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Paper :

Pavement surface materials used in urban areas

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-The range of urban materials-

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Summary

A wide variety of pavement surface materials have been used in urban areas. The choice of the surface material depends on a range of rational and irrational arguments. In former days the availability of the materials was a dominant factor. Nowadays a broad scale of materials is available and functional requirements play an important role in the decision for a certain pavement type and surface layer now.

The materials available are:

- Bituminous bound materials (asphalt concrete, mastic asphalt)
- Cement bound materials (concrete, concrete elements)
- (Small) paving elements (block pavers, modular materials, stone, terracotta)
- Composite pavements (a combination of the above mentioned ones)

In urban areas there is a wide variety of pavement users, as there are: pedestrians, wheelchair-users, parents with prams, roller-skates, bicyclists, scoot-mobiles, motorists, passenger cars and trucks.
The choice of the surface material depends on the (functional) requirements. Some of these requirements are the same as for highways; other ones might depend on the local situation. Additional requirements for urban areas might be a certain surface texture or colour for a certain image, easy to repair to guarantee the accessibility of houses, shops and other buildings, noise reducing, open for water infiltration, smooth to avoid vibrations and easy to open for accessing sewerage, gas and water systems. There might also be a need for flexible materials for creating ramps, roundabouts, cables and wiring.
For urban areas there are numerous possibilities when choosing the pavement type, depending on the use of the pavement. Because of the multiple pavement use it is sometimes difficult to find the right compromise (e.g. a bus lane in pedestrian area.)

The range of material that can be used as pavement surface in urban areas is described.

1. Introduction

In urban areas generally a wide variety of pavement materials is used. In the old days cobble stones were used very often (Figure 1). People used the local materials which were available. Later a lot of other materials have been tried. There have been wooden pavements, rubber pavements and even iron pavements. Nowadays a broad scale of materials is available and functional requirements play an important role in the decision for a certain pavement type. The choice of the surface material depends on a range of rational and irrational arguments. In urban areas esthetical aspects are very important.

Figure 1: Cobblestone pavement in Pompei (Italy)

2. Pavement users and usage

The main difference between the non urban and urban pavements is the use of the pavement. In urban areas there are footpaths, bicycle lanes, parking areas, squares, pavements in parks, service roads, paved residential areas, residential streets, district distributor roads and urban highways.
There is also a wide variety of pavement users with different types of vehicles, as there are: pedestrians, wheelchair-users, mothers (or fathers) with prams, roller-skates, bicyclists, scoot-mobiles, motorists, passenger cars, taxis, trucks and public transport as busses, trams and light rail (Figures 2 – 8).
Often urban pavements are used for different functions (during a year). For instance a square can be used as a market place, a parking place, pedestrian area, shopping areas but also as a terrace in the summer period.

In urban areas the traffic speed is (relatively) low and the roads are often designed in such a way that the drivers are forced to reduce speed. Curves, obstacles and traffic ramps are often used for this purpose.

3. Functional requirements

The choice of the pavement surface material for urban areas depends on the (functional) requirements. A part of these requirements is general and also applies for other types of roads like highways. For urban pavements there are also additional requirements, depending on the local situation.

3.1 General requirements

The road users want a road that is safe, comfortable, quiet, durable, fast to construct and easy to maintain and environmentally friendly.

Table 1 shows the user demands, the technical items and the performance requirements for pavements.

User demand	**Surface characteristic**	**Performance Requirements for Pavement**
Safety	Texture	- Skid resistance (friction) / Resistance to polishing - Surface drainage
	Horizontal (hydraulic) drainability	- Aquaplaning - Noise reduction - Splash and spray reduction
	Photometry	- Positive identification of lanes including, pavement marking, light reflection, colour contrast, etc. (Colour / Pigmentability)
	Evenness	- Longitudinal evenness (Resistance to corrugation) - Lateral evenness (Resistance to permanent deformation, Resistance to (wear due to) studded tyres, Load spreading capacity: stiffness (no uneven settlements))
Comfort	Texture	- Smooth surface (Noise reduction / absorption)
	Horizontal drainability	- Noise reduction / absorption
	Photometry	- Colour / Pigmentability
	Evenness	- Longitudinal evenness - Transfer evenness

