samples
	B				0,95	1/49		1	2	0,95	0,63	0,95		49
10_Helsinki	B	5	4,7	0,97	1,00	0/58	1			1,00	0,94	0,94		58
	A				0,98	1/53	1	2	11	0,97	0,69	0,95		53
11_Tokio	A	5	1,6	0,99	1,00	1/261	2	4		1,00	1,11	0,95		261
	B				0,95	1/31		1		0,99	0,82	0,84		31
12_London	C	11	10,8	0,94	0,93	5/71	5	6	17	0,66	0,23	0,67		71
	A				0,99	0/97	1	4		1,00	1,05	0,94		97
13_Paris	A	2	1,3	0,99	1,00	0/62	1		20	1,00	0,98	0,98		62
	C				0,93	0/71	1	2		0,97	0,65	0,86		71
14_Rome	C	14	8,9	0,96	0,98	2/87	1	1		0,99	0,80	0,97		87
	A				0,98	1/40	1		2	0,95	0,63	0,98		40
15_Athens	A	1	1,2	0,99	1,00	0/44		2		1,00	0,97	0,95		44

Figure B: *Plant Overview: Additional Presentation of Indicators for Binder*

Interpretation:

A high number of non-conforming samples, several deviations in the control charts and low levels in the PWS, P_{PK} and P_{PK}/P_P are indicators for underperforming quality in each parameter. For instance, in Figure B indicators for binder are additionally shown. The plant "12_London" has a quite high number of control chart deviations and low KPI indicators for the binder content of large asphalt mixes: Xbar has 5 deviations, MR has 7 deviations and CUSUM has 17 deviations; PWS is 0,66, P_{KK} is 0,23 and P_{KK}/P_P is 0,67. When contacting the plant, it came out that the binder weight had a defect.

4.1.2 Product View

The product view provides more details for the data analysis. The KPI per product gives an indication which property has a quality problem:

Samples from 01.06.2012 to 01.12.2012 | Max No. | Min. no of samples OCL 32 | Min. no of samples KPI/CC 15 | Region 10_Berlin | OCL view / Product view

Plant	Spec.	TT No.	KPI	# Control chard deviations	Binder #NC /#	Binder XBar	Binder MR	Binder CUSUM	Binder PWS	Binder PPK	Binder PPK /PP		Filler #NC /#	Filler XBar	Filler MR	Filler CUSUM	Filler PWS	Filler PPK	Filler PPK /PP	
10_Helsinki	AC 32 T S 50/70	1213 01	1,00	20	0/42	1			1,00	1,07	1,00		0/42	1	1	3	1,00	1,10	0,98	
11_Tokio	AC 32 T S 50/70	1812 91	1,00	8	0/28				1,00	1,27	0,96		0/28				1,00	1,76	0,59	
12_London	AC 32 T S 50/70	1213 91	0,88	68	5/45	5	3	6	0,55	0,14	0,50		2/45	4	3	23	0,95	0,57	0,73	
13_Paris	AC 32 T S 50/70	1212 91	1,00	56	0/26	1	1	9	1,00	1,07	0,97		0/26	2	1	8	0,99	0,84	0,57	
14_Rome	AC 32 T S 50/70	1313 91	0,98	2	1/26				0,95	0,63	0,96		0/26				1,00	1,12	0,71	

Figure C: Product View of an AC 32 T S 50/70 – Indicators for Binder and Filler are shown

Interpretation:

Again, a low KPI, deviations in the control charts and high number of non-conforming samples are strong indicators for underperforming quality for each product and parameter. For instance in the above example, London has the lowest KPI (0,88). This corresponds with a high number of control chart deviations (68 in total). For binder there are low values for PWS (0,55), P_{KK} (0,14) and P_{KK}/P_P (0,50).

In the following, a detailed KPI reports are shown. Figure D shows a product with a poor quality performance, whereas Figure E shows a product with an excellent quality performance.

