01.02 Sealing of Soil Surface (Edition 1993)

Overview

Definition

Sealing soil surfaces negatively affects the ecosystem and the human habitat. Ground surfaces will be considered sealed in this study when they are covered with impervious materials. Sealed surfaces can be divided into **built-up and non-built-up sealed (impervious) surfaces,** along with surfaces sealed by built-up structures which are either completely sealed by asphalt and concrete, or covered by materials of varying permeability. These are also defined as sealed, although some, such as grass trellis stones and widely-spaced cobblestones or flagstones, do allow a limited growth of vegetation and access of water into the soil.

The greatest effects of surface sealing are found in urban and metropolitan areas where large portions of total area are sealed. Continued development increases the degree of sealing. This is particularly true of Berlin. The reunification of Germany and the transfer of the government to the new capital has increased the demand for construction and the development of new property areas.

Effects of Surface Sealing

The following text describes the effects of surface sealing on climate, water, soil, plants, animals and the human habitat.

Sealing contributes to an **urban climate**. Air is warmed by the high heat storage capacity of buildings and asphalt streets. This reduces cooling in the night, especially during summer (cf. Fig. 1).

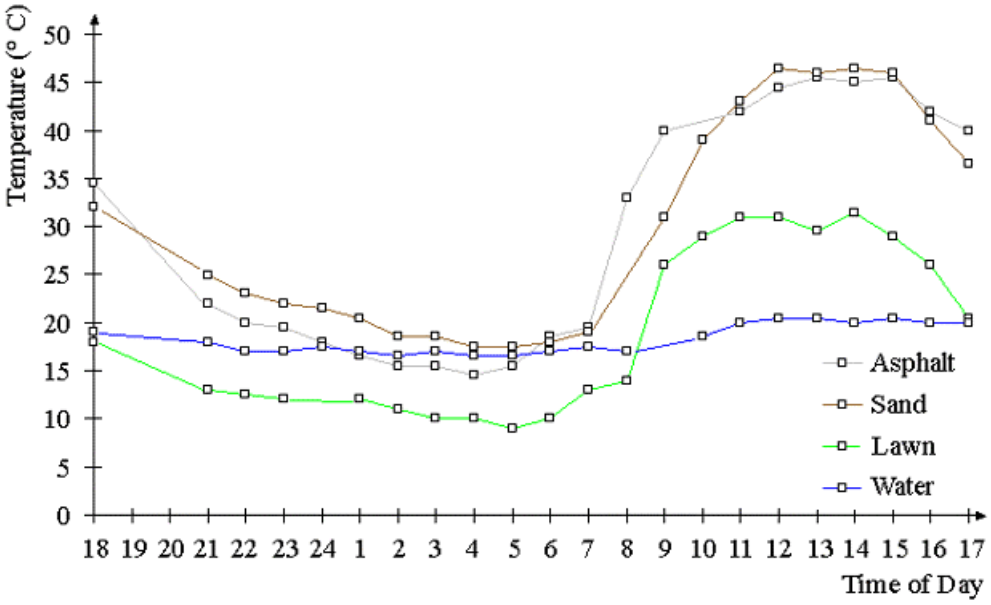

Fig. 1: Temperature Range above Various Surfaces (Kessler 1971 in: Mählenhoff 1989)

Relative humidity is decreased at the same time because vegetal surfaces and their cooling evaporation (evapotranspiration) are lacking (cf. Maps 04.04, 04.05, 04.06, 04.07 SenStadtUm 1993) (SenStadtUm - Berlin Department of Urban Development and Environmental Protection). This can produce extreme levels that considerably reduce human quality of life.

Non-sealed surfaces, such as parks, exert a great influence. Positive climate effects on human well being can be documented beginning with areas as small as 1 ha. Vegetal areas also influence dust and pollutants in the air, for the large surface area of leaves can bind dust and other air pollutants.

Sealing reduces surfaces available for infiltration (absorbing precipitation). This results in far-reaching changes in the **water balance**. Groundwater recharge (formation of new groundwater) necessary for the water supply, is reduced. Rain water on sealed surfaces is polluted by tire residue, dust and dog faeces. This polluted water is transported by sewers either directly into drainage canals or discharged by way of sewage plants (cf. Map 02.09 SenStadtUm 1992b). In urban areas with two-pipe drainage systems (separated rain water and sewage), rain water flows directly into surface waters. Small bodies of water are particularly affected by these loads of filth. In areas with combined rain water and sewer systems, heavy rainfall can overload the sewage drainage system or the pumping stations. Untreated mixed effluents can then also flow directly into surface waters. Increased sealing levels can also increase dangers of flooding in certain areas; this was a great influence in the collecting (catchment) area of the Panke River (Geiger 1992).

