Universal Design 2016: Learning from the Past, Designing for the Future
H. Petrie et al. (Eds.)

doi:10.3233/978-1-61499-684-2-382

Planning and Measuring Luminance Contrast in Staircases

Leif D. HOUCK[1], Kristoffer GUNDERSEN and Ola STRENGEN
Norwegian University of Life Sciences, Department of Mathematical Sciences and Technology, Ås, Norway

Abstract. Norwegian legislation has requirements concerning luminance contrast for different elements in staircases. This paper investigates how architects work to meet the requirements, how to measure the actual built luminance contrasts and finally 21 staircases are measured using two different methods. The results show that some architects do not reflect on luminance contrasts at all, some use their "experience" and some try to measure the reflectance value of different materials during planning. The investigations also reveal that there is not any official predefined way to control luminance contrast, and this investigation shows that different approaches will give different results. To perform the measuring of the built staircases, it has been necessary to develop a defined measuring method. The results of the measuring generally shows that only a few of the staircases studied fully meet the legislation requirements.

Keywords. luminance contrast, staircases, measuring method, Universal Design

1. Introduction and Background

This paper aims at both finding a practical methodology of measuring luminance contrast in build staircases as well as how to plan for sufficient contrast in staircases. Norwegian legislation [1] as well as Norwegian Standards NS 11001-1 Universal Design of building works, Part 1: Buildings open to the public [2] and NS 11001-2 Universal Design of building works Part 2, Housing [3] require luminance contrast of 0,8 between handrail and its background in staircases. In addition, there is a requirement of visual contrast on the front edge of the going of each step with a minimum luminance contrast of 0,8.The International Standard ISO 21542 [4] Building construction – Accessibility and usability of the built environment also requires visual contrasts, but these requirements are expressed differently [4]. Example given, for the handrail to the adjacent background there should be a visual contrast provided on the edge of the going of each step with a minimum difference in LRV (luminance reflectance value) of 60 points. This article will focus on the challenges to meet the Norwegian legislation requirements for luminance contrast in the planning of staircases and how to measure the final built results.

[1] Corresponding Author, Department of Mathematical Sciences and Technology, Norwegian University of Life Sciences, Box 5003 NMBU, 1432 Ås, Norway; E-mail: leif.daniel.houck@nmbu.no.

1.1. Orientation

The purpose of the luminance contrast requirements in the NS 11001-1 [2], NS 11001-2 [3] and in the legislation is to secure that buildings are Universal Designed, which again means that it should be easy to find and identify staircases and to move safely in them. To be able to use unfamiliar areas effectively, safe and independent, the user has to be able to collect the necessary information from the physical environment. This means to detect potential danger, or find means for orientation. The more easy a user can identify different building elements and details like staircases and handrails, the higher is the usability [5]. Emma Newman's book "Kulør & Kontast" (Hue & Contrast) [6] describes what it means to orientate: *"To know where you are, to find the way to your goal, to know when you have arrived"*. In a research executed by Synovate AS [7], accidents and dangerous situations linked to built indoor and outdoor environment was investigated. The results showed that 10% of the Norwegian population above 15 years of age had experienced dangerous situations or accidents indoor due to staircases or edges [7]. Additionally, the accidents in staircases had generally a more severe outcome than accidents linked to other kinds of built environment. The research also showed that seeing impaired have more accidents than the average population. Swedish interviews showed that many seeing impaired persons refused to visit unknown buildings and built outdoor areas [6].

1.2. Standards and Legislation

The Norwegian Standards NS 11001-1 Universal Design of building works Part 1: Buildings open to the public and NS 11001-2 Universal Design of building works Part 2 came out in the year 2009 [1,2]. Parallel, but delayed, the authorities developed a new building code, especially with the goals of energy reduction in buildings and codes to improve the Universal Design of buildings. The requirements in the Norwegian legislation [1] in this field is more or less an adoption of the requirements in the Norwegian Standards in Universal Design [2,3]. The perspective of the requirements in the legislation is the user perspective. Jonny Nersveen is known as the "architect" behind the luminance contrast requirements in the Norwegian standards [2,3]. According to him, the luminance contrast levels in the requirements are based on statistics on the seeing ability of 80 year old people. This paper has a different perspective – namely the practitioner's. Any architect or building planner with any contract and any client, has to fulfil the legislation. So, from a practitioner's perspective it is important to ask how it is possible to plan, get built and there after prove – that a designed and built staircase meet the luminance contrast requirements in the legislation?

