Preventive Weed Control on Pavements: Reducing the Environmental Impact of Herbicides Part 2: A Laboratory Study

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Summary
The recent phase out of herbicidal use on public pavements by the Flemish government triggers the development of new, alternative weed control strategies on small element paving. In a second part of an extensive research program (see other conference paper “Preventive weed control on pavements: trying to reduce the use of herbicides – Part 1: a field survey study”, Boonen et al., 2012) concerning weed control in paved areas, a laboratory study was conducted. In this study, different joint filling materials for pavements were assessed towards their effectiveness in weed control through: a) a “pot” test (artificial conditions); b) a “mini” paving test (controlled, more realistic conditions; and c) an “in situ” test on a parking lot (natural, changing conditions). Tested joint fillers included some classic materials (white sand, porphyry, limestone) as well as some innovative fillers, especially designed to be weed inhibiting (such as Rompox®-easy epoxy bound sand, Dansand® sodium salt enriched sand). In the pot test, joint fillers were mixed with different levels (0 - 80 % by volume) of fine compost to simulate in situ, organic pollution of joints. Subsequently, the fillers were sown with up to 6 different weed species to investigate inter- and intra-specific differences in weed growth on the short term.

Next, in the ex situ paving test, a selection of fillers was tested in a mini pavement consisting of concrete paving blocks, two types of paving bed (open or closed structure) and two sizes of joint width (3 and 11 mm) to study the effect of joint fillers, joint widths and paving bed on the long term. Finally, two types of joint filler were tested on an existing test parking, comprised of different types of water pervious pavement blocks, situated at the estates of BRRC in Sterrebeek. To this end, the parking was seeded with a selection of weeds predominantly occurring on pavements (see Part 1, Boonen et al., 2012), to study weed growth in realistic, changing atmospheric conditions. In summary, the results of the three tests phases reveal a strong dependence of weed inhibition effect on type and particle size of the applied joint filler, degree of pollution, width and percentage of the joints, type of paving bed and pavement block. These findings show an opportunity for weed prevention by using suitable joint fillers in combination with the paving bed and paver type, in the construction of pavements.

Keywords: preventive weed control; concrete block pavements; herbicides reduction; joint filling materials; weed inhibition

1. Introduction

To meet the European Water Framework Directive, concerning pesticide residues, the Flemish government agreed to phase out the use of herbicides on public pavements by 2015 (Flemish Government, 2008). This phase-out triggers the development of new, alternative weed control strategies on modular element pavements. Besides the search for effective non-chemical curative methods, there is also a need for weed preventive strategies during the construction of pavements. Indeed, it has been indicated that a well thought-out design with appropriate use of materials could prevent later weed control problems (Guldemond et al., 1997; Rask and Kristoffersen, 2007; Boonen et al., 2012). In particular, the type of joint sealing compound and also the type of modular paving element in general (material, dimensions…) can significantly influence weed growth on the pavement (Riemens et al., 2005). Hence, in order to obtain an acceptable weed level in the street scene, both preventive and curative methods will be necessary when herbicides are no longer in use (Kempenaar et al., 2006).

In this study, covering the second phase of a joined research project (see Boonen et al., 2012), different joint filling materials for pavements were assessed for their effectiveness in weed control through three different types of tests: 1) a so called "pot" trial under artificial conditions; 2) a "miniature" block paving test (*ex situ*) under controlled but more realistic conditions; and finally 3) an *in situ* test on an existing, experimental parking lot with natural (changing) meteorological conditions. Besides the effect of the type of *joint sealing compound*, also the influence of other construction parameters such as *joint width*, organic *pollution*, type of *paving bed* material and type of *paving block* on weed germination and total weed coverage of pavements was studied.

