

# Evaluation of oncoming salinity concentration and deposition on structural surface in corrosion deterioration

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# Infrastructure Asset Management in Asian Megacities

## Activities in Materials and Structures Group



Bangkok



Singapore



Shanghai

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**MS11: Self-Sustaining Technologies for Small Infrastructures Using Local Materials (traditional)**

**MS12: Maintenance Strategy for Concrete, Steel and Hybrid Structures (modernized)**



# Field observation



Amarube br.



Ohnaruto br.



# 調査名：橋梁細部における海塩粒子の付着量推定と腐食劣化予測手法の検討業務 [新規]

## ■調査の必要性

国道42号古座大橋など、沿海部の道路橋は塩害による損傷が発生している。塩害が発生すると、すべて除去し補修することは困難を極める。そのため、橋梁の各部位に付着する塩粒子が予測できれば、的確な塩害対策が可能となる。

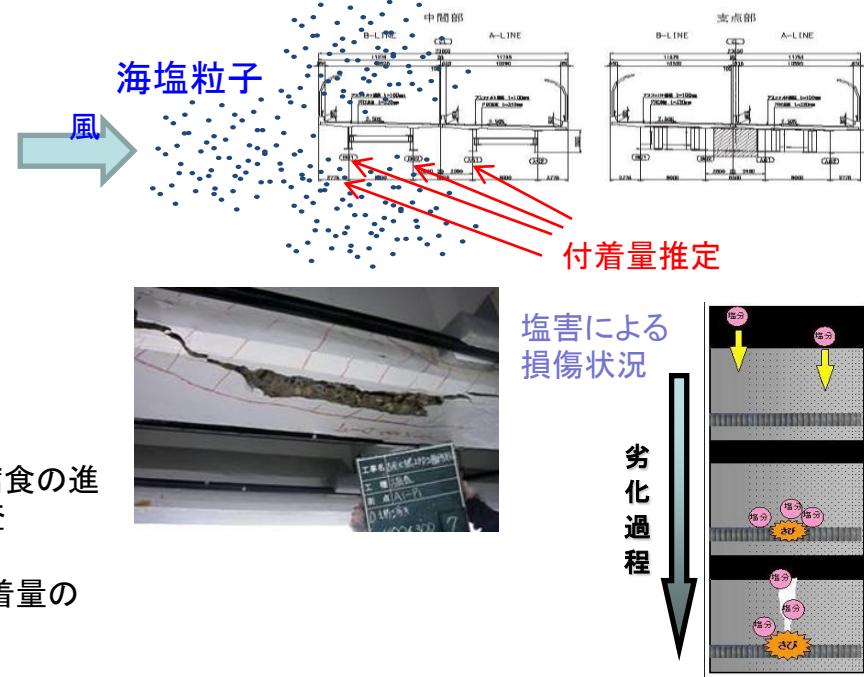
腐食が進んでいる橋梁を見れば、部位によって腐食の進行状況は全く異なり、橋梁位置周辺の環境因子だけで、腐食の程度を説明できないことは明らかである。この要因の一つとして、海塩粒子の付着量が橋梁部位によって異なることが考えられる。橋梁各部位への海塩粒子の付着量を正確に推定することにより的確な補修を行うことができる。