Sealing and density greatly impair **soil functions**. The reduction of water and oxygen entrance into the earth destroys organisms in the soil. Because water cannot infiltrate into the ground, pollutants transported by air and precipitation cannot be held in the soil. They are washed into surface waters.

Complete sealing of soil causes complete loss of **flora and fauna**. Even partial surface sealing causes a loss of habitat. Biotopes are cut up or isolated. Sensitive species are displaced to the advantage of a few more adaptable species.

The sealing of urban area directly effects the **human habitat**. A high degree of sealing is usually paired to a disparity between population size and available open spaces. The construction of buildings tightly rowed onto each other, often separated only by asphalt or concrete surfaces, can exert an oppressive, monotonous effect on those who live there. Nature, even in the change of seasons, cannot be directly experienced in dense residential areas. Long distances to the city's edge or into surrounding areas have to be traveled in order to make up for missing contacts with nature.

Development of Sealing

The **development** of sealing is reflected in the expansion of **residential areas and traffic areas**. Residential areas include the attendant open spaces within residential blocks, such as yards, parks and playgrounds, following the definition of the Federal Agency for Statistics. These areas are differentiated in the Map of (Impervious) Sealing.

The percentage of developed property and traffic areas (not including train facilities) in **West Berlin** rose by 2.4% from 1979 to 1989, primarily at the cost of agricultural areas. That corresponds to a daily loss of open spaces of 3,400 sq. meters, about the size of half a soccer field. An average of 115 ha per year was taken for settlement in West Berlin during that period of time. The Britz Garden, in comparison, has an area of 85 ha; the recreational center Wuhlheide has an area of 114 ha.

No precise figures for the development of residential areas in **East Berlin** are available. Construction within settlement areas was minimal up to the middle of the 70s. Large areas formerly used for sewage farms and agriculture at the edge of the city were taken for construction of the residential areas of Marzahn, Hellersdorf and Hohenschönhausen (including gigantic high-rise housing blocks) at the end of the 70's and beginning of the 80's. Residential construction in West Berlin in recent years was much lower. About 148,350 residential units were constructed in East Berlin from 1981 - 1990. About 64,100 residential units were built in West Berlin in the same time period (cf. Map 06.03, SenStadtUm 1995c).

Statistical Base

Sealing calculations for West and East Berlin were made on the basis of different statistical data.

The **West Berlin** figures are based on satellite data from the (Landsat 5 satellite thematic mapper system (TM) gathered between August, 1985, and May, 1988. Factors affecting the choice of time of data determination were vegetal development, cloud cover and haze. Verification of satellite data was by supplemental data of areas of known ground sealing, and Color Infrared Photos (CIR) (at a scale of 1:4,000) taken in 1985. Aerial photographs were regularly taken in commission of the Berlin Department of Construction and Housing. This analysis was updated in 1991 on the basis on CIR aerial photographs from the 1990 flights, also in a scale of 1:4,000. Determination of area size was on the basis of municipal planning data of Department II (State Planning and Zoning) of the Berlin Department of Urban Development and Environmental Protection.

Sealing data for **East Berlin** are based on the interpretation of CIR aerial photographies in a scale of 1:6,000 from flights in 1990 and the evaluation of a map of Berlin in a scale of 1:5,000, in which building plot outlines are accurately portrayed.

Methodology

The degree of sealing was derived by different methods because of the different statistical data available in West and East Berlin.

West Berlin

The 1985 Environmental Atlas contained a map of sealing for West Berlin prepared by the Institute for Ecology of the TU (Technical University) in 1985 (SenStadtUm 1985). It shows the estimated degree of sealing at the level of housing blocks based on aerial photography taken in 1979.

An expert opinion for the updating and extension of the map was made in 1988 (AGU 1988). The goal was a complete and new determination of sealing and the entering of this data into the Environmental Information System of the Berlin Department of Urban Development and Environmental Protection. The degree of sealing of referenced areas in the Environmental Information System was determined by analysis of satellite photography. These referenced areas correspond to statistical blocks, but when there were different uses within a statistical block, the statistical blocks were further divided into **uniform-use block segments**. They form the Spatial Reference System in the Environmental Information System (digital surface map 1:50,000) and are illustrated with their uses in Maps 06.01 and 06.02 (SenStadtUm 1995).

The land use categories Forest and Agriculture were assigned an assumed degree of sealing of 1% and 2% respectively; ruderal, 7%; and parks, 10%. The analysis was thus concentrated on 10,000 areas relevant for sealing, which made up about 50% of West Berlin.