2. Materials and methods

2.1 Pot test

This experiment included seven "standard" joint sealing compounds, three innovative joint fillers that were specifically designed for weed prevention and one "experimental" material (slag sand), see Table 1. Tested standard materials were: fine white sand, sea sand, porphyry (grain size fractions 0-6.3 mm and 2-6.3 mm) and limestone (0-2 mm, 0-6.3 mm and 2-6.3 mm). The weed preventive compounds used were Rompox®-easy (polymeric bound sand), two types of Dansand® (sodium silicate enriched sand) and Biozand® (also salt enriched sand). The slag sand is a secondary (waste) material which is not yet commercialized as joint filler. All joint fillers were mixed with fine compost up to six levels, *i.e.* 0 (= pure), 5, 10, 20, 40 and 80 % of compost by volume. These levels were designed to simulate *in situ* organic pollution of joints as most of the older pavements are contaminated with organic matter (OM, see also Boonen et al., 2012). The study was conducted as a growth chamber pot trial, as shown in Figure 1. Joint fillers and compost levels were arranged in a randomized complete block design with 4 repeating blocks. Weed suppressive ability of joint sealing materials was tested by examining the growth response of six weed species (one species per pot trial) in pure or polluted filler substrate. Selected test species were dandelion, annual meadow-grass, greater plantain, white clover, common mouse-eared chickweed and Canadian horseweed, all dominant, hard to control weed species on pavements (see Part 1: Boonen et al., 2012). After sowing, pots were kept for 30 days at a fixed diurnal temperature and light regime (16h of photoperiod at 25°C followed by 8h in darkness at 15°C). Pots were watered twice a day by automatic sprinkler irrigation (1.4 mm of water per day). Weed emergence was weekly counted and weed dry biomass was determined 30 days after sowing.

Table 1 – Tested joint sealing compounds in pot trial

Joint filler	Nature	Grading[1]
Fine white sand	Dried quartz sand	0/1
Round sand	Sea sand	0/2
Broken sand	Limestone	0/2
Polymer-bound sand	Rompox®-easy	-
Porphyry	Porphyry	0/6.3
Porphyry	Porphyry	2/6.3
Limestone aggregate	Limestone	0/6.3
Limestone aggregate	Limestone	2/6.3
Quartz sand enriched with salts	Dansand®	Fine (0/1)
Quartz sand enriched with salts	Dansand®	Coarse (0/4)
Quartz sand enriched with salts	Biozand®	0/2
Slag sand	Iron slag	0/2

[1] According to NBN EN 933-1, 2006

Figure 1 – Pot trial in climate chamber.

2.2 Ex situ paving test

In this “miniature” pavement trial (see Figure 2 on the left) 96 concrete block paving plots were set up under a rain shelter. These block paving plots were arranged in a randomized complete block with 3 replications. Each paving plot consisted of a conventional (non-permeable) concrete paver on top of a paving bed supported by a base layer with the whole being placed inside grass grid concrete tiles, as shown in Figure 2. In this paving test a combination of 5 joint sealing compounds, 2 joint widths (3 or 11 mm), 2 pollution levels and 2 types of paving bed material were studied. Tested joint filler materials (see also Table 1) were: fine white sand, sea sand, crushed porphyry (2/6.3mm), crushed limestone (2/6.3mm) and Dansand® (fine, 0/1mm). These were all evaluated in pure and organically contaminated (10% by volume of fine compost) state. Paving bed materials under investigation comprised crushed porphyry 2/6.3 (a highly water permeable aggregate = *open* paving bed), and crushed limestone 0/6.3 (a less water permeable aggregate = *closed* paving bed). After construction of the block paving plots, each “mini” pavement was seeded with a mixture of dandelion, annual meadow-grass, greater plantain and white clover, and watered three times a day by automatic sprinkler irrigation (2.1mm/day). The weed inhibitory effect was subsequently determined by examining weed germination and weed coverage of the surface. Weed germination was recorded monthly during the first five months after sowing, while weed coverage was monitored monthly over a two-year period (2009-2011) using image analysis software.

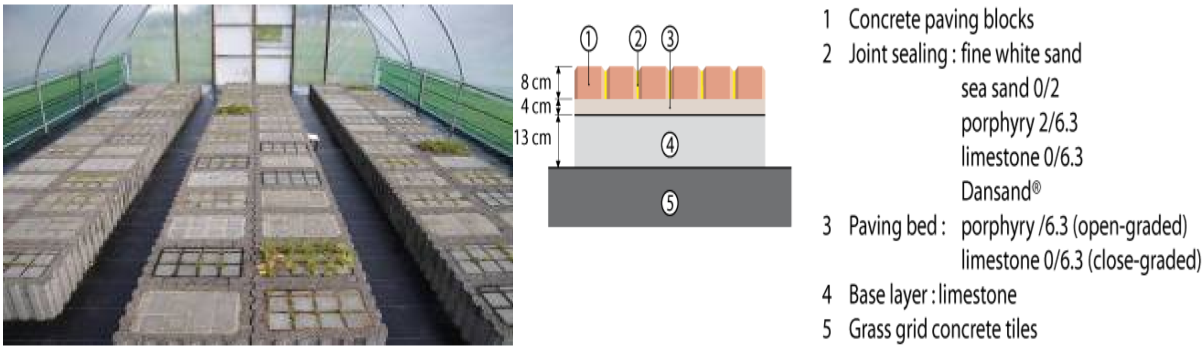

Figure 2 – Ex situ paving test and structure of block paving plots.

