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PRESENTATION

# RESEARCH AND TEACHING

**Dr. RAJA RIZWAN HUSSAIN**
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Department of Civil Engineering
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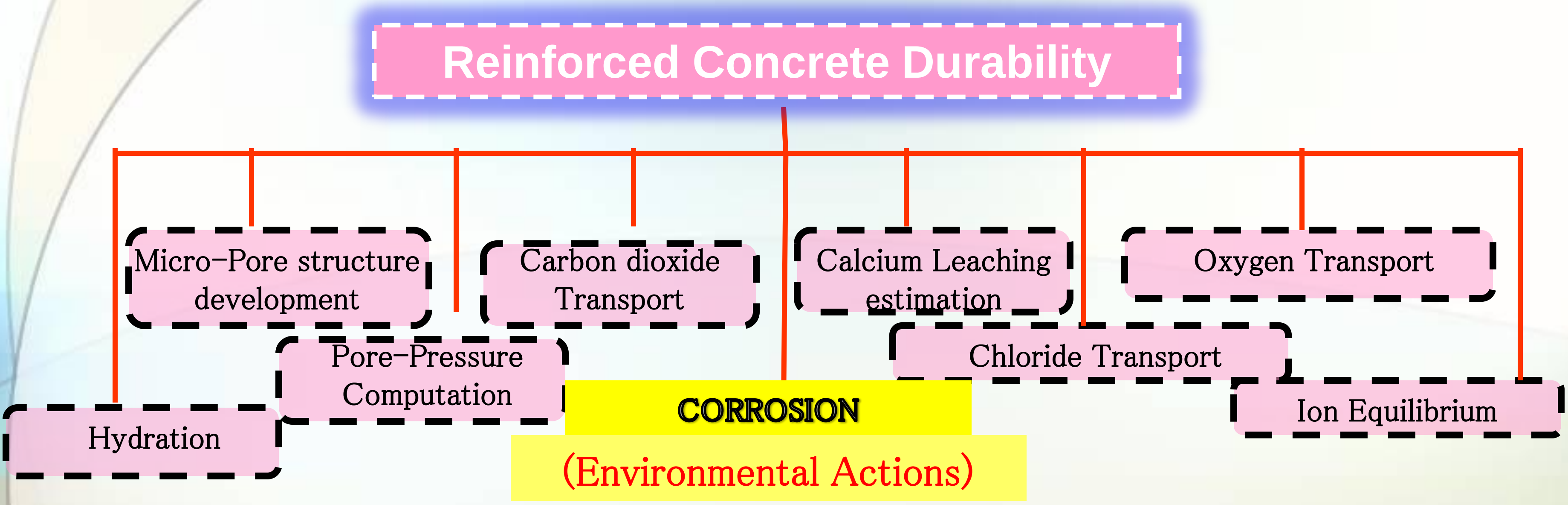
# My Research Achievements to Date

**Rapid Publication Rate:**
128 publications after Ph.D in just 5 years (2009-2014)
19 publications during M.Sc and Ph.D Tenure (2004-2008)
Total 147 publications in total.

**Versatile and Universal Research Experience:**
**I have attended international conferences and presented research papers throughout the word in more than 50 countries.**

**Excellent Rate of Government Research Grant Funding Acceptance:**
15 research projects (2010-2014) with a total researh grant of more than 20 million SR (5 million USD approx.)

# RESEARH & EDUCATION



## Reinforced Concrete Durability

- Micro–Pore structure development
- Carbon dioxide Transport
- Calcium Leaching estimation
- Oxygen Transport
- Pore–Pressure Computation
- Chloride Transport
- Hydration
- Ion Equilibrium

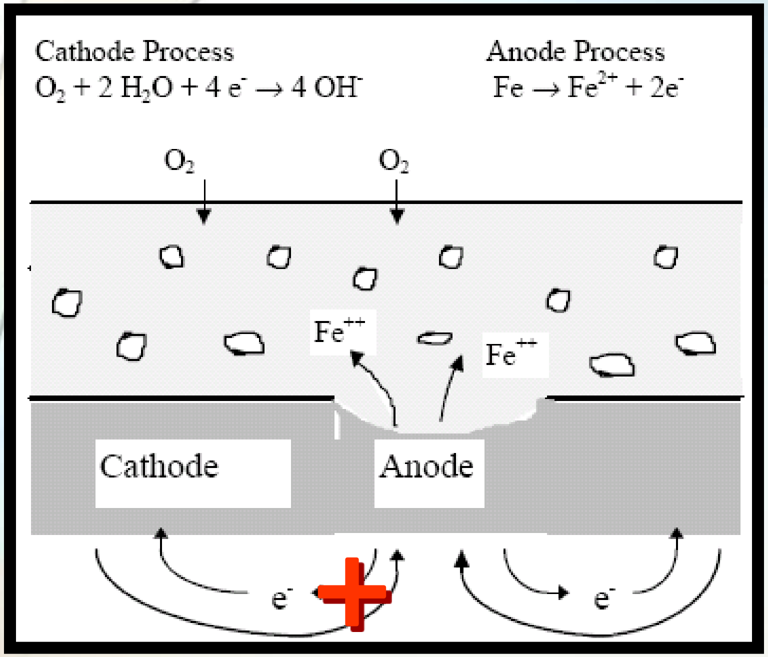
**CORROSION**

(Environmental Actions)

## RESEARCH OBJECTIVES FOR THE NEXT 3 YEARS

- **Investigation of the severe environmental effects on reinforced concrete structures through mass and energy transfer.**
- **Experimentation and Modeling based on semi-empirical approach.**