The **degree of sealing** of the referenced areas was initially determined by an interpretation of Landsat-TM satellite photos made in 1985 and 1988. Satellite photos were calibrated and classified into a ten point scale of sealing on the basis of test areas with known sealing degrees from maps produced on location. A color slide was published as a provisional result. It represented the sealing classes for 30 meter by 30 meter grids. The digital land map was then overlaid; the number of elemental areas separated by sealing class for each block segment was counted. Then the degree of sealing in percentage for each block segment was calculated.

A comparison of values determined by satellite photo interpretation and the values given by mapping of test areas showed only minimal average deviances. Deviances determined by a plausibility control were corrected with the aid of aerial photographs in order to achieve higher precision.

These data were updated in 1991 by comparison with aerial photographs taken in 1990.

East Berlin

A degree of sealing for each block segment in **East Berlin** was also determined.

The easily recognizable degree of built-up development, in scale of 1:5,000, was initially estimated in percentage of total area. If old maps were used, the degree of built-up area was corrected with current aerial photographs, if necessary. The degree of sealing of a surface is determined by the components "**degree of built-up development"** and "**other sealing"** (non-built-up sealing). Non-built-up sealed surfaces include roads, parking places, loading and storage areas, etc.. The non-built-up sealed surfaces were also estimated in percent of total surface by interpretation of aerial photographs. Great difficulty was encountered in estimating the degree of sealing (and the non-built-up sealed surfaces themselves) in the dense interior courtyards dating from the late 19th century. The difficulty was caused by the shadow-effect of buildings and trees in the 1:6,000 scale aerial photographs. This diffused the view of the courtyard surfaces. Average values for this type of surface were applied in these cases.

A degree of sealing was determined by adding to the already determined degree of built-up surfaces. The degree of built-up surface is the more precisely determinable size. Degree of sealing values thus tend to be more precise when the degree of built-up surface is high.

Degrees of sealing were assigned to certain minimally-sealed surfaces, like parks and green spaces, only when they deviated from the general average.

A certain number of construction areas were mapped in East Berlin. Their condition at the time of survey did not allow information about their future type and thus their future degree of sealing. A category of "Indeterminable Degree of Sealing" was introduced for such cases.

The degree of sealing for streets is not shown in the map because the Spatial Reference System of the Environmental Information System only registers statistical blocks, but not streets themselves.

It was necessary in some cases to conduct a **redetermination of non-built-up sealed surfaces**. The satellite photo classification did not allow a differentiation between non-sealed surfaces without vegetation and sealed surfaces. The maintenance of a uniform classification did not enable these surfaces to be differentiated in the interpretation of aerial photography either. Vegetation-free areas such as beaches, dunes and barren lots were later classified as **non-sealed** surfaces**.**

Other vegetation-free (sub)areas, like stamped earth or gravel surfaces on railroad land, have a certain water permeability. They were initially classified as sealed. However, they should not be assigned a 100% degree of sealing, but only 40%. A **reduction of the degree of sealing** was thus calculated afterwards. This primarily concerned railroad surfaces having large areas covered with crushed stone; and industrial, small business and utilities areas. They have large areas of undeveloped surface used for storage. These reductions caused no great changes in the total map. Those statistical block segments whose degree of sealing was changed did not usually make up the entire area of the surfaces described above, but rather were carried in the calculations according to the proportions of their area.

Surface Sealing Classes

Several viewpoints are imaginable for surveying the **effects of sealing on the ecosystem** as differentiatedly as possible. Climatic effects, for example, are better interpreted if it is known whether the sealed surface is built-up or non-built-up and how high built-up portions are. The observation of effects on groundwater recharge and the run-off behavior of precipitation leads to the conclusion that not all artificial surface sealers have the same ecological properties. A widely-spaced mosaic of flagstones, for example, is much more water permeable than a concrete surface. A parking place laid with grass-trellis stones has a different micro-climate effect than an asphalt parking place.

These considerations have already been taken into account in the interpretation of data for this map. Four **surface sealing classes** were formulated, each with different effects on the ecosystem (see Table 1).

