

EGU 2011, ERE 5.3: Sustainability of traditional construction materials in modern society

Sustainable use of natural stone as paving material

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Contents

- Paving stones
- Sustainability
- Yesterday
- Present requirements
- Failures
- Guidelines and design fundamentals (*this time we only deal with unbound construction*)



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Sustainable use – What is that?

- Selecting a durable stone
- Preferably locally produced which means short transportation distance, low energy consumption and low emissions
- Paying the right price which means that the stone supplier can survive economically
- Fit for purpose: strength (normally not an issue) pedestrian crossing, tactility, surface finish- friction, smooth ride etc
- Aesthetically pleasing (use stone 😊)
- **AND: a proper construction to cope with the loads**

Natural stone paving in use

Slabs (EN 1341)

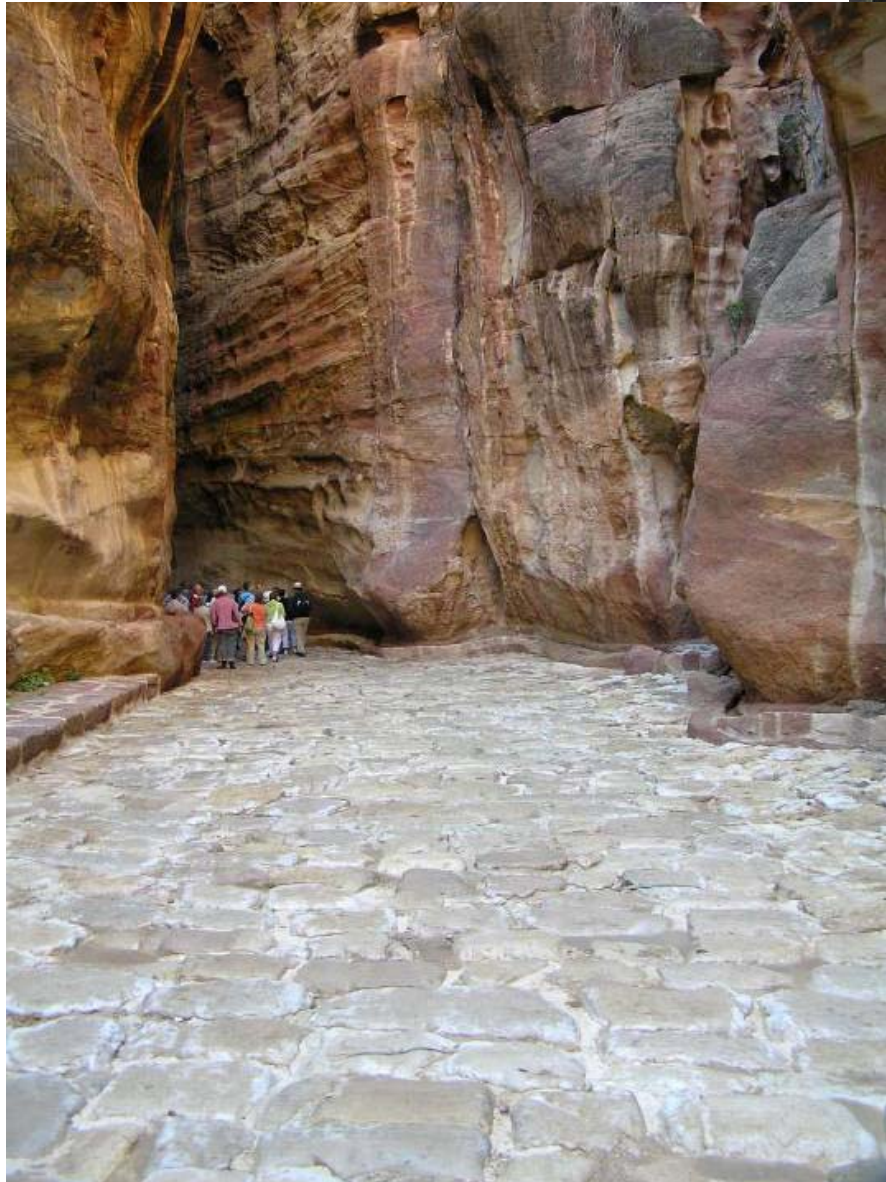
Setts (EN 1342)

