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SINTEF Building and Infrastructure

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FA 2 Competitive constructions

SP 2.1 Robust and highly flowable concrete with controlled surface quality

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Preface

This study has been carried out within COIN - Concrete Innovation Centre - one of presently 14 Centres for Research based Innovation (CRI), which is an initiative by the Research Council of Norway. The main objective for the CRIs is to enhance the capability of the business sector to innovate by focusing on long-term research based on forging close alliances between research-intensive enterprises and prominent research groups.

The vision of COIN is creation of more attractive concrete buildings and constructions. Attractiveness implies aesthetics, functionality, sustainability, energy efficiency, indoor climate, industrialized construction, improved work environment, and cost efficiency during the whole service life. The primary goal is to fulfil this vision by bringing the development a major leap forward by more fundamental understanding of the mechanisms in order to develop advanced materials, efficient construction techniques and new design concepts combined with more environmentally friendly material production.

The corporate partners are leading multinational companies in the cement and building industry and the aim of COIN is to increase their value creation and strengthen their research activities in Norway. Our over-all ambition is to establish COIN as the display window for concrete innovation in Europe.

About 25 researchers from SINTEF (host), the Norwegian University of Science and Technology - NTNU (research partner) and industry partners, 15 - 20 PhD-students, 5 - 10 MSc-students every year and a number of international guest researchers, work on presently eight projects in three focus areas:

- Environmentally friendly concrete
- Economically competitive construction
- Aesthetic and technical performance

COIN has presently a budget of NOK 200 mill over 8 years (from 2007), and is financed by the Research Council of Norway (approx. 40 %), industrial partners (approx. 45 %) and by SINTEF Building and Infrastructure and NTNU (in all approx. 15 %).

For more information, see www.coinweb.no

Tor Arne Hammer
Centre Manager

Summary

This report gives the findings from a collaboration project between the Norwegian Public Roads Administration (NPRA) and the COIN FA 2.1 project managed by SINTEF Building and Infrastructure which was start in spring 2010.

The COIN FA 2.1 project "Robust and highly flowable concrete with controlled surface quality" is a sub-project of the COncrete INnovation centre (www.coinweb.no) running from 2007-2014. One of the objectives of the COIN FA 2.1 project is to develop an objective classification tool for concrete surfaces cast against smooth formwork. The classification tool should assess pores, grey level and grey level variations. The state of the concrete surface is documented using photographic equipment. The images are analysed using Matlab based image analysis software called BetongGUI. The image taking procedure and image analysis tool were under development during the collaboration project.

The NPRA's project "Askimporten tunnel – Field test of surface treatment of wall segments" started in 2010, aims to document the long-term effects of different surface treatment with respect to maintaining a light grey surface colour and reducing the environmental impacts on the concrete elements. In total 9 different surface treatment products were tested.

The NPRA has invited the COIN FA 2.1 project into this collaboration project to document the wall segments with regards to grey level as a case study for implementation of their classification tool.

Regarding the surface treatment products it could be concluded that products 4, 5a and 7 seemed to perform best over time. Product 1a also maintains a lighter visual appearance than the reference before washing, but has similar reflection values as the reference after washing. All these products contain white pigments. None of the colourless surface treatments maintain a lighter appearance than the reference fields over time.

During the collaboration project several improvements were made to the classification tool:

- flash settings are to be kept constant
- a pop-up white calibration object was used during the last site visit instead of white cardboard to prevent folds and hence erroneous reflections
- the grey scale calibration object appeared to be too glossy and therefore only the lightest field of the calibration object is used for greyscale calibration in combination with linearized images
- robustness problems with the white calibration software and image analysis software were dealt with.

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1 Introduction

1.1 Principal objectives and scope

The objective of this project is to document the grey scale level of concrete tunnel segments treated with different surface treatment products in Askimport tunnel on E18 in Østfold over time as part of the "Askimporten tunnel – Field test of surface treatment of wall segments" project. The lightness of the surfaces is assessed by the surface classification tool being developed by SINTEF within the COIN FA 2.1 project.

1.2 Project information

A collaboration project between the Norwegian Public Roads Administration (NPRA) and the COIN FA 2.1 project managed by SINTEF Building and Infrastructure was started in spring 2010.

The COIN FA 2.1 project "Robust and highly flowable concrete with controlled surface quality" is a sub-project of the COncrete INnovation centre (www.coinweb.no) running from 2007-2014. One of the objectives of the COIN FA 2.1 project is to develop an objective classification tool for concrete surfaces cast against smooth formwork. The classification tool should assess pores, grey level and grey level variations. The state of the concrete surface is documented using photographic equipment. The images are analysed using Matlab based image analysis software called BetongGUI. The image taking procedure and image analysis tool were under development during the collaboration project.

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The NPRA has invited the COIN FA 2.1 project into this collaboration project to document the wall segments with regard to grey level as a case study for implementation of their classification tool.

2 Test programme

Askimporten tunnel is part of the new E18 in Østfold, and was opened for traffic on November 23rd 2010.

Six surface treatment suppliers are involved in the project, and a total of nine products are tested. In Table 1 is an overview of the products used in this project. The products are both pigmented and colourless surface treatments. Further information on the products can be found in the VD Report 16 from the Norwegian Public Roads Administration. Untreated reference areas are established as well, close to each of the testing areas.

Table 1 Surface treatment products: notation, product type and whether white pigmented

Notation	Product type	White pigment
1a	Hydrophobic impregnation, silicon molecules in a nano-structured emulsion	X
1b		
2	Impregnation/hydrophobic impregnation * (based on modify hybrid materials in a water solution)	
3	Hydrophobic impregnation, silane gel	
4	Coating, water based epoxy coating	X
5a	Impregnation/hydrophobic impregnation*	X
5b	Hydrophobic impregnation	
6	Hydrophobic impregnation, silane based cream	
7	Coating, cement based	X
I – V	Reference fields	

* Not clear from the product documentation if the product is classified as an impregnation or a hydrophobic impregnation

The testing area is located close to the tunnel opening, and includes a total of 15 wall elements. Each element has a width of 5 metres and a height of about 3.5 metres. The elements are cast against smooth formwork. Figure 1 shows an overview of the test field with the product notation and Figure 2 is an image of the test field.

Askimporten tunnel has been visited 4 times. The test programme for documentation is shown in Table 2. Documentation of lightness of the test elements was performed before the tunnel was opened for traffic and two times in connection with washing of the tunnel. It is of interest to investigate if there is a difference between the products both in how well they protect the concrete against dirt and discolouration and how easily the dirt can be washed off the surfaces.

The images to document the grey scale level are taken in the same position and distance from the wall for all rounds. For details see Appendix.

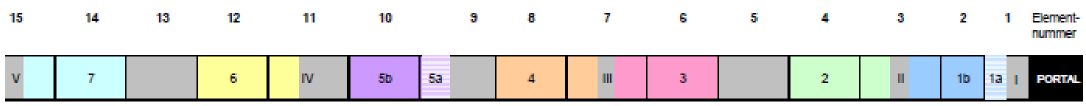

Figure 1 Overview of the test field and product notation. From: VD Report 16, Norwegian Public Roads Administration

Figure 2 Test field after applied products, element 1 (in the front) to element 15 (in the back). From: VD Report 16, Norwegian Public Roads Administration

Table 2 Conducted test programme

Round	When	Who	What
1	18 October 2010	Kristin Kaspersen and Mari Bøhnsdalen Eide, SINTEF Karen Klemetsrud and Eva Rodum, NPRA	Photographic documentation of surface before the tunnel was opened for traffic
2	7-8 June 2011	Mari Bøhnsdalen Eide, SINTEF Karen Klemetsrud and Eva Rodum, NPRA	Photographic documentation of surface before and after washing
3, part 1	22-23 April 2012	Mari Bøhnsdalen Eide, SINTEF Karen Klemetsrud and Eva Rodum, NPRA	Photographic documentation of surface before washing
3, part 2	22 May 2012	Mari Bøhnsdalen Eide, SINTEF Reidar Kompen and Eva Rodum, NPRA	Photographic documentation of surface after washing

3 Experimental set-up

3.1 Equipment

The equipment used is as follows:

- Camera: Olympus E-620 DSLR
- Lens: Olympus Zuiko Digital 14-42mm F3.5-5.6
- Flash: Olympus FL-50R
- Diffuser: PhotoFlex LiteDome Q39 softbox Medium
- 2 tripods, one for the camera and one for the flash and softbox
- Calibration tool from Edmund Optics: Large Greyscale target.
- White calibration tool (matte white paperboard or pop-up lighting calibration tool from Lastolite)

3.2 Set-up

The test area is 60 x 60 cm and marked directly on the concrete wall with permanent marker. Camera and flash + softbox are fastened to their tripods, and the camera is placed in front of the softbox/flash. See Figure 3 and Figure 4 for details on set-up.