# MY RESEARCH

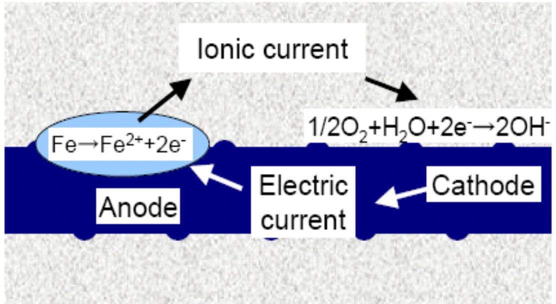


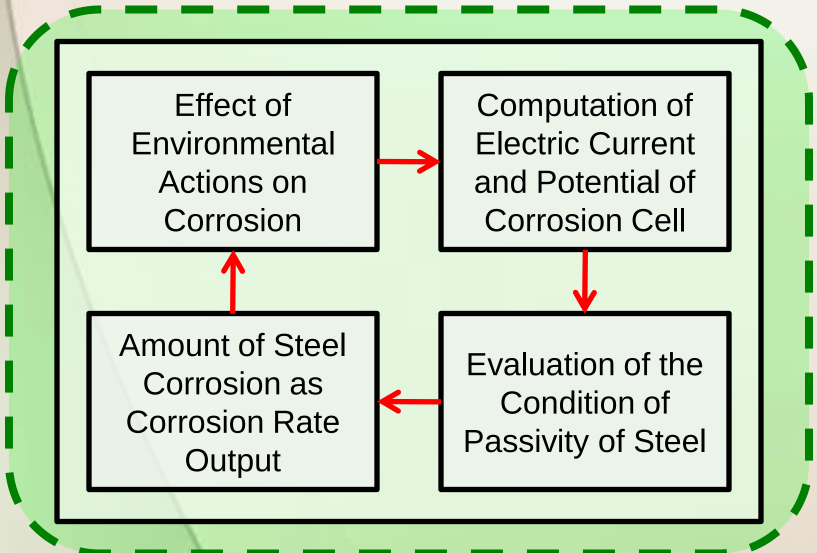
$$Fe(s) \rightarrow Fe^{2+}(aq) + e(Pt)$$

$$E_{Fe} = E^{\ominus}_{Fe} + (RT/z_{Fe}F)\ln h_{Fe^{2+}}$$

$$O_2(g) + 2H_2O(l) + 4e(Pt) = 4OH^-(aq)$$

$$E_{O_2} = E^{\ominus}_{O_2} + \left(RT/z_{O_2}F\right)\ln\left(P_{O_2}/P^{\ominus}\right)$$
$$-0.06\,pH$$



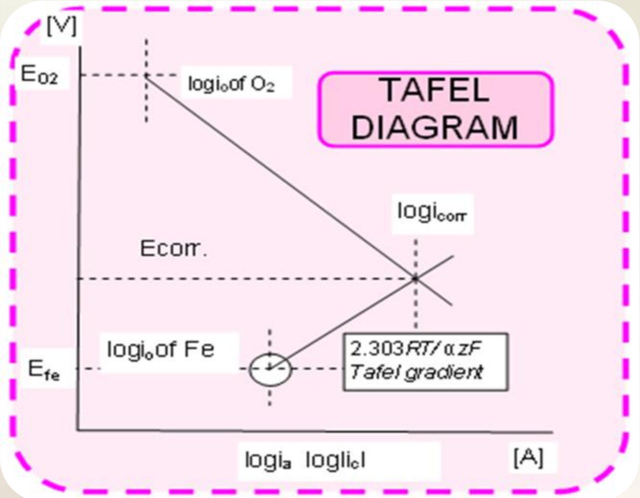


Effect of Environmental Actions on Corrosion

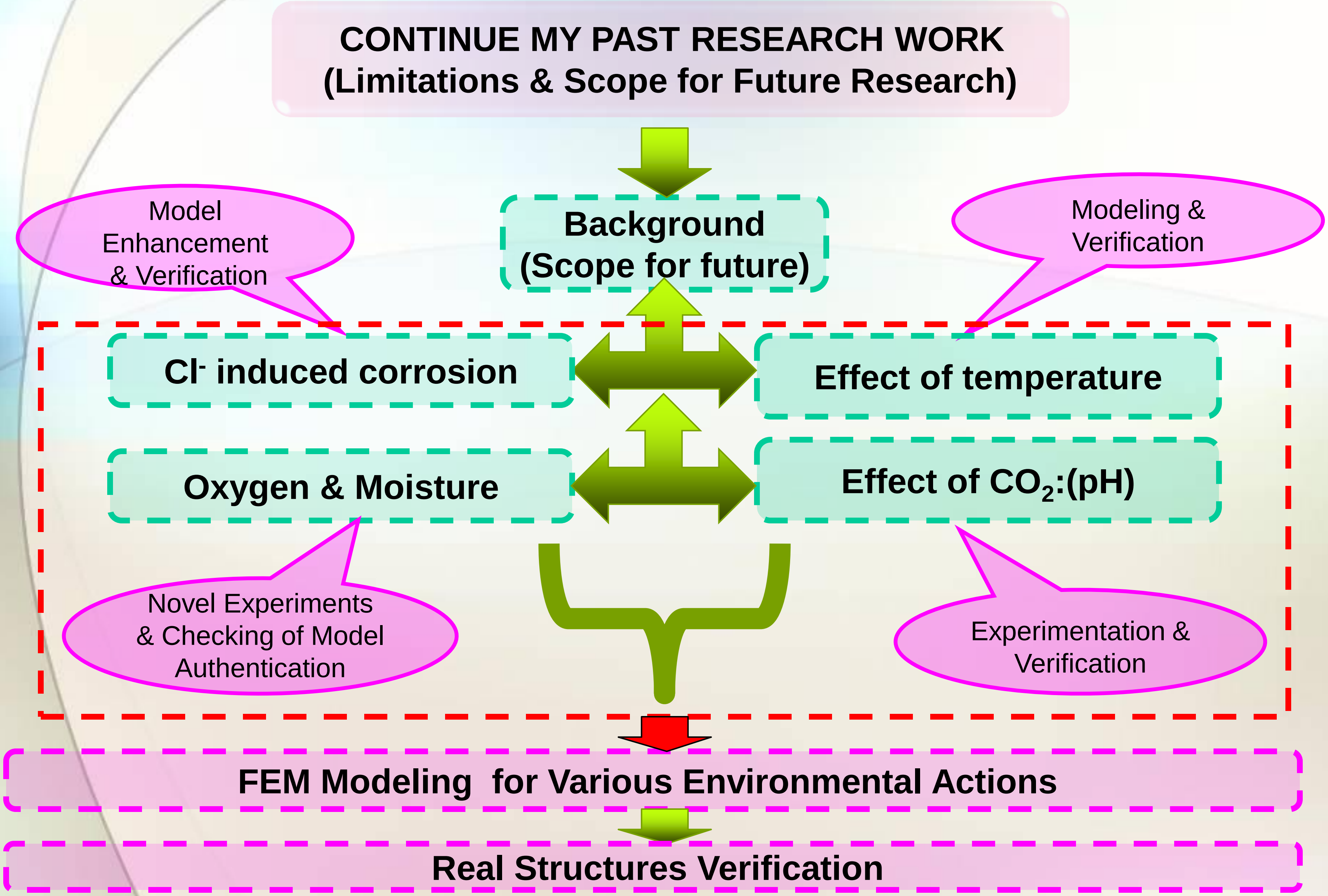
Computation of Electric Current and Potential of Corrosion Cell

