9th. International Conference on Concrete Block Paving. Buenos Aires, Argentina, 2009/10/18-21
Argentinean Concrete Block Association (AABH) - Argentinean Portland Cement Institute (ICPA)
Small Element Paving Technologists (SEPT)

SWEDISH EDUCATION AND TRAINING ON CONCRETE BLOCK PAVEMENTS

SILFWERBRAND, Johan, Professor.

Swedish Cement and Concrete Research Institute (CBI)
SE-100 44 Stockholm, SWEDEN
Tel.: +46-8-6961100, Fax.: +46-8-243137, johan.silfwerbrand@cbi.se

SIMONSEN, Erick, Dr.

HeidelbergCement/ Cementa AB
P.O. Box 47210, SE-100 74 Stockholm, SWEDEN
Tel.: +46-8-6256815, Fax.: +46-8-6256898, erik.simonsen@cementa.se

Note: The following is the notation used in this paper: (.) for decimals and ( ) for thousands.

Summary

Since 1999, the Swedish Concrete Block Paving Association (SCBPA) has published seven handbooks on concrete block pavements (CBP). They present recommendations and ideas for architects, landscape architects, owners, designers, contractors, homeowners, and local authorities. Special handbooks deal with use and maintenance and industrial CBP.

In order to promote the use of the handbooks and ultimately the use of CBP, the launching of some of the handbooks has been combined with education and training courses.

The paper summarizes two Swedish and one Norwegian course as examples of the Scandinavian education and training activities. The first Swedish course covered the use of CBP in urban areas whereas the second one was devoted to industrial CBP. The Norwegian course covered most aspects of CBP.

1. INTRODUCTION

The SCBPA is a technical cooperation between three manufacturers of concrete pavers and flags (Nordform, Starka Betongindustrier and S:t Eriks) and one cement producer (HeidelbergCement / Cementa). The aim is to increase the knowledge dissemination concerning CBP.

The work focuses on developing the technical support for the production of publications and other educational materials for landscape architects, designers, clients, and contractors. Since 1999, the SCBPA has published seven (7) handbooks on CBP (see Figure 1). They are devoted to the following topics:

1. Streets for human beings – Handbook for landscape architects (SCBPA, 1999)
2. Concrete block & flag pavements – Handbook for engineers, designers, and clients (SCBPA, 2000, 2002)
3. To construct concrete block & flag pavements – Handbook for contractors (SCBPA, 2001, 2002)
4. Concrete block and flag pavements for urban use – Condition assessment for city administration engineers (SCBPA, 2003)

5. Operation and maintenance of concrete block pavements – Handbook for city administration engineers (SCBPA, 2005)
6. Design of industrial concrete block pavements – Handbook for engineers, designers, and contractors (SCBPA, 2006)
7. The city floor – Architectural design of concrete pavers and flags (Hårde & Bergsjö, 2008)

The seven (7) handbooks are all primarily written for the Swedish market and have not been translated, with one exception. The handbook for construction has been translated into Norwegian.

Some of them are also used in the other Scandinavian countries, Denmark and Norway, which have closely related languages. In total, Denmark, Norway, and Sweden have 18 million citizens.



Figure 1. Handbooks on concrete block pavements produced by the SCBPA.

2. SWEDISH COURSE ON CBP IN URBAN AREAS

During the 1990s and the early 2000s, the use of CBP increased in Sweden (see Figure 2). The SCBPA had observed that the requirements on not solely technical performance but also on economy, environment friendliness, and aesthetics, had increased. This was the major reason for developing the handbook devoted to engineers, designers, and clients (1999) and this was also the reason to organize education on CBP in general, and on the new handbook specifically.

In spring 2000, the SCBPA organized eight (8) full-day education seminars on CBP in eight (8) Swedish cities in cooperation with the Swedish National Road and Transport Research Institute, the Swedish Association of Local Authorities and Regions, and the Royal Institute of Technology in Stockholm. The number of participants varied between 25 and 100 per occasion (totalling 400) depending mainly on the size of the city. The majority of the participants were landscape architects and city administration engineers.