Kerbs (EN 1343)



The old days

Roman road in Petra, Jordan



300 years in Borås

Today's requirement: Form and function

E.g. red and white granite
for the crossing



Parking place, here
diabase and granite



Tactile units for blind or
weak-sighted people



Durability includes e.g. frost resistance, abrasion, rusting and strength

Frost issues



"Rusting"



European product standards, provide very little information

- Previous versions of the European standards required that the stones could carry all loads unsupported.
- The revised versions differ between slabs and kerbs placed in unbound and bound foundation – Good!
- but still no guidance is given about the actual construction. This is left completely to the engineer. Let's hope they have sufficient knowledge

$$t = \sqrt{\frac{1500 \cdot P \cdot L \cdot F_s}{W \cdot R_f}}$$



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Dimension L (mm)	Safety factors, F_s , for slabs on				
	Paving over		Paving over a gap, supported		
	concrete using mortar and joints (bound construction)	sand or aggregate (unbound construction)	on 4 sides	on 2 sides	on 4 corners
≤ 600	1,2	1,8	2,4	2,7	3,0
> 600	1,8	2,4	2,7	3,1	3,5

Even when the stone is strong enough for its intended application...

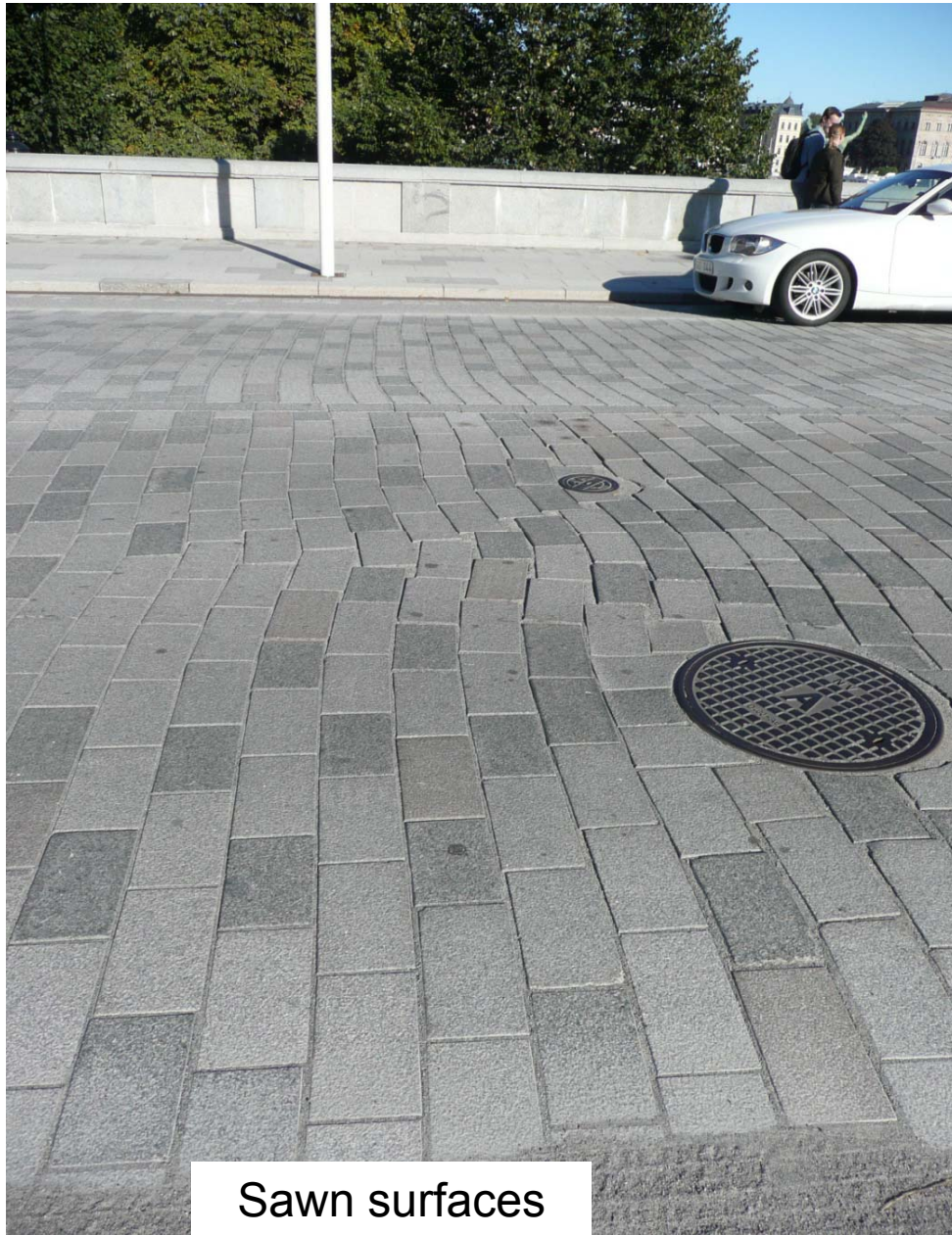
Inadequate design for traffic loading



Inadequate support for type of paving element



Construction errors occur all the time



But we do have Guidelines!

Sweden

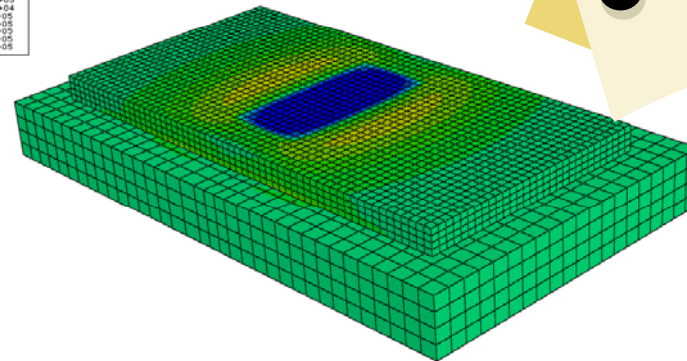
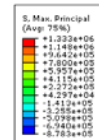
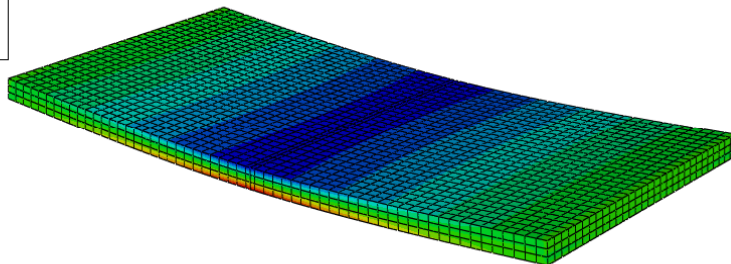
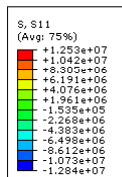
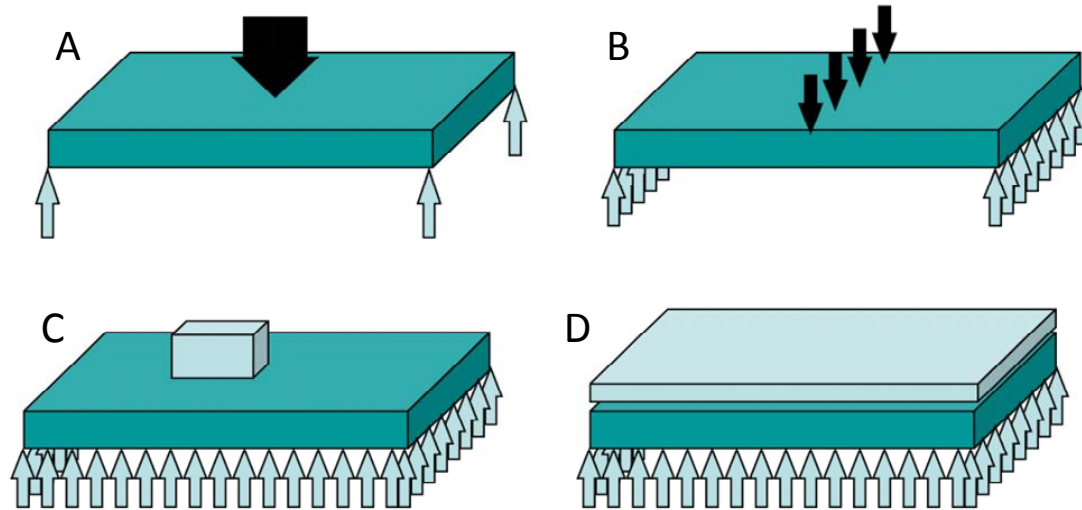
UTEMILJÖ



