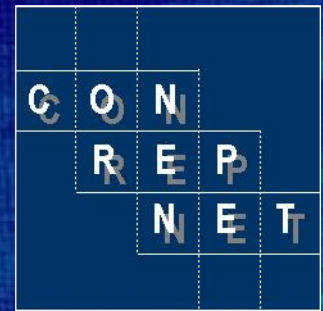


# CON REP NET

## Thematic Network on Performance Based Rehabilitation of Reinforced Concrete Structures



NETWORK INTERACTION MEETING

9+10 FEBRUARY, BRUSSELS

### FUTURE PERFORMANCE WP 4



# Objectives of WP 4

- Understanding client aspirations and needs.
- Developing an industry response for achieving them
- Vision for performance concepts
- Identifying future RTD needs
- Co-ordinating RTD and other activities
- Linkage to European standardisation and CPD



Explore and develop strategies, techniques and processes for delivering durable and effective rehabilitation of concrete structures

# RESULTS OF WP 2 INVESTIGATIONS

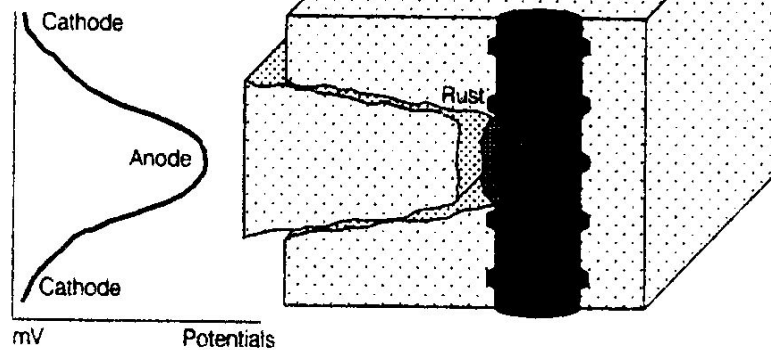
Within the limited scope of the investigation the following conclusions can be drawn:

- 1/ Poor workmanship = one of main causes of deterioration of structures
- 2/ Steel corrosion = main limitation factor of service life
- 3/ 70% of structures repaired at the age between 10-30 years
- 4/ Dominating types of repair:  
patch repair, coating, crack injection
- 5/ 30% of repairs failed in 5 years
- 6/ Causes of failed repairs equally distributed  
(Diagnosis, design, material, workmanship)

# PATCH REPAIR RISK (FREQUENT TYPE OF REPAIR)

## Local Corrosion

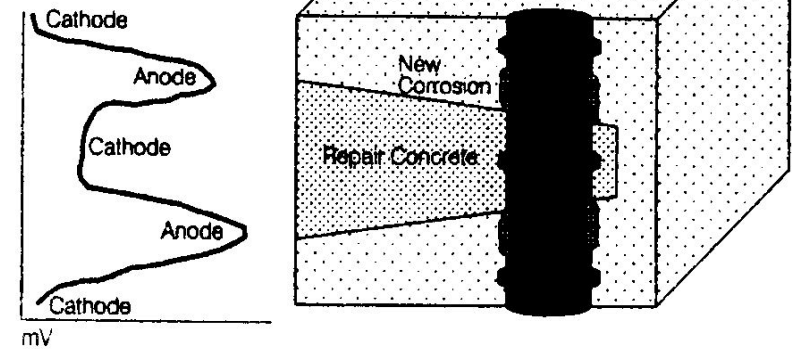
Chlorides / Carbonation



*Figure a* Damage due to local chloride induced corrosion. The electro-chemical potentials of the reinforcement are also indicated, with low potentials indicated, location of corrosion. The spalling is due to the expansive effect of the rust products.

## Local Corrosion

Traditional Patch Repair



*Figure b* Traditional patch repair of the damage illustrated in Figure a. Due to the corrosion in the neighbouring concrete the corrosion is just moved but continues.