Figure 3: Set-up of camera, flash and softbox in principle

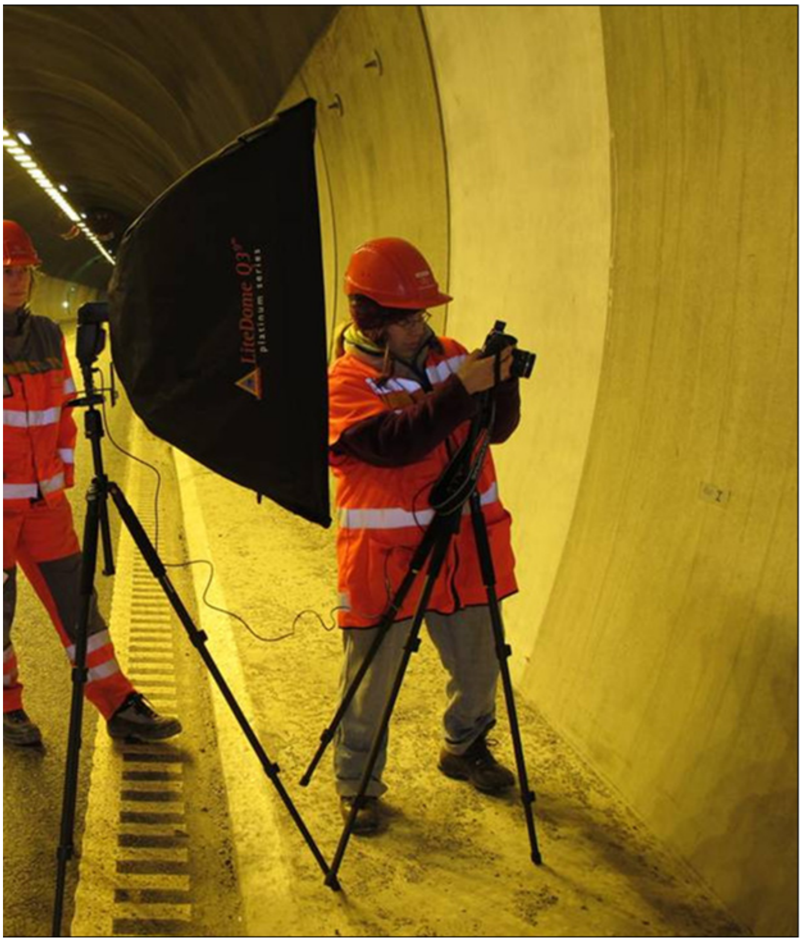

Figure 4: Set-up of camera, flash and softbox in tunnel

3.3 Camera settings

- Aperture: 22
- Shutter: 1/10 sec
- Lens/zoom: 14 mm
- White balance: fixed (5400 K)
- ISO: 100
- Distance camera - wall: 40-50 cm
- Focus: Manual, set for first image and then held fixed within each image series
- Picture section: approx. 75-80 x 100-110 cm
- Lighting: Flash (TTL Auto) + fluorescent lighting in tunnel ceiling

3.4 Photographic procedure

Each image series consists of four images. First a picture of the test area is taken. Then the white calibration sheet is placed in front of the test area and a picture is taken. This image is used to adjust the final image for the flash distribution. Third, a picture of the large greyscale target inside the test area is taken for greyscale calibration. Finally, a picture of the test area alone is taken once again. See Figure 5 for example of images.

It is of utmost importance that the camera is kept in the exact same position while the four pictures are taken**.**

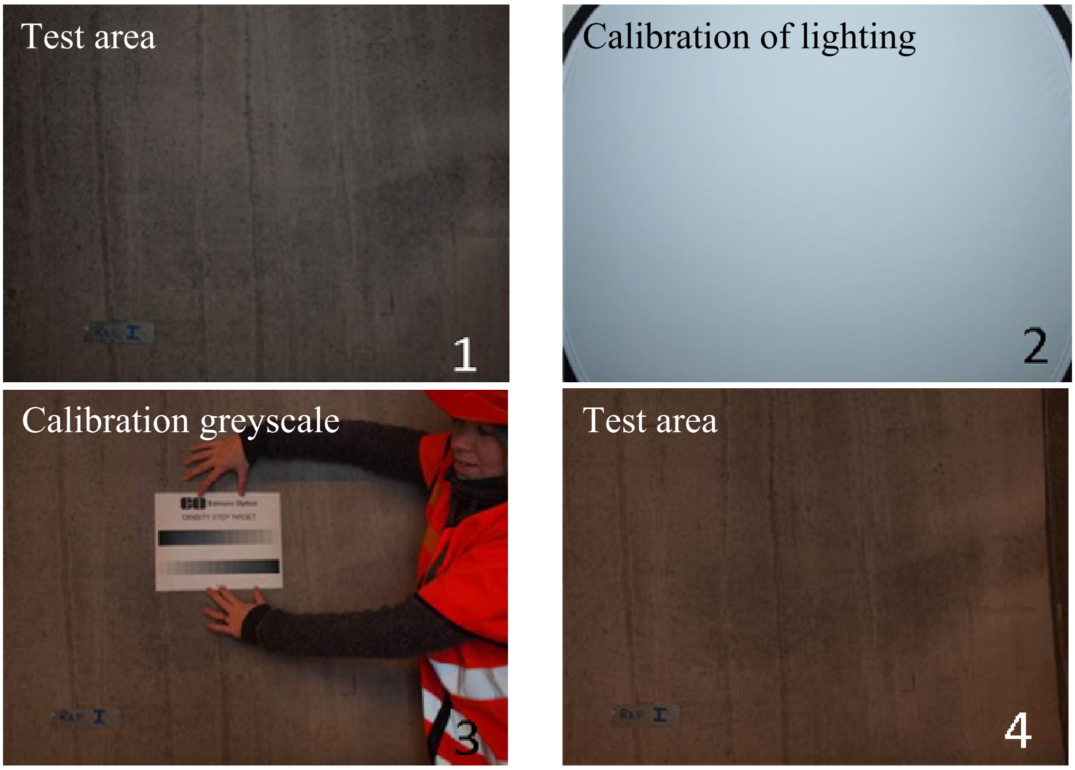

Figure 5: Example of the 4 standard images

3.5 Definition of greyscale

3.5.1 The calibration tool from Edmund Optics

Figure 6 shows the greyscale calibration tool from Edmund Optics (http://www.edmundoptics.com/testing-targets/test-targets/color-grey-level-test-targets/large-grayscale-target/1329) used in the third picture of Figure 5. The calibration tool has 15 optical density or reflection steps. The relation between the density value and the reflection value is as follows: $reflection = 10^{-(density)}$. The optical density ranges linearly from 1.5 to 0.09 with steps of 0.1007, and the reflection values increase according to a power function from approx. 0.03 ($10^{-1.5}$) to 0.81 ($10^{-0.09}$), see Figure 6 below.

Optical density	1.5	1.4	1.3	1.2	1.1	1	0.9	0.8	0.69	0.59	0.49	0.39	0.29	0.19	0.09
Reflection	0.03	0.04	0.05	0.06	0.08	0.10	0.13	0.16	0.20	0.25	0.32	0.41	0.51	0.64	0.81

Figure 6: Greyscale calibration tool with optical density and reflection values for the upper part of the scale (the values are reversed for the lower part of the scale).

3.5.2 Greyscale values

The greyscale can be defined numerically in several ways, depending on whether whiteness or blackness is the measured value. In this report the greyscale will be defined in terms of reflection with values from 0-1, where 0 is all black (no reflection) and 1 is all white (total reflection).

BetongGUI uses the reflection values from 0.03-0.81 from the calibration tool and inter/extrapolates to obtain a continuous scale from 0-1.

3.6 Data analysis

The images were initially analysed with the programmes Hvitkalibrering and BetongGUI developed by SINTEF ICT, at the department for Optical measurement systems and data analysis.

Hvitkalibrering automatically calibrates each image series with respect to the information from image 2 and 3 in the series (see chapter 3.4). Image 2 is used to correct the images for uneven lighting and image 3 gives the image grey levels according to the reference scale.

In BetongGUI the images are first imported and filtered. Then the area to be analysed is selected. The blue frame in Figure 7 indicated the calibration object and the red frame the analysed area. The analysed area is kept as similar as possible for each image series.

From the main window the action “Measure grey level” is chosen, see Figure 7.

The “measure grey level” window is shown in Figure 8. For greyscale the output is a histogram, and statistics regarding the overall greyscale of the area. Pores are filtered out and not included in the analysis as the shadow in pores can influence the grey level. The results can be saved to a text file in a format that can be imported to Microsoft Excel for further analysis.