2. Research Question and Method

2.1. Research Question

In this paper we want to examine how to plan and evaluate luminance contrast in staircases. To do this we will look at the following research questions:

- What tools or methods do the building planners use in the building planning to be secure meet the luminance contrast requirements in the Norwegian building legislation – TEK10?
- How well does resent built staircases perform according to the luminance requirements?

To answer the research questions there was performed a literature study, interviews and field measurements. There were also held meetings with Norwegian experts in the field of Universal Design and light. In the research 21 staircases in 12 projects in the Oslo area have been measured. 17 of the staircases were in school buildings, 4 in office buildings and one in a sports hall. The chosen staircases were all in recent built building projects, and some were still under construction (but the staircases were finished). Due to the limited space in this article, we have reduced the focus on the theory and literature findings and prioritized to show more of the results.

2.2. Interviews

To answer the first research question, the building planners in the different cases were interviewed, partly in personal meetings, partly per email, and partly per phone call. The interviewees were asked the following questions:

- What is your attitude towards the luminance requirements in the TEK 10?
- Have you received any negative feedback on the built staircase(s)?
- Did you do any specific planning to fulfil the requirements in the TEK 10?
- If so – what tools or methods were used to secure to meet the luminance contrast requirements in the finished built result?
- Have you evaluated the luminance contrasts?
- If so – what tools or methods were used to evaluate luminance contrasts in the built result?

2.3. Measuring

There were several challenges linked to the measuring of the luminance contrast in staircases. First of all the legislation does not prescribe any method for measuring luminance contrast. Nor is there any other official method. Through previous work on the subject through the master thesis of Brunvatne [8], it was clear that the best way to measure luminance contrast would be to use a luminance camera. Brunvatne detected 3 such cameras in Norway, and the cost is above twelve thousand euros. This method was considered neither to be within the economy of the project, nor was it considered to be an investment one could expect any architecture office to do. During the literature search and interviews, the unofficial recommended method was found to be the use of a lux meter and a NCS colour scan, both costing about 120 euros each. In this research this is decided to be the "colour scanner method" and calculate the luminance contrast using the Weber's formula, see figure 1. However, this method is not adequate for glossy surfaces. A more accurate method would be to use a luminance meter costing about 400 euros. The Norwegian University of Life Sciences already owned a Konica Minolta T-10A luxmeter and a NCS Colour Scan 2.0. The Norwegian University of Science and Technology, department Gjøvik let us use their LMT L-1009 luminance

meter. Using the luminance meter will be a more accurate method, and is in the further called the "luminance meter method". The equipment used is shown in figure 2.

$$C = \frac{LRV_1 - LRV_2}{LRV_2} \cdot 100\%$$

LRV_1 = Luminance reflection value - object
LRV_2 = Luminance reflection value - background
C = Contrast in percent