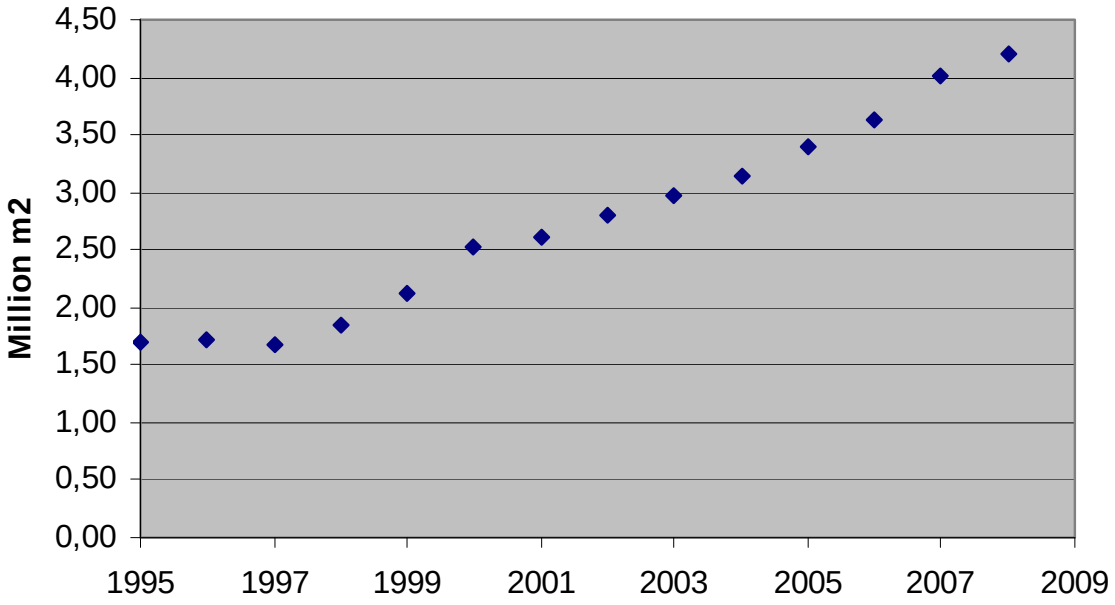

Figure 2. The Swedish use of concrete pavers and flags.

The aim of the course was to transfer knowledge concerning planning and design of CBP. The course covered the following lectures:

1. Introduction, general information on CBP including history and usage areas.
2. Urban use of CBP including purchasing, operation, maintenance, and future trends.
3. Design and construction.
4. Theoretical aspects on design.
5. Exercises on design and case studies.
6. Summary and conclusion.

The course followed largely the content of the handbook (2000) that consists of the following chapters:

1. Introduction.
2. Concrete pavers and flags.
3. Planning.
4. Design.
5. Construction.
6. Operation and maintenance.
7. Traffic safety.
8. Economy.
9. Other aspects.
10. References.

In Chapter 2, the Swedish Standard **SS 22 72 11**, the definition of a concrete paver, is reproduced as follows:

1. Thickness is between 60 and 120 mm.
2. Length is less or equal to 280 mm.
3. Surface area is less or equal to 0.05 m^2.

Other precast concrete products for pavements are denoted flags. Concrete flags are mostly used in squares, parks, and in pedestrian and bicycle pavements, whereas concrete pavers are used primarily on streets with a traffic speed limited to 50 km/h and on industrial or heavy-duty pavements.

Chapter 3 presents the characteristics and requirements for the various layers in the CBP system (see Figure 3). It also states the recommendation that the transverse slope of the pavement ought to exceed 2.5% in order to secure proper surface flow-of and drainage.