Evaluation of the Condition of Passivity of Steel

Amount of Steel Corrosion as Corrosion Rate Output



# RESEARCH PLAN & RESEARCH OBJECTIVES



CONTINUE MY PAST RESEARCH WORK
(Limitations & Scope for Future Research)

Background
(Scope for future)

Model
Enhancement
& Verification

Modeling &
Verification

$Cl^-$ induced corrosion

Effect of temperature

Oxygen & Moisture

Effect of $CO_2$:(pH)

Novel Experiments
& Checking of Model
Authentication

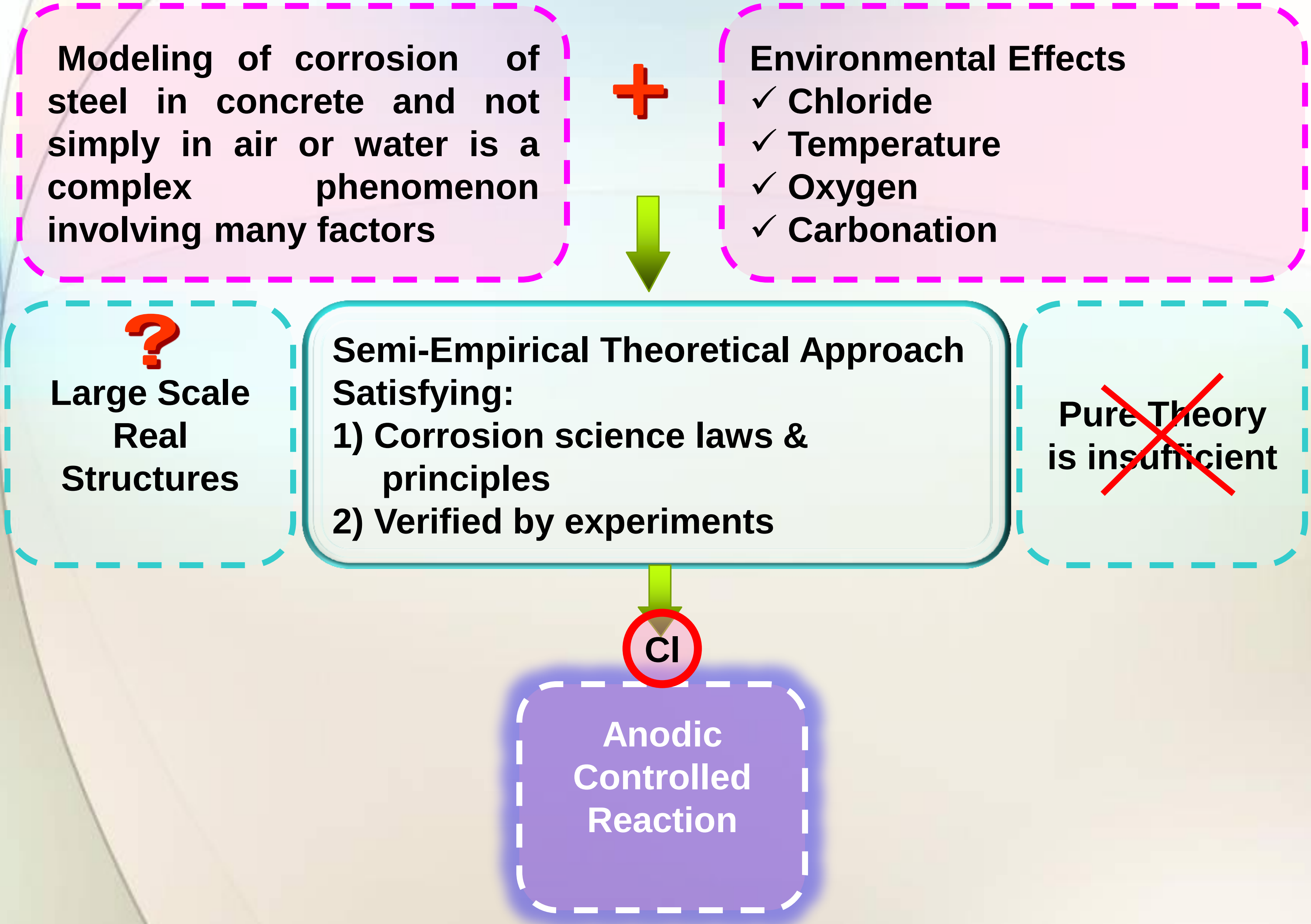
Experimentation &
Verification

FEM Modeling for Various Environmental Actions

Real Structures Verification

**‘4’ RESEARCH AREAS & ‘8’ PROBLEM STATEMENTS FOR THE NEXT 3 YEARS**

# Problem 1: Redefining of Cl$^-$parameters in the model based on semi-empirical theoretical approach and more meaningful boundary conditions is required



Modeling of corrosion of steel in concrete and not simply in air or water is a complex phenomenon involving many factors

+

Environmental Effects
- ✓ Chloride
- ✓ Temperature
- ✓ Oxygen
- ✓ Carbonation

?

Large Scale Real Structures

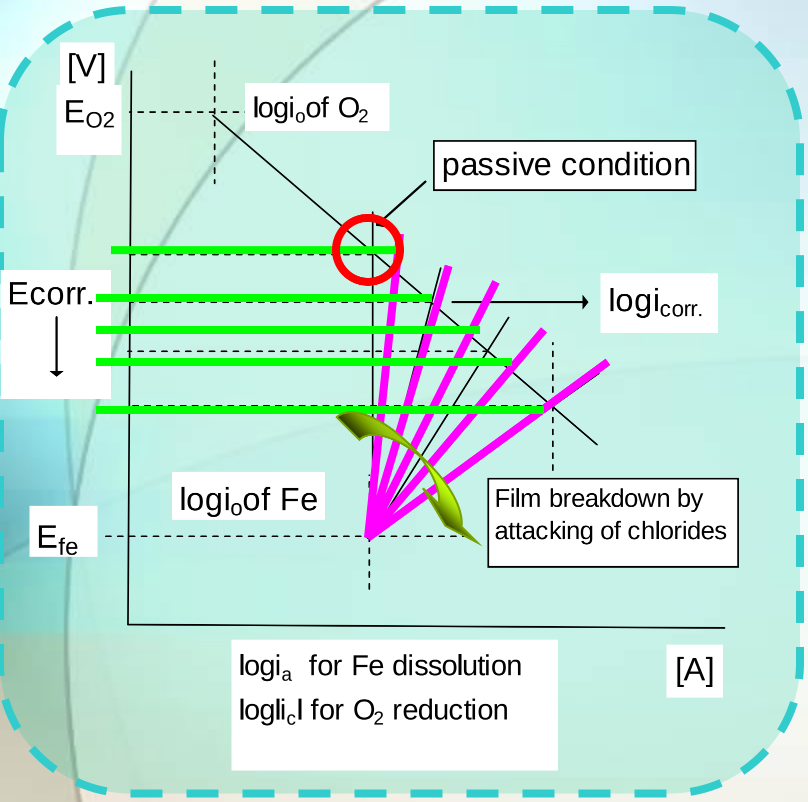
Semi-Empirical Theoretical Approach Satisfying:
1) Corrosion science laws & principles
2) Verified by experiments