Figure 1: Weber's formula

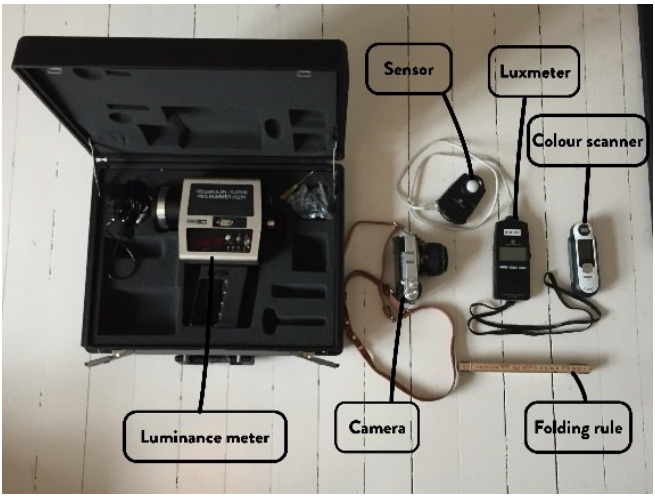


Figure 2: The equipment used for measuring

To measure the luminance, we have to define from which point or points the luminance contrast should be measured. In this research it was decided to measure from two points; 1) 1,5 meter in centred in front of the bottom of the staircase, 1,5meter above ground 2) 1,5 meter centred in front of the top of the staircase, 1,5 meter above ground as shown in figure 3.

In this research the following was measured with both methods:

- luminance contrast between handrail and its background
- luminance contrast on the front edge of the going of each step (requirement)
- luminance contrast of the guiding pattern at the bottom of the staircase
- luminance contrast of the attention pattern at the top of the staircase

The luminance contrast requirements in the Norwegian Standard and in the legislation is a luminance contrast 0,8 for all the above listed elements.

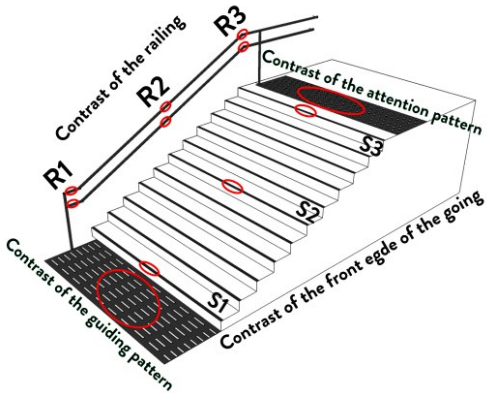


Figure 3: Points/fields measured in the research

3. Results

3.1. The Interviews

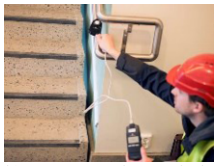
The very most interviewees are positive to the idea of Universal Design, but several find the luminance contrast requirements too strict, but only one is directly negative to the level. None of the interviewees have ever received negative comments to their ongoing or built staircases. The planner of staircase one admits not to have thought of the luminance contrast requirements. In project 9 there was used a specialist for the planning of the luminance contrasts (but not for the handrail). When it comes to the tools and methods, five interviewees have used "their experience" and two have used the NCS Colour scanner. Some of the interviewees do not inform, with or without purpose, whether they have used any method. In two of the investigated 8 projects the interviewees say that the luminance contrasts in the built staircases have been controlled.

3.2. Measuring Results

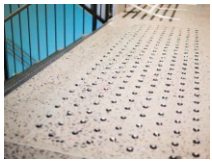
The results show that mostly, the staircases do not meet the luminance contrast criteria in the legislation. Also the results show that the NCS scanner method measures more positively than the Luminance meter method. We will look more closer into this in the following.

When measuring there are several challenges that can influence on the results, see figure 4. On party clouded and windy days, daylight variation may influence the registered result. Also strong sunlight might give strong reflections affecting the results compared to measurements conducted on a cloudy day. It can sometimes be challenging for the person executing the measurement not to have his own shadow influence the result. Different angel and position of the e.g. lux meter and the colour scanner will lead to wrong measurements. Inhomogeneous materials, represent difficulties when measuring. When measuring non planar materials, light pollution may occur and has to be handled. Strongly reflecting surfaces can be challenging when using the luminance meter.

a) Where to measure? Or is the contrast always ok by the natural dark an bright stripes



b) An extension unit is used to avoid shadowing while measuring lux



c) Inhomogeneous materials – how to measure?

d) Strong reflections lead partly to weak luminance contrasts

Figure 4: Aspects to consider when measuring

In Figure 5 we have chosen to show the average measurement for each staircase for the front edge of the going of each step and in figure 6 the railing versus the background surface. In the figures the values of the two different measurement methods are shown as black and blue dots. Theoretically, the luminance meter method should be the "true" one, whereas the colour scanner method is the more price friendly and easy. The green coloured columns show measurements where both measuring methods are showing a positive result. Yellow columns show measurements where only one of the measuring methods meet the legislative luminance criteria. Also yellow columns are used to show results that are close to the requirements. Example given, one could argue that a measure of 0,75 luminance contrast (or higher) is sufficient to fulfil a 0,8 luminance contrast requirement.

