



RESEARCH ARTICLE

Pedological Construction Supervision during the construction process—Status of implementation and future prospects

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Abstract

Background: In Germany, soil protection plays an increasing role in environmental protection. But construction sites are still not enough incorporated in soil protection measures. Pedological construction supervision (PCS) in construction projects can help to prevent soil damage during the construction processes.

Aims: This study aims to evaluate the state of implementation of PCS in Germany and the PCS courses for soil professionals in Germany.

Methods: A questionnaire survey has been conducted to get information about how strong the PCS is deployed and accepted.

Results: The legal basis of PCS is described and its development as well as the state of implementation is explained. The PCS is more and more incorporated in construction processes especially related to large ground movements for energy cables. The new DIN 19639 specifications supported this process. A PCS certification course for soil experts has been established in Germany to get a certificate as soil expert. Meanwhile, about 160 certified PCSs work in the field of soil protection at construction sites.

Conclusions: PCS on constructions sites is well established in Germany but it has to be applied on more construction sites in the future. A new soil protection ordinance in Germany in 2023 and the planned legislative change in the soil protection act will strengthen PCS. There is a great demand for certified pedological construction supervisors (PCSs). Training courses on PCS are needed, and PCS knowledge should be integrated into university courses.

KEYWORDS

BBodSchG, BBodSchV, certification course PCS, construction projects, DIN19639, energy line construction, Pedological Construction Supervision

1 | INTRODUCTION

Due to the expansion of human living space, the pressure on soil as a carrier of ecosystem functions is increasing. In the past, the focus of precautionary soil protection was on preventing soil contamination (BBodSchG, 1998; Blume, 1992). Due to the pressure on land use and the advancing climate change, it is becoming increasingly important

to consider physical soil protection too (Amprion GmbH, 2017; Bundesnetzagentur, 2020; Bundesregierung, 2021). This means protection against damage to soils through wind and water erosion, agriculture practices, and during construction processes, caused by mechanical impacts. By protecting the soil, the soil functions can fulfill their role in the ecosystem. Especially the construction of linear structures in the course of the energy transformation in Germany requires soil

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protection measures against impacts and lasting impairments. However, even large-scale construction works, such as development areas, should be accompanied by soil experts in order to prevent damage of any kind to the soil (Amprion, 2017, Bundesamt für Umwelt, 2015; Bundesnetzagentur, 2020, 2021).

Pedological construction supervision (PCS) is a necessary measure that makes soil protection possible and will also be anchored in the revised soil protection ordinance in Germany from 2023. Large projects in the construction sector, according to DIN 19639 with an area >5000 m², already involve a pedological construction supervisor (PCS) in order to avoid harmful soil changes, such as soil compaction with destruction of aggregates and so forth. Like the well-established environmental construction supervision, PCS has become part of the consultation in the construction process. The extent to which this is done and whether enough experts are available for PCS is of interest and will be analyzed in this paper. The objectives of this paper are (1) to describe the development of PCS in the field of planning and construction, (2) to explain the state of implementation in Germany up to the present day, (3) to present training courses for PCS, and (4) to point out future prospects.

1.1 | What does Pedological Construction Supervision mean?

According to DIN 19639—Soil protection in the planning and implementation of construction projects (Deutsches Institut für Normung, 2019), Pedological Construction Supervision is defined as “the monitoring of the construction process by persons who have specialist knowledge of soil protection and who support project developers in the planning and realization of the construction project with regard to soil-relevant projects.” DIN 19639 refers to soil protection during construction, with the goal to avoid and minimize harmful soil changes by means of a soil protection concept and PCS during the planning and construction phases. Thus, PCS extends over the entire planning and implementation phase and ends with the acceptance and documentation of the successful restoration of the soils and their natural soil functions affected by the projects impact. That means that recultivation and/or melioration must have been done, if necessary.