## ■調査の内容

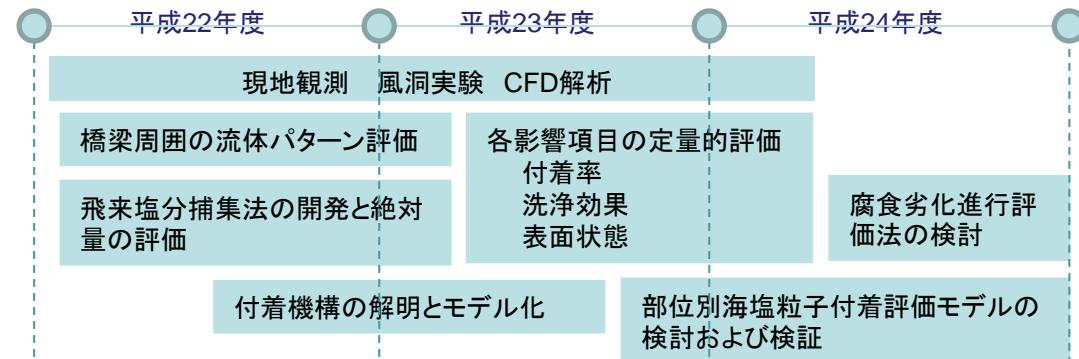
- ①現地観測による海岸部の橋梁各部位別の飛来塩分付着量ならびに腐食の進行状況等の調査、ならびに風向・風速、降水量、飛来塩分量の調査
- ②CFD解析による橋梁周囲の流体パターンの推定
- ③現地観測結果、CFD解析結果に基づく、空気の流れと飛来塩分の付着量の関係の解明
- ④風洞実験もしくは屋外実験による海塩粒子の付着メカニズムの解明
- ⑤降水による洗浄効果、表面状態による付着率の評価
- ⑥橋梁各部位における海塩粒子の付着量の評価モデルの構築、および腐食劣化の進行評価する方法の検討

## ■平成22年度調査の目標

- 現地観測による飛来塩分付着量、腐食進行状況、気象データの計測
- 飛来塩分量捕集方法の開発と性能照査
- CFDによる橋梁周囲の流体パターンの推定
- 飛来塩分付着機構に関する調査検討



新都市社会技術融合創造研究会  
海塩粒子の付着量評価モデルに関する研究  
プロジェクトリーダー 白土博通 京都大学教授



# Causes of Deterioration

## Natural

- Atmospheric corrosion  
(water, oxygen, sea salt)
- Erosion
- Wave action
- Natural Calamities: earthquake, flood, typhoon, etc.
- Ultraviolet
- Oxidized Sulfur

## Man made

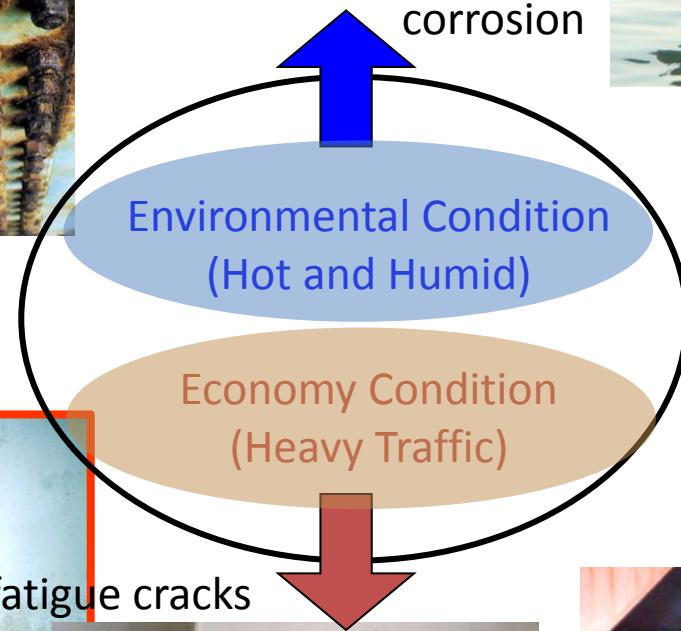
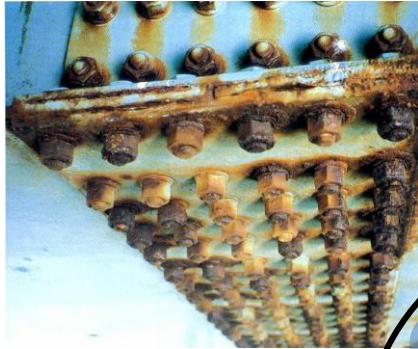
- Stress corrosion
- Fatigue failure
- Material characteristic: brittleness
- Overloading
- Out-of-plane bending
- Accidents
- Fire damages
- Pollution effects: Effluent contact, fumes, etc,