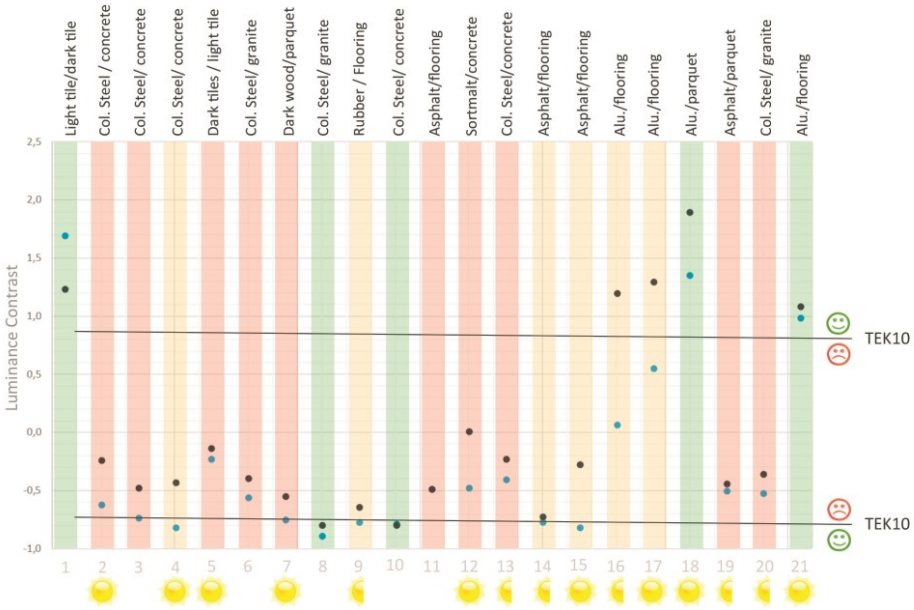


Figure 5: Luminance contrast for the front edge of the going of the steps. Staircase number 1-21Blue dots: Colour scanner method. Black dots: Luminance meter method. Weather conditions during the measuring is indicated by no sun, half sun or full sun. Red: The requirements are not met with any of the measuring methods. Green: The requirements are met with both measuring methods. Yellow: The requirements are met with only one of the measuring methods, or the result could be rounded up to the wanted result.

Figure 5 shows the mean value of the measured luminance contrast for the edge of the going of the first, middle and last step. In 5 of the 21cases the luminance contrast fulfils the requirements in the legislation with both the NCS scanner and the luminance meter measuring methods. Only looking at the measurements with the luminance meter, 7 of the 21 cases fulfils the requirements.