The guideline of the Bundesverband Boden e.V. (2013; Merkblatt 2) defines: “According to §2 Bundes-Bodenschutzgesetz (BBodSchG, 1998), the aim of PCS is to preserve and/or restore soils and their natural functions as close to nature as possible. After completion of a project, a soil that has been affected in the construction process should retain its natural functions as a (a) basis of life and habitat for humans, plants and soil organisms, (b) part of the natural balance, especially with its water and nutrient cycles, and (c) medium for filtering, buffering, and material conversion, in particular for the protection of groundwater” (Bundesverband Boden e.V., 2013).

In 1974, a 165-km transit gas pipeline in Switzerland, from the German to the Italian border, was put into operation. During construction, no consideration was given to soil protection issues. Great damage was caused to the soil. The soil was stripped completely and work was done

without considering the soil water content for example. This led to permanent crop failures after the land was taken into use again by the farmers. When the natural gas network was to be extended 20 years later, there was much resistance from the landowners (Bono et al., 2014).

As a reaction of this failed construction, the Federal Office of Energy, the Federal Office for the Environment of Switzerland and representatives of the natural gas industry, the cantonal soil protection agencies, and soil protection experts provided the “Guideline on the protection of soil during the construction of underground pipelines” (Bundesamt für Energiewirtschaft, 1997) at the beginning of the 1990s. The Federal Office for the Environment in Switzerland (BAFU), which is responsible for the legislation of soil protection in Switzerland, supported the development of a system of PCSs from 1997 on (Bono et al., 2014; Bundesamt für Umwelt, 2015; Laustela & Grünenfelder, 2018) and also promoted the installation of a training concept for this specialist field. Together with the Swiss Soil Science Society, a training concept for PCSs was developed. The further training for PCS is carried out by SANU future learning ag (SANU) in Biel-Bienne, Switzerland (Bodenkundliche Gesellschaft der Schweiz, 2019). The training lasts 17 days and allows the participants to prepare for the PCS exam.

2 | MATERIALS AND METHODS

In order to evaluate the state of the implementation of the PCS in Germany, first, a literature review was conducted. Second, all activities related to PCS at the national level as well as at the state level have been examined. In the course of this investigation, the legal situation for the application of the PCS in Germany was analyzed.

Since 2017, 162 PCSs have been educated in the courses from the BVB and the University of Osnabrück. The nine courses took place in different regions of Germany. The dataset from the registration and the information given by the participants during the courses were evaluated. Information about their place of employment was collected from list of PCSs in the German Soil Association (BVB).

For further information on the state of the PCS in Germany in 2022, a form with seven questions was sent via email to experts for preventive soil protection, organized in the BVB. In total, 550 single experts, planning offices, universities, and governmental organizations were contacted. Fifty-six filled forms returned and were evaluated.

3 | RESULTS

To deal with problems of soil damage during construction process in Germany, PCS as part of the construction supervision process is known since the beginning of the second decade of 2000. In 2009, the newly founded PCS expert committee (FA BBB) of the Bundesverband Boden e.V. (BVB) met for the first time (Bundesverband Boden e.V., 2009). Feldwisch (2012) outlined the possibilities of soil protection during construction measures and Gebhardt et al. (2012) described soil protection on line construction sites in an article in the same year. In 2013,



FIGURE 1 Extensive soil movements and construction activities for the ring road of the town Belm, near Osnabrück in 2017 (Photo: Maïke Bosold)

the BVB's Guideline on PCS (Bundesverband Boden e.V., 2013; Feldwisch et al., 2014) was published by the FA BBB. Up to that time, it was the only set of rules on PCS in Germany, besides the DVGW Merkblatt G 451 (M) of the Deutscher Verein des Gas- und Wasserfaches e.V. (DVGW, 2013). Until the publication of DIN 19639 in 2019 (Deutsches Institut für Normung, 2019), also DIN 18915 (Deutsches Institut für Normung, 2002; Thieme-Hack & Appel, 2017) "Vegetation technology in landscaping," which regulated soil work, and DIN 19731 "Recycling of soil material" (Deutsches Institut für Normung, 1998; Lehmann, 2014) gave instruction for the handling of soil material.