# CLIENTS NEEDS

„ I sometimes think that the construction industry is like the person who seeks the wonder cure: the elixir that will provide eternal life with no effort at all on their part. Wouldn't it be wonderful if by simple expedient of adding ingredient X all would be solved? Life is not that simple .....

[ C.D. Pomeroy ]

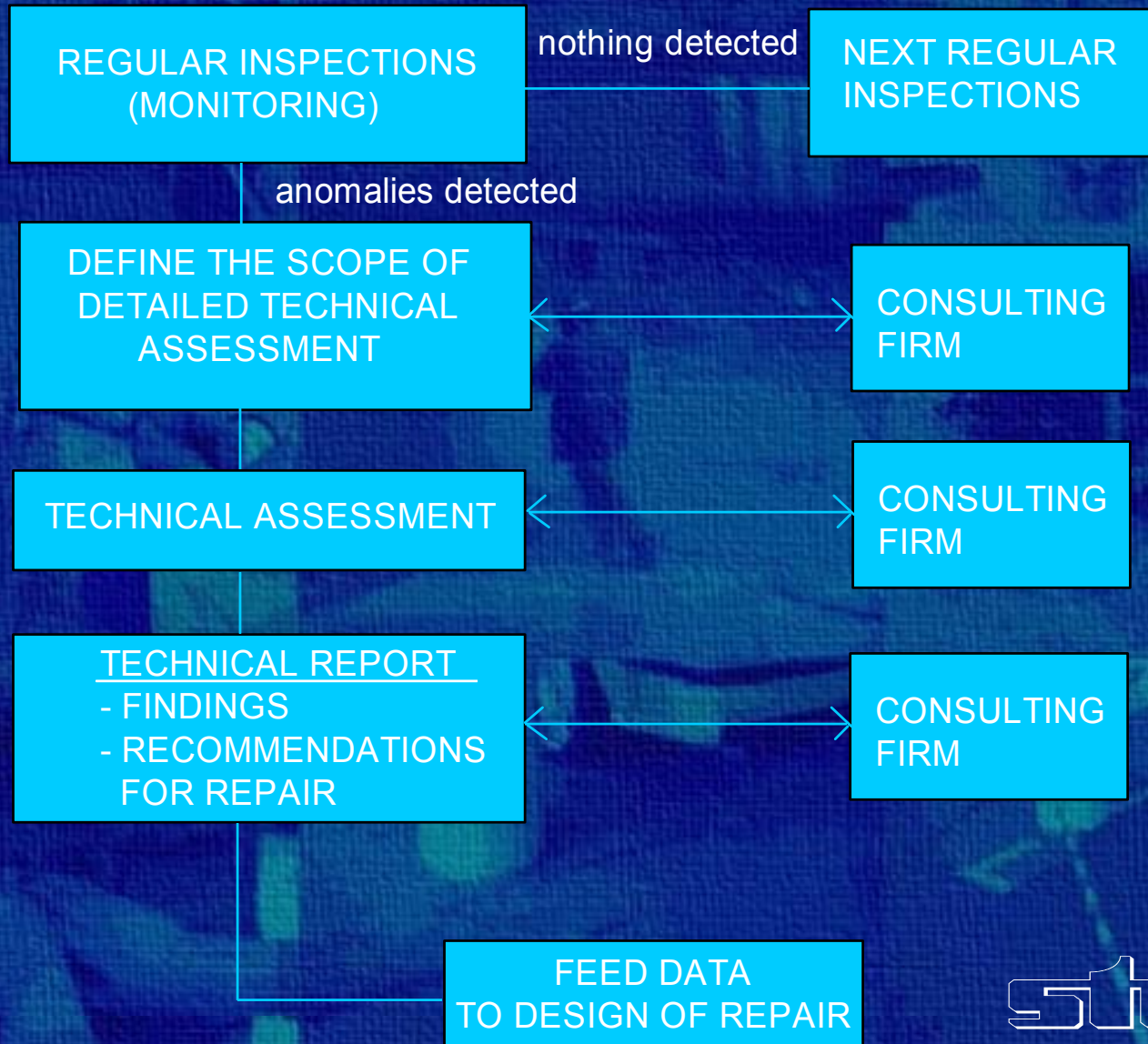
# REPAIR STRATEGY FACTORS



# BASIC QUESTIONS TO BE ANSWERED BEFORE THE REPAIR DESIGN CAN START

- 1/ What is the technical condition of the structure ?
- 2/ For how long the structure will be used ?
- 3/ What are the functional requirements ?  
Did they change ? Will they change in future ?
- 4/ What are the environmental conditions ?  
Did they change ? Will they change in future ?
- 5/ What are the restrictions for the repair ?
- 6/ Other questions.

# WHAT IS THE TECHNICAL CONDITION OF THE STRUCTURE?



# FOR HOW LONG THE STRUCTURE WILL BE USED ?

## EXAMPLE OF POSSIBLE ANSWERS:

- **10 years -->**

Maintain the structure to meet the serviceability, safety, reliability requirements during DEFINED PERIOD

- **Will know in 10 years -->**

Maintain the structure REPAIRABLE to meet the serviceability, safety, reliability requirements during DEFINED PERIOD

- **No idea -->**

Maintain the structure REPAIRABLE to meet the serviceability, safety, reliability requirements during UNDEFINED PERIOD  
(Expensive ! Wrong !)

FEED DATA TO DESIGN OF REPAIR



# WHAT ARE THE FUNCTIONAL REQUIREMENTS ?

The structure may be used to different purpose than originally designed.