2.3 In situ pavement test

To assess the weed inhibitory effect of two types of joint sealing compound in a practical situation (with natural, changing weather conditions), an existing experimental parking lot at the premises of BRRC (see Beeldens and Herrier, 2006) was sown in October 2009 with a selection of weed species, predominantly occurring on modular pavements (dandelion, annual meadow-grass, greater plantain, white clover, common knotgrass, common mouse-eared chickweed, procumbent pearlwort and Canadian horseweed, see Boonen et al., 2012). This test parking consists of 10 different zones with 4 types of pavement blocks: conventional (non-permeable) concrete blocks, pervious pavement blocks, blocks with enlarged joints, and blocks with drainage openings, as shown in Figure 3. Two complying joint sealing compounds were used: porphyry 2/6.3 for the large joints and sand of Lustin (sandstone) 0/2. All zones were contaminated with organic material (OM = 20% by volume of fine compost), except for 2 zones of porous pavement blocks. As for this type of paver, twice as much of surface area is available; the influence of organic pollution can be compared to the two "clean" zones. The test sections are divided into 4 blocks, to have 4 repetitions for statistical analysis. In May 2010 finally, a vegetation monitoring was carried out to investigate the surface coverage (%) by weeds and the composition of the weed flora, as a function of pavement type.

Figure 3 – Schematic of experimental BRRC parking lot in Sterrebeek, Belgium.

3. Results and discussion

3.1 Pot trial

An example of the *dose-response* results is shown in Figure 4 (for dandelion), from which it appears that the more polluted the joint filler gets, the higher the weed growth will be. This is quite important as actual practice has shown that older pavements are indeed contaminated with organic matter (10% OM by mass on average, see Boonen et al., 2012).

Figure 4 – Dose-response for dandelion in different joint filling materials.

Innovative filler materials (Rompox®-easy, Dansand®) generally reduced the weed biomass significantly, irrespective of pollution level or test species as, for example, is illustrated in Figure 5. Biozand® however, which is also a silicate sand just as Dansand®, does not succeed that well in supressing weed growth and only in pure or less polluted conditions. The action of these materials is often based on the chemical composition (pH, salt concentration) and/or the technical characteristics (available water) of the joint sealing compound.

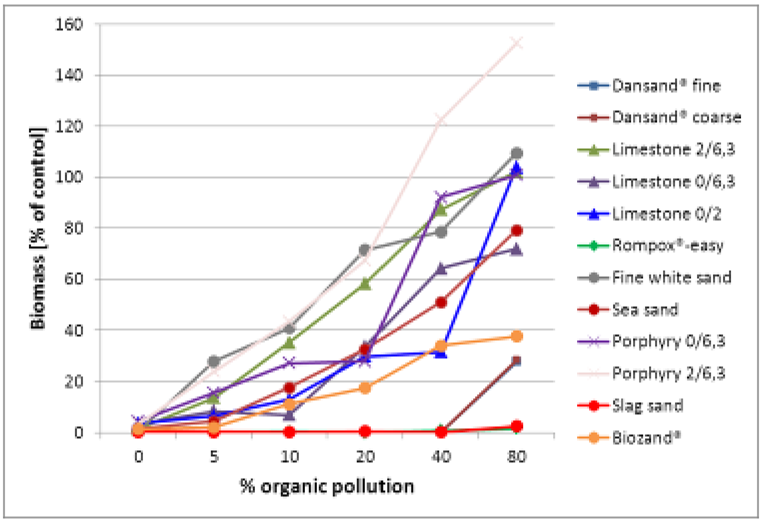

Figure 5 – Weed suppressing ability of joint sealing compounds, measured in pot trial with greater plantain.

Within the standard joint fillers, pure fine white sand and the coarser materials (limestone as well as porphyry) also reduced biomass, but their inhibitory effect dropped quickly once polluted with organic matter. Contrary to the other standard fillers, fine limestone (0-2 mm) showed a longer-lasting inhibitory effect on weed growth: even at higher pollution levels (up to 40% of compost by volume) the total biomass remained low. Sea sand reduced seedling emergence of all species tested, especially when pure or slightly organically contaminated.