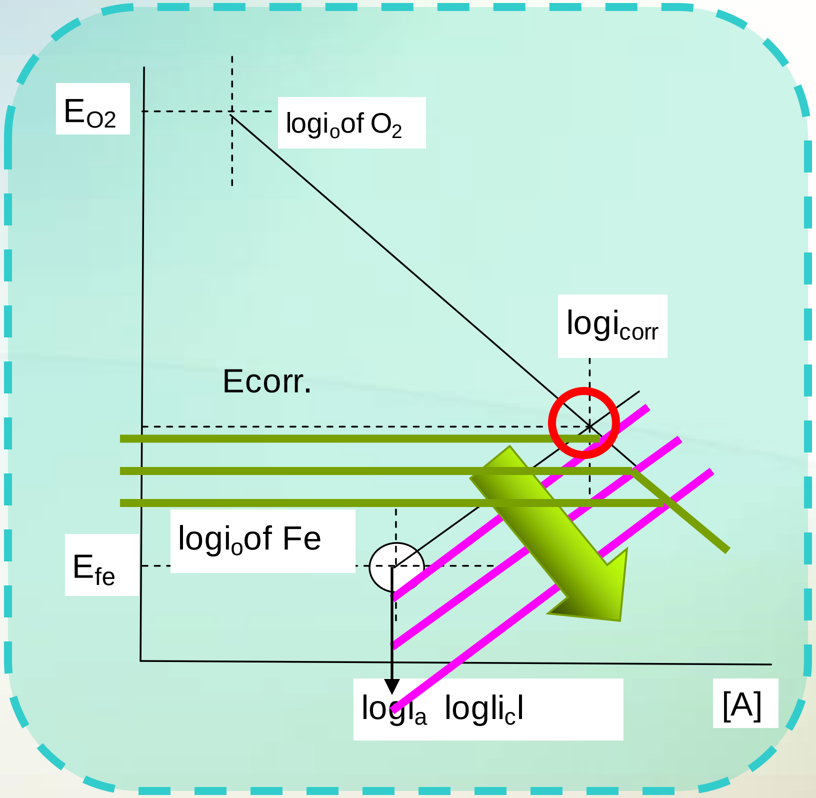
~~Pure Theory is insufficient~~

Cl

Anodic Controlled Reaction

# Problem 2: The model is a two staged series model





**Enhanced Anodic Tafel Gradient Factor**

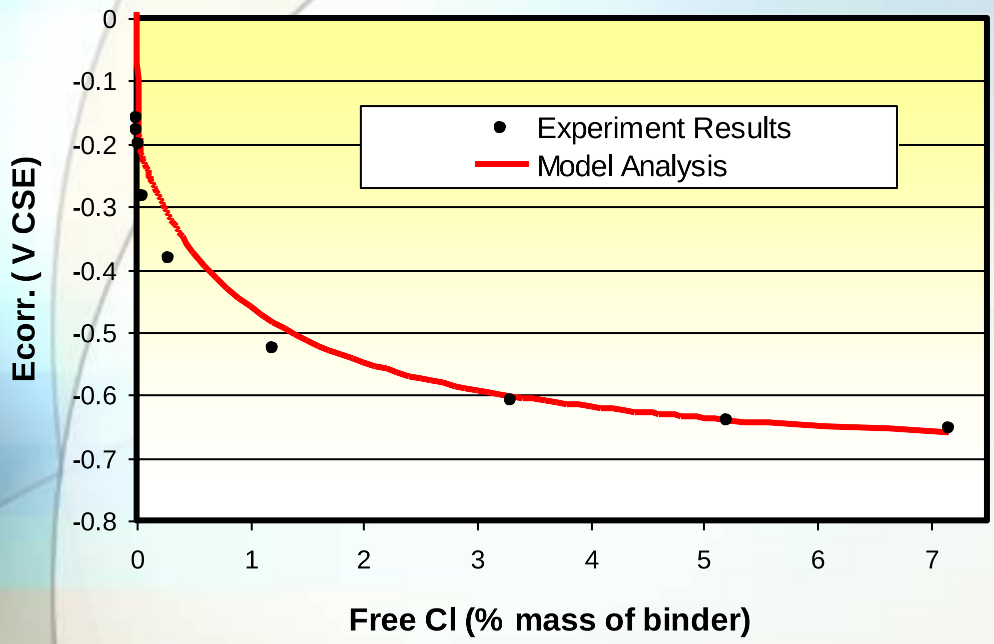
**Stage 1**

**Enhanced Anodic Potential Factor**

**Stage 2**

## Visualization of the model

# Problem 3: Verification of Corrosion Potential and Corrosion Rate Models

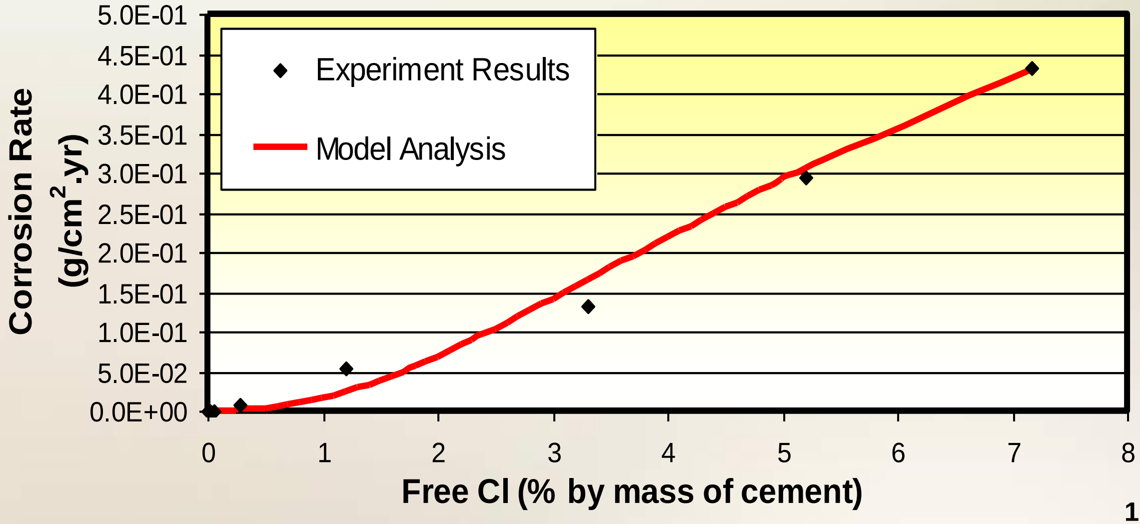


Verification by experiment results (Hussain et. al. 2010-2013)

