Abstract

Accessibility was identified as an important goal in all areas of public life. This goal has received additional importance with the increasing number of mobility-restricted persons. In terms of accessibility, the street space can be defined as accessible if it can be used continuously without any particular difficulty and without the assistance of another person. However, infrastructural characteristics, such as road sections or intersections and its elements cause often problems for persons with disabilities or other mobility-restrictions.

On account of demographic changes, there must be a consideration of the needs of elderly, as well of the handicapped people, in the road design process. An excellent example is the preferred height difference between the kerb and street. People with wheelchairs, and pedestrians, prefer dropped kerbs to cross the road in a safe and comfortable way. Blind and visually impaired people recommend higher kerbs, which prevent them from stepping accidentally into the roadway. This increased height might be a problem for many people with disabilities or reduced mobility, e.g. people with wheelchairs or walkers. In addition, visually impaired persons need a perceptible distinction in the ground surface in order to get the information on where the sidewalk ends and the roadway begins.

This conflict in requirements is particularly significant at crossing facilities. Crossings with adjacent crossing areas with different kerb heights (dual crossing) can solve the problem in many cases. In certain cases, it may only be possible to build a kerb with an uniform height. Additionally, ground surface indicators are required at crossing facilities to help blind and visually impaired people in their orientation. However, these indicators may hinder the mobility of pedestrians and people with wheelchairs or walkers.

This research investigation, which was both objective and subjective, indicates the following: kerb-heights at crossing facilities with a uniform height in conjunction with ground surface indicators. This compromise in height satisfies the requirements of elderly people, persons with disabilities, and other restricted users.

Keywords: older pedestrians; handicapped people; barrier-free design; crossing facilities; traffic safety; persons with disabilities; kerbs; tactile ground surface indicators; accessibility; ageing society; elderly.

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1. **Introduction and Objective**

Germany – as well as most countries in Europe – is being affected by significant effects of a demographic change. At the time of writing (2014) every fifth inhabitant in Germany is at least 65 years old. According to estimates by the Federal Statistical Office (even based on moderate assumptions for immigration and birth rate) this is considered even for more than a third of the population in Germany by the year 2060 (Destatis 2009). As a result – despite of the fact that mobility restrictions occur often at a later point of time in old age – the number of people with physical or visual impairments will increase.

Hence, accessibility will be an important goal in all areas of public life in the near future to enable long-lasting, autonomous and safe mobility for elderly people. In terms of accessibility, the street space can be defined as accessible if it can be used continuously without any particular difficulty and without the assistance of another person to a large extent. However, infrastructural characteristics, such as road sections or intersections and its elements often cause problems for persons with disabilities or other mobility-restrictions.

With the ratification of the UN Convention on the Rights of Persons with Disabilities in the year 2009 Germany confirmed to make efforts to reach accessibility in all areas of life. The goal aims “to enable persons with disabilities to live independently and participate fully in all aspects of life” and “[…] to ensure […] persons with disabilities access, on an equal basis with others, to the physical environment [and] to transportation, […]” (§ 9 “Accessibility” 9 para. 1 of the Convention on the Rights of Persons with Disabilities) (German Bundestag 2008). Germany passed the *Equal Treatment for the Disabled Act* (BGG) in 2002 which required “buildings or other facilities, public ways, squares and roads and public accessible transport facilities to make accessible” (§ 8 para. 2 sentence 1 BGG) (German Bundestag 2002).

The design for the accessibility in the planning and construction are detailed for many road and intersections in technical guidelines. The design of crossing facilities described in the *Directives for the Design of Urban Roads* (Richtlinien für die Anlage von Stadtstraßen, RASt 06) (FGSV 2006) and the *Guidelines for the Design of barrier-free Traffic Facilities* (Hinweise für barrierefreie Verkehrsanlagen, H BVA) (FGSV 2011) of the Road and Transportation Research Association.

2. **Basic explanations**

Crossing facilities are designed to increase the safety of pedestrians and cyclists when crossing roads. This goal is difficult when considering all users of the facility; especially users with disabilities. People with wheelchairs or walkers prefer dropped kerbs to cross the carriageway in a safe and comfortable way. Blind and visually impaired people recommend higher kerbs to prevent them from stepping accidentally into the roadway. Blind and visually impaired persons may need perceptible distinctions in the ground surface in order to get additional information about the crossing. Those ground surface indicators may hinder users of wheelchairs and walkers because of its rough surface.