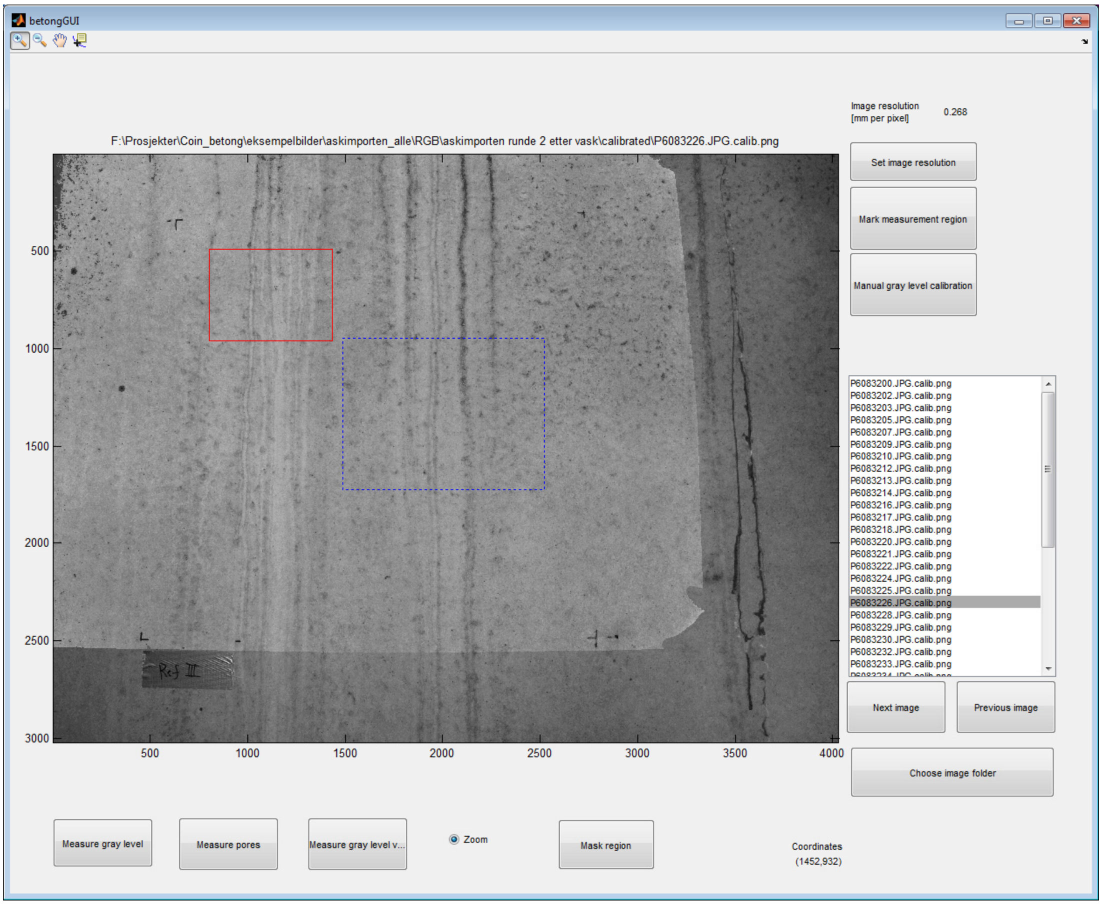

Figure 7: BetongGUI main window

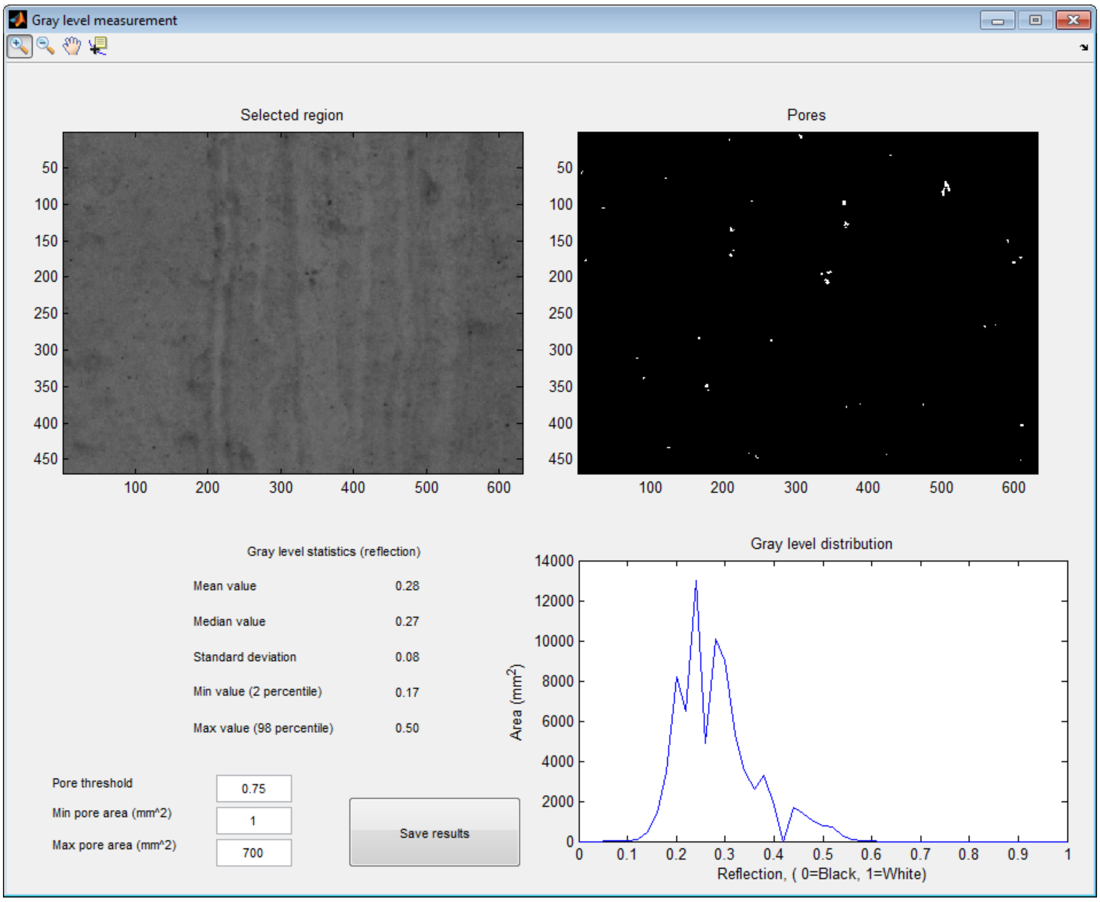

Figure 8: BetongGUI greyscale analysis

After the initial analysis it was discovered that the results for the dark regions were not correct due to problems with the reflectance properties of the calibration object. Figure 9 shows an example of this, with the grey level shown as colours for better visualisation. We see that the dark fields in the upper row appear to be lighter than the dark fields in the lower row. To remedy this we have implemented a new algorithm that only uses the lightest field (reflection = 0.81) of the calibration object as reference. The relative reflection error is much smaller for the lightest field than for the darkest field, so this gives a much more stable and correct calibration than we get from instead of using all the fields of the calibration object.

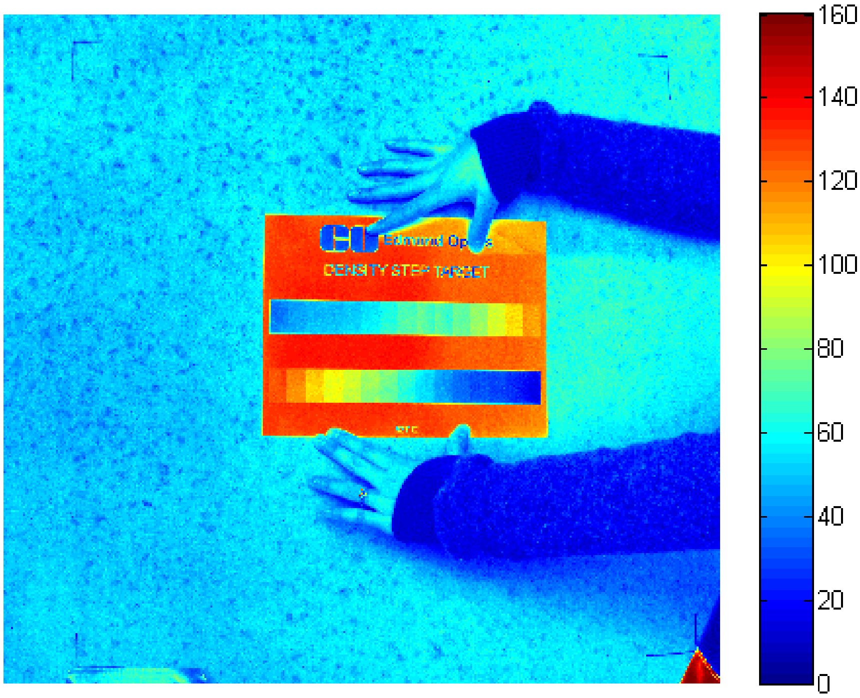

Figure 9 Example of image where the dark fields of the calibration target give incorrect values due to too high reflection.