(Model shows good agreement with the experiment results )

## Limitations of the model

**Variation of temperature and oxygen are not considered**

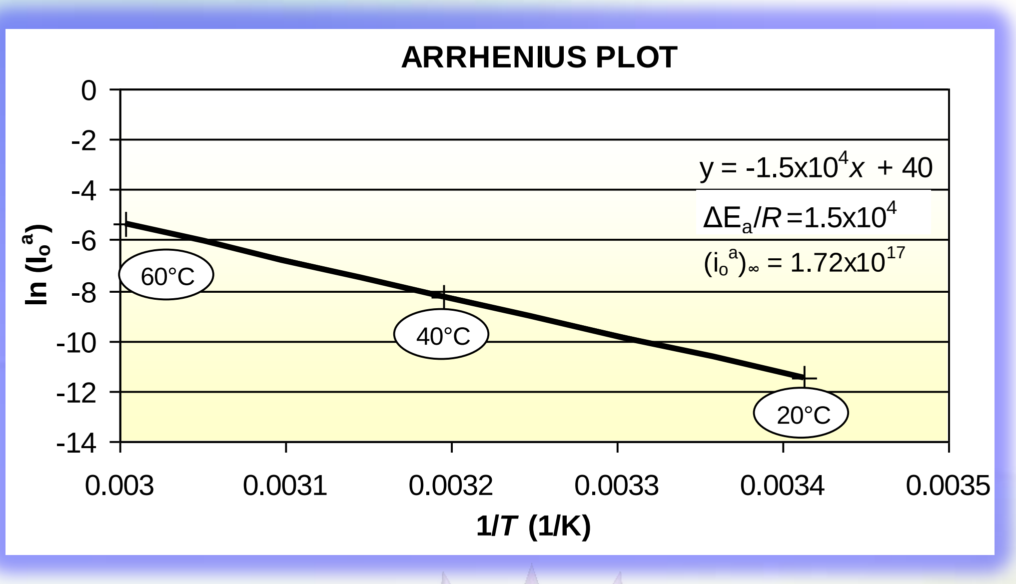


# Problem 4: Application of Temp. Induced Corrosion Model for various Cl Cases

**Setting of referential values for variable chloride conditions from 20˚C to 40˚ C and 60˚C**

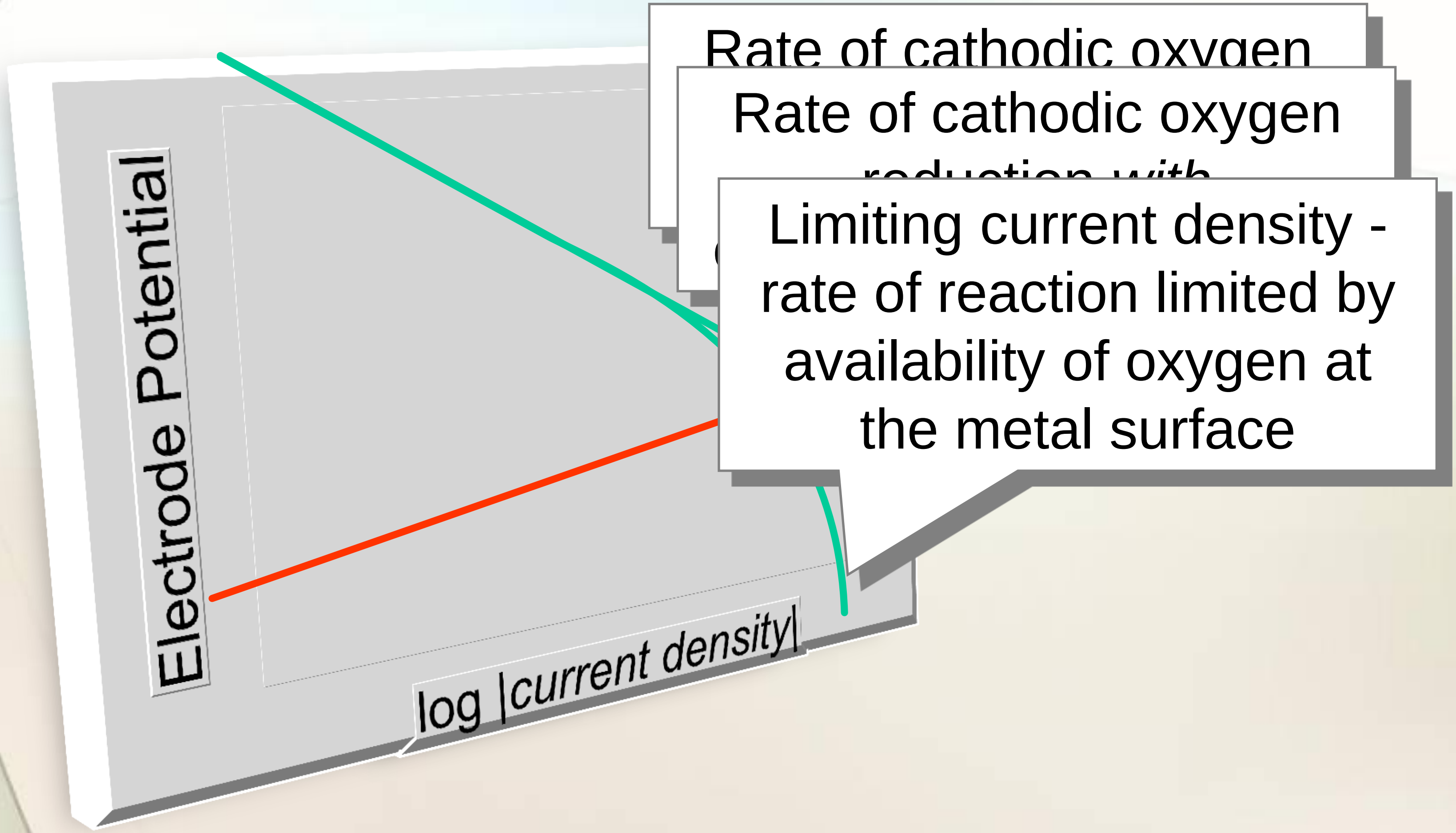
**Averaged Treatment**

- No way to measure the value of anodic current directly from experimentation.
- The referential values are back calculated by using standard value of anodic current $1.0 \times 10^{-5} A/m^2$ at 20˚ C
- Sensitivity analysis
- .Arrhenius plot analysis
- Unique activation energy
- Anodic current is the only variable