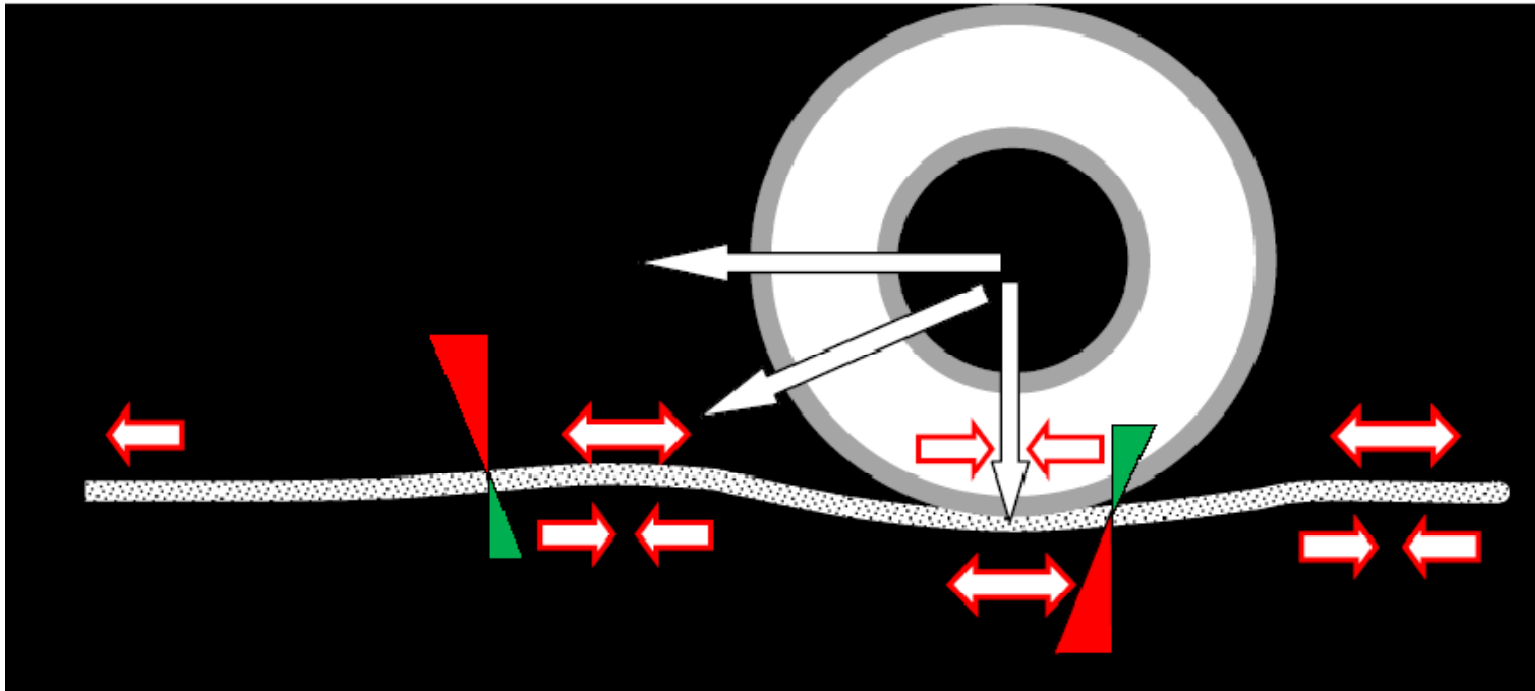
Germany .. +++



and better testing and modelling possibilities



but do we understand the dynamics?