Binder analysis of 1213 91 for the period 04.06.2012 - 20.11.2012

Plant	**12_London**
Region	**10_Berlin**
Mix Category	**1213 91**
Test Type	**Binder**

OCL Parameters for 1213 91	
Mean value criterion	pass
Single value criterion	7
Resulting OCL Level	B

Statistical Parameters	
Number of observation	45
Mean value	0,37
Standard deviation	0,73
04.06.2012 - 20.11.2012	

Key Performance Indices			
Plant KPI	0,88	PPK	0,29
Mix Category KPI	0,88	PP	0,59
CTS (%)	84,4	CPK	0,14
PWS (%)	0,55	CP	0,28

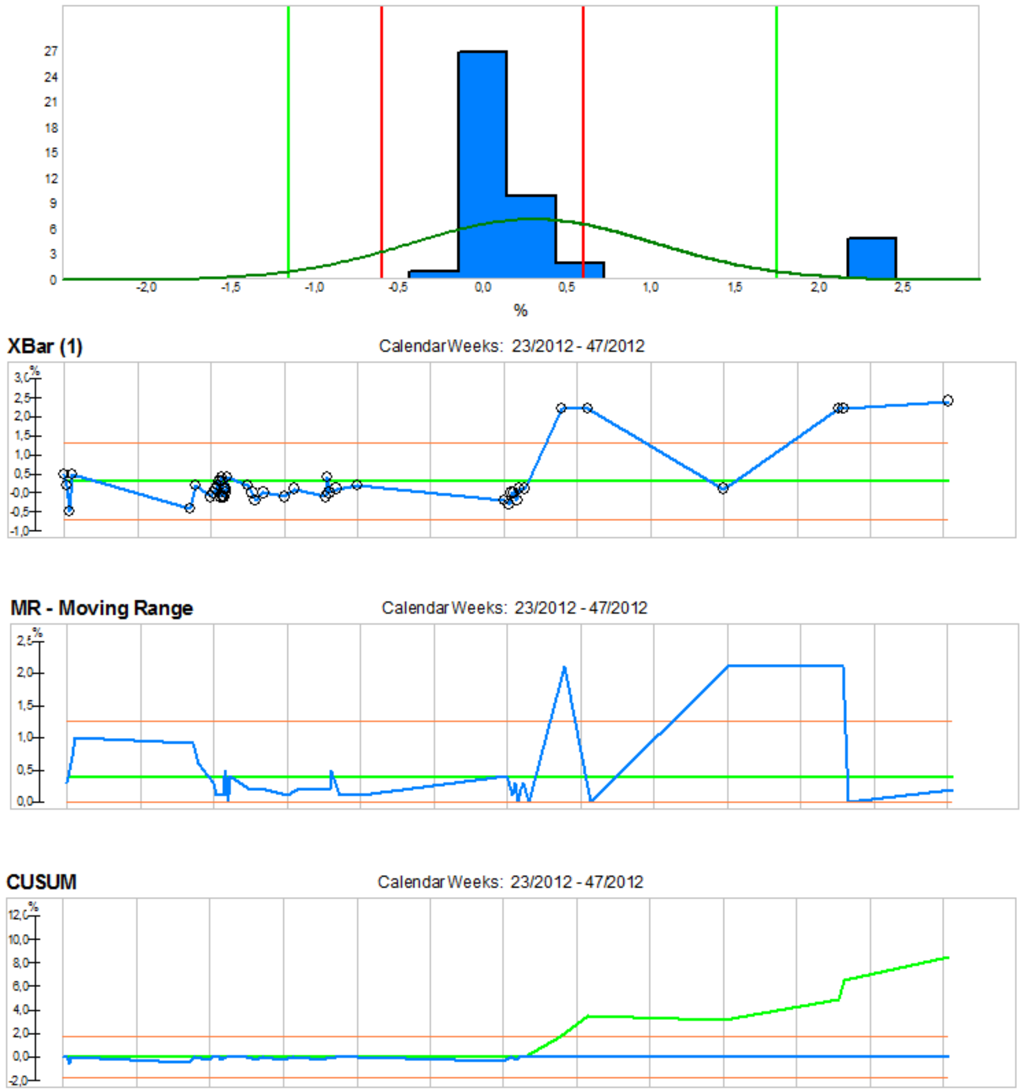


Figure D: Example for a KPI Report for the Plant "10_London" for AC 32 T S 50/70 for Binder Content with a low quality level