- Serviceability criteria changed,
- Higher resistance to certain chemical substances required ... etc.

TO DESIGN OF REPAIR  
FEED DATA



# WHAT ARE THE ENVIRONMENTAL CONDITIONS ?

## EXTERIOR / INTERIOR ENVIRONMENT (moving targets)

- Temperature
- Number of freeze / thaw cycles
- Concentrations of CO<sub>2</sub>
- Concentrations of chlorides
- Humidity

TO DESIGN OF REPAIR  
FEED DATA

# WHAT ARE THE RESTRICTIONS FOR THE REPAIR ?

- Time
- Use of some materials and technologies not allowed
- Budget
- Monuments protection / Aesthetics
- Other

TO DESIGN OF REPAIR  
FEED DATA

## CONSERVATIVE APPROACH

Based on standards and regulations  
+  
professional experience

## MODERN APPROACH

Performance-based design.

Use of complex tools including :

- service life models
- life cycle cost analyses

Professional experience however remains important!

## Recent advantages in service life design

It is foreseen that within five to ten years reliability based overall service life designs may well have taken over today's general design procedures for concrete structures.

[CEB 1997] and [DuraCrete 1999]

# Probabilistic performance based service life design

- Transformation from the level of RTD to the level of engineering design is going on.
- New way of designing safety and durability
- Modelling throughout the service life of structures
- Owners now being able / forced to take decisions regarding the long-term performance and the consequences regarding maintenance and costs
- Life Cycle Cost Optimisation