**<u>Semi-empirical-analytical calculation methodology:</u>**
**Rather new and has not been adopted in the previous research works. Overall Arrhenius plot method is in accordance to work done in past**

# Oxygen concentration polarization

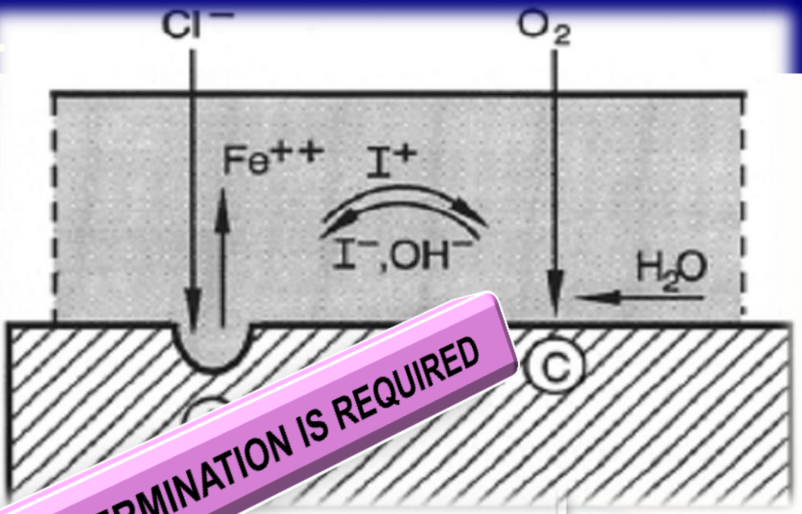


Rate of cathodic oxygen

Rate of cathodic oxygen reduction *with*

Limiting current density - rate of reaction limited by availability of oxygen at the metal surface

# OXYGEN DIFFUSION CONTROL……………



$$i_{lim} = \frac{zF\,D_{O2}\,\Delta c_{O2}}{x_{O2}}$$

where

$i_{lim}$ = limiting diffusion cu sity in µA/cm²

$z$ = sum of bond a numbers for the elec-trode re

$F$ = Fa nstant (96487 As/mol)

$D_{O2}$ = n diffusion coefficient in cm²/s

$\Delta c_{O2}$ = oxygen concentration gradient in mol $O_2$/cm³

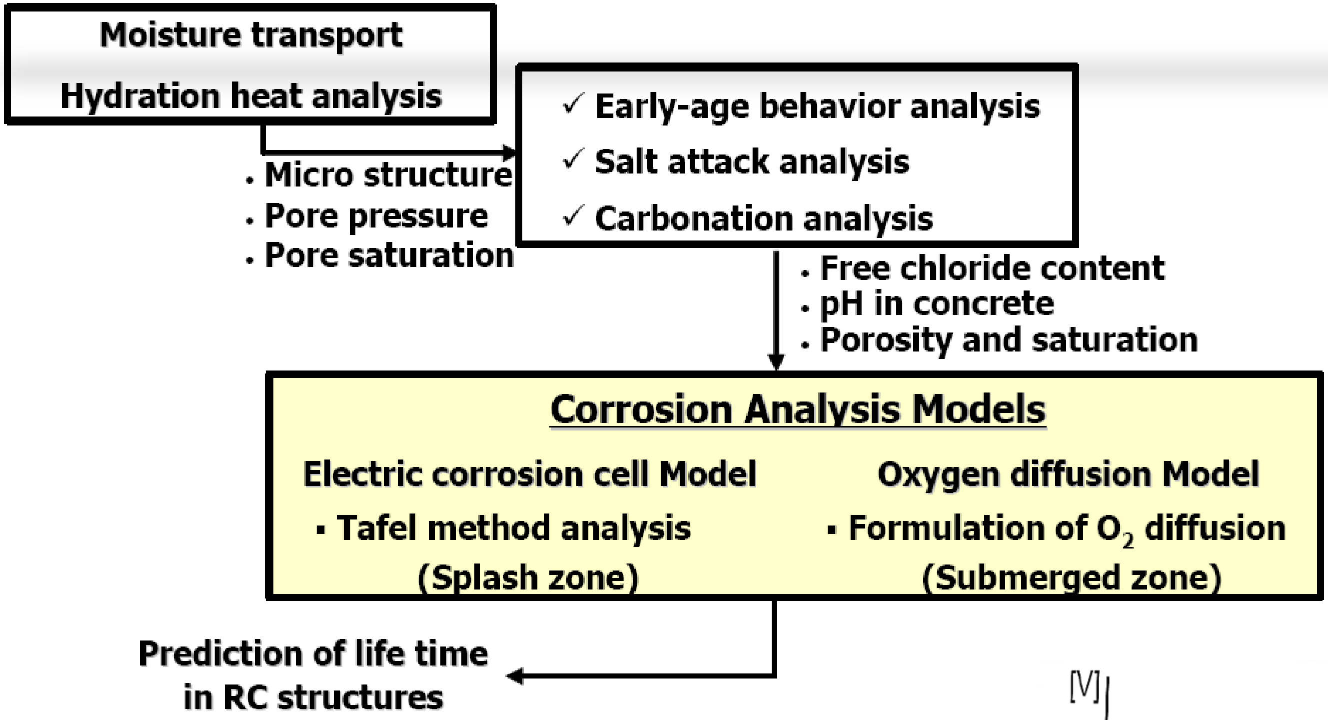
$x_{O2}$ = mean oxygen diffusion path in cm.