**Focus on specific causes common in Asian Megacities**

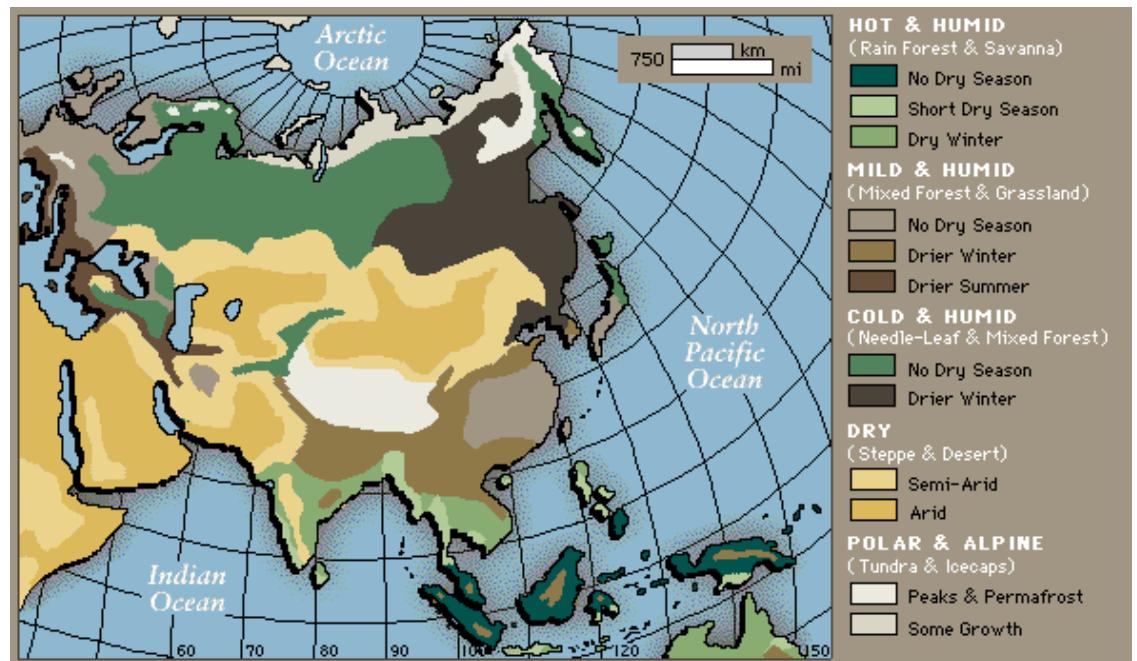
**Climate: Hot and Humid & Growing Economy: Heavy Traffic & Pollution**

# Deterioration of Structures



# Environmental Factors for Corrosion Damages

- Air-borne sea salt
- Wetting duration
- Precipitation
- Temperature
- Humidity
- Daylight
- Ultraviolet
- Wind conditions
- Sulfur dioxide
- others



Asia Climate Map

Most of megacities are located in “**Hot and Humid**” conditions

# Weathering steel

- Protective corrosion layer
- Corrosion penetration
- Painting, coating for coastal area

# Ordinary steel

- Heavily protective painting

# Quantitative Prediction of Corrosion Depth

- Corrosion depth

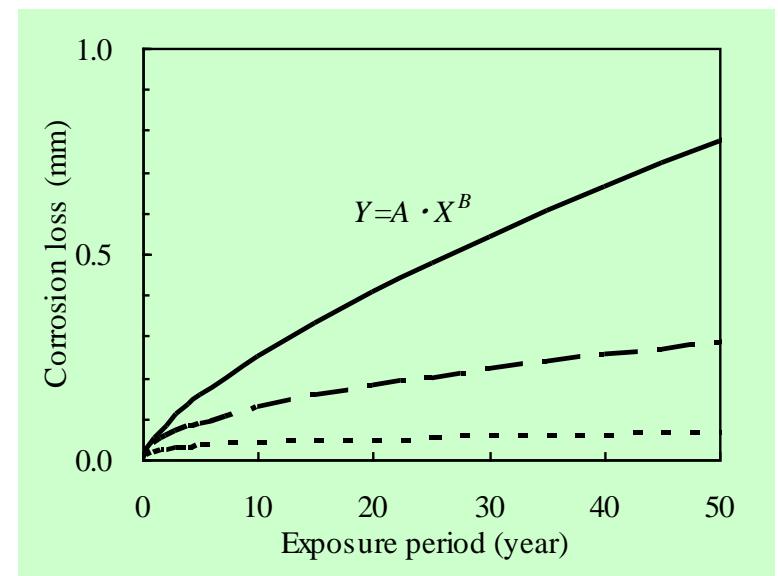
$$Y = AX^B$$

Environmental factors

Y: corrosion depth

X: exposure time (y)