Fine limestone (0/2) and sea sand actually demonstrate a greater ability to reduce weed biomass than fine white sand. In (highly) polluted circumstances, the inhibitory effect is also larger for fine materials compared to coarser ones. Finally, the weed inhibitory effect of joint fillers is also species dependent and within one type of material (*e.g.* limestone) grain shape and size distribution is an important parameter regarding weed growth. This is clearly illustrated in Figure 6.

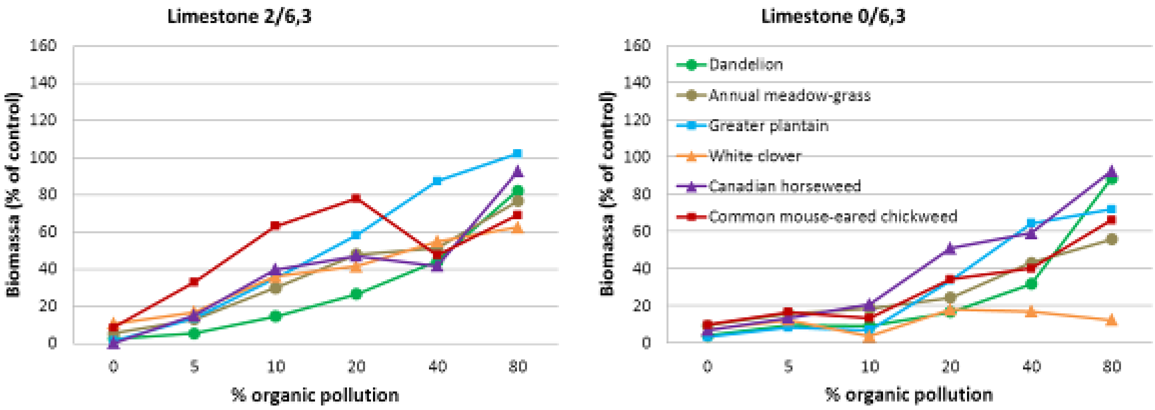

Figure 6 – Intra- and interspecific differences in growth response for limestone joint fillers. This highlights the need to determine the impact of joint fillers on weed growth for all common species found in paved areas. Furthermore, it will be important to prevent and/or remove as much as possible organic pollution of the joint sealing compounds (for example by regular sweeping of the pavement). Not all “so called” weed suppressing products on the market are as effective (cf. Biozand®), so some prudence is called for when selecting the joint filler. It should also be noted here that for practical application of these materials, besides the weed inhibitory effect also the behaviour under traffic load should be investigated (which in the framework of current research has *not* been done).

3.2 Ex situ paving test

In this experiment, not only the effect of joint sealing compound but also the influence of the bedding layer material (open or closed) and the joint width could be studied. For wide joints are applied for some types of water pervious pavements (Beeldens and Herrier, 2006), but also often occur in case of long-standing pavements (after construction works, subsidence, etc.). These then form rather quickly problematic areas for weed growth.

Figure 7 – Impact of joint width on weed coverage in “mini” paving trial, for pure sea sand. Left: 3mm; Right: 11mm

An example of the impact of *joint width* is shown in Figure 7. For all fine joint fillers (white sand, sea sand and Dansand®) weed germination and total coverage was higher in the case of wide joints (11 mm) compared to narrow joints (3 mm). This effect was seen in pure as well as polluted conditions. [For the coarser materials, porphyry 2/6.3 and limestone 0/6.3, this effect could not be investigated as these materials are only applicable in wide joints].

Concerning the standard joint sealing compounds, concrete block pavements with *pure, coarse* joint filling materials (limestone 0/6.3, porphyry 2/6.3) are generally less susceptible to weed growth than those with *pure, fine* materials (fine white sand, sea sand 0/2). *Polluted fine* joint fillers are also more prone to weed growth compared to *polluted coarse* joint sealants. These results largely correspond with the findings of Part 1 (Boonen et al., 2012) concerning the effect of joint filler (the coarser, the better).
Furthermore, it appears that paving sealed with Dansand® always show less weediness compared to concrete blocks filled with the classic materials (white sand, sea sand, porphyry and limestone), irrespective of the type of paving bed or the contamination of the joint filler. The weed inhibitory effect seems to decay in time though. In contrast to the first test year (2009) the pavements with Dansand® did show a measurable surface coverage by weeds in 2010, in the pure as well as polluted conditions. This is possibly related to leaching of the “active”, weed inhibiting components of the joint sealing compound.

The influence of the type of *paving bed* on the weed suppressing ability is dependent on the joint filling material used and the pollution level. This means there is an interaction between the type of bedding layer material and joint filler and/or organic pollution. Probably, this effect is also linked to the amount of water available for the plant within the paving bed.

