Average wear of different road marking systems on the test field in the Harz Mountains, Germany

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Introduction

Regarding microplastic emissions by road marking materials it is necessary to know how much road markings wear out on average. The worn off material is suspected to decrease to microplastic particles that eventually enter into the oceans.

There was an opportunity to gather such information on a test field for road markings operated by The German Road Marking Association (DSGS, Deutsche Studiengesellschaft für Straßenmarkierungen e. V.) in September 2022.

DSGS opened this road trial in the Harz Mountains in Germany in September 2006. There were 91 samples present in September 2022. The objective of this test field was to learn which marking materials were suitable for the use in regions where a lot of snow ploughing and other kinds of winter service takes place. This is why there were commonly used materials and also new materials to be tested present. The following explains how information on the average wear of road markings was collected and evaluated.

Test field

Each sample on the test field consisted of 8 lengthwise stripes according to EN 1824 (Road trials), each stripe was 2 metres long and 15 centimetres wide, the distance between two stripes was 20 centimetres and the gap between two samples was 1 metre (see picture 1).

The mean traffic was about 8.000 vehicles per day. The test field was laid out in the Harz Mountains near the village of Torfhaus on the route B4. This is a region with heavy winter service, at least in normal winters. As is known the latest winters had almost no snow at all. But the height above sea level at Torfhaus is about 600 metres, so in the beginning there was an average of about 300 snowplough pass overs (only steel blades) and 400 salt uses per year. Nowadays it is approximately half as much.

Each year DSGS removes some samples that do not perform any more (regarding mainly nighttime-retroreflectivity) and new ones are applied instead. That is why a lot of different marking materials, systems with different durations since application, systems that perform and systems that do not perform are present on the test field.

Picture 1 Test field in the Harz Mountains, Germany

The annual measurements took place in week 35, 2022 (end of August 2022). At the same time the data presented in this paper was collected. The samples present at the time were classified into the following marking systems:

9 x CP flat line
12 x CP agglo irreg.
5 x CP agglo irreg. + old agglo
9 x CP agglo reg.
2 x CP agglo reg. (+underline)
11 x CSP

11 x TP flat line type I
9 x TP flat line type II
3 x TP flat line preformed
2 x TP flat line/inlay
2 x TP agglo reg.
7 x TSP

5 x tape profiled
4 x tape profiled (yellow)

abbreviations:
CP = cold plastic
CSP = cold spray plastic
TP = thermoplastic
TSP = thermo spray plastic
agglo = agglomerate
reg. = regular
irreg. = irregular

Collection of data and results

In table 1 the collected data as well as the evaluation is shown. Each row represents one sample on the test field (91 altogether). The rows were ordered into marking systems as classified above and after duration since application.

In column 1 to 5 the collected data is assembled (duration since application [years], kind of marking material, kind of application, type I or II and the original thickness [µm] when newly applied). For agglomerates the original thickness is replaced by the amount of material applied [kg/m²].

In column 6 the remaining thickness [µm] or remaining amount of material applied [kg/m²] was determined. For this, little bits of the remaining material were quarried out at representative places and the remaining thickness of the material was determined by a magnifying glass with graduation. In case of agglomerates the remaining amount of material was estimated. The remaining thickness or amount of material was averaged over the still existing material. In column 7 the remaining area compared to the original image was estimated from a bird's eye view (average over the whole sample).