A,B: shape parameters



# Corrosive index on site environment

Kihira, et al. (JSCE, 2005)

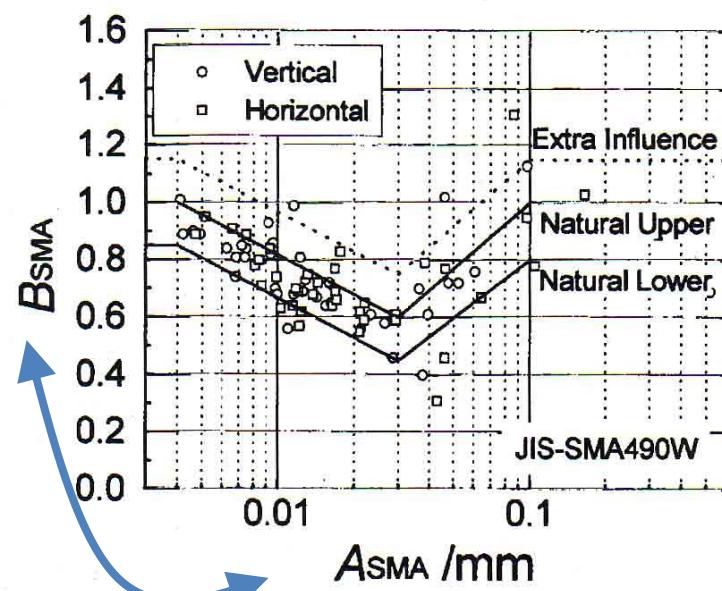
$$Z = \alpha \cdot TOW \cdot \exp(-\kappa \cdot W) \cdot \frac{C + \delta S}{1 + \varepsilon CS} \cdot \exp\left(\frac{-E_a}{RT}\right)$$

For horizontal members

$$A^H = f(Z)$$

For vertical members

$$A^V = g(Z)$$



# convection-diffusion-sedimentation model for air-borne sea slts

$$u \frac{\partial c}{\partial x} - w \frac{\partial c}{\partial z} = \frac{\partial}{\partial z} \left( K \frac{\partial c}{\partial z} \right) - Q$$

