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NEW TYPES OF ROAD MARKING FOR STANDARDISED AND SELF EXPLAINING ROADS

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Abstract: The redraft of the German guidelines for the design and alignment of rural roads (RAL) pursue the objective of creating recognisable and clearly distinguishable road types. By that, the driver will know how to behave on a special road type or they will adapt their behavior on this situation intuitively. According to the design standards, drivers shall adapt their driving behavior. For rural roads four design classes (EKL 1 to 4) are intended in the RAL. Roads of different design classes are supposed to be significantly different from each other. This concept of recognisable and self-explaining roads can only be implemented, if the geometrical design is combined with clear markings and traffic signing.
To research and recommend an effective, efficient and recognisable road marking, two research projects were issued by the Federal Road Research Institute (BASt). The first project (design class 1) researches the influence different elements for separating traffic directions have on accidents, driving behaviour and traffic safety on roads with a cross section of 15.5 (separating traffic directions a central line with a width of 1.00 m). The second project (design class 4) deals with the influence of different markings on cross-section for local roads. This design features neither edge marking nor central reservation. Stripes are marked beside the edge of the carriageway, instead.
The results of both projects were considered in the redraft of the RAL.
Keywords: 2+1 road, 2-1 roads, road marking, self explaining roads, road safety

1. INTRODUCTION AND OBJECTIVES

In 2001 the European Commission adopted a white paper to reduce the number of road deaths on Europe's roads by half in the next 10 years. In 2009 Europe-wide 35.000 traffic deaths occurred, that is 36 % less than 2001. Due to several measures in the field of road safety the number of traffic deaths decreased by 40 percent.

One measure in Germany is the launch of new design directives for rural roads (RAL). This directives deal with a new concept: For rural roads four design classes (EKL 1 to 4) are intended in the RAL.

Roads of different design classes are supposed to be significantly different from each other (see Fig 1).

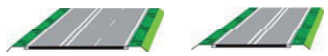
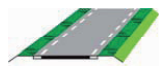
Design Class	Cross Section Type
EKL 1	
EKL 2	
EKL 3	
EKL 4	

Fig. 1. Design class and cross section type

These road types led to a driving behaviour depending on the design standard. The concept of recognisable or self-explaining roads can only be implemented if the geometrical design is combined with clear markings and traffic signing. Particular importance in the RAL are to ensure safe overtaking maneuvers and the prevention of accidents due leaving the road.

The main target of this paper is to recommend an effective, efficient, recognisable and understandable road marking for the design classes “EKL 1” and “EKL 4”.

2. INVESTIGATION METHOLOGY

For both objects of investigation all relevant literature from home and abroad were analysed for effects in context with self explaining roads and new marking. Based on this, own suggestions for road markings the design classes 1 and 4 were developed. The different variants of these were tested on test routes.

2.1. DESIGN CLASS “EKL 1”

For the design class “EKL 1”, the influence of different types of driving direction separations on the driving speed and lane behavior as well as traffic safety investigate. Furthermore, advantages and disadvantages of different variants are compared and the acceptance by drivers and Road Construction Authorities are determined.

Therefore four three-lane test sections were equipped with different elements of driving direction separation. In previous condition the variants of the separation of the driving directions were various. For a with/without comparison a double lane limiting line and for a before/after comparison central reserves of 0.75 m and 1.00 m width were used. On the test sections five different elements were applied (grid of diagonal markings, orange marking, green marking, traffic cones traffic (see fig.2) and traffic cones in combination with color). The width of the central reserve was 0.75 m afterwards for the variant with green road marking and 1.00 m for all others.

Fig. 2. Test sections 2+1 roads

The survey of driving speed and lane behavior was carried out with a laser scanner type SICK LMS 200. In this investigation two positions have been considered. These were situated in the middle of the one-lane sections and on each of the beginnings of the critical transition (both driving directions). Due to laser measurements in the middle of the cross section the vehicles distance from the central reserve as well as their driving speeds can be analysed.

For this investigation irregular overtaking maneuvers have been observed by video recording. The cameras have been positioned in a way that they were not recognisable by road users. By that the influence on the (irregular) behavior could be avoided.

Two years after the redesign of the separation of the driving directions surveys of road users have been carried out on all sections. For each driving direction 120 drivers were questioned on-site on perception and feeling of security after passing the test sections.

The effects of the variants of the separation on traffic safety have been evaluated by analysing accidents. For all test sections accident data of the past years as well as one year after the redesign have been collected.

While implementing the measures, employees of Road Construction Authority and Road Maintenance Service were questioned on their experiences with different variants. The authorities should comment on material/design, costs, lifespan, overtaking options (in case of operation services), winter maintenance and acceptance by drivers.