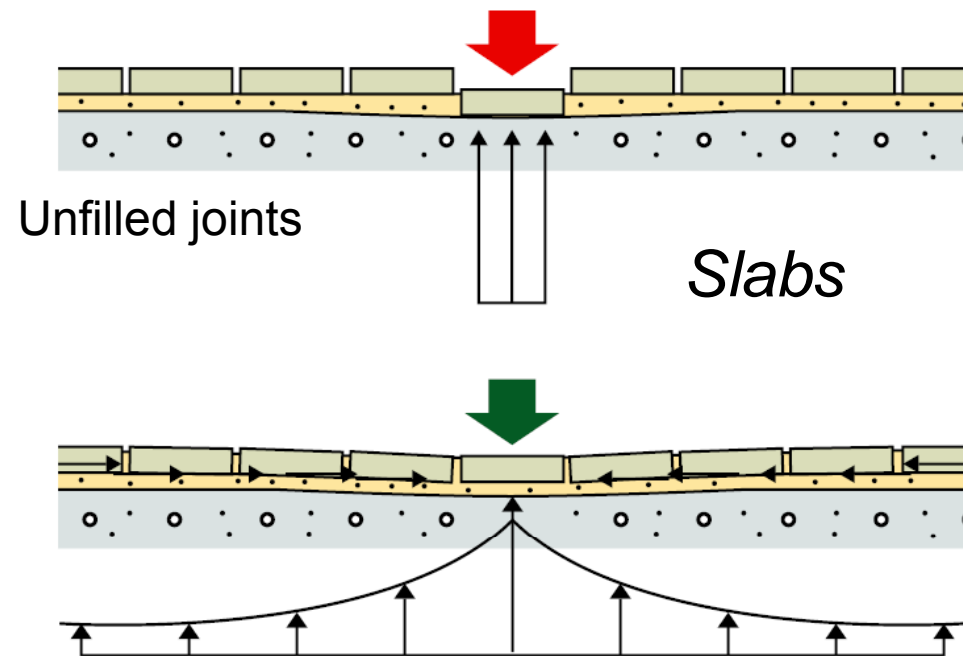
Pavements flex under dynamic stress.

Pressure waves cause buckling and deflection, weak bonds fail in strain

Important factors to consider

- Everything is flexible, even the stiffest granite is constantly flexing under load.
- Nothing is infinitely stiff, all structures and all materials deflect under load
- All parts interact

Friction! No friction
without movement!



Design fundamentals

There are 3 types of paving element.....

- **Full depth setts**
primarily “joint dependant”
- **Shallow setts**
both “joint” and “bedding” dependant
- **Slabs and Flags**
primarily “bedding dependant”

Simple rules

Shallow setts are those having depth less than width.

- Specifying shallow setts makes a more economical use of the raw material used in their manufacture.
- But the pavement construction requires to be designed more carefully and there is an upper limit to the level of traffic which can be carried.
- A concrete base must be provided when specifying shallow setts!