Accelerated by the planned power line constructions in the course of the energy transformation (Bundesnetzagentur, 2020, 2021) of the Federal Government, the necessity to accompany constructions with large ground movements in a professionally qualified manner increases (Figure 1). The Bundesnetzagentur, as the institution responsible for power line planning, is supporting the implementation of PCS and the communication between the soil experts, for example, from BVB and the project developers. The Bundesnetzagentur makes use of the technical expertise of the BVB and requires the project developers to have the construction projects accompanied by qualified soil experts. Thus, the PCS is involved in the planning of the pipeline construction projects. The project developers publish their own guidelines on soil protection in construction projects (Amprion GmbH, 2017; TenneT TSO GmbH, 2021; Transnet BW, 2018). Beside conferences on PCS (Hochschule Osnabrück & Universität Osnabrück, 2017), research on the impact of underground power cables on soils was initiated (Götz, 2021; Knauff, 2021; Schade et al., 2021; Trüby, 2014; Weyer et al., 2021).

Although the necessity for PCS can be derived from the existing Federal Soil Protection Act (BBodSchG) and the Federal Soil Protection

and Contaminated Sites Ordinance (BBodSchV) on the basis of the precautionary principle, there is no explicit law that requires or regulates it at the present time.

3.1 | Status of the implementation of PCS in Germany

The issues relating to soil as a protected resource are governed by the Federal Soil Protection Act (BBodSchG) and, subordinately, by the Federal Soil Protection and Contaminated Sites Ordinance (BBodSchV, 1999). The Act is only directly applicable where the primary legislation (Closed Substance Cycle Waste Management Act, Building Act, Federal Immission Control Act, etc.) does not contain specific material requirements for soil protection. §1 BBodSchG states, in essence, that the soil functions have to be secured and restored and harmful soil changes have to be avoided. §7 BBodSchG regulates the duty of soil precaution for everyone. This means the mandatory duty of everybody who impacts the soil in any way. Also, the §4, section 1 of the BBodSchG regulates hazard prevention. Everyone must act in such a way that danger is averted from the soil and harmful soil changes are not caused (BBodSchV, 1999). Based on these paragraphs, a PCS can be justified for projects $\geq 3000 \text{ m}^2$ on the basis of DIN 19639 to avoid harmful soil changes.

Since January 2021, the PCS and the soil protection concept, which has to be written for a PCS according to the DIN 19639, have been incorporated in the state law of Baden-Württemberg in Article 3 of the Land Soil Protection and Contaminated Sites Act, for the first time. According to this, a soil protection concept has to be prepared

TABLE 1 Structure of the PCS certification course based on DIN 19639 and the BVB-Merkblatt 2

Module 1 (15 lecture hours)	Module 2 (14 lecture hours)	Module 3 (4 lecture hours)
Introduction to PCS and legal basics	From the soil protection concept to PSC	Written examination
Planning and approval of construction projects	PCS service phases	Communication skills during PCS of construction work
Soil protection-relevant basics of construction technology	PCS commission	Practical examination (soil profile description in the field)
Soil physical and soil mechanical basics for PCS (including field soil scientific and laboratory technical methods)	Building tenders	
	Pedological evidence collection prior to the construction project	
	Tasks of the PSC during the construction phase	
	Avoidance and measures of mitigation	
	Reclamation measures and interim management	
	Examples - PCS in practice (workshop)	

for construction projects of more than 5000 m². For projects with an area of more than 10,000 m², the competent authority may require the developer to appoint a PCS for monitoring purposes (LBodSchAG, 2021).