**QUANTITATIVE EXPERIMENTAL DETERMINATION IS REQUIRED**

$1/2O_2+2e^-+H_2O\rightarrow 2OH^-$

**PROBLEM 5**

# Problem 6: MODELING OF THE EFFECT OF LIMITED OXYGEN ON CORROSION



**Moisture transport**

**Hydration heat analysis**

- **Micro structure**
- **Pore pressure**
- **Pore saturation**

✓ **Early-age behavior analysis**

✓ **Salt attack analysis**

✓ **Carbonation analysis**

- **Free chloride content**
- **pH in concrete**
- **Porosity and saturation**

**Corrosion Analysis Models**

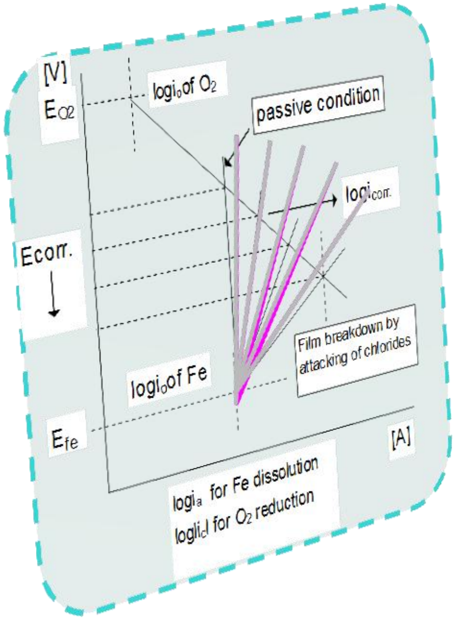
**Electric corrosion cell Model**

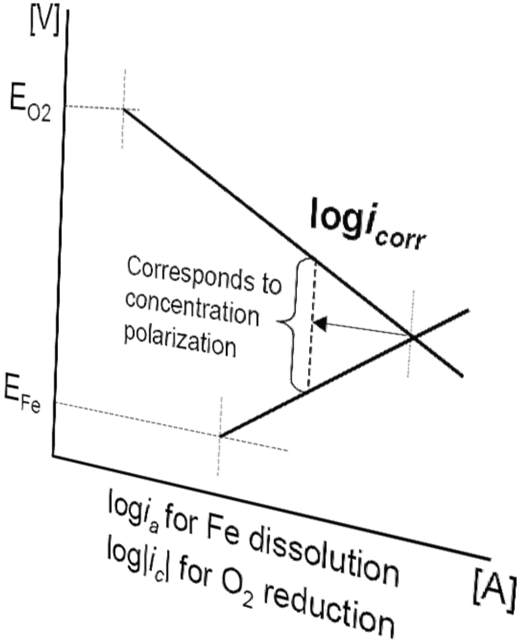
- **Tafel method analysis (Splash zone)**

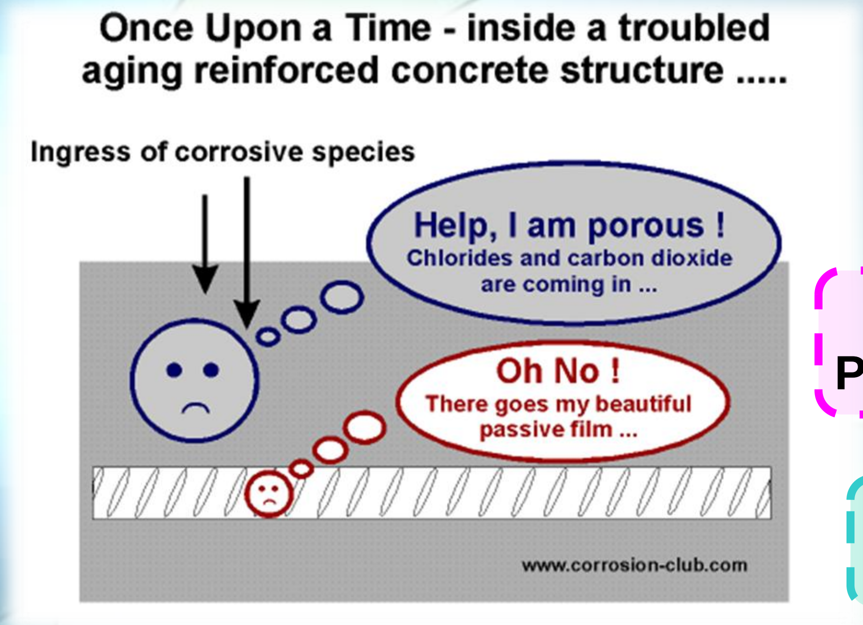
**Oxygen diffusion Model**

- **Formulation of $O_2$ diffusion (Submerged zone)**

**Prediction of life time in RC structures**







Is carbonation really a threat ?

## Objective

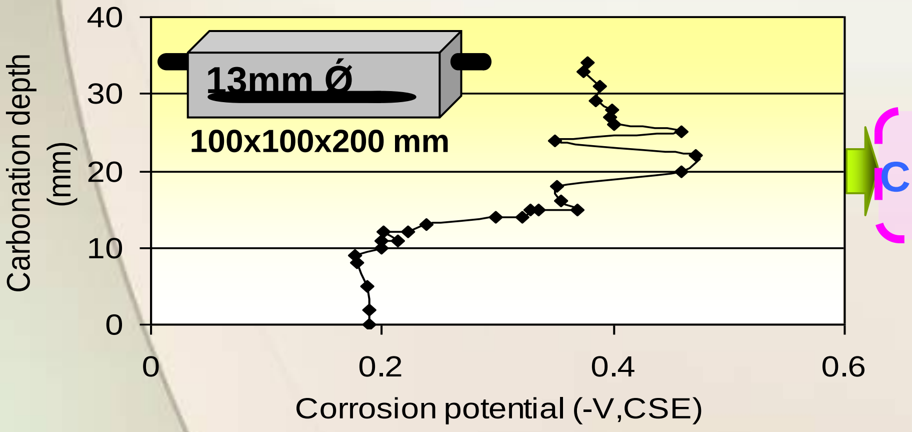
**Prob. 7:** Max. corr. damage due to carbonation

## Experiment Conditions

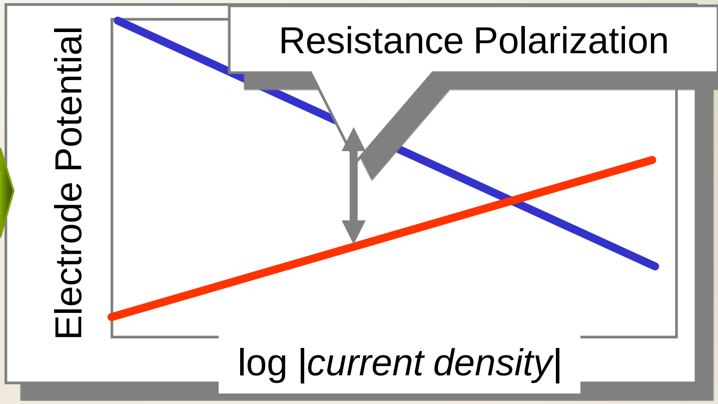
Humidity:55% Temperature30° $CO_2$:10%

## Experiment Observation

Relation b/w carbonation depth Vs corrosion potential and corrosion mass loss



CONCLUSION



## Final Task

**Problem 8:** Checking the Authenticity of Carbonation Induced Corrosion Model

# ORIGINALITY OF THE RESEARCH

**Noble experimentation considering a variety of variables, new modeling techniques applicable to versatile boundary conditions & integration of various developed and proposed models**