Apart from the survey of Road Construction Authorities individual talks with people who were responsible for the redesign were made. In these individual conversations the same questions were asked as stated above.

2.2. DESIGN CLASS “EKL 4”

For the design class “EKL 4” the road marking should be without a clear separation of driving direction. This should increase the awareness among drivers and reduce driving speeds.

Fig. 3. Test sections 2-1 road

The small carriageway between the markings encourages the driver to be careful by oncoming traffic particularly (see Fig. 3). Especially when situations with oncoming traffic involving bigger cars (e.g. trucks) occur, interactive coordination is necessary. Generally the drivers should use all available space to avoid any obstruction.

For the before/after comparison of driving behaviour three test sections were chosen. The roads had a paved road width of 5,00 m; 5,50 m and 6,00 m. In its original condition the road with paved width of 5,00 m had markings on the roadside only. The other two roads were marked with a central line marking additionally.

The new road marking was applied as follow: At the road with width of 6,00 m, a central driving lane of a width of 4,00 m was marked by intermittent edge lines leaving an area of 1,00 m on both sides. At the road with a width of 5,50 m a central driving lane of a width of 4,00 or 3,00 m was marked by intermittent edge lines leaving an area of 0,75 or 1,00 m on both sides. At the road with a width of 5,00 m a central driving lane of a width of 3,00 m was marked by intermittent edge lines leaving an area of 1,00 m on both sides.

All test sections were marked with an intermittent line with a dash of 1,00 m and a gap of 1,00 m.

The driving behaviours were collected with three different research methods. The speed behaviour was determined by: tracking by car (BMW 525 d Touring) and by cross-section measurement. Overall 30 drivers per road and direction were tracked. Cross-section measurements were made for lines and curves using a laser scanner and radar (Type SICK LMS 200 and radar manufactured by Sierzega). By using the same laser scanner, data of lane behaviour at selected lines and curves was also recorded. The recorded videos can be used for future investigations about oncoming traffic and cyclists.

3. RESULTS

3.1. DESIGN CLASS “EKL 1”

3.1.1. Speed Behavior

The analysis of the driving speed behavior on the different test sections reveals different results depending on the vehicle class and the measurement system.

The speed values measured by the laser scanner spread widely. Only in a few cases the values are in the range of high speeds ($V_{85} > V_{acceptable}$) as expected by literature research. Very often the measured speeds were in the range of the maximum permitted speed. Deviating from that, resulted after-measurements with a lateral radar at the same cross sections significantly higher driving speeds. At these cross sections it is assumed that the laser scanner was, despite being camouflaged, noticeable by drivers and due to that had an influence on the driven speeds. The results of the laser scanning revealed differences between the individual measures before and after the measurement. The green marked separation of the driving directions at two different test sections (B 169 and B 83) did not lead to an uniform result. The before/after-comparison on the B 169 resulted in slightly higher and the with/without-comparison on the B 83 resulted in slightly lower driving speeds V_{85}. The before/after-comparison showed that the separation of the driving directions with “traffic cones” led to a reduction in driving speed V_{85} of about 10 km/h.
Whereas the comparison between cross sections with raised elements and those without showed an increase of driving speeds for cars:

- compared to traffic cones a grid of diagonal markings and orange colored central reserves for cars to an increase of 6.4 km/h
- compared with “traffic orange and traffic cones a grid of diagonal markings and orange colored central reserves led to an increase of 9.2 km/h

For the separation of driving directions with a grid of diagonal markings a reduction of the V_{85} of 4.8 km/h was determined by a before/after-comparison. Also the variant „traffic orange“ led to a reduction of the V_{85} of 8.4 km/h.

The driving speed measurements with the lateral radar resulted in consistently very high driving speeds. Insofar the high level of driving speed known from literature is reached after the redesign.

The before/after-comparison for free driving trucks and leader of platoons with a V_{85} of 80 km/h no changes were observed for all variants. This is certainly due to the maximum permitted speed of 60 km/h for trucks.

3.1.2. Lane Behaviour

The investigations of lane behaviour resulted that only a few vehicles use the critical lane positions in total. Therefore only very few vehicles drive on the separation of the driving directions or on the lane limiting marking. The majority of car and truck drivers

drive on tracks in the middle of the lane. For the variants of a grid with diagonal markings and traffic orange a similar lane behavior could be shown. The before/after comparison showed that the greatest distance could be detected for the type of separation with “traffic cones”. On average for design variants with no risen elements the lowest distance was kept.