Using only one reference field instead of the full greyscale does however require that the output from the camera is linear (so that we have it has to be so a linear relationship between the reflection level of the wall and the measured pixel value is obtained). This is not the case with RGB images (Red Green Blue colour images) from a standard camera. Since the human eye has a nonlinear intensity response, the output from the camera sensor is transformed by a nonlinear function (gamma curve) to create images that appear visually correct to a human. Hence, Tto obtain images with a linear scale we must therefore measure must the gamma curve of the camera must be measured and use the inverse of this curve must be used to linearize the RGB images before the greyscale analysis. Since it is we only wish to measure the reflection that i's measured (and not colour), we was use only the green channel of the image was applied used, because it has the smoothest gamma curve for the camera that was used in the this experiments. Figure 10 shows the gamma curve of the green channel. The curve was measured at SINTEF with the same camera as used in the field by taking images of a uniform, white surface with fixed aperture and increasing shutter time (from 1/4000 to 6 seconds). The linear intensity value is proportional to the shutter time. The RGB value is the mean value of each image.

Figure 11 shows an example of the same image before and after linearization. Both images are scaled so that black is zero and white is the maximum value in the image. We It can be seen that the linear image (c) appears to have much less contrast than the original image (b). See http://en.wikipedia.org/wiki/Gamma_correction for more information about gamma correction of images.

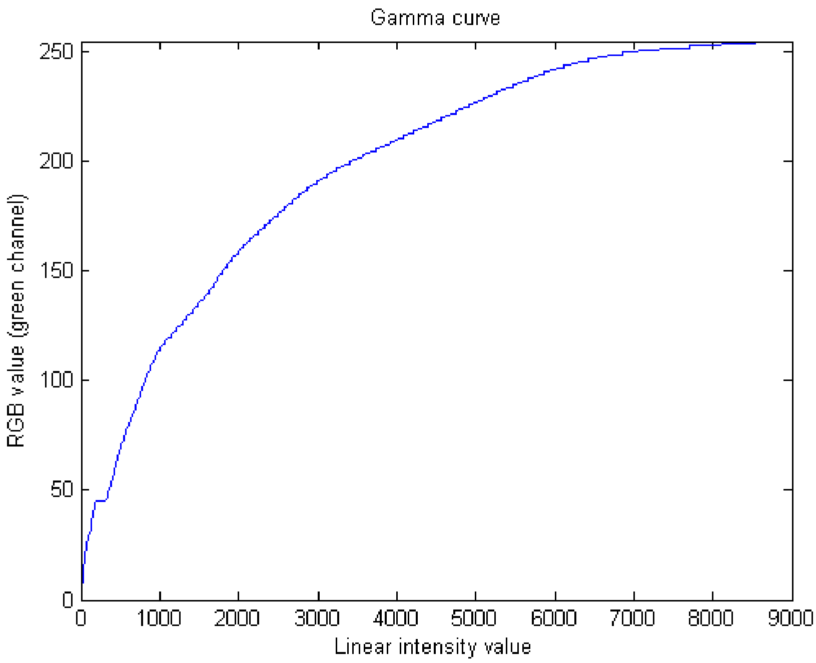

Figure 10 Gamma curve for the green channel of Olympus E-620.

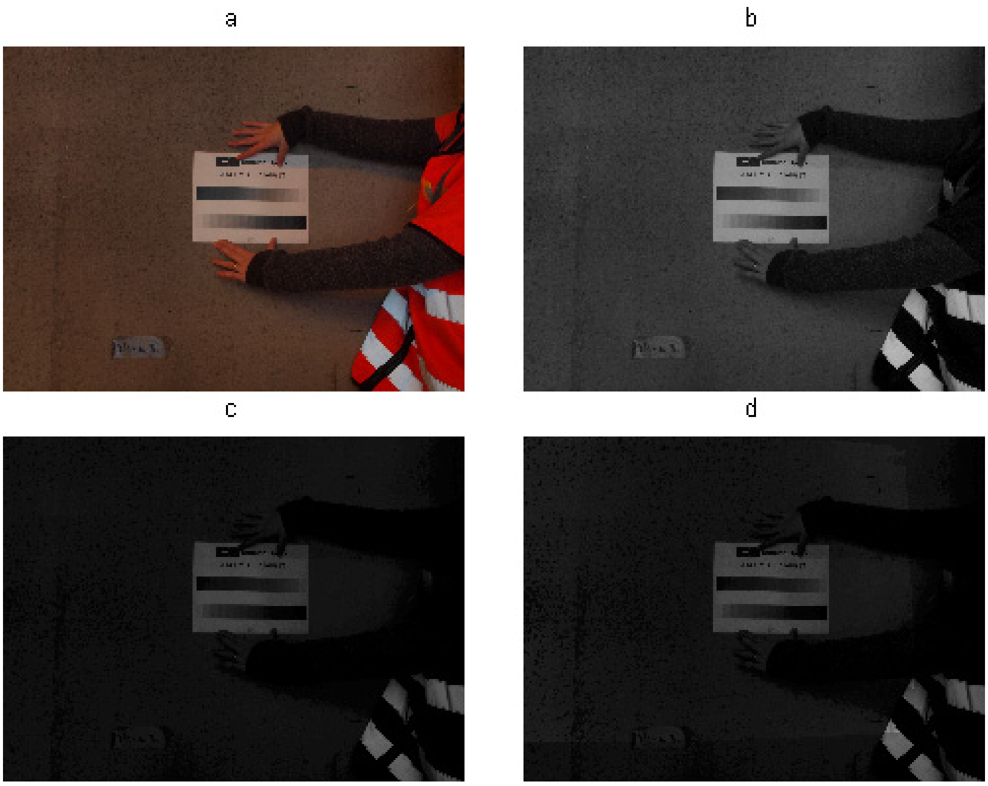

Figure 11 Visual appearance of the same image (Ref. 1 in Round 1) with and without use of the gamma curve: a) RGB image, b) The green channel of the RGB image, c) The green channel after linearization, d) The green channel after linearization and correction for uneven lighting.

4 Results and discussion

4.1 General

The overall grey level, or reflection, is expressed as a value between 0 and 1, where 0 is black and 1 is white, see section 2.5. All the values have been computed for flash corrected, linearized images, using only the lightest field of the calibration object as reference, as described in chapter 3.6. The regions for computation of mean values and standard deviations were chosen manually to be as similar as possible for each image series. The size and positioning of the regions may nonetheless differ slightly between the rounds. It should be noted that the standard deviation given in the tables is a measure of the variability of the reflection within each measurement area, and not a measure of the variability of the measurement method as such. The only exception is the standard deviation (σref) of the mean reference values (μref), which is the standard deviation of all the reference reflection values. These values are used to evaluate the statistical significance of the results for the surface treatment products. The result for a surface treatment product (μprod) is considered significantly different from the reference measurements if the difference in mean value is larger than three standard deviations ($\mu prod - \mu ref > 3\sigma ref$ or $\mu prod - \mu ref < -3\sigma ref$).

Since the images in Round 1 were taken in the autumn on a rainy day, the walls were covered with dew in parts of the tunnel. To avoid getting reflections from the water droplets in the images were, the walls twere dried off with paper towels as good as possible.we tried to wipe off the walls with paper towels. This did however result in some darker spots and an overall darker appearance of these regions. Some of the reflection values from Round 1 are therefore lower than they would have been if the walls had been dry (as they were during the other rounds). These values are marked by red in the result tables.

Manual inspection of the resulting images shows that the algorithm for correction of uneven lighting overcompensates in some of the images in Round 2 (products 5a, 6 and 7). The reason for this is not clear, but these values have been marked by blue in the result tables. For these cases we also show the mean value of the lighting corrected and the original value in black. This value is lower than the lighting corrected value and should be closer to the true value for these images. This mean value is also used in the graphical presentation of the results for these three products in Round 2.

The results for the surface treatment products are presented in section 4.2, and the results for the reference areas are presented in section 4.2.5. We first present the results for all the rounds together, then the results for each round separately and finally for all the rounds after washing.

4.2 Results for surface treatment products

The results for the surface treatment products are summarized in Table 3 and illustrated graphically in Figure 12. We see that the pigmented treatments show a much larger difference in grey level before and after washing than the other treatments. Several of the products have too low reflection values in Round 1 due to problems with wet walls, as described above. This is particularly noticeable for Product 6, as illustrated in Figure 13. Table 4 shows the difference between each product and the mean value of the untreated reference areas. Differences that are statistically significant according to the definition in section 4.1 are marked by green and yellow.

Table 3 Grey level statistics for surface treatment products: Reflection mean value ± standard deviation of measurement region for flash corrected images. Red indicates too low values due to wet walls. Blue indicates too high values due to overcompensation in the correction for uneven lighting.