duration since application [years]	kind of marking	kind of applikation	Type I / II	thickness (new) [µm] or [kg/m²]	thickness average ca. (August 2022) [µm] or [kg/m²]	remainig area ca. (August 2022) [%]	remainig material ca. (August 2022) [%]	total wear ca. (August 2022) [%]	Average wear per duration since application [%]
2	CP	flat line	II	3000	2950	99.5	97.8	2.2	2.2
5	CP	flat line	II	2000	1950	99	96.5	3.5	3.5
7	CP	flat line	II	2000	1950	90	87.8	12.3	
7	CP	flat line	II	2000	1900	99	94.1	6.0	
7	CP	flat line	II	2000	1950	97	94.6	5.4	
7	CP	flat line	II	2000	1800	97	87.3	12.7	
7	CP	flat line	II	2000	1900	98	93.1	6.9	
7	CP	flat line	II	2000	1700	99	84.2	15.9	9.9
8	CP	flat line	II	2200	2000	99	90.0	10.0	10.0
1	CP	agglo irreg..	II	2.4	2.3	100	95.8	4.2	
1	CP	agglo irreg.	II	2.4	2.3	100	95.8	4.2	
1	CP	agglo irreg.	II	2.4	2.3	100	95.8	4.2	
1	CP	agglo irreg.	II	2.4	2.3	100	95.8	4.2	
1	CP	agglo irreg.	II	2.4	2.3	100	95.8	4.2	4.2
2	CP	agglo irreg.	II	2.2	2.1	98	93.5	6.5	
2	CP	agglo irreg.	II	2.3	2.2	99	94.7	5.3	5.9
5	CP	agglo irreg.	II	2.4	2.2	98	89.8	10.2	10.2
6	CP	agglo irreg.	II	2.7	2	75	55.6	44.4	44.4
7	CP	agglo irreg.	II	2.9	2.5	93	80.2	19.8	19.8
8	CP	agglo irreg.	II	2.0	1.7	98	83.3	16.7	16.7
9	CP	agglo irreg.	II	2.2	2	95	86.4	13.6	13.6
6	CP/CP	agglo irreg. + old agglo	II	1.7	1.5	97	85.6	14.4	
6	CP/CP	agglo irreg. + old agglo	II	1.5	1.2	80	64.0	36.0	
6	CP/CP	agglo irreg..+old agglo	II	1.5	1.3	92	79.7	20.3	
6	CP/CP	agglo irreg..+old agglo	II	1.45	1.2	97	80.3	19.7	22.6
7	CP/CP	agglo irreg..+old agglo	II	1.4	1.2	97	83.1	16.9	16.9
1	CP	agglo reg.	II	2.8	2.75	99.5	97.7	2.3	
1	CP	agglo reg.	II	2.8	2.75	99.5	97.7	2.3	2.3
2	CP	agglo reg.	II	2.4	2.35	95	93.0	7.0	7.0
7	CP	agglo reg.	II	2.0	1.8	99	89.1	10.9	
7	CP	agglo reg.	II	2.0	1.9	99	94.1	6.0	
7	CP	agglo reg.	II	2.2	2	99	90.0	10.0	9.0
9	CP	agglo reg.	II	2.5	2.4	95	91.2	8.8	
9	CP	agglo reg.	II	2.5	2.4	97	93.1	6.9	
9	CP	agglo reg.	II	2.5	2.3	95	87.4	12.6	9.4
1	CP	agglo reg, (+underline)	II	2.7	2.65	99	97.2	2.8	2.8
2	CP	agglo reg, (+underline)	II	2.65	2.6	99	97.1	2.9	2.9
1	CSP	flat line	II	625	600	80	76.8	23.2	
1	CSP	flat line	II	625	600	90	86.4	13.6	
1	CSP	flat line	II	625	600	95	91.2	8.8	
1	CSP	flat line	II	625	600	86	82.6	17.4	
1	CSP	flat line	II	625	600	86	82.6	17.4	16.1
2	CSP	flat line	II	600	550	95	87.1	12.9	12.9
7	CSP	flat line	II	600	300	88	44.0	56.0	56.0
8	CSP	flat line	II	600	400	92	61.3	38.7	
8	CSP	flat line	II	600	300	88	44.0	56.0	
8	CSP	flat line	II	600	300	90	45.0	55.0	
8	CSP	flat line	II	600	200	98	32.7	67.3	54.3
4	TP	flat line	I	3000	2900	90	87.0	13.0	
4	TP	flat line	I	3000	2900	82	79.3	20.7	
4	TP	flat line	I	2000	500	93	23.3	76.8	
4	TP	flat line	I	2000	1800	99	89.1	10.9	
4	TP	flat line	I	3000	2000	92	61.3	38.7	
4	TP	flat line	I	3000	2000	95	63.3	36.7	
4	TP	flat line	I	2000	1500	97	72.8	27.3	
4	TP	flat line	I	3000	2800	99	92.4	7.6	28.9
6	TP	flat line	I	3000	1300	30	13.0	87.0	
6	TP	flat line	I	3000	2000	40	26.7	73.3	80.2
8	TP	flat line	I	3000	1800	30	18.0	82.0	82.0
2	TP	flat line	II	2000	1900	25	23.8	76.3	76.3
4	TP	flat line	II	3000	2900	92	88.9	11.1	
4	TP	flat line	II	2500	1000	91	36.4	63.6	
4	TP	flat line	II	2000	1500	93	69.8	30.3	
4	TP	flat line	II	3000	2700	98	88.2	11.8	
4	TP	flat line	II	3000	2800	99	92.4	7.6	24.9