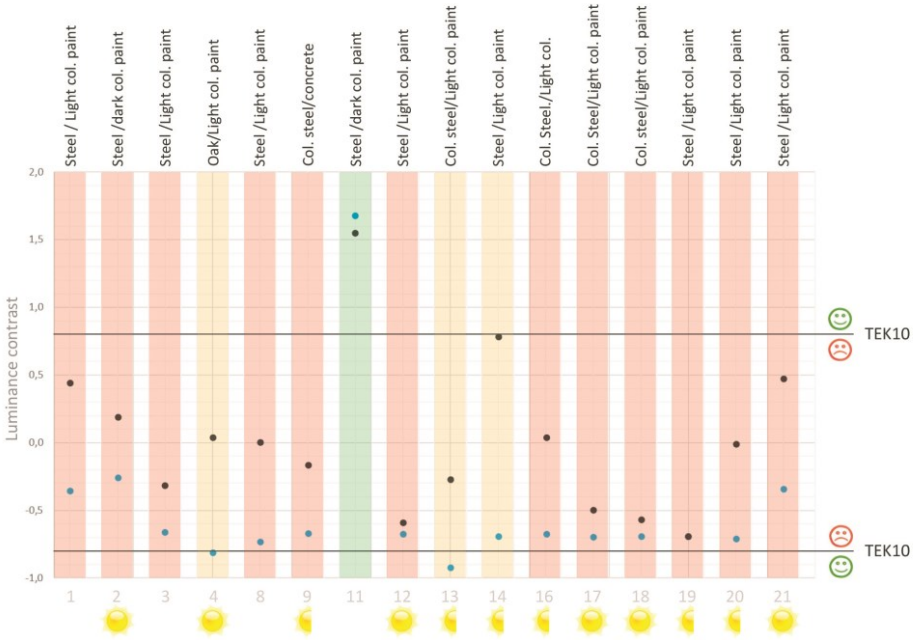


Figure 6: Luminance contrast for the upper railing versus the background surface. Staircase number 1-21. Blue dots: Colour scanner method. Black dots: Luminance meter method. Weather conditions during the measuring is indicated by no sun, half sun or full sun. Red: The requirements are not met with any of the measuring methods. Green: The requirements are met with both measuring methods. Yellow: The requirements are met with only one of the measuring methods, or the result could be rounded up to the wanted result.

Figure 6 shows the mean value (top, middle, bottom) of the measured luminance contrast for the upper railing versus the background surface. In only one of 16 cases the luminance contrast fulfils the requirements in the legislation with both measuring methods.

Figure 5 and 6 only shows the results of two of the six measuring rounds. To accumulate the information of the measuring rounds, table 1 and table 2 has been developed. Table 1 shows that in average, 55% of the measured elements fail to meet the legal requirements on luminance contrasts, and in an additional 24 % of the measured elements the measured values are disputable. In none of the measured staircases, all the legislative requirements were undisputable met. Studying table 1, it is hard to identify any obvious correlation between the building planners' planning method and the results.

Table 1. The measuring results for each staircase showing on which elements the luminance contrast requirements are met. N=No (requirements not met), Y=Yes (requirements met), D=Disputable (Only one of the measuring methods gives a positive result, or the measuring has to be rounded up to meet the requirements). S=Sunny conditions during the measuring, H=Half clouded. Planning methods used by the building planners: C=NCS Colour scanner was used, E=Planning based on experience, G=Manual grey tone scale was used, ?= Method used is unknown. Blanc spots: The building elements were missing or the used materials gave too uncertain measuring results.

Staircase number	Attention pattern	Guiding pattern	Front edge of the going of the stair - downstairs	Front edge of the going of the stair - from above	Upper handrail	Lower handrail	S=Sunny, H=Half cloudy	Planning method
1			Y	Y	N	D		0
2	N		D	N	N	N	S	C
3	N	Y	D	N	N	N		C
4	N	D	D	D	D	D	S	C
5	N	N	N	N			S	E
6	N	Y	N	N				E
7			N	N			S	E
8	Y	D	Y	Y	N	N		E
9	Y	Y	Y	D	N	N	H	C
10	Y	N	Y	Y				E
11	N	Y	N	N	Y	Y		E
12	N	N	N	N	N	N	S	E
13			N	N	D	D	H	E
14	N	N	Y	D	D	D	H	?
15	D	D	Y	D			S	?
16			N	D	N	N	H	?
17			D	D	N	N	S	?
18			Y	Y	N	N	S	?
19	D	N	N	N	N	N	H	G
20	D	D	N	N	N	N	H	G
21				Y	N	N	S	?
Fail to meet requirements %	57	38	45	48	75	69		

To answer the question on the differences between the two measuring methods, table 2 shows that in 57 of 99 cases the NCS scanner method measured more a more positive result than the Luminance meter method. This equals 57%. The more positive results with the NCS scanner method would lead to the conclusion that the requirements were met in 20 more cases than the results from the Luminance meter method. This again means that of the 57% more positive measured results with the NCS scanner method, 35% percent of the results would lead to the conclusion that the legislative requirements are met.