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Simple rules

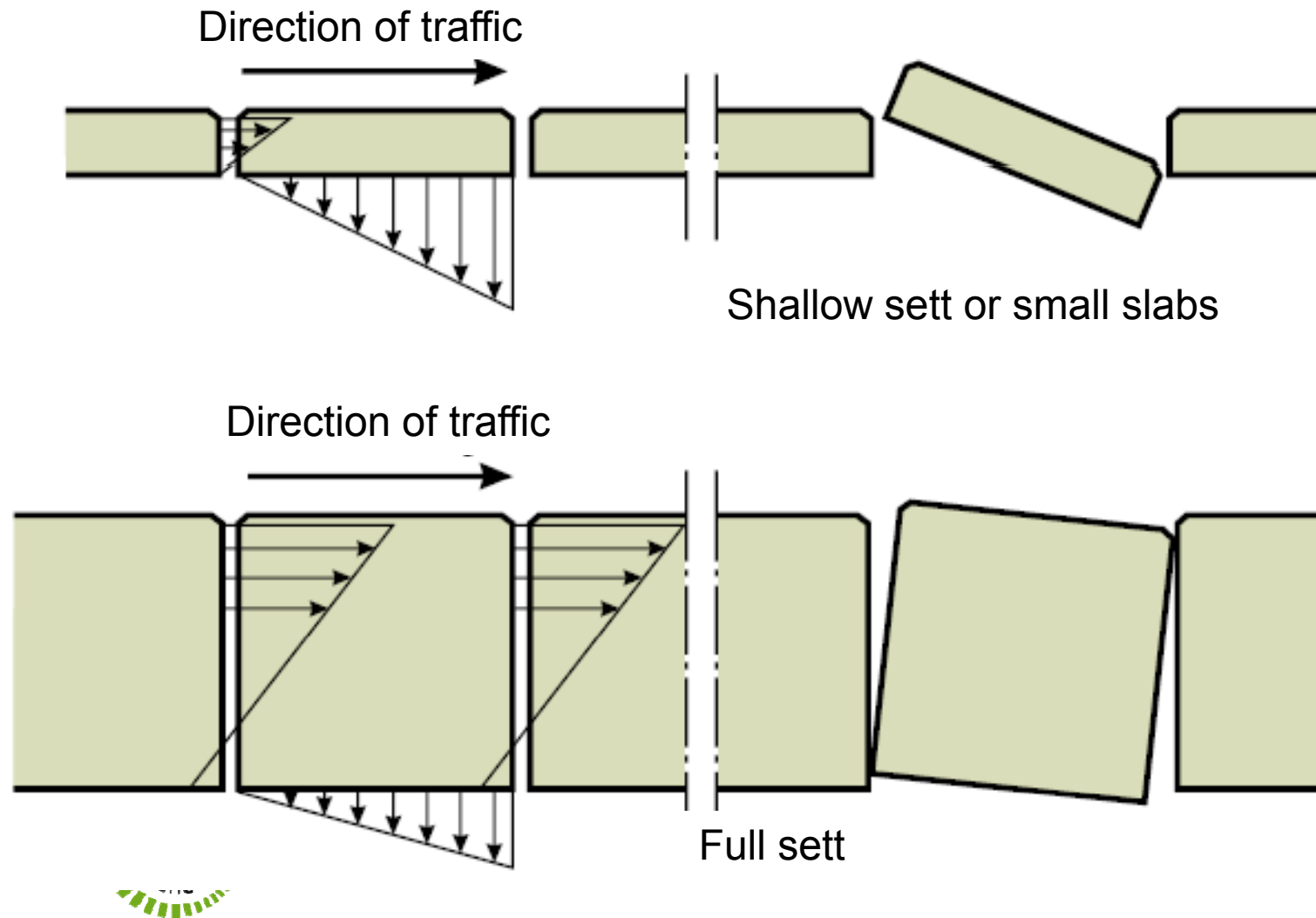
- **Full setts are those having depth not less than width.**

For many centuries the "golden rule" was that setts must be at least as deep as they are wide.