### 1) NOVEL EXPERIMENTATION CONSIDERING A VARIETY OF VARIABLES

Limited experiment data for the effect of oxygen on corrosion. So, detailed experimental investigation for the effect of oxygen on corrosion will be carried out in this research

### 2) NEW SEMI-EMPIRICAL MODELING TECHNIQUES & VERSATILE BOUNDARY CONDITIONS

Various researchers proposed different models in the past (Maruya et. al. 1998a, 2003, 2010, 2011; T. Nishida 2005; B. Oh et. al. 2004; Ha W. Song 2010; V. Zivica 2002, 2009, 2006; P. Lambert and C.L. Page 1991). But the modeling methodology proposed in this research plan is unique and has not been adopted in the past. For example the implementation of Arrhenius Law by back calculation of parameters and breaking of passive layer as a function of Cl represented by the anodic tafel parameters etc. Furthermore, in this research the model validations will be carried out from normal to extreme boundary conditions such as very high chloride and temperature environments which has not been carried out in this past research works

### 3) INTEGRATION OF VARIOUS MODELS TO EXECUTE AS ONE SINGLE UNIT

Another novelty of this research plan is integration of various corrosion models to work as a single unit with real time sharing of variables in time and space. Few researchers have proposed such unified formations in the past (Maekawa and Ishida et. al.1999,2003; 2000 Maruya et.al. 2007;2011 Page et.al.2005; 2010 Melchers et. al. 2008; 2011)

# TEACHING STATEMENT 1

## My Five Steps Approach

Civil Engineering, especially Concrete Technology in Materials & Structures is elegant, powerful, and often surprising. As a teacher, I make it a priority to share these perceptions and create enthusiasm for Civil Engineering. At the same time, it is of the utmost importance that my students actually learn the material covered in the course. This means that students should both gain a conceptual understanding of the subject matter, as well as learn how to actually do the civil engineering involved, whether it be evaluating integrals in a RC structural design class or writing proofs in a more advanced course. It is my responsibility to give students every possible opportunity to accomplish this learning. The goal of enlightening students to the beauty of concrete engineering is intimately related to that of ensuring that they learn the material. As every student and teacher knows, it is much easier to learn when the subject fascinates you. The most prevalent force keeping students from enjoying concrete is a lack of understanding for the subject. Over the years I have had the luck to learn from some extremely talented teachers, and they all had one thing in common: they were able to explain concepts clearly and precisely, while at the same time engaging their students and creating excitement for the subject. It is this, above all else, that I strive to accomplish every time I teach. I am always looking to improve my ability in this respect, but here are some things I have found work very well.

# TEACHING STATEMENT 2

First, I encourage an atmosphere in which civil engineering subjects are appreciated. In class and out, I never hide my own enthusiasm for the material. While students sometimes scoff at this, my hope is that my attitude is contagious. Additionally, by showing my students that I really do love teaching them this amazing subject, it encourages them to seek my assistance outside of class if needed. I never want my students to fail to visit me in my office because they are afraid I will resent having to spend time doing civil engineering with them.

# TEACHING STATEMENT 3

Second, I try to strike a balance between providing clear explanations and engaging the student to participate in the lesson. While it is always a struggle to get students involved, there is no better feeling as a teacher than when every topic you planned for the day comes as an answer to students' questions. I encourage students to speak up in class, even to interupt me with questions (no hand-raising necessary). When students claim to not have questions, I turn it around, and interupt my own explanations with questions for them. Not only does this discussion style of lecture keep students active in the lesson (and awake), but it demonstrates the dynamic and lively nature of mathematics itself. As for the lecture itself, I work hard to come up with explanations that are intuitive and which even non-concrete engineering inclined students can relate to. By illustrating \what's really going on here," and a good way to think of this," I demonstrate that civil engineering really is more than dry equations and calculations. I try to point out connections between a new concept and ones we have already learned. This is by no means a proof that the civil engineering formulas works, but it definitely helps students remember the formula, as well as reinforce earlier concepts (and their importance).

# TEACHING STATEMENT 4

Third, I make sure that students stay with the lesson and don't fall behind. I strive to always give the best explanations possible, but I realize that what seems easy and obvious to me, is not always as transparent to my students. (This is especially true after having taught the same course a few times; I often need to remind myself that just because I saw the material last semester, my students probably did not.) Another advantage of the more open dialog lecture style I employ is that it is easy to notice when students get confused, and adjust explanations until they \click" with everyone. Sometimes no matter how many different approaches I try this just does not happen, so I encourage the students to also explain the material to each other. This is helpful for all the students involved, and is a pleasure for me when I discover a new way of thinking about a problem. When possible, I extend this exercise by assigning group work. This takes more time than lecturing, but is certainly worth it. When students teach each other the material they master it themselves. Additionally, group work gives students an opportunity to do mathematics for themselves, in an environment where I can step in and help in case they get frustrated.

# TEACHING STATEMENT 5

Finally, I do my best to keep students motivated throughout the semester. In part, this is done through assigned work. For homework/assignments , I assign problems which both provide practice and extend the concepts taught in lecture. Like group work, the homework also gives students a chance to master techniques with the help of their peers (if desired). Regular quizzes give students the chance to test themselves on the material when the stakes are low. Exams, while in the students' eyes mostly exist for the purpose of evaluating them, serve as yet another opportunity for the students to review, and perhaps gain greater insight into, the material. After an assignment is turned in, I get it graded and back to the students as quickly as possible, and provide solutions and feedback as appropriate. Students appreciate this, and it also gives me a chance to determine what areas, if any, I need reemphasize. To help students stay on top of the class, I provide a course website, where students can and an updated schedule of topics and homework problems, download study materials for the exams, and even check their grades in the course so far. My hope is that through these various techniques, I can make the task of learning mathematics as easy and enjoyable for my students as possible. Although most students would deny it, I have a huge advantage in that it is mathematics that I teach. I believe that if we give students an opportunity to actually do mathematics, they will have no choice but to enjoy it. Who wouldn't enjoy solving a mystery? How could anyone not appreciate the raw power of the techniques civil engineering taught us? Why wouldn't someone be astounded by the amazing connections between seemingly unrelated concepts? By making the material accessible through clear explanations and insightful examples, I can not only teach my students the civil engineering subjects, but also give them a glimpse of its majesty.

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