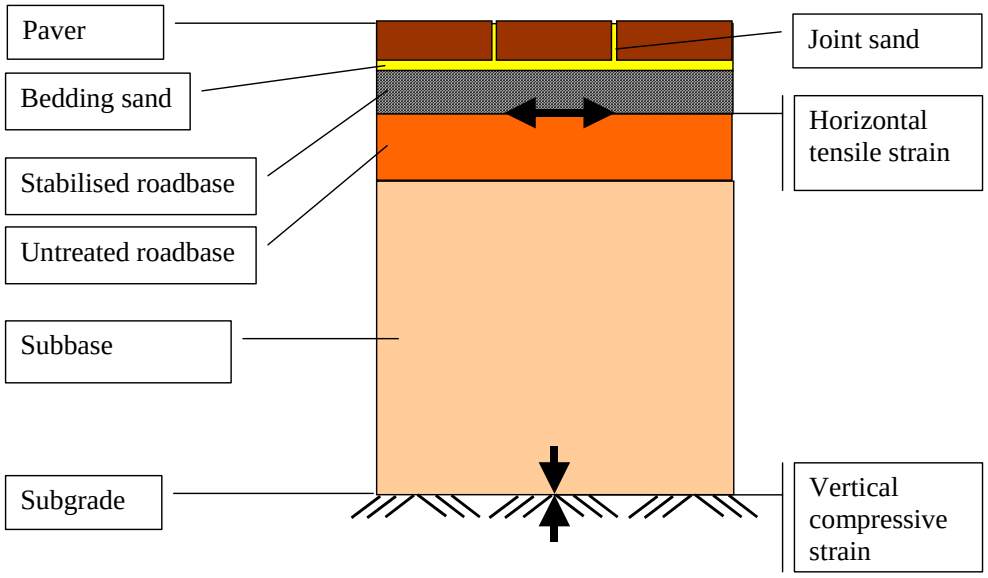

Figure 3. Swedish CBP system containing a stabilized road base. Horizontal tensile strain in the stabilized road base, if any and vertical compressive strain are the design criteria used.

The distance from south Sweden to north Sweden is 1 572 km. It means that the climate varies substantially. In the northern part, it is very important to consider the risk of frost heave (frost depth might reach 4 m below surface). The natural materials in the subgrade vary also considerably, regarding both stiffness and frost susceptibility. Chapter 4 describes the design process that can be summarized into the following steps:

1. Determine appropriate climate zone.
2. Determine appropriate evenness class.
3. Determine intended service life.
4. Estimate the number of standard axles by multiplying the number of heavy vehicles per day and the intended service life.
5. Determine the type of material of the existing subgrade.
6. Determine the total thickness of the pavement system according to the Chapter's tables by using selected data for items Nos. 1 to 5.
7. Select suitable concrete paver thickness accommodating the prerequisite for the Tables.
8. Modify the layer thicknesses if the desired paver thickness deviates from the default value (80 mm) by using the appropriate Table.
9. Modify the thickness of the untreated road base if natural gravel should be used in the road base instead of crushed gravel that is the default material by using the appropriate Table.
10. Determine the frost susceptibility class according to the Chapter's Table.
11. Determine total pavement system thickness to prevent frost heave according to Chapter's Tables.

12. Determine total pavement system thickness by selecting the highest value of item Nos. 6 and 11.

Chapter 5 stresses the importance of even layers, even joint spacing, appropriate compaction, repeated filling of joint sand, and suitable detailing concerning edge restraint, drainage wells, and manholes. Chapter 6 emphasizes that cleaning vehicles using vacuum suction should be avoided during the first 1 to 2 years to prevent loss of joint sand, critical to paver interaction and, consequently, pavement performance. Chapters 7 to 9 contain interesting general information, however, not taught at the course.

An important part of the course was to describe how to use the design procedure, summarized above for practical design cases. Consequently, at least three (3) cases were dealt with at each education seminar. They covered a pedestrian CBP, an urban street CBP with traffic speed limit of 30 km/h, and an urban street CBP with traffic speed limit of 50 km/h (the speed limit does not influence the design, however, higher speed limits are usually connecting to higher traffic volumes, and this influences the design).

3. SWEDISH COURSE ON INDUSTRIAL CBP

In 2006, the SCBPA published the handbook on industrial CBP (2006) in cooperation with the Swedish Cement and Concrete Research Institute. These two organizations also developed a course based on the handbook.

The people involved in industrial CBP are much fewer than those working with urban CBP. Consequently, only one course occasion was provided. It was organized on November 29, 2007, at the Swedish Cement and Concrete Research Institute in Stockholm. The number of participants was 21. The course covered the following lectures:

1. Introduction including historical perspectives, state of the art, R&D behind the handbook, and potentials of CBP.
2. Structural behavior of CBP.
3. The pavement system.
4. General aspects on the design of CBP.
5. Prerequisite for the design computations.
6. The design process.
7. Design examples.