Durability (to avoid road closure due to maintenance)	Integrity	- Structural strength ((Indirect) tensile strength) - Resistance to (surface) cracking - Resistance to aggregate loss - Resistance to (fatigue) cracking - Resistance to reflective cracking - Fuel resistance - Resistance against de-icing fluids
Environment	Recyclability	- Recyclability (amount of 'foreign' matters)
	Leaching / emissions	- No leachable components
Construction - maintenance	Construction time	- Short construction period
	Maintenance time	- Easy to repair and to maintain

Table 1: General requirements for a road surface

3.2 Additional requirements for urban areas

In urban areas there are usually a lot of activities going on. People live and work there, they recreate, meet, relax and shop in urban areas too (Figure 2). That means that the pavement should contribute to a nice and attractive environment. In an urban area are also several utility infrastructures as water, gas, electricity, telephone, internet, etc. These items lead to additional requirements like [3]:

The liveableness and perception value

- preserve the esthetical and historical and/or architectural identity (in historical centres)
- specific design with a variety in pavement types, element shapes and colours
- a certain surface texture or colour for a certain image
- quality of the outside environment;

Figure 2: Pedestrians / shopping area

Additional comfort requirements

- easy to build and repair to guarantee the accessibility of houses, shops, offices and other buildings,
- smooth to avoid vibrations and hindrance in the buildings and houses (caused by vibrations due to traffic and rail traffic).

Requirements for trees and plants

- open pavements for water infiltration and air

Utility works

- the ability of taking the pavement up the pavement for accessing sewerage, gas and water systems and cables for maintenance and repair.
- porosity of the pavement in case of gas leakage

Safety

- for pedestrian areas the passability / walkability (also for people with e.g. stiletto heeled shoes) is important

- flexible materials for creating ramps, roundabouts, utility manholes, cables and wiring in the pavement surface for traffic Information Technology Systems (ITS), etc..
- urban roadway lighting. The intensity of lighting is important to recognise and identify objects/people.
- on squares non-removable pavements might be required to avoid people throwing stones during a demonstration.

Figure 3: Lanes and colours for different users

4. Materials available

There are a lot of materials available that can be used for constructing pavements in urban areas. The main categories of pavement materials that can be used in urban areas are:

- Bituminous bound materials
- Cement bound materials
- (Small) paving elements
- Composite pavements

Each category of material has several (surface) materials that can be used. Table 2 gives an overview of pavement materials that can be used in urban areas.

Material category	**Pavement materials for urban areas**
Bituminous bound materials	Asphalt concrete Coloured asphalt concrete Asphalt concrete with a print (Figure 6) Asphalt concrete with pieces of mirror Mastic asphalt Coloured mastic asphalt Stone Mastic Asphalt Thin and Ultra thin asphalt concrete layers Double layered porous pavements Pervious pavements
Cement bound materials	Concrete slabs Reinforced concrete slabs Continuously reinforced concrete Concrete elements in different sizes Concrete with a (street) print Pervious pavements
(Small) paving elements	Block pavers Pavers for porous pavements Cobblestones Terracotta pavers Pre-formed modular pavers of brick Pre-formed modular pavers of concrete
Composite pavements	Grouted Macadam Embedded rail

Table 2: Overview pavement materials for urban areas

So for urban areas there are numerous possibilities when choosing the pavement type, depending on the use of the pavement. Because of the multiple pavement use it is sometimes difficult to find the right compromise (e.g. a bus lane in pedestrian area.)

Different pavement types can be used next to each other. That means that for instance the surface (and also the pavement thickness) of a parking area along a road can be different from the pavement (type) of the road itself.

Some of the pavement materials mentioned in table 2 are described in the next paragraphs.

4.1 Bricks and concrete block pavers

Bricks are often used for architectural reasons because of there colour and shape (Figure 8). It is easy to take the pavement up for utility works. The noise emission is higher than the reference surface 'standard asphalt concrete'.

Figure 4: Small paving elements

4.2 Silent concrete block pavers

Silent concrete block pavers often have an optimised fine structure and an open structure at the (top) surface. Special attention has to be paid to the road base layer for the evenness. Silent concrete block pavers can have a slight noise reduction compared with the 'standard asphalt concrete'.

4.3 Stone Mastic asphalt (SMA)

SMA is often used in urban areas for noise reduction. It is also a durable surface type (about 15 years). The noise reduction is based on a good ratio between the micro/macrotexture and the macro/megatexture. SMA 0/6 is a good noise reducing pavement in urban areas.