In the course of the last decade, numerous recommendations and guidelines on PCS have been published at state level, for example, in Schleswig Holstein (Landesamt für Landwirtschaft, Umwelt und ländliche Räume des Landes Schleswig-Holstein (LLUR), 2020, 2021), Niedersachsen (Landesamt für Bergbau, Energie und Geologie, 2019), Nordrhein-Westfalen (Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen, 2017), Sachsen (Landesamt für Umwelt, Landwirtschaft und Geologie, 2016), and Hessen in cooperation with Rheinland-Pfalz (Hessisches Landesamt für Naturschutz, Umwelt und Geologie & Landesamt für Geologie und Bergbau Rheinland-Pfalz, 2018). In addition, the project promoters in pipeline construction have had extensive information material printed on soil protection during power line construction, such as Tennen (TenneT TSO GmbH, 2021) or Amprion (Amprion GmbH, 2017) to name but a few.

In July 2021, the so called *Mantelverordnung* was published including a revised soil protection ordinance in Germany that will be put into force in August 2023. Among other things, it will regulate with the new §4 section 5, that in the case of projects "...where materials are placed on or into a rootable soil layer over an area of more than 3.000 m², soil material is excavated or removed from the topsoil or subsoil, or the topsoil and subsoil is permanently or temporarily compacted in whole or in part, the authority responsible for approving the project may, in consultation with the authority responsible for soil protection, obligate parties to commission PCS in individual cases..." (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, 2021).

At present, the German government strives to establish a law amendment for the soil protection law based on the coalition agree-

ment (Bundesregierung, 2021). It is expected that soil protection during construction processes will be considered.

3.2 | Advanced training courses on PCS

Since the requirements for a PCS are very specific and this qualification is not taught in any standard course at a University, the Bundesverband Boden (BVB) has been offering training courses to get a certificate for this area of work in cooperation with the Osnabrück University since 2017. According to the requirement, there are also 1-day training courses for people from the administration. The participants from these 1-day courses need to know the processes of the PCS to formulate corresponding demands and tenders in the planning process, but they do not get a certificate. The core of the training courses, however, is the certification courses for PCS, which have a scope of 27 h and conclude with a 2-h written examination on the contents of the subject matter of PCS and a field examination (Bosold et al., 2018) (Table 1).

The target group of the course includes persons who work in soil protection and have to make statements on soil impairments in their function as an expert in an office or as an employee of a soil protection authority in the context of construction projects. Basic knowledge of the field soil science was formulated as an important prerequisite for registration. There should be sound knowledge of addressing soil profiles according to the Soil Science Mapping Instructions of Germany (KA5) (Ad-hoc AG Boden, 2005). Overall, the participants must fulfill and prove the following requirements: (1) completion of a course of study with soil science content; (2) a certificate of employment for at least 3 years of professional activity in the field of soil protection; and (3) proof of participation in mapping courses or internships in field soil science or proof of mapping activity or proof of the preparation of

TABLE 2 Academic background of the certified PCSs from 2017 to 2022 ($n = 162$)

Academic background of certified PCS	Number of PCSs
Geography, geoecology	71
Geology, geo-sciences, mining engineering	36
Pedology, soil science, soil protection	21
Environmental engineering	20
Agronomy, forestry	10
Garden and landscaping, landscape architecture	4

expert reports showing that soil profile descriptions were carried out in the field.

Upon completion of the course, the PCS should be able to work for the prevention of

- impairment of the soil structure (compaction),
- erosion and material discharges,
- contamination,
- mixing of different soil substrates, and
- admixtures of technogenic substrates.

The academic background of the 162 participants of the PCS courses is quite diverse. The largest group is made up of people who have studied geography or geoecology, followed by geologists, geoscientists, and mining engineers. The smallest group is made up of horticulturists and landscape architects (Table 2).

3.3 | Experience with the PCS training program

The first certification course in PCS took place in spring 2017 with 19 participants in Osnabrück. By spring 2022, nine certification courses have taken place in Germany, in Osnabrück, Dresden, and Stuttgart. During this time, 162 PCSs have obtained their certificate from the University of Osnabrück (Figure 2).