Tab. 1: Overview of Surface Sealing Classes

Sealing class	Estimated effects on ecosystem	Sealing type
1	extreme	Asphalt, concrete, paving stones with joint sealer or concrete substructure, plastic materials
2	high	Artificial stone and plates (edge length > 8 cm), concrete-stone composites, clinker, medium and large-sized paving stones
3	medium	Small and mosaic paving stones (edge length < 8 cm)
4	low	Grass trellis stones, water-bound cover (i.e. ash, pebbles, tamped ground), crushed rock, gravel

Tab. 1: Overview of Surface Sealing Classes

The surface sealer class division for each referenced area was derived from the categorization of coded areas and the representative determination of the material class divisions for each type of surface sealer (see Table 2). The sealing types were only surveyed for non-built-up sealed surfaces, on the assumption that built-up surfaces cannot be differentiated according to these criteria. This data are applied for the transposition of secondary methodologies (i.e. calculation of groundwater recharge).

Tab. 2: Average Degree of Sealing and Construction and Surface Sealing Class Distribution for Non-Built-Up Sealed Areas by Area Types

Area type	degree of sealing	of which		sealing class for non-built-up areas			
		built-up sealed areas	non-built-up sealed areas	1	2	3	4
	%	%	%	%			
Residential areas							
Courtyard	82	52	30	56	22	3	19
Decorative and garden court	60	37	23	62	27	10	1
Reconstruction area	70	42	28	62	17	8	13
Shed court	60	30	30	46	29	13	12
Post-war block-edge	68	38	30	41	27	4	28
Unplanned reconstruction	70	38	32	45	28	13	14
Large-scale residential area	46	21	25	15	67	7	11
Large court	45	29	16	20	37	32	11
Fifties and later row	40	20	20	49	46	3	2
Row yard	27	15	12	25	65	3	7
Yard	26	13	13	18	74	2	6
Park-like garden	28	16	12	15	60	12	13
Yards / semi-private re-greening	32	18	14	20	64	4	12
Open settlement development	22	13	9	18	74	2	6
Village	32	17	15	21	39	22	18
Core areas	77	40	37	50	34	9	7
Industrial / small business areas							
Mixed area II / industry and small business (built-up area < 50 %)	74	26	48	48	38	1	13
Mixed area II / industry and small business (built-up area >=50 %)	89	55	34	74	20	1	5
Utilities Areas	63	23	40	31	56	1	12
Public facilities							
Law enforcement	55	14	41	54	25	3	18
Postal	83	36	47	54	25	3	18
Administrative	66	30	36	41	42	15	2
Cultural	66	29	37	41	42	15	2
University/ reasearch	50	24	26	15	70	12	3
Hospital	39	18	21	42	38	8	12
Schools	53	19	34	45	40	2	13
Sports f+Z(31)Sacility	48	6	42	18	28	1	53
Water sports	35	16	19	46	29	13	12
Church	47	20	27	65	7	16	12
Child day care center	41	18	23	7	42	5	46
Playground	40	1	39	14	29	3	56
Retirement home	47	24	23	4	62	18	16
Youth center	26	10	16	4	62	18	16
Green and open spaces							
Allotment garden	21	11	10	5	31	4	60
Cemetery	16	2	14	14	27	5	54
Tree nursery / horticulture	35	18	17	35	45	9	11
Green space / park	12	2	10	30	20	5	45
City square / promenade	46	2	44	50	20	10	20
Forest	2	0	2	5	5	0	90
Agriculture (farmland)	1	0	1	10	10	0	80
Vacant areas	7	0	7	20	10	0	70
Campground	12	2	10	20	20	0	60
Weekend Cottage area	21	9	12	11	43	2	44
Traffic areas							
Parking lot	70	4	66	31	53	7	9
Railroad property	73	7	66	5	5	0	90
Airport	96	7	89	85	10	0	5
Other traffic areas	84	16	68	42	32	19	7

Green spaces within traffic areas or industrial and small business areas have been treated as vacant areas (e.g. vacant areas adjacent to airport taxiways); airports are only the sealed parts, streets were not considered

Tab. 2: Average Degree of Sealing and Construction and Surface Sealing Class Distribution for Non-Built-Up Sealed Areas by Area Types

Map Description

Description by Land Use Categories

The highest degrees of sealing occur in **old residential areas** within the city rail circle line. Residential blocks constructed with mostly closed courtyards have a sealing degree of over 90%. But large **industrial and small business areas** are also strongly sealed, especially areas along the Spree River from Spandau to Köpenick used industrially for a long time, and the large industrial areas in the Lichtenberg, Marzahn and Hohenschönhausen boroughs, which are over 90% sealed.

Taken as a whole, the degree of sealing generally decreases from the inner city towards the edge of the city. This corresponds to the fact that development is looser at the edge of the city. The city edge is either completely undeveloped (forest, agriculture) or contains areas of single-family homes. Exceptions are conspicuous. The **matured development** of cities independent until 1920, like Spandau and Köpenick, have a sealing degree around 60%. Their core areas are over 90% sealed. The large **new high-rise housing blocks** at the city's edges, like Marzahn, Hellersdorf, Hohenschönhausen, Gropiusstadt in Rudow, and “Thermometersiedlung” in Lichterfelde have a sealing degree from 50-80%.

