Concrete Structures for Sustainable Community

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CONCRETE MIX UTILIZING OIL SHALE ASH

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ECO-INNOVATION
WHEN BUSINESS MEETS THE ENVIRONMENT

CIP Eco-innovation
Pilot and market replication projects
Call 2008

Call Identifier: CIP-EIP-Eco-Innovation-2008

ECOCRETE

Reducing the Environmental Impact of Concrete
by Knowledge-based Design
and Utilisation of Industrial Waste Materials

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OIL SHALE PRODUCTION

Oil shale is used by the energy sector in many countries
- Brazil, China, Estonia, Jordan

Considered by several others
- Australia, USA and Canada

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OIL SHALE PRODUCTION

Result of combustion of 100 kg oil shale fuel:

- Electrical energy
- 55 to 75 kg of oil shale ash (OSA)

OIL SHALE PRODUCTION

Importance of oil shale

90% of the electricity in Estonia

1 billion tons of oil shale has been mined during the last 80 years

OIL SHALE PRODUCTION

Disposal of the waste ash is a huge problem

Leaching from the unsightly ‘mountains’ of waste

Pollution of rivers and lakes

OIL SHALE PRODUCTION

OIL SHALE PRODUCTION

Utilisation of oil shale ash

To replace a proportion of cement content in concrete mix

Industrial waste can be beneficially used to control product properties and improve the environment

CEMENT REPLACEMENT

OSA can be utilised in the manufacturing of cement clinkers

Up to 15% of OSA can be used with typical Portland cement clinker without significant effecting the main properties

CEMENT REPLACEMENT

Direct substitution of cement by OSA in a concrete mix is step towards

- improvement of concrete sustainability
- reducing the carbon footprint
- utilising wastes causing environmental problems
- potential cost savings
- improvements in durability of the concrete

CHEMICAL COMPOSITION OF OSA IN ESTONIA

Chemical composition of OSA can vary a lot composition and the particle size distribution depends on

The origin of oil shale
Temperature of combustion
The collection point

Explains why the findings of various authors are contradictory

CHEMICAL COMPOSITION OF OSA IN ESTONIA

Estonian OSA

Influence of particle grading on chemical composition is shown in Table

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CHEMICAL COMPOSITION OF OSA IN ESTONIA

Composition and properties of Estonian OSA (%)

Component	Range of chemical composition		
	course -grained	medium	fine
CaO	50-57	40-53	30-48,5
SiO_2	19-29	19-34	25-34,5
SO_3	3,2-3,8	4,0-6,7	6,0-9,5
MgO	4,0-5,5	3,5-5,0	-
CaO_{free}	20-32	16,5-28,0	7,5-25,0
Size of particles	Limit range of grades		
< 30	2-12	20-62	65-95
30-100	18-70	25-62	5-28
> 100	30-80	5-30	0-10

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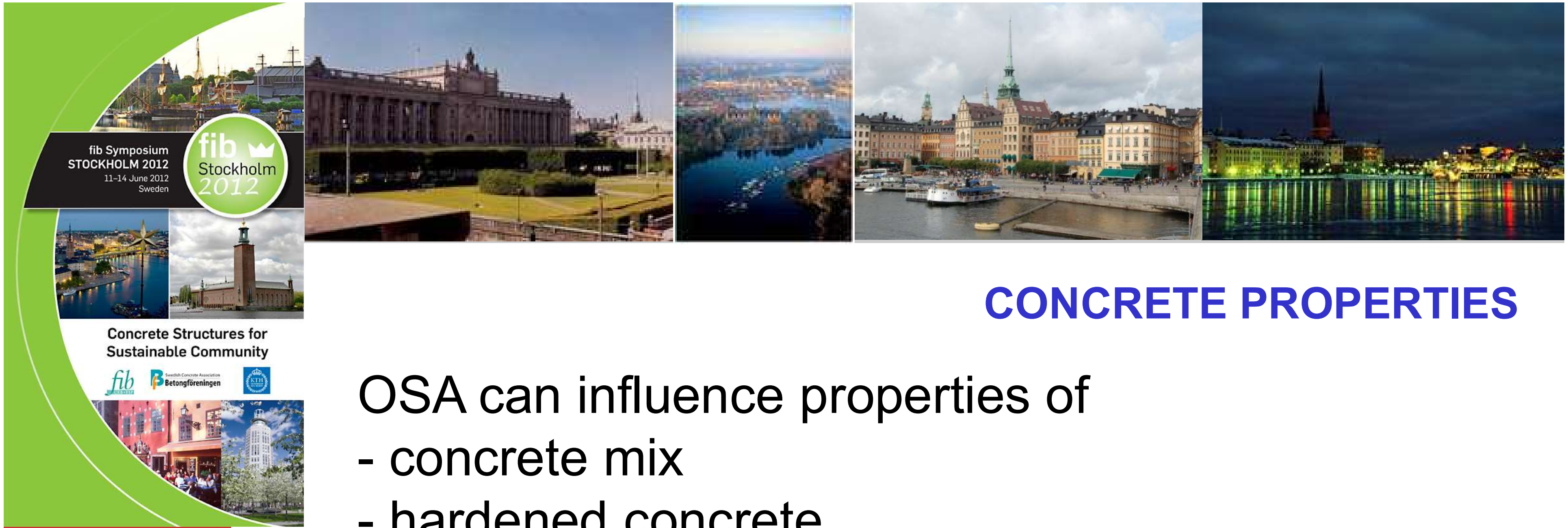