For the last years at most crossing facilities in German municipalities built kerbs with an uniform height at crossings (“one kerb for all”). According to the specifications in the technical regulations this uniform height required an installation level of 3 cm (e. g. FGSV 2006). This height was considered as a compromise between the requirements of the different groups: rollability and perceptibility. The reasoning for this height comprise was that it could be managed by a large part of wheelchair users yet also perceived by blind and visually impaired people using a white cane. As the usage of walkers in the street space increased, so did the feedback about problems in dealing with kerb heights. As a result, some municipalities dropped kerbs to the level of carriageway for the walkers, sometimes even without considering (e. g. no ground surface indicators) blind and visually impaired people. However, this practice is in conflict with the requirements of blind and visually impaired persons. They express an unsafe feeling if no perceptible distinction exists in the ground surface in order to indicate where the sidewalk ends and the roadway begins. An installation level of only 3 cm lies already at the lower limit of perceptibility for them. Since the design is only 3 cm, there can be problems with the building tolerances and accumulation of dirt in the gutter.

To solve the oppositional requirements of all users, it is possible to build crossings with adjacent crossing areas with different kerb heights (see Fig. 1 - dual crossing) (FGSV 2006, p. 112 and FGSV 2011, p. 51).
This type of crossing is divided into two different, adjacent crossing areas. One area designed to be perceptible for blind and visually-impaired people with white canes due to a higher kerb (installation level of usually 6 cm) and the other area, for people with wheelchairs or walkers, with a dropped kerb (on carriageway level) to facilitate access to the sidewalk. Road users without any restrictions usually can easily use both. However, the dual crossing has some disadvantages, and it is not always possible to build. For example:

- the design needs more space in width, which may probably cause problems at crossings in minor roads or in existing roads;
- the technically complexity leads to increased costs;
- proper drainage in the gutter maybe a concern, specifically along the dropped kerb-area, which may lead to an accumulation of dirt; this is a problem especially in existing roads if they height of the slab cannot easily be adapted.

In certain cases, only solution may be to build a kerb with a uniform height. With this solution there is a conflict with the requirements. Blind and visually impaired people prefer a sharp-edged kerb which they describe as more perceptible. Users of wheelchairs or walkers prefer rounded kerbs which they describe as easier to roll over. In practice in Germany, however, a variety of kerbs (and sometimes heights of kerbs) is used at crossings (see Fig. 2).

Fig. 2: Examples of crossings with uniform kerb heights and tactile ground surface indicators (ridges) [Photos: Boenke]
b) Rounded kerb (radius 2 cm, installation level 1 cm)

c) Rounded kerb (radius 5 cm, installation level 3 cm)

Additionally, tactile ground surface indicators are required at crossing facilities to help blind and visually impaired people in their orientation (see Fig. 1). The sometimes extensive use of those indicators – truncated cones/blisters or ridges – leads to another conflict of goals. In some cases rough surfaces may hinder wheelchairs and walkers in their mobility or when crossing the street.

So far, there was only a small number of individual studies dealing with this issue and have been conducted with few participants. These studies lack objective and reliable results. This research investigated\(^3\), which was both objective and subjective, the following: kerb-heights at crossing facilities with a uniform height in conjunction with tactile ground surface indicators. This compromise in height satisfies the requirements of elderly people, persons with disabilities, and other restricted users.

3. Investigation methodology

This study employed different qualitative and quantitative analyses as well as objective and subjective methods. The research began with an investigation and analysis of national and international literature containing information on barrier-free design of crossings. Technical rules and regulations were also considered, including recommendations of consortiums and/or representatives of the disabled, recommendations of road construction carriers as well as research projects and/or empirical investigations of a third party. The different sources served initially to derive general organisation principles for barrier-free crossings.

Apart from this analysis with the support of the German Association for the Blind and Visually Impaired (DBSV), a survey was conducted of 1,384 blind and the visually impaired people regarding their experiences with the mobility in street space in order to receive empirically substantiated statements of individual mobility and orientation of the blind and visually impaired in general as well as at crossings (dropped kerbs, tactile ground surface indicators) in particular.