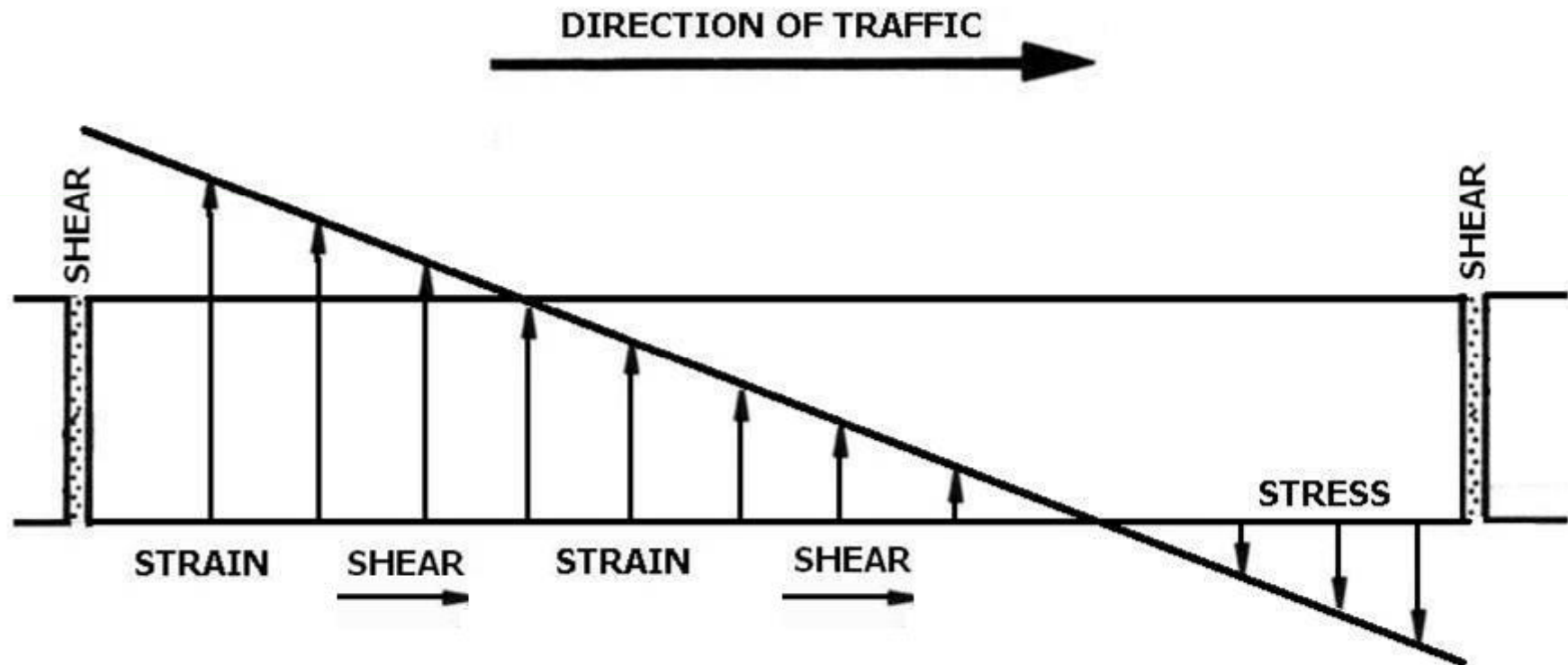
- The heavier the traffic loading, the deeper the sett in relation to its width.
- Before the advent of concrete and mortar, when jointing, bedding and supporting base were all unbound, this rule was very necessary.

The deeper the sett in relation to its width, the more the strength of the pavement is taken by the joints between the setts. So, with deep, full setts we can sometimes lay over an unbound or a bituminous base, even for heavy traffic.

Thin or thick stones



Flags and slabs

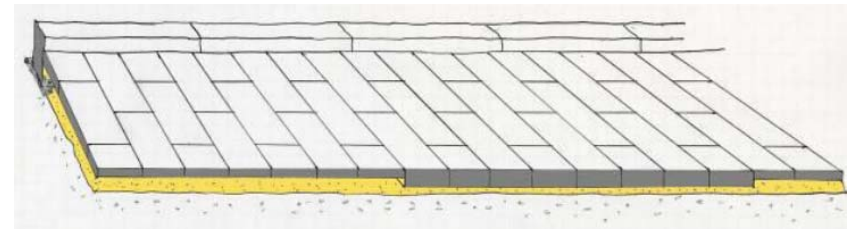
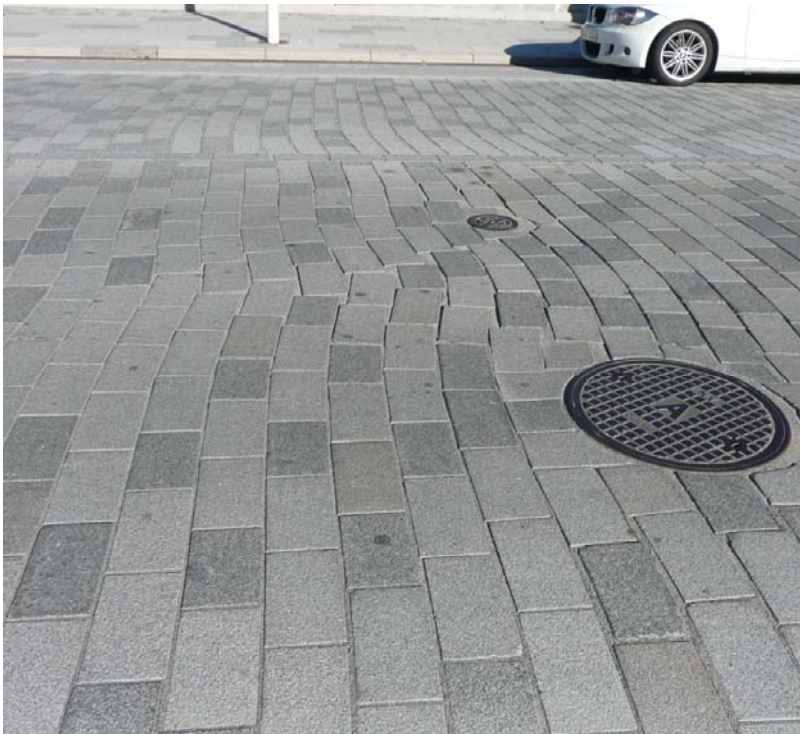