CONCRETE PROPERTIES

OSA can influence properties of
- concrete mix
- hardened concrete

OSA can help
- reduce concrete expansion due to alkali-silica reaction
- shrinkage and creep
- the same values when 15%
- 30% of OSA shrinkage and creep have higher values

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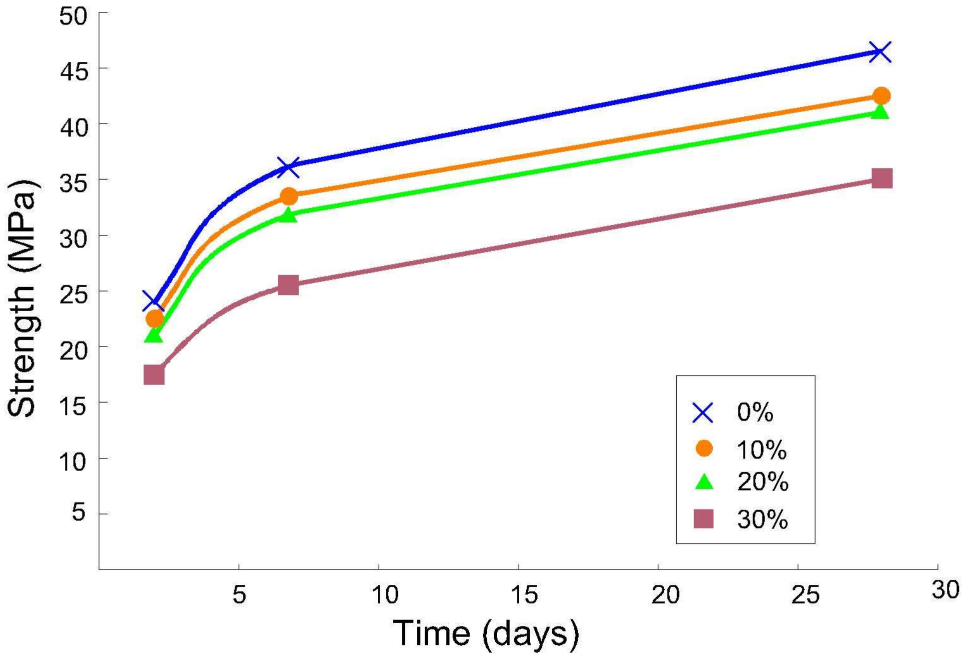
CONCRETE PROPERTIES – STRENGTH DEVELOPMENT

Tests of concretes containing OSA showed

- slower development of compressive strength
- strength values after 28 days are slightly lower