After the compilation of the literature review and survey results, the following steps were performed:

- Tactility and Ascending of kerbs:
  - objective measurement of the energy expenditure when ascending over different kerb forms with rolling aids (walker or wheelchair),
  - objective measurement of the energy expenditure with different installation heights of a kerb,

\(^3\) „Barrier-free crossing points on main roads - design of dropped kerbs and tactile ground surface indicators in detail. Research Project“ (FE 77.0500/2010) on behalf of the the Federal Ministry of Traffic and Digital Infrastructure represented by the Federal Highway Research Institute.
- objective measurement of the tactility (strength resistance) with contacting and/or going over the different kerb forms with the cane,
- subjective evaluation of the tactility and ascending of different kerbs by test subjects with a disability, who use an aid with their mobility
- subjective evaluation of the tactility and ascending of different kerbs by test subjects of a comparison group (the non-disabled), who use an aid.

- Tactility and ascending of surface indicators:
  - objective measurement of the vibrations on the cane when in contact with the different surface indicators with this aid,
  - objective measurement of the vibrations working on the handle when rolling over various surface indicators with a wheeled walker,
  - subjective evaluation of the tactility and rolling of different structures of surface indicators by test subjects with a disability who use an aid for mobility,
  - subjective evaluation of the tactility and rolling of different surface indicators by test subjects of a comparison group (people without disability) who use an aid for mobility.

The investigation was fully supported by the “National Centre of Competence for Accessibility” (Bundeskompetenzzentrum Barrierefreiheit – BKB⁴). Representatives from the German Association for the Blind and Visually Impaired (Deutscher Blinden- und Sehbehindertenverband – DBSV) as well as the Social Association of Germany (Sozialverband Deutschland – VdK) were involved consecutively in the work progress for BKB. In addition an industry forum as well as a workshop were conducted for all the disabled whose representatives as well as mobility instructors were involved in the discussion.

4. Summary of Test Results

The test section contained six different kerb designs (Fig. 3) and eight different ground surface indicators (Fig. 6, Fig. 7. The assessment was based on the rating system of one to six (1 = very good, 6 = insufficient).

<table>
<thead>
<tr>
<th>Kerb</th>
<th>Principle</th>
<th>Kerb</th>
<th>Principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Rounded kerb (r = 1,5 cm)</td>
<td>B4</td>
<td>Chamfered kerb (3 cm/3 cm, 45 degrees)</td>
</tr>
<tr>
<td>B2</td>
<td>Rounded kerb (r = 2,0 cm)</td>
<td>B5</td>
<td>Sinusoidal kerb</td>
</tr>
<tr>
<td>B3</td>
<td>Rounded kerb (r = 5,0 cm)</td>
<td>B6</td>
<td>Ramp</td>
</tr>
</tbody>
</table>

Fig. 3: Selected kerb forms

⁴ A private association of German welfare and disabled organisations which are active throughout Germany.
4.1. **Design of the kerb**

Concerning the height of kerbs at crossings with uniform ground level, the existing compromise installation height of 3 cm has thus far proven to be suitable. Based on measurements of the force required to transverse kerbs, small wheels have extreme difficulties ascending over the edge starting from 4 cm. When cane users descended kerbs installed on the test track with a height of 3 cm were not detected by almost a third of the cane users and thus moved beyond the kerb. This observation also confirmed by the results of the survey.

The key requirement factors for an adequate kerb for all users is the assessment/tradeoff between

- the guarantee of a relatively safe perceptibility with the cane by the blind and the extreme visually impaired particularly in downward direction and
- the guarantee of a relatively simple ascending particularly in upward direction.

With regards to the movement direction, the users provided different evaluations of the kerbs based on the direction of movement.

4.1.1. **Test Results in the upward direction**

In the upward direction, blind cane users reliably recognised the kerbs regardless of the shape of the kerb. In contrast, users of rollators, in particular, generally expressed difficulties in negotiating the upward direction (see Fig. 4). Wheelchair users showed less difficulty in this regard. Ultimately, all test subjects with rolling aids were able to manage all kerbs, even though this was associated with considerable effort in some cases.

![Fig. 4: Mean assessment of kerb forms from test subjects dependent on the aid used (upward direction).](image)

There were clear differences in the assessment by the wheeled walker users depending on the form of the kerb.