$c$  : concentration of air-borne sea salt

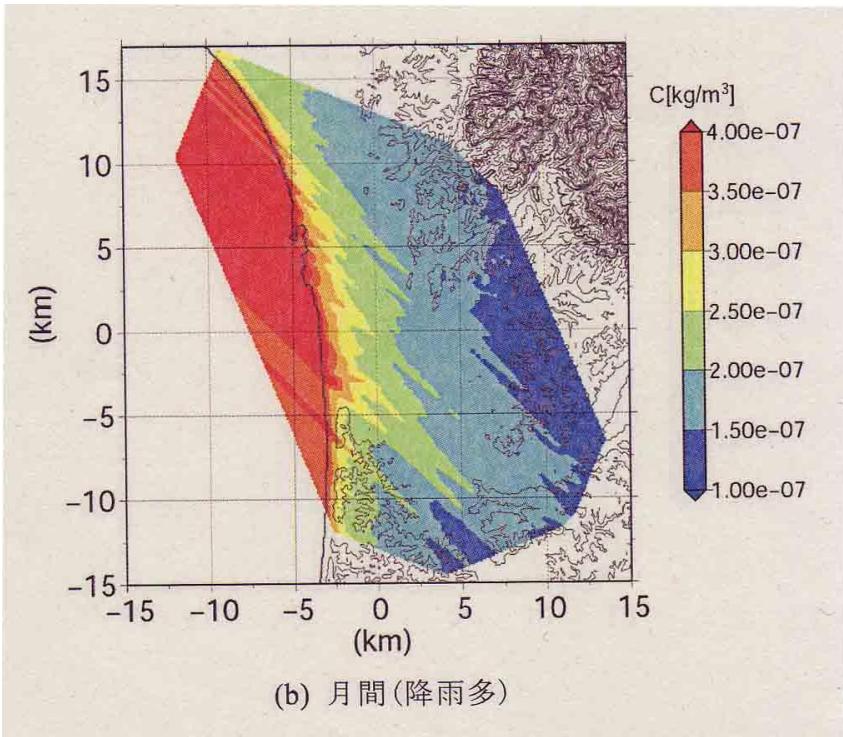
$u$  : longitudinal wind velocity

$w$  : vertical wind velocity (positive downward)

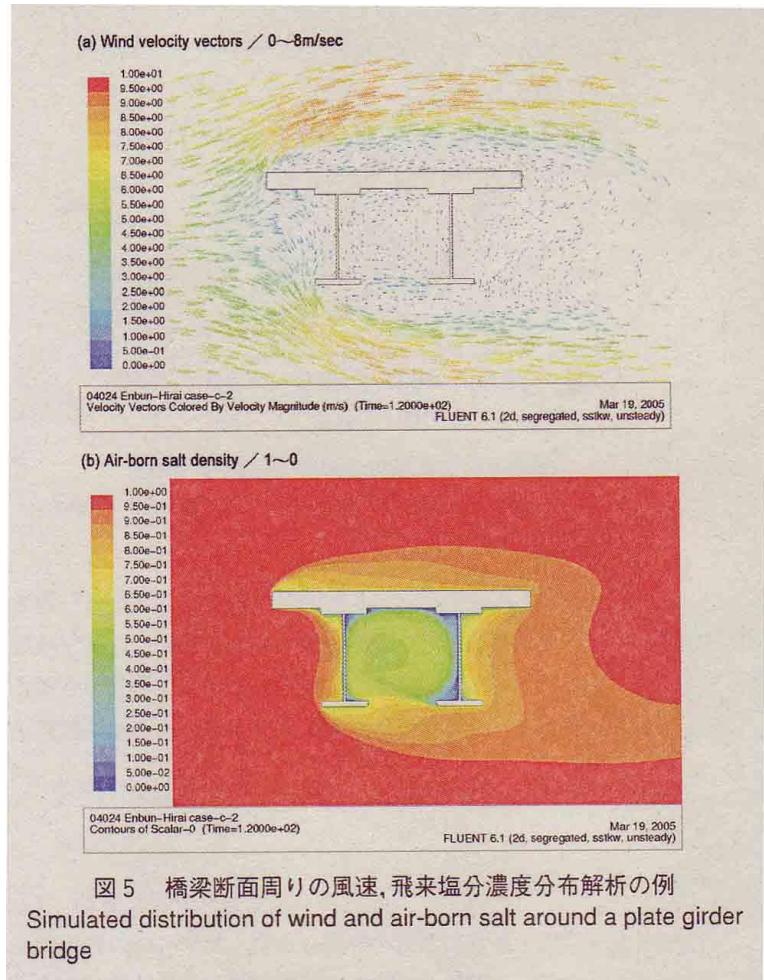
$K$  : diffusion factor of air-borne sea salt

$Q$ : sedimentation

# Numerical predictions



Sudo, et.al (CRIEPI rep., 2008)



Kihira, Matsuoka, et.al (JSCE, 2003)

# convection-diffusion-sedimentation model

$$u \frac{\partial c}{\partial x} - w \frac{\partial c}{\partial z} = \frac{\partial}{\partial z} \left( K \frac{\partial c}{\partial z} \right) - Q$$

Longitudinal and lateral diffusion?

Lateral convection?

$c$  : concentration of air-borne sea salt

$u$  : longitudinal wind velocity

$w$  : vertical wind velocity (positive downward)

$K$  : diffusion factor of air-borne sea salt

$Q$ : sedimentation

cohesion, adhesion, washing due to rain???