CONCRETE PROPERTIES – STRENGTH DEVELOPMENT



Compressive strength development

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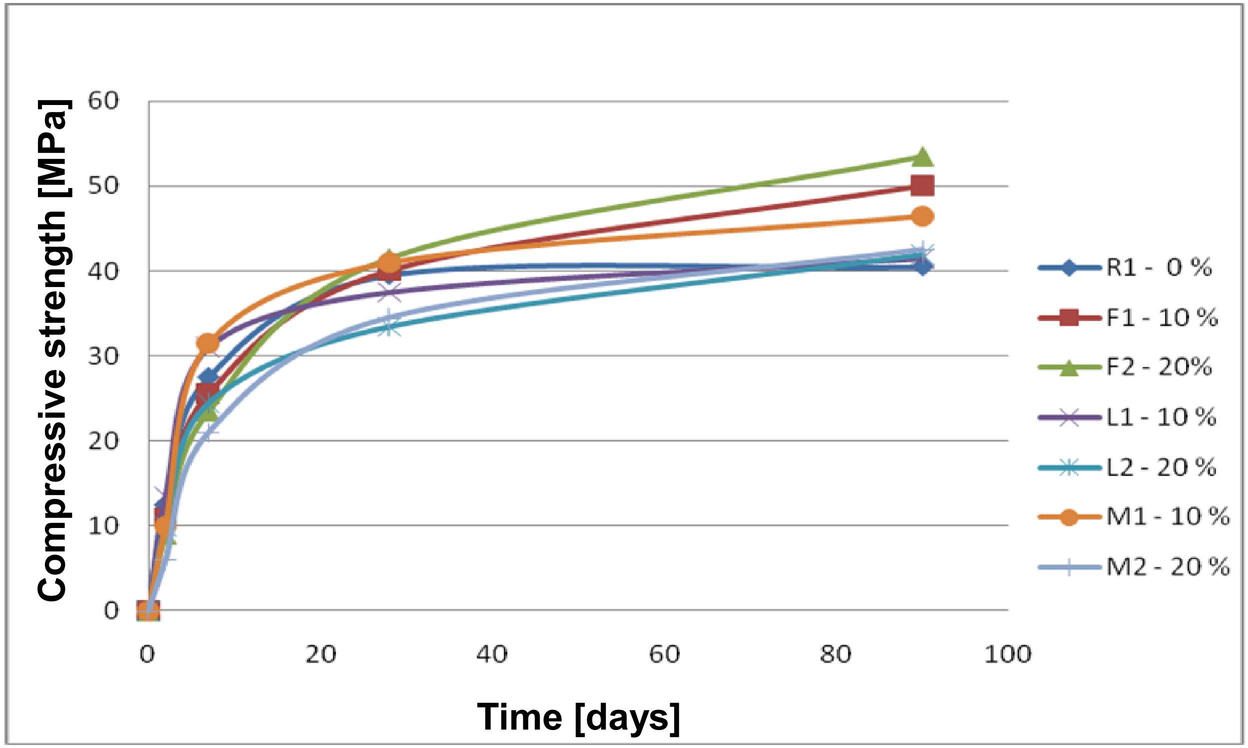
CONCRETE PROPERTIES – PARTICLE SIZE EFFECT



Strength development

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CONCRETE PROPERTIES – PARTICLE SIZE EFFECT

A reference concrete mix without ash

Mixes when 10 or 20% of cement is replaced by FA

Benefits in longer term

Strength continues to develop after 28 days

CONCRETE PROPERTIES – PARTICLE SIZE EFFECT

Replacing a proportion of cement by the fly or oil shale ash can improve workability

mix, R, had a slump of 80 mm 90 minutes, mixes F had slump of 110 mm

SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCM) AND SUSTAINABLE DEVELOPMENT

Reduction of cement content of a mix does not

result in concrete of reduced environmental impact

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SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCM) AND SUSTAINABLE DEVELOPMENT

To build a column supporting the same static design load

75 MPa unreinforced concrete involves 50% less cement

one-third aggregate compared to a 25 MPa concrete

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SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCM) AND SUSTAINABLE DEVELOPMENT

Savings in cement and aggregate are less impressive for concrete elements working in flexure but

Are estimated to be of the order of 20 to 25%

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SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCM) AND SUSTAINABLE DEVELOPMENT

Sustainable concrete requires a performance-based design approach taking account

- material composition

- resulting concrete properties

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SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCM) AND SUSTAINABLE DEVELOPMENT

If design takes advantage of the75 MPa strength using less concrete

Then material resources beneficially used.