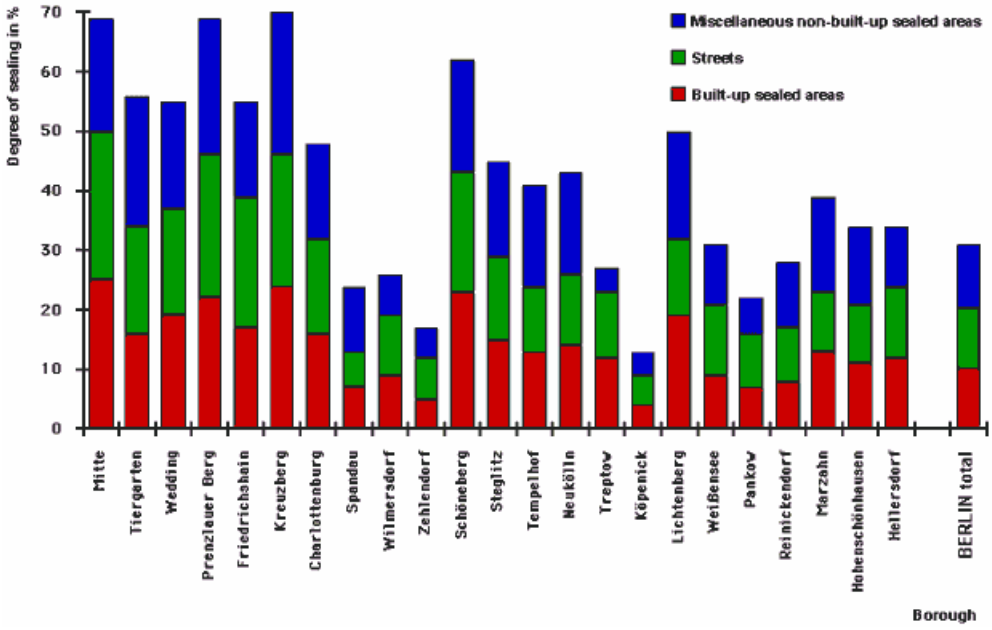

Fig. 2: Degree of Sealing by Borough

The **loosely built-up areas** at the edges of the city have differing sealing degrees. More remote locations like Heiligensee, Frohnau, Kladow and Müggelheim are low density, with sealing degrees between 10 and 30%. The classical single-family and row housing areas in Lichterfelde, Marienfelde, Kaulsdorf, Mahlsdorf, Karow and Blankenburg have sealing degrees between 20-40%. Areas that include more urban functions, like Dahlem, Westend and Friedrichshagen are up to 60% sealed.

Forests and agricultural areas are usually unsealed. But there are uses that have conspicuously high sealing degrees. Multiple uses in Grunewald make it look like a patchwork quilt on the map. Military and former military areas (Teufelsberg, firing ranges and ammunition depots), a tree nursery, allotment gardens and equestrian areas sometimes have high sealing degrees. Conspicuously high sealing degrees are also present around the broadcast tower atop the Schäferberg in Düppel Forest, and around two large day-trip restaurant areas in Köpenick's Bürgerheide, with their very large parking lot at the south shore of Müggelsee Lake.

Traffic areas take up 9.1% of Berlin's total sealed area. In the inner-city bourough of Kreuzberg is this 20 % of the entire bourough surface. For Köpenik on the edge of the city, it is only 4 %, compaired to 5 % of the built-up and not built-up area, an image of the lower density settlement areas in this district.

Overall View

Berlin is about 34,3% sealed, whereby less than half is non-built-up sealed (see Fig. 2). The average sealing degree is for the total area of a borough or the city. Built-up areas and streets are illustrated in the total borough area.
The built-up sealed ratio amounts to 10,6 %, areas of streets relating to the entire area of Berlin 9,1 %.
Köpenick with 15% degree of sealing is the least sealed borough. Kreuzberg, Mitte and Prenzlauer Berg boroughs are the highest, 72, 73 and 69 % sealed. The proportion of built-up area is also greatest in these boroughs.

Berlin and its metropolitan area are predicted a strong growth rate over the next 20 years. Berlin's location has become attractive since the reunification of Germany and may become an intersection of East-West trade. There will be an enormous demand for space which will lead to an increase in sealing, among other things.

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