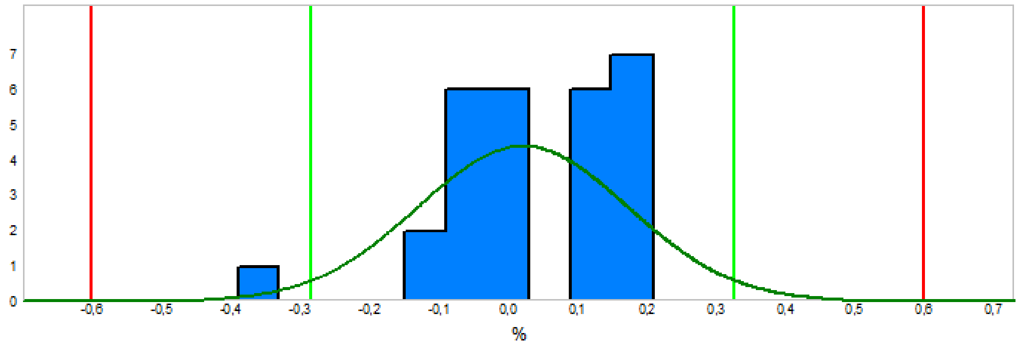
Binder analysis of 1812 91 for the period 21.09.2012 - 21.11.2012

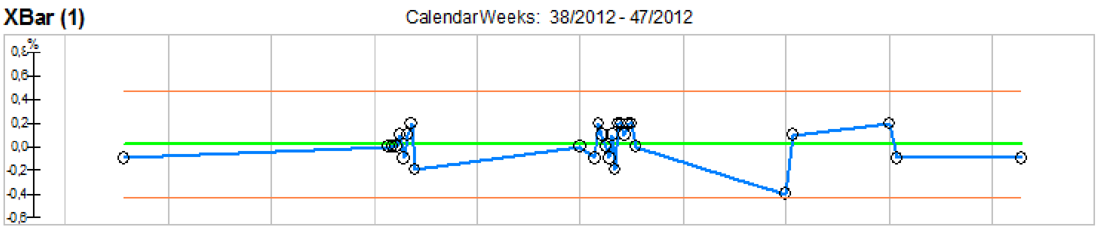
Plant	**11_Tokio**
Region	**10_Berlin**
Mix Category	**1812 91**
Test Type	**Binder**

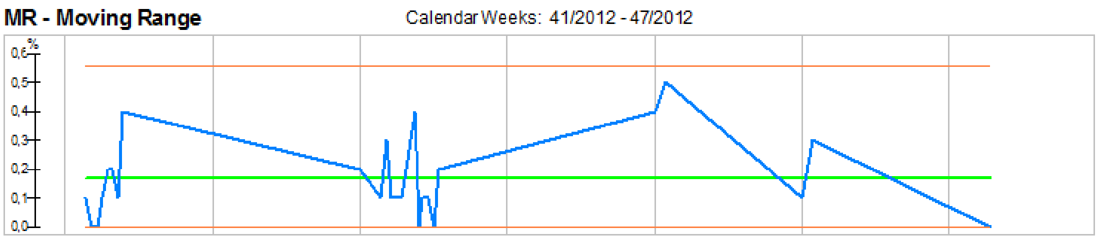
OCL Parameters for 1812 91	
Mean value criterion	pass
Single value criterion	
Resulting OCL Level	A

Statistical Parameters	
Number of observation	28
Mean value	0,00
Standard deviation	0,15
21.09.2012 - 21.11.2012	

Key Performance Indices			
Plant KPI	1,00	PPK	1,28
Mix Category KPI	1,00	PP	1,32
CTS (%)	100	CPK	1,27
PWS (%)	1,00	CP	1,31







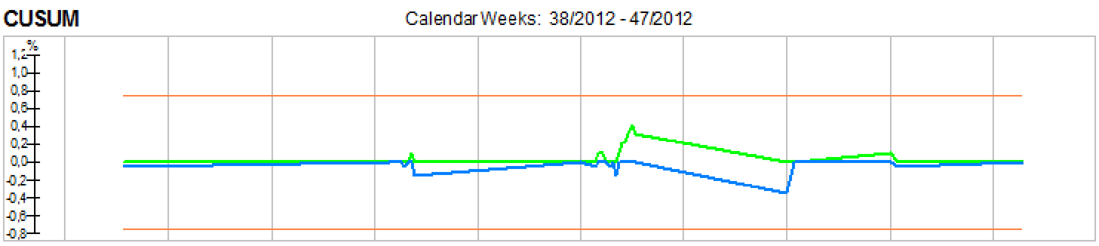


Figure E: Example for a KPI Report for the Plant "11_Tokio" for AC 32 T S 50/70 for Binder Content with a high quality level

Example: If the Problem in the Asphalt Plant originates in the Source

Veidekke integrated the quality control of its asphalt plans as well as its quarries into one LASTRADA system. Hence, if problems are detected in an asphalt plant, they can be easily located if the reason for them originate in the quarry.