The driving over the separating elements and barred areas by critical transition could not be detected on any test section with the measurement-based evaluation.

Concerning the distance of vehicles on the overtaking lane from the separation of the driving directions different results were found. Therefore it can be assumed that drivers concentrate mainly on the overtaking maneuver than on the distance to the elements of separation.

3.1.3. Irregular Overtaking

Irregular overtakings were only determined on one test section. The pre-measurement captured six and the post-measurement captured two irregular overtakings.

3.1.4. Accident Occurrence

In general only very few accidents happened on the analysed road sections. With three to four decisive accidents in one year on each of the test sections there are only such a small number of accidents by which no accident parameters can be deduced.

3.1.5. Acceptance by Drivers

By means of the road user survey a high acceptance of the measures on all test sections was shown. Many drivers were positive to the survey. In total the majority of the respondents recognized a difference compared to other rural roads concerning the “form of operation”, “separation of driving direction” and “quality of traffic”. The majority of the drivers drove unaffected by the separation on the road sections, considered the overtaking ban as justified, assessed the length of the one and two lane sections as “just right” and declared themselves in favor of a more often use of this form of operation.

The sense of security during an overtaking maneuver in a two lane section is higher (“secure to fairly secure”), than during driving in the on lane section with oncoming traffic (“secure to neutral”). Furthermore 3.6 % of all surveyed drivers (26 persons) stated that they were overtaken in the one lane section.

Depending on the test section the variant with raised elements (“traffic cones“) also in combination with orange colored markings as well as in comparable amounts a colored separation are considered to be the “safest”.

The majority of the surveyed drivers preferred clearly a colored marking as well as a combination of an orange marking with “traffic cones” as a separation of the driving direction. Traffic cones without a colored design are less preferred. Known elements as the

grid with diagonal markings and the double lane limiting line are only preferred by a few drivers as a separation of driving directions.

3.1.6. Experiences of the Road Construction and Transport Authorities

According to the experiences of the Road Construction and Transport Authorities the grid of diagonal markings as separation for driving directions is the most economical variant.

The preferred variant resulting from the survey is a colored design for the separation of driving directions. This variant has a negative effect on the work of the road maintenance service and especially the winter road maintenance. The costs are higher than for the variant with a grid of diagonal markings but the colored design have a greater durability. Due to a lack of experiences the current implementation is still complex. Furthermore a colored design represents the principle of recognisable roads as recommended in the RAL.

The use of “mitres” as a separation of driving directions is due to problems with the work of the road maintenance service and especially the winter road maintenance (increased expenditure of removal) as well as negative effects on traffic safety (e.g. partly lying or additional effort during winter period) not recommended. Furthermore incalculable additional costs arise due to the replacement of knocked down reflectors.

3.2. DESIGN CLASS “EKL 4”

3.2.1. Speed Behavior

On the test sections the speed behaviour was determined for 30 cars by tracking by car and also by cross-section measurement. The results are different for both directions. At the road with a width of 5,00 m and at the road with a width of 6,00 m was found that a higher speed V_{85} in one direction and lower speed in the other direction is present. This could be stated as an effect of the new road markings. On the test section with a width of 5,50 m the speed V_{85} increased by 0,3 km/h in one direction and by 4,7 km/h in the other direction. In contrast to these results, it was shown by the cross-section measurements, that the V_{85} decreases on the two test sections. In straight lines, a significant decrease of the speed V_{85} from 4 to 7 km/h was found. The decrease in speed V_{85} in curves was still 1 to 5 km/h.

3.2.2. Lane Behavior

On all test sections could be proven that the driver keep a greater distance from the right edge of the roadway when driving uninfluenced. The distance to the right edge of the roadway increased to 0.45 m. It depends on the width of the road how much the track behaviour changes in uninfluenced driving. The distance to the right edge of the roadway does change differently for roads with a small width of 5.00m compared to roads with a

width of 6.00m. In left-hand bends and right-hand bends the distances to the edge of the roadway have increased for uninfluenced driving.

The analysis of lane behaviour by oncoming traffic shows that drivers decreased their distance to the edge of the roads until the moment of encounter. After the oncoming traffic passed by, the distance increased again. In case there is a cyclist ahead, drivers reduce their speed before overtaking.

4. INFERENCES

4.1. DESIGN CLASS "EKL 1"

The design of the separation of the driving directions has no influence on the driven speed of cars and trucks in uninfluenced driving in the one lane sections of the 2+1 cross section.

The lane behavior remains unchanged by the design of the separation of the driving directions. Only the arrangement of raised elements influences the distance to the separating elements. Only a very few vehicles have been driven on the boundary of the lanes or the separation of the driving directions. A connection between the distance from the separation of the driving directions and the width of the central reserve could not be detected.