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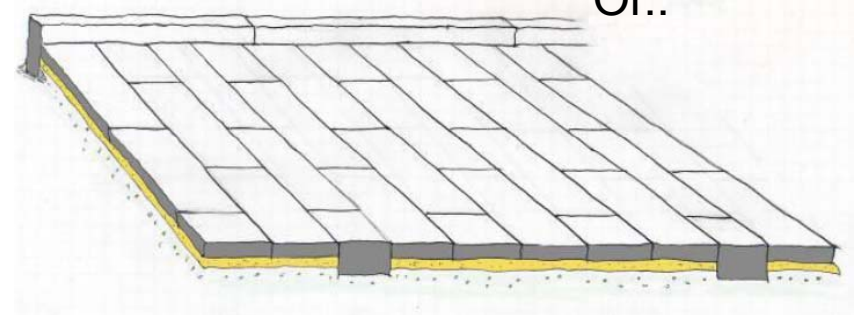
A possible compensation for small tolerances and too smooth surfaces



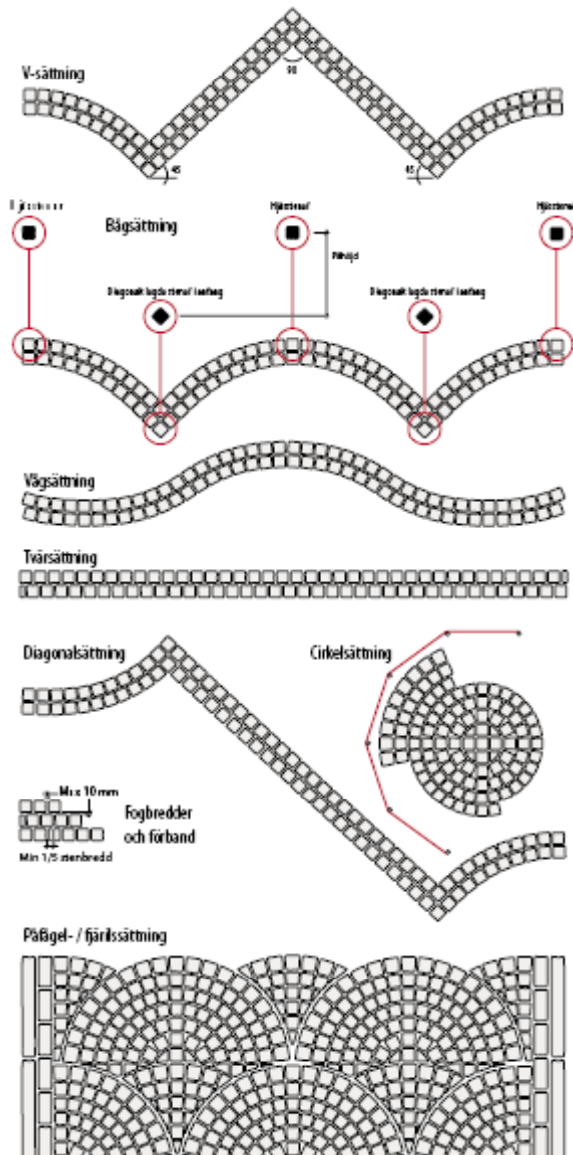
Fast production, fast placing => problems



Or..



Use of patterns to stabilise the paving



Follow the rules and you get a sustainable paving and in harmony with other building products



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Thank you for your attention!



David Burton and me