	Round 1	Round 2 before washing	Round 2 after washing	Round 3 before washing	Round 3 after washing
Product 1a	0.60 ± 0.05	0.30 ± 0.04	0.39 ± 0.04	0.22 ± 0.02	0.32 ± 0.04
Product 1b	0.30 ± 0.05	0.28 ± 0.03	0.28 ± 0.03	0.15 ± 0.03	0.27 ± 0.02
Product 2	0.26 ± 0.04	0.25 ± 0.04	0.24 ± 0.02	0.12 ± 0.05	0.28 ± 0.03
Product 3	0.25 ± 0.04	0.27 ± 0.03	0.26 ± 0.03	0.10 ± 0.07	0.27 ± 0.03
Product 4	0.55 ± 0.04	0.27 ± 0.07	0.56 ± 0.03	0.16 ± 0.11	0.42 ± 0.04
Product 5a	0.51 ± 0.05	0.26 ± 0.04	0.49 ± 0.05 0.44	0.17 ± 0.07	0.43 ± 0.05
Product 5b	0.32 ± 0.03	0.29 ± 0.03	0.35 ± 0.04	0.12 ± 0.06	0.32 ± 0.03
Product 6	0.23 ± 0.06	0.29 ± 0.04	0.35 ± 0.04 0.33	0.11 ± 0.06	0.26 ± 0.02
Product 7	0.64 ± 0.05	0.19 ± 0.09	0.52 ± 0.08 0.42	0.18 ± 0.11	0.37 ± 0.06
Mean ref.	0.32 ± 0.004	0.25 ± 0.02	0.34 ± 0.03	0.16 ± 0.04	0.27 ± 0.03

Table 4 Difference in reflection between the regions with surface treatment products and the mean value of the untreated reference areas. Regions that have significantly higher reflection than the reference areas are marked by green ($\mu_{prod} - \mu_{ref} > 3\sigma_{ref}$). Regions that have significantly lower reflection than the reference areas are marked by yellow ($\mu_{prod} - \mu_{ref} < -3\sigma_{ref}$).

	Round 1	Round 2 before washing	Round 2 after washing	Round 3 before washing	Round 3 after washing
Product 1a	0.28	0.05	0.05	0.06	0.05
Product 1b	-0.02	0.03	-0.06	-0.01	0.00
Product 2	-0.06	0.00	-0.10	-0.04	0.01
Product 3	-0.07	0.02	-0.08	-0.06	0.00
Product 4	0.23	0.02	0.22	0.00	0.15
Product 5a	0.19	0.01	0.11	0.01	0.16
Product 5b	0.00	0.04	0.01	-0.04	0.05
Product 6	-0.09	0.04	-0.01	-0.05	-0.01
Product 7	0.32	-0.06	0.08	0.02	0.10

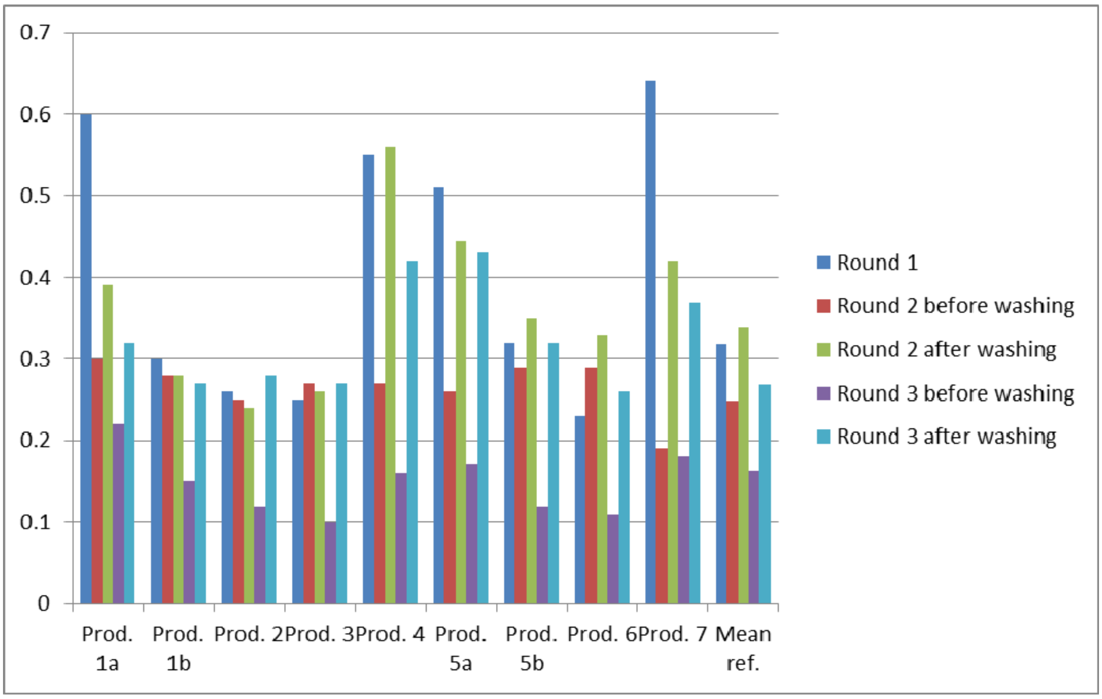

Figure 12 Reflection values for surface treatment products together with the mean value of all the untreated reference areas. All the values are for images after lighting correction, except for products 5a, 6 and 7 in Round 2 after washing. For these three images the mean value of the corrected and original image is shown due to overcompensation by the lighting correction algorithm.

Product 6 - Round 1

Product 6 - Round 2 after washing

Figure 13 Illustration of darker spots and overall lower reflection due to wet walls in Round 1 (upper image) compared to round 2 (lower image).

4.2.1 Round 2

Figure 14 shows the reflection values for the surface treatment products in Round 2 before and after washing. The mean value of all the untreated reference areas is shown for comparison. For products 1b, 2, 3, 5b and 6 the differences in reflection before and after washing are clearly not statistically significant (within or just above the standard deviation of the measured areas). For the other products there is a clear increase in reflection after washing, but only products 4 and 5a are significantly lighter than the reference areas after washing, whereas product 2 is significantly darker than the reference areas even after washing (see definition of significance with respect to untreated reference areas in section 4.2).

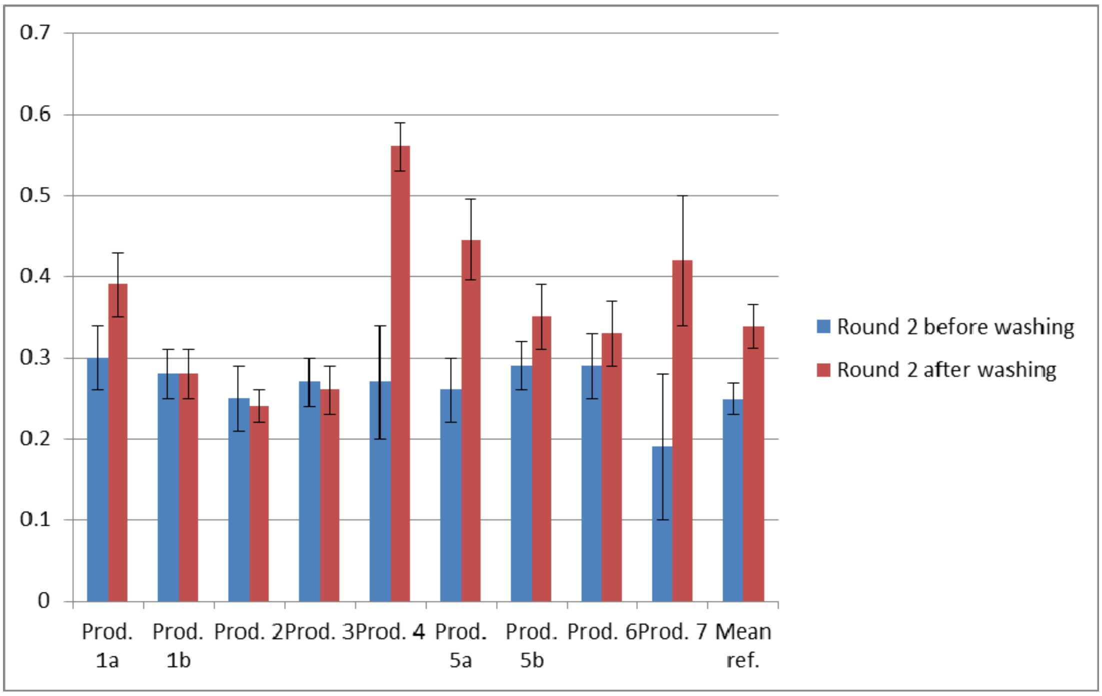

Figure 14 Reflection values for surface treatment products in Round 2 together with the mean value of all the untreated reference areas. All the values are for images after lighting correction, except for products 5a, 6 and 7 in Round 2 after washing. For these three images the mean value of the corrected and original image is shown due to overcompensation by the lighting correction algorithm.

4.2.2 Round 3

Figure 15 shows the reflection values for Round 3 before and after washing. The mean value of all the untreated reference areas is shown for comparison. In this round there is a clear increase in reflection after washing for all the products. However, similar to in Round 2, only products 4, 5a and 7 are significantly lighter than the reference areas after washing (see definition of significance with respect to untreated reference areas in section 4.2).