The course emphasized the structural behavior of the CBP in order to increase the participants' understanding of the relationship between requirements on the CBP, its structural behavior, and its design. The following three requirements are fundamental to provide structural interaction between the pavers and thus make substantial load distribution possible:

1. Joint sand: If joint sand is missing, the interaction between adjacent pavers will be dramatically reduced (see Figure 4). Furthermore, water will penetrate the pavement system and possibly destroy its stability.
2. Drainage: Insufficient drainage may result in entrapped water standing in the bedding sand. This may in turn lead to instability and large permanent deformations.
3. Edge restraint: Insufficient edge restraint may lead to large horizontal deformations that starts at the edges and continues to the interior parts of the pavement (Figure 5). Eventually, this will lead to losses of joint sand, stiffness, and load-distribution ability.

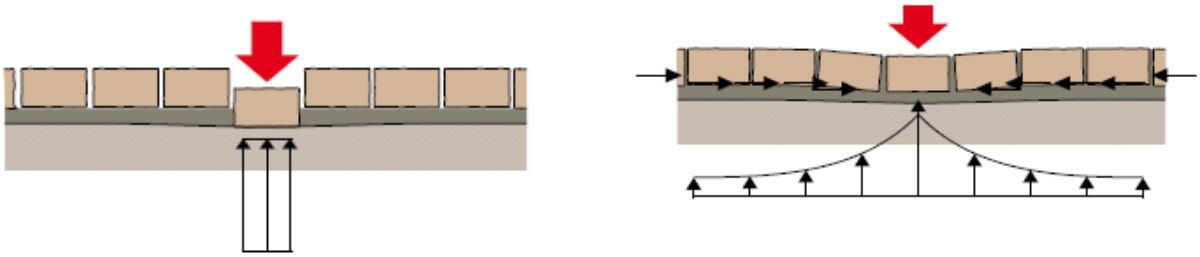

Figure 4. Structural behavior of a CBP with (left) and without joint sand (right).



Figure 5. If edge restraints are missing, the lateral support will be poor. Photographer: 1st author.

After the course, the participants were encouraged to complete a questionnaire. They were asked to evaluate the seven (7) lectures listed above. Was the presentation very good (4), good (3), decent (2), or poor (1)? Was the content of the lecture practically useful or theoretically interesting? Were the participant's expectations on the course fulfilled or not?

Unfortunately, only seven (7) course participants answered the questions. The average grading was 3.2. All respondents that answered the last question considered that their expectations were fulfilled. Lectures Nos. 1 and 7 were primarily considered "practically useful", whereas lectures Nos. 2, 4, 5, and 6 were primarily considered "theoretically interesting".

The classification of lecture No. 3 was evenly distributed between those two alternatives. It is somewhat surprising that lecture No. 6 was considered "theoretically interesting" since it was intended to provide a practical tool to carry out the design of CBP. This is something that the teachers have to consider when planning a second version of the course.

4. NORWEGIAN COURSE ON CBP

Concrete pavers and flags are frequently used as outdoor pavements also in Norway. The use goes from terminals and other heavy-duty pavements with very heavy loading to terraces in vicinity to residential buildings. The pavement system of the CBP has several similarities with other pavement systems, e.g., concrete pavements and asphalt pavements, but the CBP has also specific possibilities and requirements. Both possibilities and requirements were thoroughly discussed in a CBP course that was the most extensive one ever given in the Scandinavian countries.

The course was given by the Norwegian University of Science and Technology (NTNU) during spring 2008. It consisted of eleven days including an exam on the ending Saturday. The course days were distributed on two weeks, one in early February, and one in early March.

The course is primarily directed towards consulting engineers, clients, and contractors, but also to landscaping architects, engineers, construction supervisors, and people responsible for operation and maintenance of CBP. Since the competence on CBP is still under development at the technical faculties at Norwegian universities, international teachers were involved in the course.

The course covered the following themes:

1. (a) Introduction. (b) Concrete pavers and flags.
2. Design of CBP for roads and squares.
3. (a) Top quality CBP. (b) Examples of good and poor solutions.
4. (a) Standards and description texts. b) Laboratory task.
5. (a) Products of natural stone. (b) Excursion to various sites in Trondheim.
6. (a) Design of industrial CBP. (b) Excursion to terminal and parking lot.
7. (a) Aesthetics and material selection. (b) Construction of a CBP.
8. (a) Permeable CBP. (b) Case studies.
9. (a) Solutions for visually handicapped people. (b) Excursion to various sites in Oslo.
10. Operation and maintenance.
11. Exam.