4.4 Porous asphalt

Normal porous asphalt does give a real noise reduction in urban areas because here the driving speed is (relatively) low.

Figure 5: Tramway in historical centre

4.5 Double layered porous asphalt

Double layered porous asphalt can be used in the main roads (that are not used by pedestrians and bicyclists) with a design speed of 50 – 70 km/h.
In areas that are used by pedestrians porous asphalt is not recommended because of the garbage that is dropped on the pavement like chewing gum, dog shit, paper, etc.
The standard double layered porous asphalt has an open lower layer (45 mm) of 11/16 mm and a surface layer (15 tot 25 mm) of 4/8 mm. Some products do have a surface layer with an even smaller gradation.

3.6 Porous Concrete
Porous concrete road pavements have good drainage effects and noise reducing capacities due the large accessible porosity. Polymer emulsions are added to obtain a sufficient strength and durability. It can be compared with porous asphalt and the noise reduction is comparable to porous asphalt. In the same way as porous asphalt, the noise reduction at low speed in urban areas is minimal.

4.7 Thin and ultra thin asphalt concrete layers
Thin and ultra thin asphalt concrete layers were developed to combine noise reduction and durability. They are often used in urban areas and the durability is comparable with SMA.

4.8 Pervious Pavements
A pervious pavement is a permeable pavement surface with a stone reservoir underneath and it can be used in low traffic areas and parking areas [1].
The reservoir temporarily stores surface runoff before infiltrating it into the subsoil. Runoff is thereby infiltrated directly into the soil. Pervious pavements can be created using Porous Asphalt or by special shaped concrete element blocks. The advantage of pervious pavement is the recharge of the groundwater and it can be helpful for the trees in urban areas.

4.9 Embedded rail
To reduce the noise of rail systems, rails of the tramway or light rail systems can be embedded in concrete pavements and in asphalt pavements. The advantage of rails integrated in the pavement means a shorter building period, longer life and less maintenance. For the urban areas it means less traffic disruption and less hindrance for the public.
The embedded rail system can be used by the ‘road’ traffic without any problem. In case embedded rails in the asphalt pavement, the top layer(s) consists of grouted macadam. That is porous asphalt where the voids are filled with grout (polymer modified sand-cement slurry). The grouted macadam can consist of one or more layers, being part of the bituminous pavement paved on a (moderate) hydraulically bound granular road base.

5. Selection of pavement type

The selection of the pavement type to be used in a certain project depends on numerous criteria. The most important one is the use of the pavement. The number of commercial vehicles per day is important for the pavement structure that can consist of several layers. That means that a wide variety of surface materials can be used if the underlying layers are design in such a way that the totals pavement construction can withstand the (heavy) traffic loadings.
A second important issue is then comfort and safety. In many urban areas noise reduction is becoming a very important item for the people

Figure 6: Streetprint

living along a road. High noise barriers in urban areas are avoided for several reasons. They are expensive and for aesthetic reasons there are not preferred.
In historical cities the choice of the pavement type is lead by aesthetic arguments.
All the (functional) requirements and the additional requirement mentioned in this paper will influence the choice of the pavement type (as far as they are applicable for that project).

Figure 7: Bus lane

There are also pavement construction issues that might be an important item in the selection process of the pavement type. These issues can include:

- pavement thickness constraints, like overhead clearances and level of adjacent footways, bicycle lanes, houses and/or buildings.
- impact of utilities below the pavement like cables, pipes and sewerage systems and possible future utility upgrades that might be needed or other rehabilitation treatments.
- impact of road closures and the effects on detours, bypasses, alternate routes, and public transport routes during the construction phase.
- budgetary issues and initial costs and the impact on maintenance operations, including winter maintenance.
- life-cycle cost analysis.


Figure 8: Block paving

6. Conclusions

For the urban architects there is a wide variety of pavement surface materials available that can be used in urban areas. The choice of the surface material depends on rational and irrational arguments.
For choosing and using the right product in urban area, the different possible uses have to be known to be able to select the best compromise.
There is a list of functional requirements and additional requirement shown in this paper that can be used in selecting the best (technical and esthetical) solution. By taking these requirements into account the pavement engineer should be able to exchange ideas with the urban architect in such a way that they can find the best solution.

7. References

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