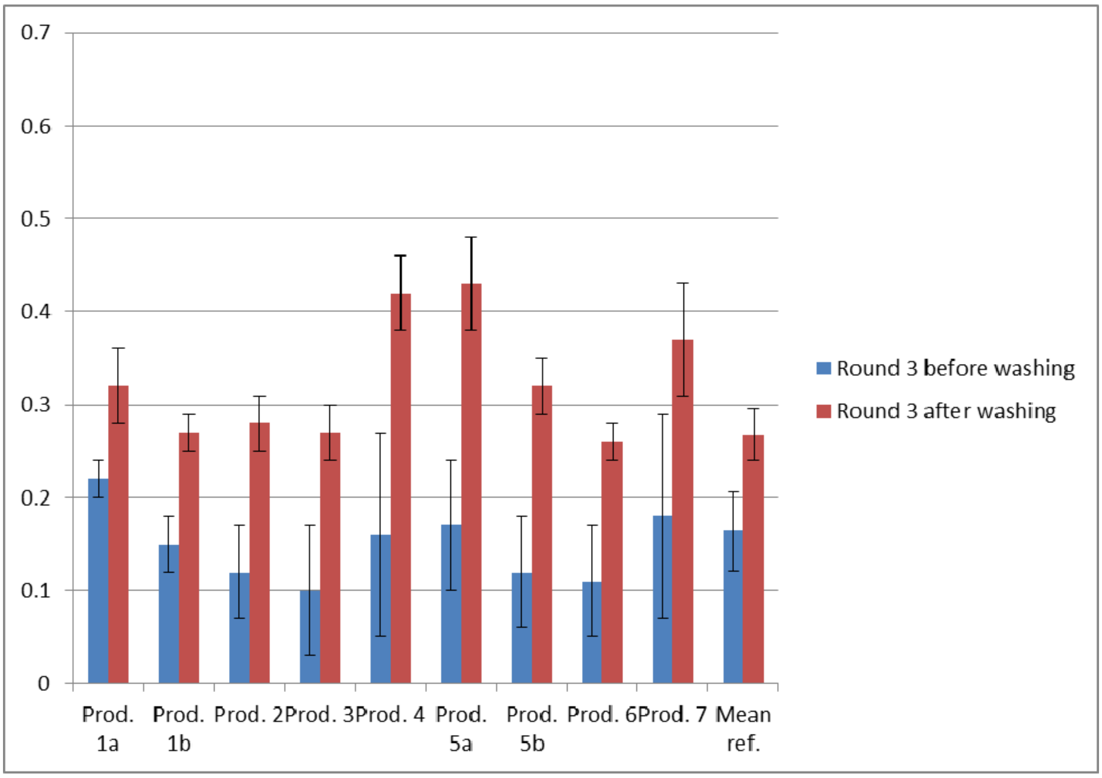

Figure 15 Reflection values for surface treatment products in Round 3 together with the mean value of all the untreated reference areas. All the values are for images after lighting correction.

4.2.3 All rounds before washing

Figure 16 shows the reflection values for both rounds before washing. The mean value of all the untreated reference areas is shown for comparison. In Round 2 before washing the differences in reflection are not significant except for product 7 which is darker than the reference area. In Round 3 before washing there is no significant difference between any of the products and the reference areas (see definition of significance with respect to untreated reference areas in section 4.2).

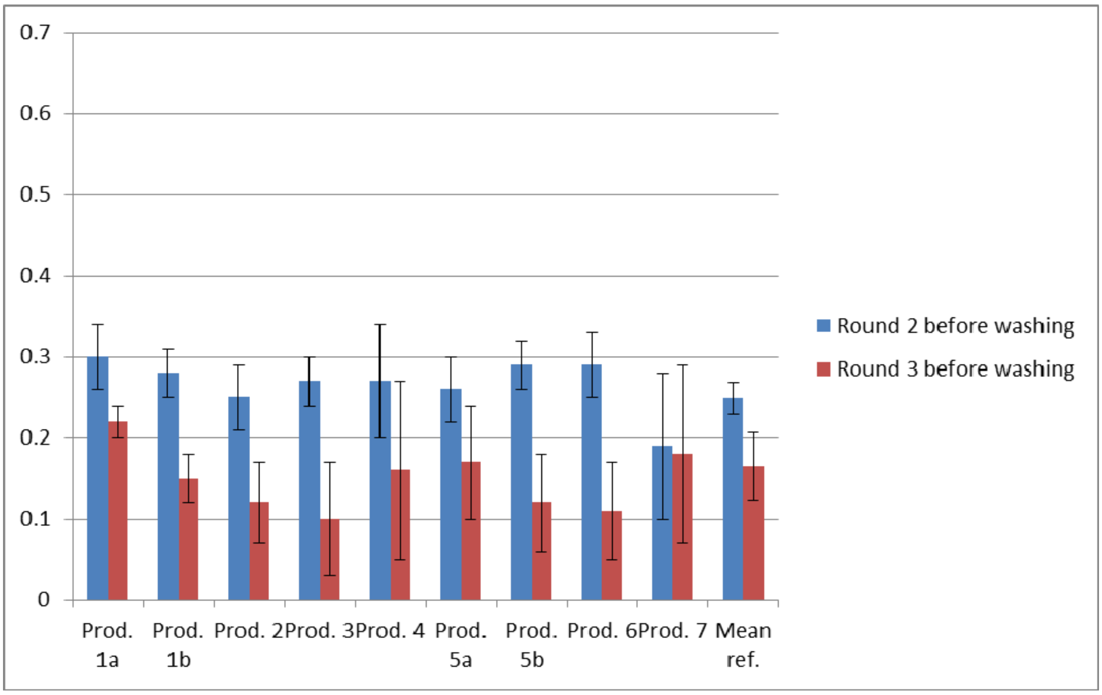

Figure 16 Reflection values for surface treatment products in both rounds before washing together with the mean value of all the untreated reference areas. All the values are for images after lighting correction.

4.2.4 All rounds after washing

Figure 17 shows the reflection values for all the rounds after washing. The mean value of all the untreated reference areas is shown for comparison. We see that the products that have the lightest visual appearance in Round 1 have the largest decrease in reflection over time. Several of these products do however still maintain a markedly lighter appearance over time than the reference areas. For products 1b, 2, 3 and 5b there is no significant difference in reflection between these three rounds (within the standard deviation of the measured areas). Products 5a and 6 also show little difference between these rounds. Overall products 4 and 5a seem to perform best, with product 7 as the third best alternative.

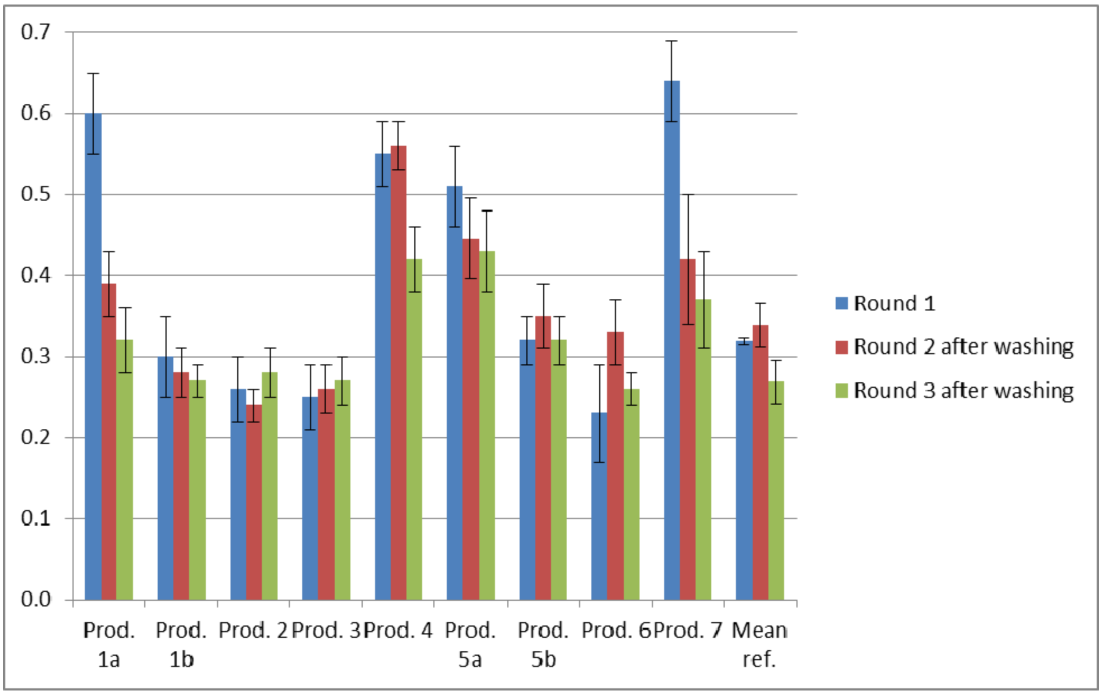

Figure 17 Reflection values for surface treatment products in all rounds after washing together with the mean value of all the untreated reference areas. All the values are for images after lighting correction, except for products 5a, 6 and 7 in Round 2 after washing. For these three images the mean value of the corrected and original image is shown due to overcompensation by the lighting correction algorithm.

4.2.5 Results for reference areas

The results for the reference areas are summarized in Table 5. The values are similar for all the reference areas in round 1. The overall reflection is markedly lower in round 3 before washing than in round 2 before washing. The values after washing are still lower in round 3 than in round 2, but the differences between the rounds are much smaller than before washing.