4.1.2. **Test Results in the downward direction**

In the downward direction, blind and severely visually impaired persons had difficulties in clearly recognising the kerbs. It should be noted, that roughly a quarter to a third of the blind and severely visually impaired users moved beyond the kerb - independently of the kerb form. The less distinct (sharp-edged) the edge was formed, the poorer the tactility was assessed (see Fig. 5).

There is only a small differences between the mean assessment of wheelchair users and wheeled walker users in the downwards direction. Regarding the comfort, the kerbs with the round design (B1 to B3) and with the chamfer (B4) were slightly better assessed.
4.1.3. Test results in both directions

The flat board (Sinus Form, B5) proved less suitable for the installation in crossings for all users. This segmented, from all users received relatively poor assessments.

The ramp (B6) was well assessed by all users. Cane users in both directions recognised it quickly and clearly. It also received good scores in both directions from the wheelchair users. Only the wheeled walker users gave this ramp (B6) a remarkably poor score in the downward direction. Comments expressed by the users revealed that the assessment was affected by the presents of Surface Indicators in the ramp.

The objective assessment was also conducted by a control group consisting of participants without disability. The findings of the control group confirmed the results of the users with disabilities regarding tactility and ascending. Kerbs B2 (r=2 cm) and B3 (r=5 cm) performed the best in terms of safe recognition of the kerb in particular in downward direction as well as ascending in upward direction. However, a detailed review of the data revealed slight advantages for B2.

4.1.4. Design of the surface Indicators

After the objective measurements, the ground surface indicators (Fig. 6, Fig. 7) were also examined by test subjects with different capabilities as well as a control group. These groups rated the surface indicators based on the surface tactility (see Fig. 8). All surfaces were traversed by the wheelchair users and wheeled walker users even if strong vibrations with some structures were reported. Some test subjects indicated they would avoid riding over surface indicators, even if it resulted in minor detours. For cane users, all surface indicators were clearly recognised when the test subjects did not sharply depart from the ideal walking line.

<table>
<thead>
<tr>
<th></th>
<th>R1</th>
<th>R2/R3</th>
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<tbody>
<tr>
<td></td>
<td>Ridged plate</td>
<td>Ridged plate</td>
</tr>
<tr>
<td></td>
<td>38 mm between bars</td>
<td>26 mm between bars</td>
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Fig. 6: Ridged plates used during the tests
### Table

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<tbody>
<tr>
<td><strong>N1</strong></td>
<td>32 truncated cones, diagonally, diameter 33 mm</td>
<td><strong>N2a/N2b</strong></td>
<td>50 truncated cones, diagonally</td>
<td><strong>N3</strong></td>
</tr>
<tr>
<td><strong>N4</strong></td>
<td>36 truncated cones, orthogonally</td>
<td><strong>N5</strong></td>
<td>36 knobs, orthogonally</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 7:** Blistered plates used during the tests

**Fig. 8:** Mean assessment of the tactility and/or ascending from surface indicators with use of different aids in comparison

Ridged-plates with broad widths within the upper range of the orientation values of the DIN 32984 (with narrow bars, element R2) were unpopular by users with rolling aids in particular if the structure had to be rolled over diagonally. When the broad widths corresponded to the orientation values within the lower range, the acceptability increased substantially. With these structures, the stop-effect of the transverse lying ridges was preferred by cane users.

The recognisability of the spherical caps were generally poorly assessed by the blind and severely visually impaired users due to the weak tactile feedback. These poor results were also found with truncated cones. Performance appears to decrease as the knobs decrease in size and in number. Users with rolling aids have a less distinct problem with the hemispheres.

Very wide knobs in truncated cone form (N1) (dimensions of the structure within the upper range of the DIN 32984) ascended comparatively well for test subjects with wheeled walker or wheelchair.