Corrosive index in each structural member

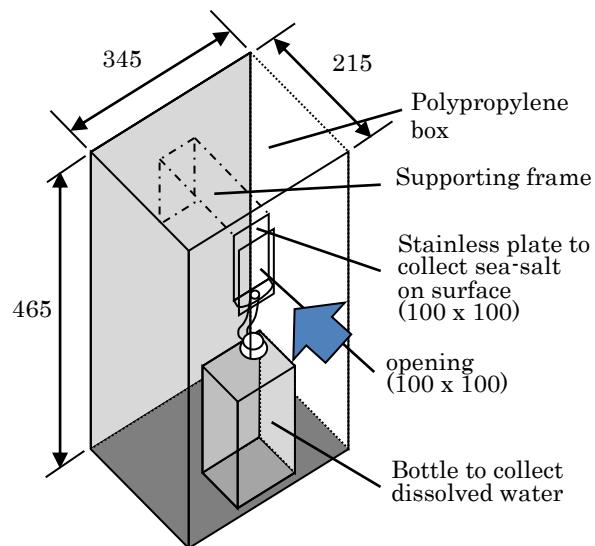
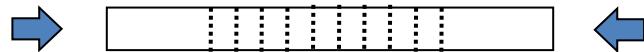
# Approaching strategy

- a. Meteorological data at local observatory
- b. Correlation of meteorological data between observatory and bridge site
- c. Momentum and substance transport model solver
- d. Convective, diffusive, cohesive, adhesive nature of air-borne sea salt
- e. Washing out due to rain
- f. Corrosive environmental index evaluation at each structural member
- g. Verification by comparing with site measurement data
- h. Statistical evaluation of corrosive environmental index