As illustrated in Figure 8, weed growth is generally larger on pavements with a closed paving bed (limestone 0/6.3) compared to those with an open paving bed (porphyry 2/6.3). This effect is more pronounced in case of contaminated joint sealing compounds.

Figure 8 – Impact of type of paving bed on weed growth in “mini” paving trial. Polluted joint filler of limestone 0/6.3 in wide joints (11 mm). Left: closed paving bed (limestone 0/6.3); Right: open paving bed (porphyry 2/6.3).

In general, weed growth is highest in pavements with *wide* joints and *polluted* joint filling materials. This is usually also the case for polluted joint fillers in combination with a *closed paving bed*. This is most likely connected to the fact that there is more water available for the plant to grow in a closed bedding layer because of the higher amount of fines (< 63 µm) present there. More important however, is the interplay which appears between paving bed, joint filler and organic pollution, and the fact that the complete structure has to be considered in view of weed prevention. Hence, the weed growth on the “mini” pavement is not always easy to predict from the weed inhibiting ability of the applied joint sealing compound alone (as tested in the pot trial).

3.3 In situ paving test

The results of the vegetation monitoring on the different zones of the test parking are shown in Figure 9, about 6 months after sowing (May 2010). It is clear that the pavements with a high percentage of joints (widened joints with 15% of joints and drainage openings with 12.5% of joints) show higher weed coverage than those with low joint percentages (conventional concrete blocks with 7% and porous pavement blocks with 6%). Just as in the case of joint width (see above) this is most probably related to the larger space available for the plant to grow. The highest weed coverage was measured on the pavement blocks with drainage holes; the lowest on the pervious concrete blocks (about 5 times lower).

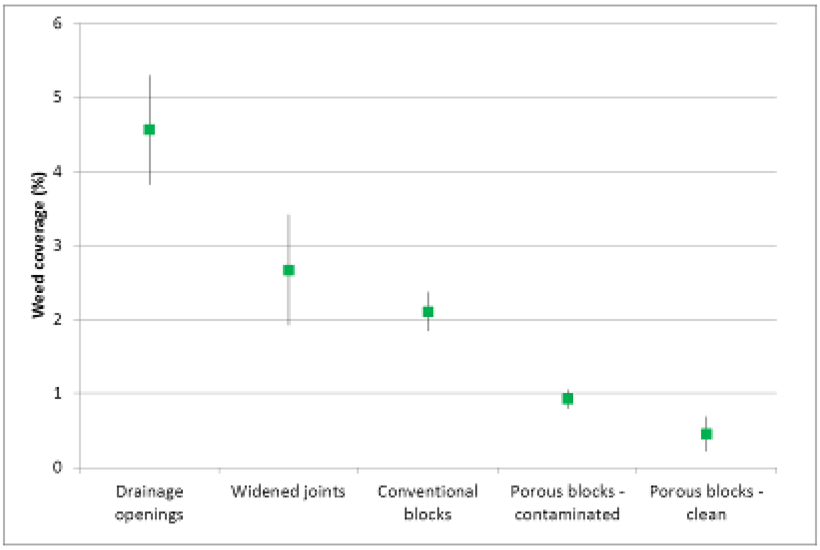

Figure 9 – Weed coverage on the experimental parking in May 2010.

In the case of pavements with a low percentage of joints weed coverage on porous pavement blocks was only half as much as on classic pavement blocks. Striking though is the high amount of mosses (a species not sown in the test) present on the surface of these porous pavement blocks. Finally, just as seen in the laboratory research (Section 3.1 and 3.2); *contamination* (with organic matter) of the joint (in pavements with pervious concrete blocks) causes a doubling in the surface coverage by weeds.

These results show that the cumulative influence of paver type and joint sealing compound (and very probably also the applied paving bed material, see before) will determine the weed growth in practical situations.

4. Conclusions

Overall, the results obtained in this research show an opportunity for weed prevention by using suitable paving materials, including joint sealing compound, paving bed material and type of concrete block paver, in the construction of pavements. Moreover, applied joint widths and contamination of the joint filler in time also play a crucial role for weed growth in pavements. Hence, the complete design of the concrete block pavement should be taken into consideration in view of weed prevention strategies. Pavements exhibiting a long-lasting weed suppressive ability might thus reduce total adverse environmental impact of curative weed control (including herbicides) by reducing its frequency required to keep weed density at an acceptable level.

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