### 5. Recommendations and Consequences for Practical Application

#### 5.1. Design of the Kerb

The different requirements by wheelchair users and wheeled walker users and the blind and the severely visually impaired users cannot be optimally fulfilled by a single solution. A compromise solution is needed. A kerb height of 3 cm over upper edge of the road surface provided a useful compromise, if the following conditions are maintained:

- The edges of the kerb should be enforced with a leveling of \( r = 20 \) mm. Boards with this roundness measure already presently belong to the frequently used standardised kerb forms (see Fig. 9). This is valid also for the transition stones of lowered range on the high boards.
• The leveling of the kerb edge by \( r=20 \text{ mm} \) with a height of 3 cm facilitates a structurally perfect separation (no open gaps between kerb and gutter).
• Suitable landmarks are recommended in main roads with a crossing with the kerb of a 3 cm installation level. This facilitates early recognition for the crossing with the cane and reduces the danger of cane users to fall downwards.
• The exact compliance to the installation level of 3 cm within the lowered range is very important (no falling below or excess). As an example an installation reference can be helpful, e.g. a mark on the kerb, which marks the installation level (based on following gutter).

![Fig. 9: Kerb with an Installation level of 3 cm and an edged Roundness of \( r=2 \text{ cm} \) [Photo: Boenke]](https://example.com/fig9)

5.2. Design of the surface indicators

The investigations confirmed that surface indicators as per the standard DIN 32984, edition 2011 are well perceived tactically with the cane, and also with the feet (see standard DIN 32984:2011 05).

In the street space, the surface finishes also must fulfill the requirements indicated in the technical rules and regulations in order to manufacture the necessary tactile contrast for a safe recognisability with the cane. Placement of surface indicators must be considered in order to provide a safe distance from the users to the vehicular traffic.

If the surface indicators with the cane and the feet are to be well noticed, the surfaces should be selected in accordance with DIN 32984 (edition 2011) and be inserted with their basis precisely to the surrounding surface (raised). Since surface indicators are used in the public area in increasing number, there should be attention to the users with rolling aids.

Knowledge of function and use of different surface indicators requires broadening and immersion within the concerned target audience of the blind and visually impaired. It is all the more important that simple, easily understandable solutions as possible are chosen. This reduces the work of planners as well and helps to avoid errors in the implementing of construction (e.g. deviate from the prescribed direction of installation).

The recommendations regarding the implementation of surface indicators on crossings derived from the test results states:

- User friendly means simple, easily perceivable, understandable and noticeable surface indicators.
- Only a few, different, easily distinguishable elements meet all users needs.
- Knob structures with orthogonal formation should be avoided due to the danger of confusion with ridge structures.
- Truncated cones with larger diameter (and thus flatter bent flanks, see Fig. 10) and dimensions within the upper range of the orientation values of the DIN 32984 are recommended, particularly in crossings particularly for locality bands on sidewalks. This design offers a good compromise between tactilely with cane and the feet as well as ascending.
- Surface indicators with warning function require a high tactility (strong “feedback”). Designs which achieve this strong feedback are surface indicators with a high number of diagonally arranged knobs, which are truncated cone (within the measure spectrum of the DIN 32984).
- For surface indicators that need to indicate stopping must have ridge structures which are parallel to the road. This is shown in the crossings with different kerb heights in area of zero-drop (see fig. 1). The ribs with dimen-
sessions within the lower range of the orientation values offer a good stop function in accordance with DIN 32984. They traversed without particular complication.  

Fig. 10: Truncated cones used with large diameter in the test [Photo: Boenke]

5.3. Extensive Recommendations

For this project, the goal was to understand the issues of all users and seek out possible solutions for the improvement of the infrastructure. This user group includes people with mobility impairment. Designers and planners should designed facilities which are safe to use without particular complications and without personnel assistance. This mobility goal requires the use of various surfaces, depending on the type of mobility impairment and individual capabilities, in order to reach an environment of mobility for all users.

There is need to improve wheeled walkers and wheelchairs to help assist users to handle small steps. Apparatuses such as tilt supporter already are available with some models as additional equipment, however they can be improved.

Professional overall design and construction implementation is required in order to ensure the safe, qualifying usability of crossings on main roads for all road users, including sensory and motor disabled people. This is especially true in the installation of kerbs with an accurate height. With planning and execution of construction, the current rules and regulations, particularly new discoveries from research require a continuous adjustment of the relevant technical rules.

References

räusberechnung. Wiesbaden.


5 Ridge slabs were used for example with a spacing of the ridges in measuring plane by 26 mm and a ridge width of 10 mm for the tests in the context of this project.