Also no influence on irregular overtakings was ascertained as those occurred seldom.

The influence on the accident occurrence could not be detected. For the determination of accident parameters too few accidents happened on the test sections in the period of one year before and after the redesign.

The measures are well accepted. The majority of the surveyed persons prefer clearly a colored marking as well as a combination of orange colored markings with "traffic cones" as separation of driving directions. "Traffic cones" without any colored design are less preferred. Known elements such as the grid of diagonal markings and the common double lane limiting line as separation of the driving directions are only preferred by a minority.

Due to experiences of the Road Construction and Traffic Authorities the grid of diagonal markings as separation of driving directions has been proven to be the most economical solution. The application of „traffic cones" is due to a negative influence on road maintenance service and especially on the winter road maintenance as well as traffic safety not recommended concerning possible lying parts on the road or additional formations of ice. Furthermore hardly calculable additional costs arise. For a renewed use a colored variant as separation of driving directions is preferred. This supports a better segregation to the oncoming traffic in the road space and is less likely to be maintenance intensive due to their durability.

For the design of 2+1 cross section within the design class EKL 1 colored markings (traffic green) are recommended for separating opposing traffic. These support according

to the principle of the RAL, standardised and recognisable roads, are accepted by Road Construction Authorities as well as drivers and have a long durability.

4.2. DESIGN CLASS "EKL 4"

The new type of road marking led to more distance between uninfluenced drivers and the edge of the roadway. Therefore the risk of accidents due to leaving the road is lower. The drivers also pay more attention to oncoming traffic and adjust their position in case of oncoming traffic by using the whole roadway. They understand the function of the road marking and know how to behave.

For the design of 2-1 cross section within the design class EKL 4 a intermittent (dash of 1,00 m and a gap of 1,00 m (1-1)) marked line with a distance to the edge of the roadway is recommended.

5. CONCLUSION

Because of the investigation new variants of road marking for different road types (design class 1 and 4) have been identified and recommended for redraft of the German guidelines. The road markings have an effect on the driving behavior and they are clearly distinguished by their forming from other markings. The new road markings support the concept of the new guideline for standardised and recognisable roads and they will be a contribution to traffic safety

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NOWE RODZAJE OZNACZEŃ DROGOWYCH DLA PROJEKTOWANIA I UJEDNOLICENIA (OZNAKOWANIA) DRÓG WIEJSKICH

Streszczenie: Przeredagowane Niemieckie zalecenia dla projektowania i przystosowania dróg wiejskich (RAL) mają na celu stworzenie szeroko rozpoznawalnych i charakterystycznych dróg. W ten sposób, kierowca będzie wiedział jak zachować się na drodze, którą jedzie lub też będzie w stanie dostosować swoje zachowanie do sytuacji na drodze w intuicyjny sposób. Zgodnie z standardami wykonania, kierowcy powinni mieć adaptacyjny styl prowadzenia pojazdu. Cztery klasy wykonania zostały utworzone dla dróg wiejskich (EKL 1 do 4) i zawarte w RAL. Drogi innych klas wykonania mają być z założenia zupełnie inne od siebie.

Pomysł rozpoznawalnych i samo-wytłumaczalnych dróg może być zrealizowany jedynie, gdy projekt geometryczny jest połączony z jednoznacznymi oznaczeniami i sygnałami drogowymi.
W celu zbadania i zarekomendowania efektywnych, wydajnych i rozpoznawalnych oznaczeń drogowych, dwa projekty badawcze zostały zrealizowane przez Federalny Instytut Badań nad Drogami (BAST). Pierwszy projekt (klasa wykonania 1) bada jak różne elementy na drodze wpływają na bezkolizyjne odseparowanie kierunków ruchu, zachowanie za kierownicą i bezpieczeństwo ruchu drogowego na skrzyżowaniach typu 15.5 (przeciwne pasy odseparowane pasem o szerokości 1.00 metra). Drugi projekt (klasa wykonania 4) analizował wpływ różnego rodzaju oznaczeń na skrzyżowaniach zlokalizowanych na obszarach wiejskich. Takimi rozwiązaniami nie są oznaczenia zewnętrznych pasów ani wydzielony pas przebiegający przez środek drogi. Zamiast tego, linie są poprowadzone poza krawędziami drogi.
Konkluzje płynące z obydwu projektów zostały uwzględnione w przeredagowanym RAL.
Słowa kluczowe: drogi 2+1, drogi 2-1, oznaczenia drogowe, drogi samo-wyjaśniające, bezpieczeństwo na drodze