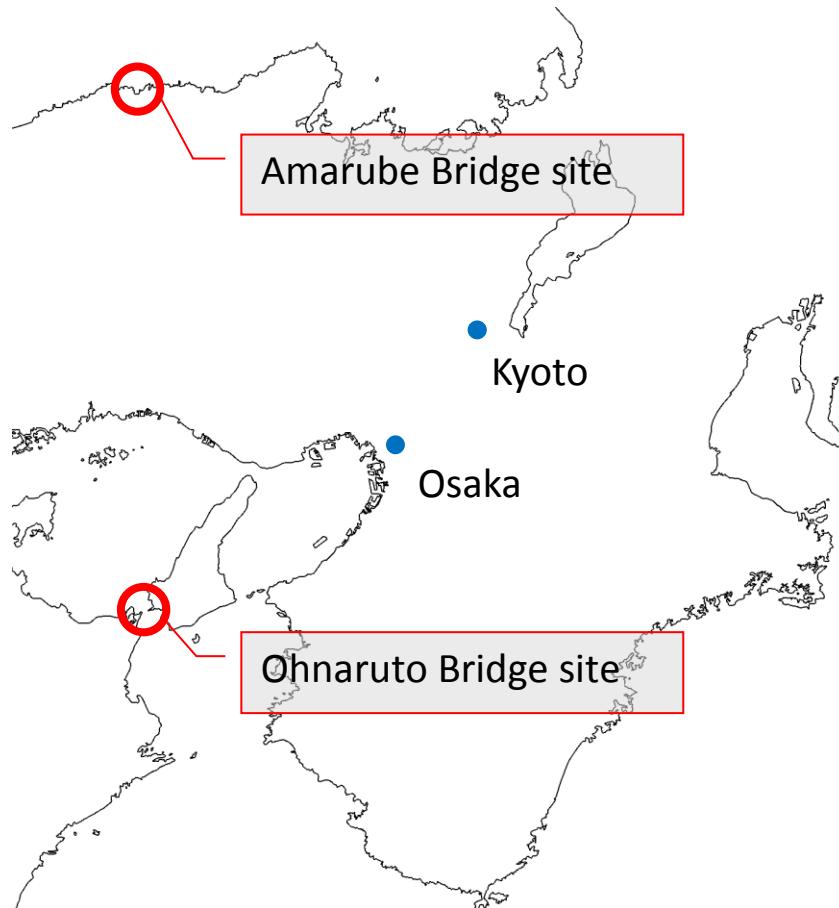
## Ohnaruto Bridge, HSBC



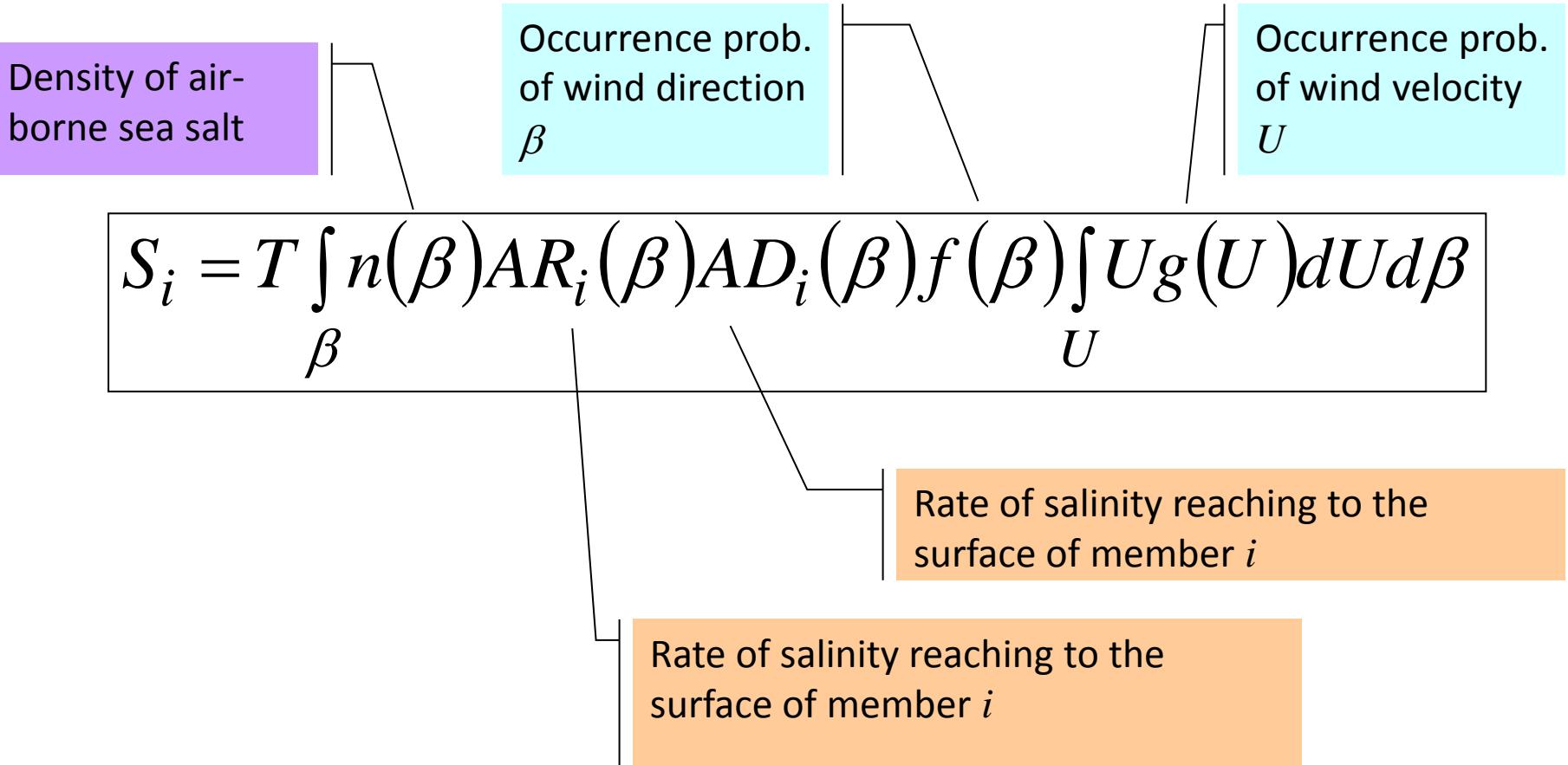
# On-site measurement of air-borne sea-salt