Table 2. The table shows a comparison between the NCS scanner method results and the Luminance meter method results. The NCS scanner method had more positive result than the luminance meter method in 57% of the cases. Explanation to the columns: *Too conservative decision* = The NCS scanner method would lead to a more negative decision on whether the luminance contrast requirements are met – compared to the Luminance meter method results. *Too positive decision* = The NCS scanner method would lead to a more positive decision on whether the luminance contrast requirements are met – compared to the Luminance meter method results.

	Total	NCS more positive than LM	NCS less positive than LM	Approx. same value	Too negative decission	Too positive decission
Front edge otg downstairs	20	9	4	7	2	0
Front edge otg from above	20	14	4	2	0	6
Upper handrail	16	12	0	4	0	8
Lower handrail	16	10	4	2	1	2
Attention pattern	14	4	5	5	1	1
Guiding pattern	13	8	1	4	0	3
SUM / and %	**99**	**57**	**18**	**24**	**4**	**20**

4. Discussion and Conclusions

The results show that the tools or methods the building planners use to be secure to meet the luminance contrast requirements in the Norwegian building legislation vary. How representative this is on a generally basis is of course unclear, but on the other hand, the interviewed building planners have been responsible for large school buildings and bigger office buildings. In the Oslo area the competition is high, and one should expect a high level of focus on quality and routines securing the fulfilment of the legislative requirements. The investigation shows poorly little correlation between the method used and the measured results (table1). According to theory, using a colour scanner to find materials with high luminance reflectance value contrasts should be the recommended way to perform good practice planning. However, the results in the examined cases show that may even this would not be sufficient to secure an outcome fulfilling the luminance contrast requirements in the legislation. Also this equipment seem to be a not reliable tool to evaluate a built staircase in terms of luminance contrast, as the results most likely will turn too positive compared to a luminance meter.

The investigated staircases do not perform well according to the Norwegian luminance requirements. Railings seem to be the hardest elements to plan and built and subsequently evaluate to be within the law. Only one of sixteen measured hand railings are measured to be within the legislative requirements, measured with the Luminance meter method. The measuring of the front edge of the going of the stair has a better result, where about 55% of the measured staircases are measured to be within the building code requirements.

It may seems necessary to clarify between the building industry and building code authorities whether the requirements are possible to meet and to what extent and with methods and means this is to be documented. The International Standard ISO 21542

Building construction – Accessibility and usability of the built environment [2] also requires visual contrasts, but these requirements are expressed through luminance reflectance values. This is a more secure way for the practitioner.

Lastly, it should be mentioned, that so to say all the studied staircases gave a visual first impression to be planned, more or less, according to ideas about visual contrast in staircases (figure 4 d). So the question comes to mind: Are the staircases in this investigation as bad as they seem according to the results on to which degree they fulfil the legislation? Or are the requirements practically too difficult to fulfil? It would absolutely be interesting to evaluate the measured staircases together with a representative group of seeing impaired users to get a better understanding of the usability.

References

[1] Plan- og bygningsloven [PBL]. (2010). *Forskrift om tekniske krav til byggverk (Byggteknisk forkskrift),* Komunal- og moderniseringsdepartementet
[2] Standard Norge. (2009). NS 11001-1 Universal design of building works, Part 1: Buildings open to the public. Norsk Standard
[3] Standard Norge. (2009). NS 11001-2 Universal design of building works Part 2, Housing e: Norsk Standard
[4] International Organization og Standardization [ISO]. (2011). ISO 21542:2011 (E). Building construction - Accessibility and usability of the built environment. Sveits: International Organization for Standardization
[5] Bright, K. & Cook, G. *(2010). The Colour, Light and Contrast Manual. London: Wiley-Blackwell.*
[6] Newman, E. (2009). *Kulör & kontrast*: AB Svensk Byggtjänst. 101 s.
[7] Synovate. (2008). Befolkningsundersøkelse: Uhell og farlige situasjoner på grunn av bygningsmessige forhold., 84232. Norges Blindeforbund: Norges Blindeforbund
[8] Brunvatne, T. (2015). *Requirements for Luminance Contrast in Practice* Ås: Norwegian University of Life Sciences [NMBU]