In the courses, the group of people working in an engineering or planning office forms the largest group with 82% (Figure 2). After that, participants from all levels of official structures are represented with 10%. Few certificates, 6%, are to be found in the area of the self-employed or freelancers. Participants from the education sector, such as universities and colleges, form the smallest group of participants with 2%. The professional experience of the participants ranges from 3 to 34 years. The highest academic degree in the course, Dr.rer.nat. or Dr.agr. or Dr.-Ing., was represented by just under 10%.

The qualified experts are now spread throughout Germany and are available as PCSs. A high distribution of experts can be found in the Ruhr area and in the southwest of Germany. The list and a map of the distribution of graduates can be viewed on the homepage of the BVB at <https://www.bvboden.de/bodenkundliche-baubegleitung/zertifizierte-bodenkundliche-baubegleiter>.

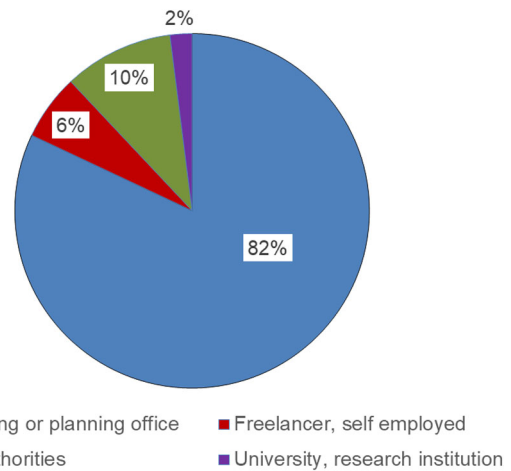


FIGURE 2 Place of employment of the participants of the PCS certification course of the University of Osnabrück and the BVB.

3.4 | Scope of application of the PCS

The demand for places in the further training program PCS shows that there is a great need on the labor market for this qualification. There are no statistics from the construction industry on the prevalence of projects in which soil protection has been included in the construction process within the framework of PCS. A survey among the members of the BVB, who are professionally involved in preventive soil protection, provided information about this. With the help of a questionnaire, 550 persons/institutions/authorities were contacted by email. The response rate was 56 completed forms. Responses from planning offices of all sizes accounted for 66%, lower soil protection authority 16%, higher soil protection authority 6%, ministries 2%, and others 9%. The further results of the questionnaire are shown in Table 3.

Forty-one percent of respondents had dealt with more than 10 projects requiring PCS in the last 5 years (Table 3a). Thirty-two percent of the respondents stated that they had dealt with between one and five projects. It was interesting to find out what type of approval procedure was involved in the projects in which PCS was embedded, since the success of a PCS depends on an early installation in the planning process. In 49% of the projects, planning approval had been granted. In 41%, a building application had been submitted and 10% were carried out within the framework of a simplified procedure (Table 3b).

In most cases, the PCS was already been incorporated in the planning approval procedure (42%). It is remarkable that even after structural damage occurred during construction, PCS was relatively often installed (15%) (Table 3c). To estimate how strong the PCS is being considered by authorities today, the members were asked "Who demanded the PCS." In 64% of the projects processed, the approving authority had required the PCS. In relation to the total amount of project 22% the project sponsor, and 8% the property developer and 6% others demanded a PCS (Table 3d). Most of the projects with PCS were embedded in power line construction (29%), closely followed by hydraulic engineering measures and others (24% and 23%, respec-

TABLE 3 Questionnaire results “Use and application of the PCS” ($n = 56$)

(a)					
Number of building projects with PCS (March 2017 to March 2022)					
	0	1–5	6–10	>10	
Percentage (%)	11	32	16	41	
(b)					
Type of approval procedure in the context of which a PCS was planned	Building application	Planning approval procedure	Simple application procedure		
Percentage (%)	41	49	10		
(c)					
Procedure steps in which PCS was integrated	Planning approval procedure	Development plan	Building tender	After soil damage had occurred	
Percentage (%)	42	18	25	15	
(d)					
Who demanded the PCS?	Approval authority	Property developer	Project sponsor	Others	
Percentage (%)	64	8	22	6%	
(e)					
Kind of construction projects with PCS	Housing development	Road construction project	Energy line construction	Water engineering measure	Others
Percentage (%)	12	12	29	24	23
(f)					
Need for PCSs to supervise construction work	More PCSs are needed	Enough PCSs are available	Certified PCSs are not needed		
Percentage (%)	84	13	3		

tively). Projects in the context of residential development and road construction had a smaller share with 12% (Table 3e).