Table 5 Grey level statistics for reference areas: Reflection mean value ± standard deviation of measurement region for flash corrected images. Red indicates too low values due to wet walls. Blue indicates too high values due to overcompensation in the correction for uneven lighting.

	Round 1	**Round 2 before washing**	**Round 2 after washing**	**Round 3 before washing**	**Round 3 after washing**
Ref. 1	0.31 ± 0.03	0.24 ± 0.03	0.32 ± 0.03	0.19 ± 0.02	0.31 ± 0.03
Ref. 2	0.32 ± 0.06	0.28 ± 0.02	0.34 ± 0.03	0.19 ± 0.02	0.24 ± 0.03
Ref. 3	0.32 ± 0.04	0.23 ± 0.03	0.42 ± 0.04 0.39	0.09 ± 0.05	0.28 ± 0.04
Ref. 4	0.32 ± 0.03	0.24 ± 0.03	0.38 ± 0.04 0.33	0.17 ± 0.02	0.25 ± 0.02
Ref. 5	0.32 ± 0.04	0.25 ± 0.07	0.38 ± 0.04 0.32	0.18 ± 0.02	0.26 ± 0.03
Mean ref.	0.32 ± 0.004	0.25 ± 0.02	0.34 ± 0.03	0.16 ± 0.04	0.27 ± 0.03

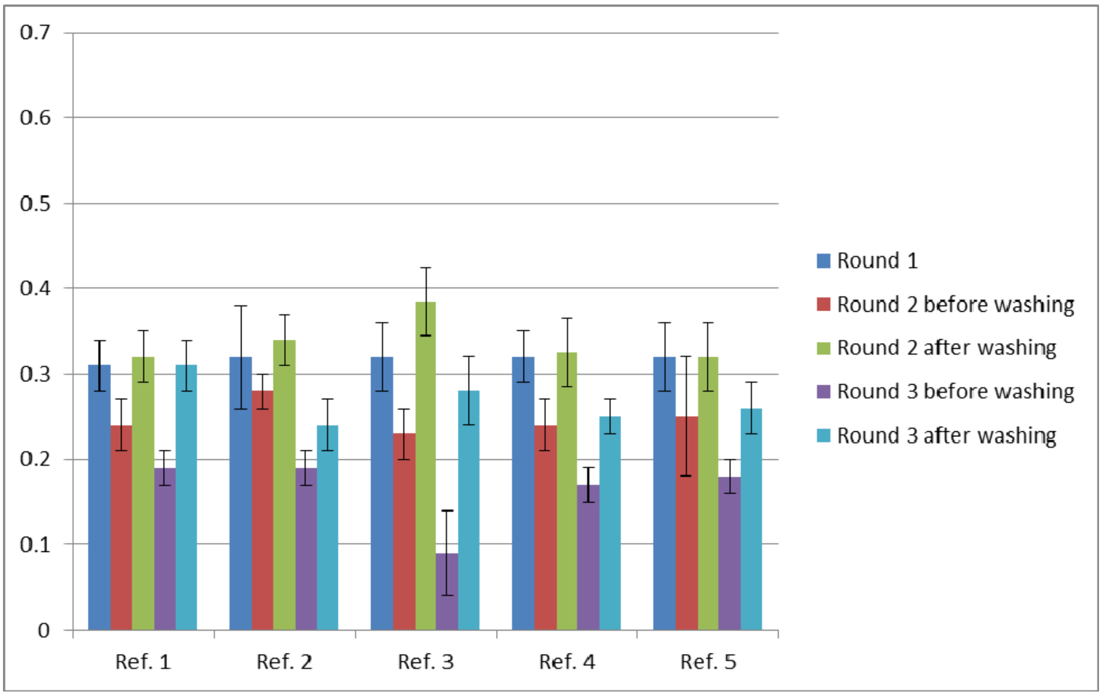

Figure 18 Reflection values for reference areas. All the values are for images after lighting correction, except for Ref. 3-5 in Round 2 after washing. For these three images the mean value of the corrected and original image is shown due to overcompensation by the lighting correction algorithm.

4.3 Findings regarding the test method

The surface structure of the concrete made it impossible to fasten the calibration sheets to the wall by adhesive tape. The calibration targets were therefore held by hand against the wall. This is not ideal since the clothes of the person holding the target may influence the measurements by causing reflections from the flash light. Having arms in the image also reduces the available measurement area. It would thus be very useful to find a means to fasten the calibration targets to the wall.

The white calibration tool was changed from cardboard to an extendable fabric before Round 3. This should not have a significant influence on the measurements, but it still contributes to the measurement variation. The new white calibration tool is both easier to transport and has a smoother and less reflective surface than the old one, so it will be used for all future experiments.

The grey calibration target turned out to be too glossy for our flash setup, which resulted in initially wrong results for the lower part of the reflection scale. This was remedied by linearizing the images and using only the lightest field of the calibration object as reference, but for the future it would be preferable to find a different calibration object with a less glossy surface.

In some cases the wall appears lighter in Round 2 after washing than in Round 1. This is because some of the measured areas were covered with dew during the first round. This emphasizes the need to perform all the measurements in similar weather conditions. Based on the experiences from Round 1, it seems preferable to avoid measuring on moist concrete surfaces.

The images in Round 3 before washing were quite dark. Although this does not affect the grey calibration in itself, it is preferable to work with images that are not too dark since the signal to noise ratio of the camera tends to be lower for darker images. Ideally the RGB values should be kept within the range 70-220. This may be achieved by adjusting the output from the flash when measuring areas which are significantly lighter or darker than average.

The flash was supposed to be used in manual mode, but was instead used in auto mode. This caused the flash to emit different amounts of light in images with and without the grey calibration target. As a workaround for this problem we only used the images with the grey calibration target for estimation of the reflection instead of using the first and last images in the series as we initially planned. This reduces the available measurement area.

In addition it was discovered that the flash did not always emit the same amount of light for each picture, which is probably due to the long charge time when batteries are used. This should be solved by simply waiting long enough (more than 30 s) in between pictures.

The adjustment for uneven flash distribution overcompensates in some of the images in Round 2. The reason for this is unclear and will be investigated to avoid such problems in the future.

In addition to the factors mentioned above, the manual selection of measurement area and a slightly variable distance and angle between the camera and the wall also affect the accuracy of the measurements. The image acquisition procedure should therefore be improved to ensure exactly equal angle and distance from the wall in all the measurements. Positioning of the camera and grey calibration target with respect to the measurement area should also be standardized to allow semiautomatic choice of the measurement area.

The results of the classification tool developed within COIN FA 2.1 should in the future be compared with other grey scale measurement methods such as NCS colour reader and NCS lightness meter.

The above named challenges will be dealt with within COIN FA 2.1 during autumn 2012 and spring 2013.

5 Conclusion

Based on the image results we found that products 4, 5a and 7 seemed to perform best over time. Product 1a also maintains a lighter visual appearance than the reference before washing, but has similar reflection values as the reference after washing. All these products contain white pigments. None of the colourless surface treatments maintain a lighter appearance than the reference fields over time. However, since this is a research project with several sources for measurement variation, this conclusion should be confirmed by more experiments.

It should be noted that by being invited into this project by the Norwegian Public Road Administration, it was made possible to evaluate the image taking procedure and image analysis software under challenging conditions (curved surfaces, wet surfaces, changing external light sources etc.), and to discover weaknesses and possibilities for improvement. The findings from this project contribute considerably to the development of a robust and applicable surface classification tool and form the basis for the further development and improvement of the tool.