# Probabilistic performance based service life design

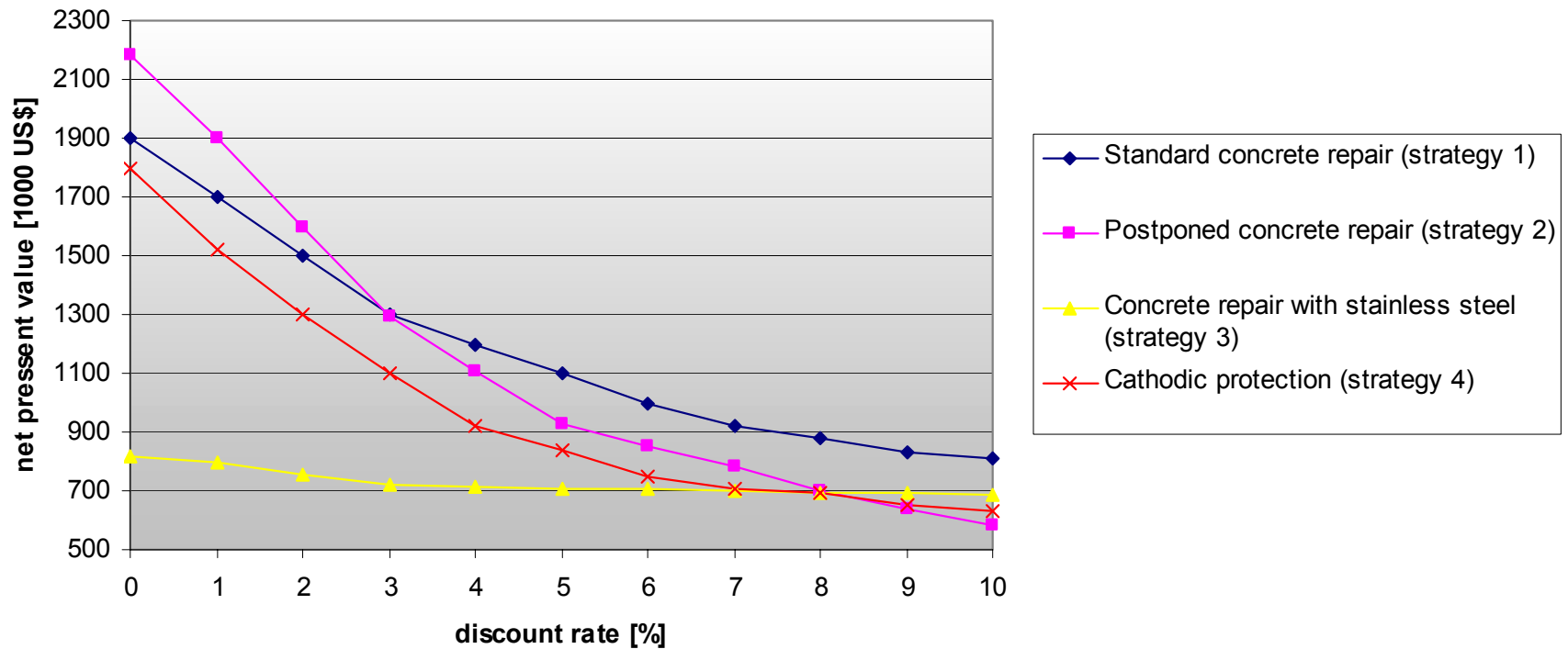
- **Reliability updating makes possible**
  - updating service life expectations
  - take necessary precautions in time
  - evaluate economic consequences of decisions taken

# CHOICE OF REPAIR STRATEGY - BRIDGE COLUMNS

Strategy	Description of repair strategy
1	<b>Repair</b> of all columns using <b>carbon steel</b> after 1 year. The repair is done over 2 m (~7 ft.) of each column involving the breaking up of the concrete to behind the reinforcement and replacement of 50% of the reinforcement. This repair takes 12 weeks with 4 lanes narrowed down to 2. After 20 years, the columns are replaced. This replacement takes 16 weeks.
2	<b>Replacement</b> of all columns after 10 years and again after 40 years using <b>carbon steel</b> . Both replacements take 16 weeks.
3	Repair of all columns using <b>stainless steel</b> after 1 year. Same repair as strategy 1 but with replacement of 100% of the existing carbon steel reinforcement with stainless steel. The repair takes 16 weeks. The 4 additional weeks compared to 1 are due to replacement of 50% more steel and establishment of connections.
4	Repair of all columns using carbon steel and installation of a <b>cathodic protection</b> system after 1 year and replacement of all columns after 25 years.

# CHOICE OF REPAIR STRATEGY - BRIDGE COLUMNS

Net present values (50 years remaining lifetime) for different discount rate



# REFERENCES

- **Structural concrete textbook on behaviour, design and performance [CEB/FIB 1999]**
- **Cost-effective enhancement of durability of concrete structures by intelligent use of stainless steel reinforcement [ARMINOX 1998]**
- **How to make today's repairs durable for tomorrow [ELSEVIER 2000]**