Samples from 01.09.2012 to 01.10.2012 | Max No. | Min. no of samples OCL 32 | Min. no of samples KPI/CC 10 | Region 09_Hamburg

Plant	Mixture category	OCL	Total KPI	KPI	Filler #NC /#	Sand #NC /#	Char. fine ... #NC /#	Char. coarse... #NC /#	D #NC /#	1.4*D #NC /#	# Total number of samples
	Small AM	C		0,93	1/36	1/36	0/18	3/32	0/36	0/36	36
10_Helsinki	Large AM	C	0,91	0,89	7/36	3/36	2/35	1/36	1/36	0/36	36
	Small AM	B		0,98	0/20	0/20	0/12	0/20	0/20		20
12_London	Large AM	B	0,92	0,87	0/29	0/29	1/29	1/29	1/29	1/29	29
	Small AM	C		0,86	4/44	3/44	2/40	6/41	0/44	1/44	44
14_Rome	Large AM	C	0,91	0,97	1/48	0/48	0/44	0/48	0/48	1/48	48

Figure F: Asphalt Plants Helsinki, London and Rome with nom-conforming Samples in the Grading

Samples from 01.09.2012 until 01.10.2012 | Max quantity of samples 50 | Min sample quantity KPI/CC 10 | (1) Standard

Mining site	Specification	# non-conf...	% non-conf...	Total KPI	KPI	% CTS	# Control chart deviati...	Under size #NC /#	Under size PWS	Under size PPK	Under size PPK /PP	Under size	Over size #NC /#	Over size PWS	Over size PPK	Over size PPK /PP	Over size
	Coarse 16/22 (Raw Mat2)				0,61	53,33	2	0/15	0,98	0,67	0,79		1/15	0,92	0,52	0,89	
	Coarse 2/5 (Raw Mat2)				0,84	78,57	12	1/28	0,96	0,63	0,88		1/28	0,91	0,46	0,72	
	Coarse 22/32 (Raw Mat2)				0,40	50,00		0/14	0,98	0,68	0,54		0/14	0,90	0,43	0,23	
	Coarse 31/56 E (Raw Mat2)				0,72		2	0/5	0,99	0,85	0,58		1/5	0,73	0,20	0,07	
	Coarse 31/63 (Raw Mat2)				0,93	89,19	34	0/37	1,00	1,05	0,93						
	Coarse 5/8 (Raw Mat2)				0,27	10,00	9	14/50	0,67	0,15	0,16		25/50	0,43	-0,06	-0,08	
	Coarse 8/11 (Raw Mat2)				0,36	18,00	5	0/50	1,00	1,10	0,71		30/50	0,38	-0,10	-0,15	
	Fine 0/2 Uvasket (Raw Mat2)				0,97	100,...							0/13	0,93	0,50	0,37	
Quarry 2	Fine 0/2 Vasket (Raw Mat2)	172	58,5	0,61	0,73	50,00							5/10	0,45	-0,04	-0,04	

Figure G: Aggregate KPI View of the Supplier "Quarry 2".

For instance, if the three plants, shown in Figure F, receive aggregate from "Quarry 2" and all the delivered asphalt plants have a jump in non-conforming samples, the quality data of the quarry should be analysed. Figure G shows a high number of non-conforming samples for the under size of product 5/8 und the over size of 5/8 and 8/11.

5 Summary

In this paper we introduced Process Capability Indices to the quality control and quality assurance of construction materials. It has been described that only a central database together with a professional quality control software can manage the huge amount of data and standardise processes – these are the prerequisites to deploy Process Capability Indices. After describing the development of the Process Capability Indices and the KPI in detail, several examples for the daily work have been presented. Finally, we are convinced that the presented KPI approach provides an effective and (at the same time) understandable and easy quality control system for the materials producer.

6 Contacts

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