Eighty-four percent of the respondents answered that the need for qualified specialists will increase. Thirteen percent agreed that there are sufficient specialists available for PCS. Only 3% said that certified soil specialists, PCS respectively, are generally not needed (Table 3f).

The evaluation within the framework of this study and the feedback from the participants in the PCS courses show that the demand for soil protection experts can hardly be met at present and will continue to increase in the coming years. Therefore, there is a need to strengthen the already existing courses of study with soil science content, to implement applied soil protection more in the curricula of universities and to continue and expand the range of further training courses. The demand for places on field soil science refresher courses also offered by the University of Osnabrück shows that there is a great need, especially for learning a routine of field soil science methodology (soil approach according to mapping instructions, measuring methods, etc.).

4 | DISCUSSIONS AND CONCLUSIONS

PCS can be installed in the planning phase of construction projects in Germany and applied during the construction process to avoid or mini-

mize harmful soil changes. The development of recent years in the field of large construction projects has shown that PCS is being used more and more widely as an instrument for precautionary soil protection (Amprion GmbH, 2017; Bono et al., 2014; Bundesnetzagentur, 2020, 2021; Götz, 2021; Tettet TSO GmbH, 2021; Weyer et al., 2021).

Accelerated by the planned power line constructions in the course of the energy transformation (Bundesnetzagentur, 2020, 2021; Bundesregierung, 2021) of the Federal Government, the necessity to accompany constructions with large ground movements in a professionally qualified manner increases. Today many construction projects in Germany are connected not only to energy turnaround but also to residential developments. This leads to an increasing pressure on soils and their natural functions, respectively. However, the currently valid version of the BBodSchV only specifies the BBodSchG with regard to material inputs and contaminated sites. Despite this, PCS is already widely demanded for construction projects based on the DIN 19639 specifications. A survey among soil specialist has shown that a high number of projects are processed with a PCS and the approval authorities asked for a PCS in the planning approval procedure.

More specialists in soil protection will be needed in the near future. To meet this demand of soil experts, training courses have been established (Bosold et al., 2018). These PCS certificate courses of the University of Osnabrück close the gap between the competences of

university graduates with pedological training and the requirement profile for a PCS. The PCS courses in Germany are not yet that much advanced like the very well-experienced courses in Switzerland (Laustela & Grünenfelder, 2018). But, on the other hand, in most of the European countries PCS courses not even exist until today.

Since many aspirants are often very uncertain about their practical experience in field soil science when registering, an additional course format was offered in 2020 and 2021 as a “Refresher Course Field Soil Science.” After a compact refresher of the knowledge of soil systematics and relevant soil characteristics according to German soil taxonomy (Ad-hoc AG Boden, 2005), the course offers intensive training in profile description in the field. The lack of training of soil profile description and the decrease of possibilities to improve this knowledge were recently pointed out in a stakeholder event with soil experts (Guggenberger et al., 2019). There is no doubt more experts on PCS including field experience in soil science will be needed in the future, and the PCS requirements should be integrated into the course profiles of the degree programs of universities in order to prepare graduates for work in planning and engineering offices.

In the future, the revised soil protection ordinance will provide a legal basis for physical soil protection on construction sites and PCS as a good instrument for the implementation of precautionary soil protection. The ongoing discussion of the German government for a new soil protection act based on the coalition agreement will also lead to a higher demand for soil protection specialists, including PCS to protect the soil during construction works in the future.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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