Appendix - Localisation of testing and reference areas

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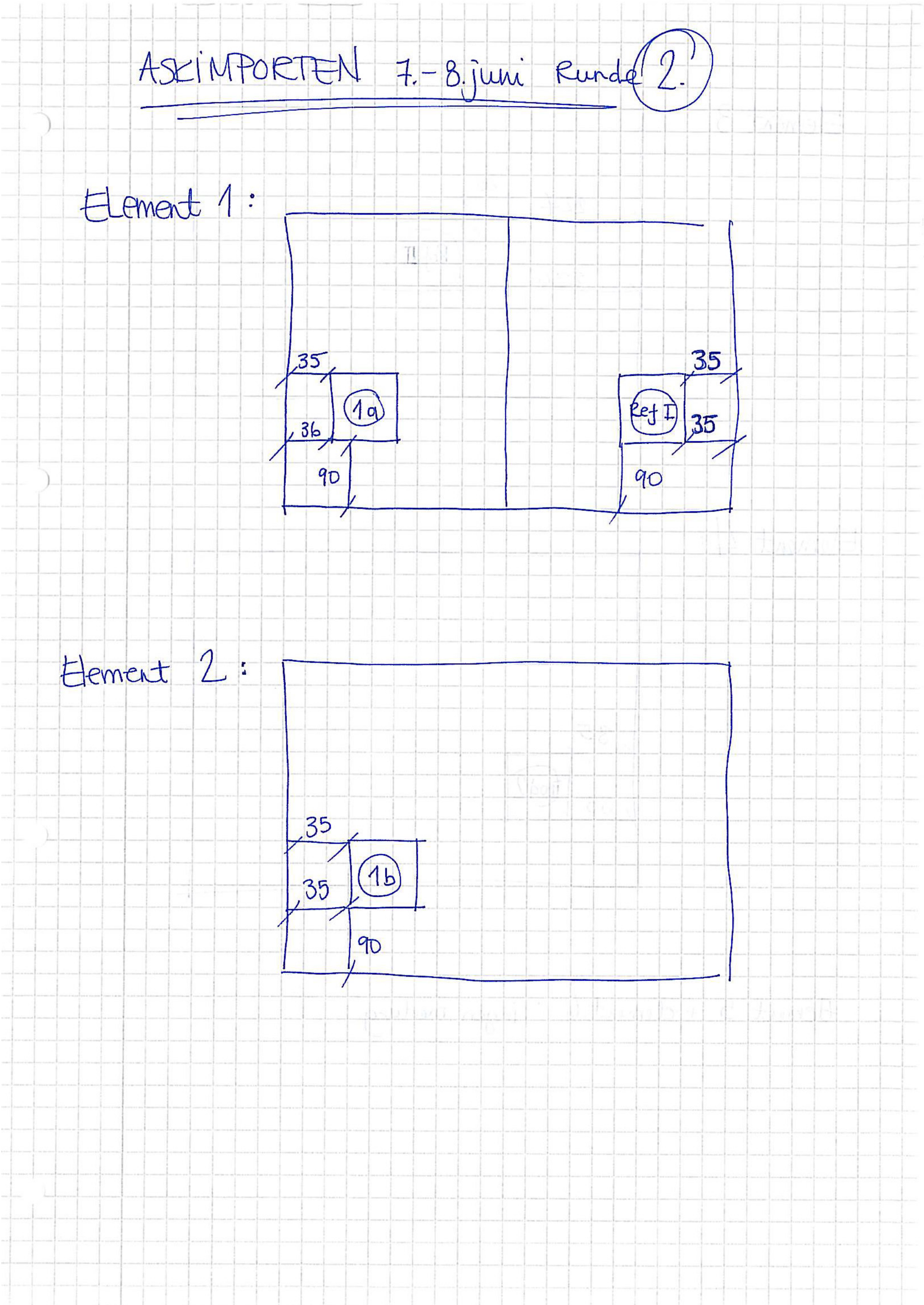

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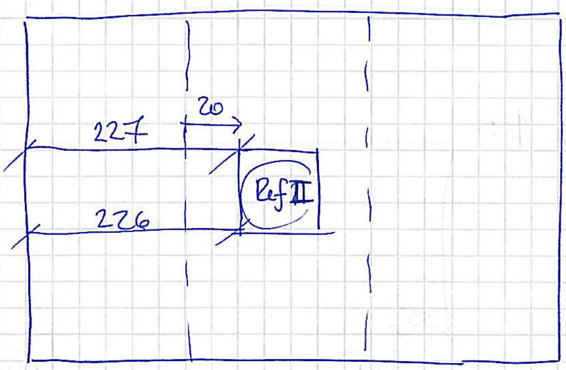
Element 3



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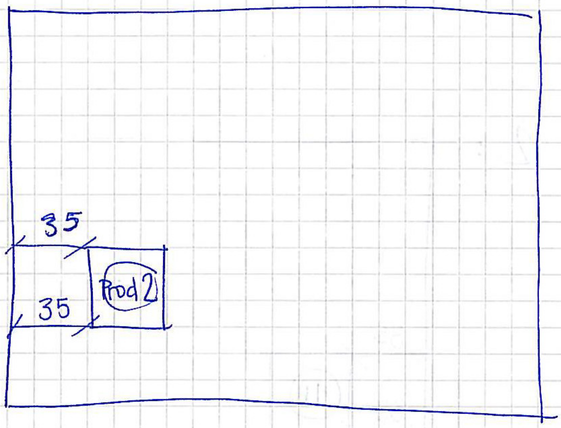

Element 5 + element 6 : ingen merking

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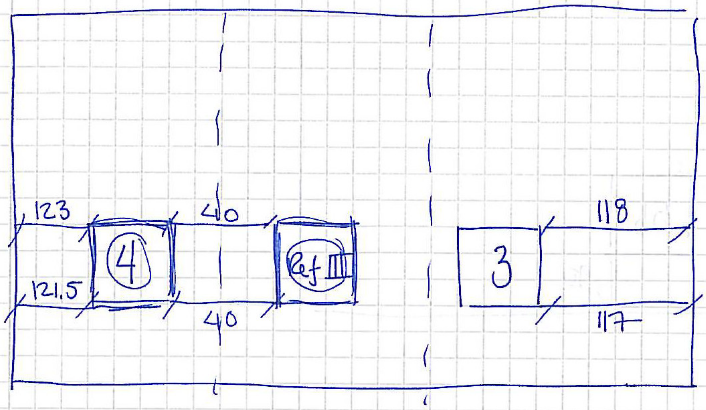
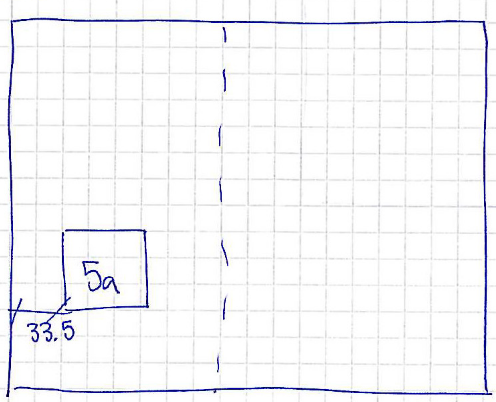
Element 7:



Element 8: utgår
Element 9:



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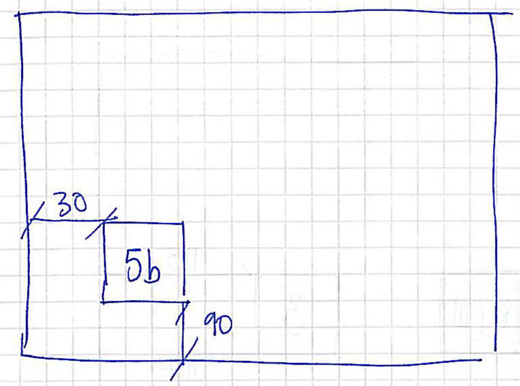

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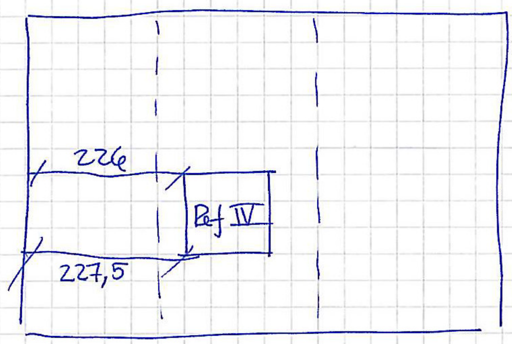

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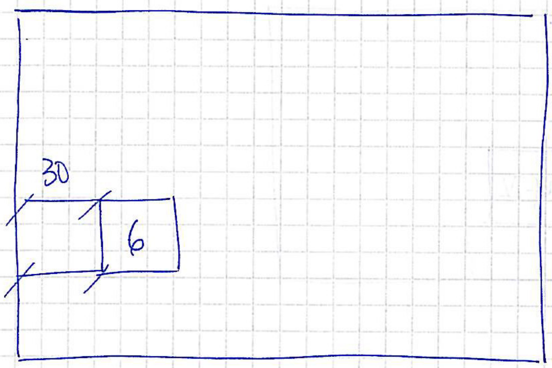

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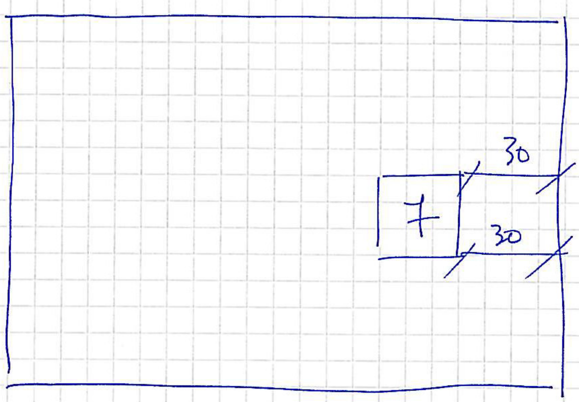

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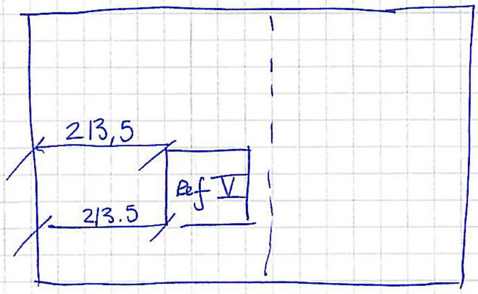

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