The number of participants was 30. Currently, NTNU is planning to give this course a second time during the autumn 2009.

5. CONCLUDING REMARKS

In the Scandinavian countries, CBP is hardly covered in the civil engineering or architectural programs at the technical universities. Consequently, there is a need for training and education of engineers, landscaping architects and other categories involved in the various stages of planning, designing, constructing, and operating CBP for various topics.

There has also been a trend towards increased knowledge and understanding of how the CBP behaves. 20 to 30 years ago, CBP were almost always designed and constructed by trial and error and in best cases on experience from success stories.

The importance of Prof. Shackel's textbook (1990) cannot be exaggerated but theoretical and practical works in several other countries have also contributed to make the design of CBP more scientific. This development has also resulted in a need of training and education.

According to the authors' knowledge, the three (3) most important Scandinavian courses are summarized in this paper. The general Swedish course on urban CBP attracted most attendees

whereas the Norwegian course seems to be unique concerning its extent. The most important data from the three (3) courses are summarized in Tables 1 and 2.

Table 1. Statistics from the three (3) Scandinavian courses on CBP.

COURSE	NUMBER OF DAYS	NUMBER OF PARTICIPANTS	PRODUCT OF COLUMNS 2 AND 3
1. SE ON CBP IN URBAN AREAS	1	400	400
2. SE ON INDUSTRIAL CBP	1	21	21
3. NE ON CBP	11	30	330

Table 2. Summary of content of the three (3) Scandinavian courses on CBP.

COURSE	1	2	3
PRODUCTS & STANDARDS			X
URBAN CBP	X		X
INDUSTRIAL CBP		X	X
AESTHETICS			X
PERMEABLE CBP			X
MEASURES FOR DISABLED PEOPLE			X
EXCURSIONS			X

6. REFERENCES

HÅRDE, U., & BERGSJÖ, A., 2008. The city floor – Architectural design of concrete pavers and flags. Swedish Concrete Block Paving Association and Svensk Byggtjänst. 93 pp. (In Swedish).

SHACKEL, B., 1990. Design and Construction of Interlocking Concrete Block Pavements. Elsivier Science Publishers Ltd, Barking, Essex, England, 229 pp.

SWEDISH CONCRETE BLOCK PAVING ASSOCIATION (SCBPA), 1999. Streets for human beings – Handbook for landscaping architects. (In Swedish).

SWEDISH CONCRETE BLOCK PAVING ASSOCIATION (SCBPA) & SWEDISH ASSOCIATION OF LOCAL AUTHORITIES AND REGIONS, 2000. 2nd Edition 2002. Concrete block & flag pavements – Handbook for engineers, designers, and clients. 127pp (In Swedish).

SWEDISH CONCRETE BLOCK PAVING ASSOCIATION (SCBPA) & SWEDISH ASSOCIATION OF LOCAL AUTHORITIES AND REGIONS, 2001. 2nd Edition 2002. To construct concrete block & flag pavements – Handbook for contractors. 24 pp. (In Swedish).

SWEDISH CONCRETE BLOCK PAVING ASSOCIATION (SCBPA) & SWEDISH ASSOCIATION OF LOCAL AUTHORITIES AND REGIONS, 2003. Concrete block & flag pavements for urban use – Condition assessment for city administration engineers. (In Swedish).

SWEDISH CONCRETE BLOCK PAVING ASSOCIATION (SCBPA) & SWEDISH ASSOCIATION OF LOCAL AUTHORITIES AND REGIONS, 2005. Operation and maintenance of concrete block pavements – Handbook for city administration engineers. 40 pp. (In Swedish).

SWEDISH CONCRETE BLOCK PAVING ASSOCIATION (SCBPA) & SWEDISH CEMENT AND CONCRETE RESEARCH INSTITUTE, 2006. Design of industrial concrete block pavements – Handbook for engineers, designers, and contractors. 55 pp. (In Swedish).