Table 1 Average wear of different marking systems

duration since application [years]	kind of marking	kind of applikation	Type I / II	thickness (new) [µm] or [kg/m²]	thickness average ca. (August 2022) [µm] or [kg/m²]	remainig area ca. (August 2022) [%]	remainig material ca. (August 2022) [%]	total wear ca. (August 2022) [%]	Average wear per duration since application [%]
8	TP	flat line	II	3000	1200	65	26.0	74.0	74.0
9	TP	flat line	II	3000	1800	38	22.8	77.2	
9	TP	flat line	II	3000	1600	33	17.6	82.4	79.8
4	TP	flat line (preformed)	I	3000	2000	96	64.0	36.0	
4	TP	flat line (preformed)	I	2500	1000	55	22.0	78.0	57.0
6	TP	flat line (preformed)	I	3000	2000	30	20.0	80.0	80.0
8	TP	flat line/Inlay	I	8000	5000	82	51.3	48.8	
8	TP	flat line/Inlay	II	8000	4000	92	46.0	54.0	51.4
2	TP	agglo reg.	II	4.6	4.5	97	94.9	5.1	5.1
16	TP	agglo reg.	II	4.9	0.8	10	1.6	98.4	98.4
4	TSP	flat line	II	1200	800	70	46.7	53.3	
4	TSP	flat line	II	1200	400	85	28.3	71.7	
4	TSP	flat line	II	1200	800	80	53.3	46.7	
4	TSP	flat line	II	1200	400	18	6.0	94.0	
4	TSP	flat line	II	1200	800	65	43.3	56.7	64.5
6	TSP	flat line	II	1000	500	40	20.0	80.0	
6	TSP	flat line	II	1000	700	45	31.5	68.5	74.3

Table 1 Average wear of different marking systems (continuation)

In column 8 the proportion of the remaining material [%] was calculated by dividing the remaining thickness (or amount) by the original thickness (or amount) and multiplying by the remaining area. In column 9 the average wear [%] was calculated by subtracting 100 minus the proportion of the remaining material. In column 10 an average was formed if there were several samples of one marking system with the same duration since application.

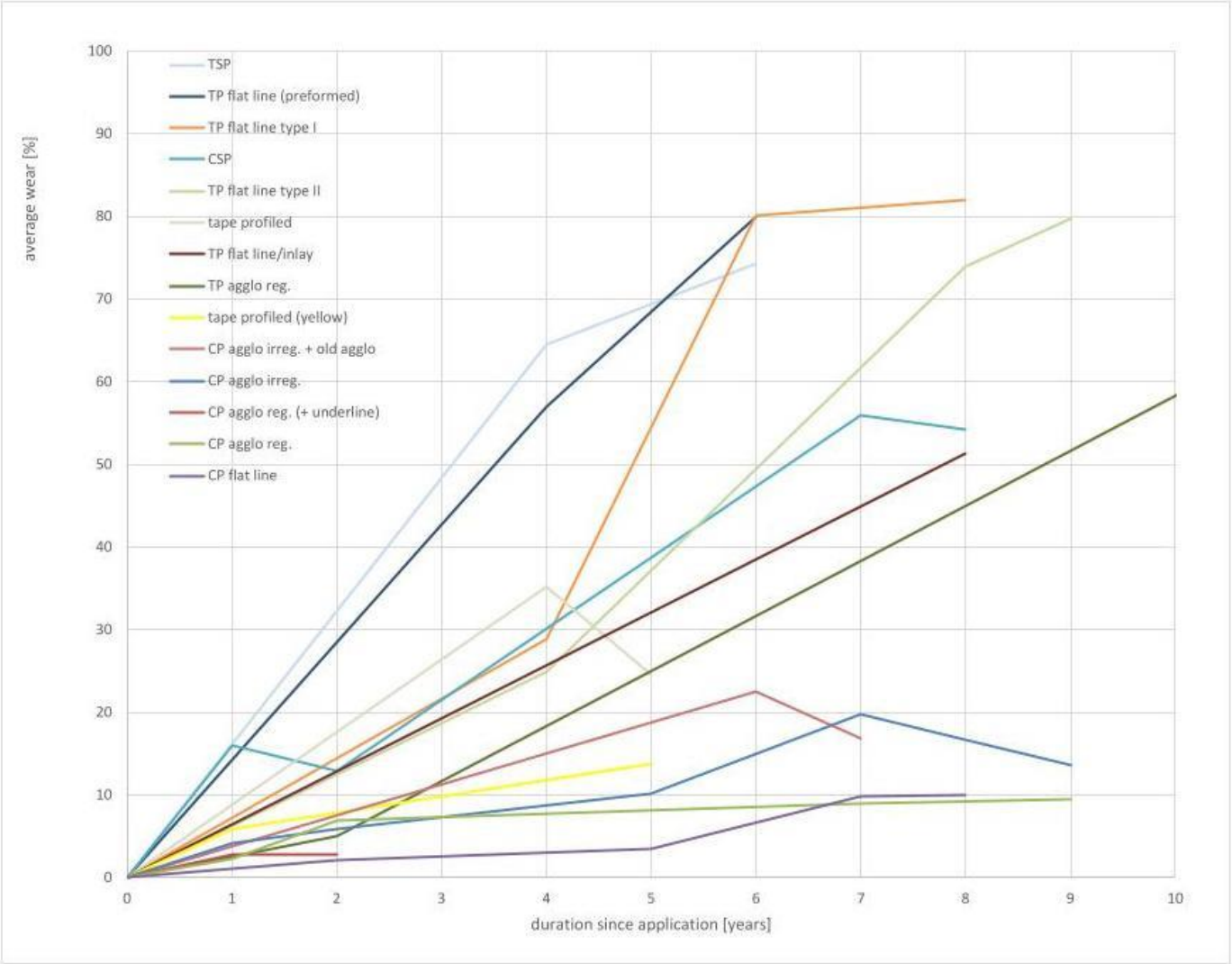
Two values were obviously spikes; They are marked in red and were not integrated into the further evaluation/diagram.