PWRI method



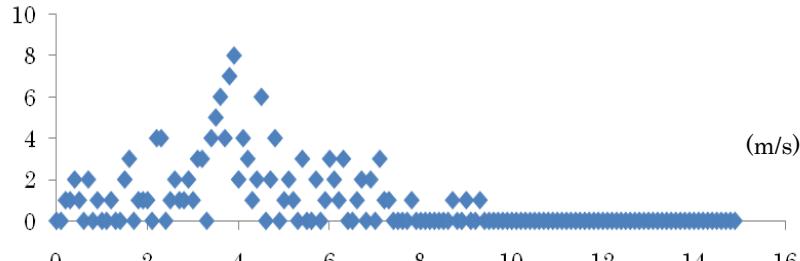
# Salinity on particular surface of structural member $S_i$



# Wind and meteorological conditions

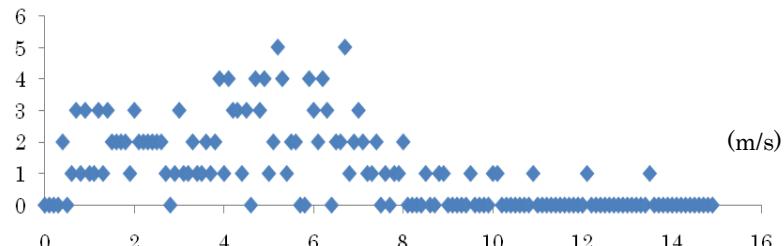
(Number of data)

NNW



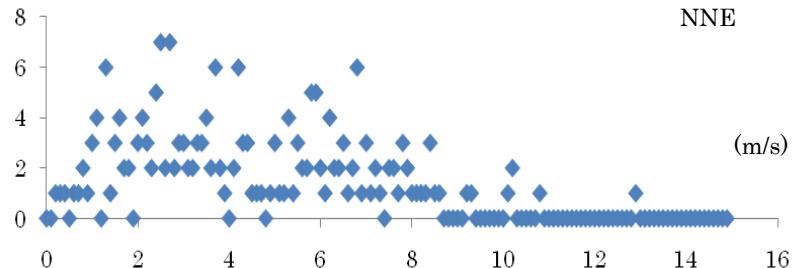
(Number of data)

N

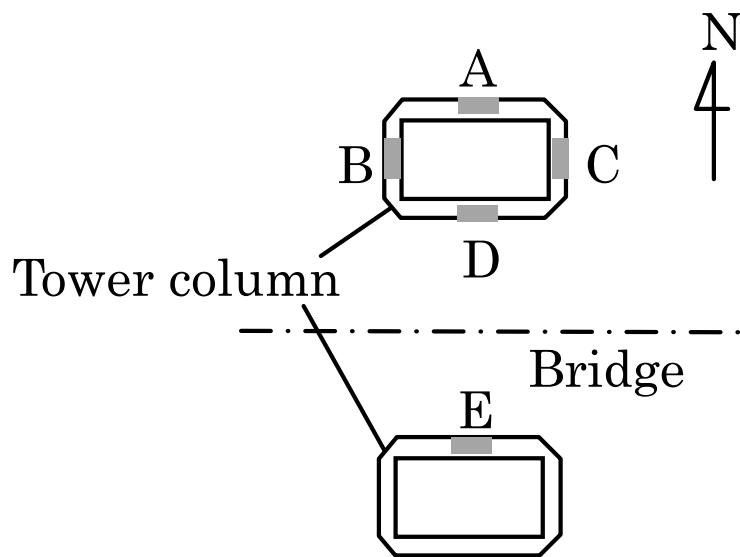


(Number of data)

NNE



## Salinity measurement on surface of structure



Measured point	A	B	C	D	E
Density of Salinity (mg/m <sup>2</sup> )	47.2	12.2	0.0	0.0	7.8

# Outcomes of the Project

- Meteorological data
- Current Design Conditions
- Present Conditions of Concrete, Steel and Hybrid structures
- Empirical Formulae for Structural Deterioration in Corrosion Environment and under Economical Condition
- Assessment of Durability and Strength Improvement Methodologies
- Maintenance Strategies



Comprehensive Guideline Text for Structural Engineers