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SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCM) AND SUSTAINABLE DEVELOPMENT

Minimize the cement content, balancing technical advantages and disadvantages together with cost

Cement plays an important role as far as reinforcement corrosion prevention is concerned

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MIX DESIGN TOOLSET

Within the ECOCRETE Eco-innovation project, design tools being developed

- optimise mix designs

- utilising locally available materials

- including oil shale ash

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CONCLUSIONS

Early age strength of mixes incorporating oil shale ash exhibit lower value for the same *w/b*

- due to slow pozzolanic reaction

CONCLUSIONS

Rate of the pozzolanic reaction can

be increased micronising oil shale ash

Potential to further reduce cement and overall content of binder

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CONCLUSIONS

Longer term pozzolanic reaction

concrete continuing to gain strength as

result of incorporation of oil shale ash in the mix

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CONCLUSIONS

Replacing a proportion of cement by oil shale ash

- can improve workability

- making the rheology of a mix easier to control

- especially with micronised or classified small-size ash

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CONCLUSIONS

Comparing mixes with and without SCMs:

- proper basis of comparison must be defined

- compare mixes providing the same performance

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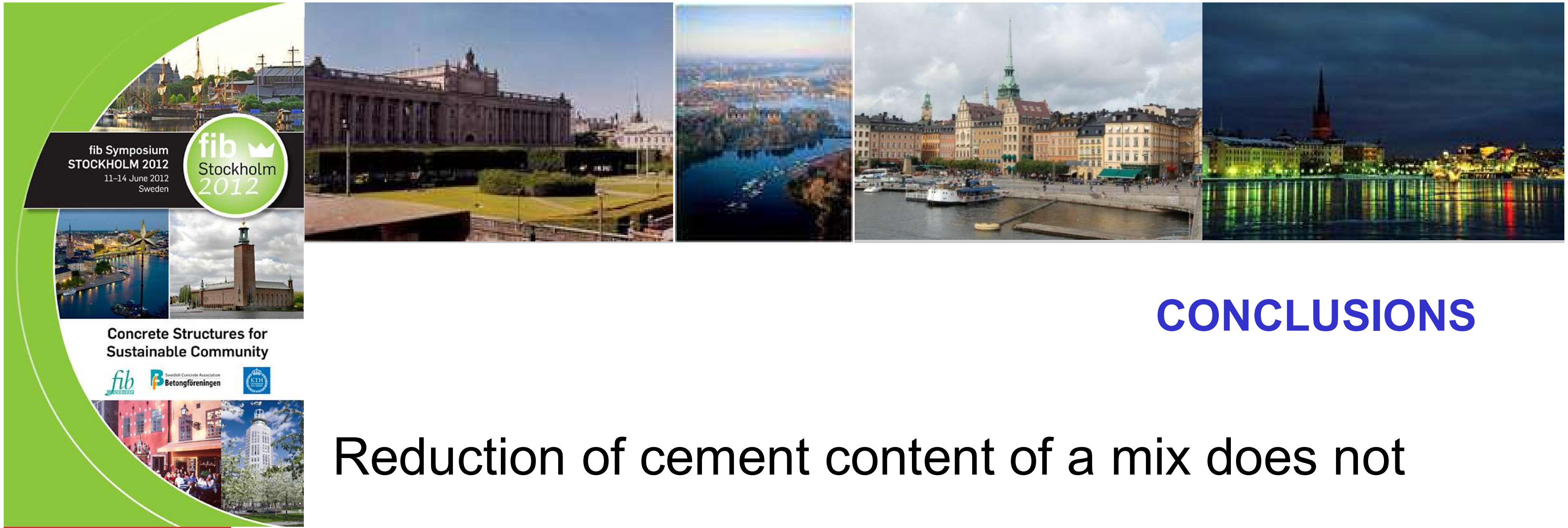

CONCLUSIONS

Reduction of cement content of a mix does not result in concrete of reduced environmental impact

Objective should be:

- design and produce 'better concrete'

CONCLUSIONS

Mix design tools:

- Input data from a small number of trial mixes using locally available materials, including wastes such as oil shale ash

- Can predict the performance of new mixes

- Accuracy of around ±10%

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Thank you for your kind attention.