For the graphical evaluation in picture 2 column 1 = x and column 10 = y. An additional point was added for each marking system representing the state of application [0,0].

This evaluation does not take into account the functional lifetime with respect to mainly the nighttime-retroreflectivity of the marking systems, which is typically much shorter than the service life (duration since application).

Graphical analysis

In a diagram (see picture 2) the average wear of marking material [%] was plotted against the duration since application [years]. Each marking system has a different colour. In the legend of the diagram the marking systems were ranked by decreasing wear.



Picture 2 Diagram: Duration since application [years] = x; Average wear [%] = y

Further evaluation

Table 2 shows additional data of the evaluation. The average wear per year [%] was calculated as well as the average duration [years] until 50 % of the marking material would have worn off. The evaluated marking systems were ranked in the same sequence as in the diagram by decreasing wear per year.

marking system	Average wear per year [%]	Average duration until 50 % wear [years]
TSP	14.2	3.5
TP flat line preformed	13.8	3.6
TP flat line type I	10.3	4.9
CSP	9.3	5.4
TP flat line type II	8.1	6.2
tape profiled	6.9	7.3
TP flat line/inlay	6.4	7.8
TP agglo reg.	4.4	11.5
tape profiled (yellow)	4.3	11.6
CP agglo irreg. + old agglo	3.1	16.2
CP agglo irreg.	2.6	19.3
CP agglo reg. (+ underline)	2.1	23.4
CP agglo reg.	2.0	24.7
CP flat line	1.1	45.1

Table 2 Average wear of different marking systems per year [%] and average duration until 50 % would have worn off [years]

Final Word

Regarding this evaluation one has to keep in mind:

- There was only a small number of samples (91 altogether, each 16 metres long), so this evaluation represents just a small excerpt on the average wear of thousands of kilometres of markings in Germany.
- The functional lifetime with respect to mainly nighttime-retroreflectivity is typically much shorter than the service life of the marking systems on the test field.
- There were two obvious spikes in the gathered data that were removed from the evaluation. Naturally, there could be more spikes that were not discovered.
- The remaining average amount of material and the remaining area was estimated as accurately as possible. Still this estimation may have been subjective.
- For some marking systems there were several samples with the same duration since application which were averaged, for some there was only one sample with a certain duration since application and for others there was no data for a certain duration since application. For this reason and the three reasons mentioned above the statistical certainty is low.
- Not all marking systems that are commonly used in Germany were present on the road trial and therefore no data could be provided on those (no water based and no solvent-based paints for example).
- Among the evaluated marking systems there were commonly used ones but also materials still in development, so they were not necessarily representative.
- The conditions on the test field were worst case scenario (with heavy winter service). Road markings that are lying in “normal” areas in Germany (with less winter service) will most likely show significantly less wear since the snowplough is one of the main causes for wear on road markings.
- Not all worn off marking road marking material directly fragmentizes to microplastics. A not insignificant part of the material breaks off in bigger particles. What happens to these bigger particles after they broke off has not really been investigated yet.

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