What is Carbonation of Concrete

- It is a process of reacting calcium hydroxide in the concrete with carbon dioxide in the atmosphere and creating calcium carbonate and water.
- $\text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}$
- This process starts with the concrete surface and gradually moves towards the inner of the concrete. The carbonation of concrete is a slow and continuous process.
- When the carbonation front reaches the reinforcement, it could start the corrosion of steel.
How does Reinforcement Corrode

- The pH value of the concrete is lowered to about 9 during the carbonation reaction.
- The protective oxide layer around the reinforcement breaks at this level enabling the occurrence of corrosion of reinforcements.
- The reinforcement is protected by the alkaline condition caused by the hydrated cement paste. This is neutralized by the carbonation allowing the corrosion in the presence of oxygen and moisture.

![Diagram of corrosion process]

Consequences of Corrosion

- Continuing this process will increase the volume around the reinforcement and then cracks will appear in the cover zone by further exposing the reinforcement to the environment.
- In addition, spalling could also occur due to this corrosion with the increase in the internal volume.
- This will affect the strength of the reinforcement leading to loss of its tensile strength.
How to Test Carbonation

- Depth of carbonation can be found very early with a simple test.
- Phenolphthalein solution having 1% phenolphthalein is sprayed in the newly exposed concrete.
- If the colour of the concrete change to pink, that area of the concrete is not carbonated.
- The area that did not change colour with the application of phenolphthalein is carbonated.

- There are other methods such as IR spectrum analysis of carbonated concrete. The CO$_2$ absorption by the specimen is measured in the method.

How to Calculate Carbonation Depth

- $t = \left(\frac{d}{k}\right)^2$
  - $t$ – Time for carbonation, $d$ – Concrete cover, $k$ – Permeability of concrete

- Using this equation, we can find the time required to the carbonation front to reach the reinforcements.
- If we know the age of the building, we can check whether the reinforcements are affected by carbonation.
How to Avoid Carbonation

- Since the higher water-cement ratio contributes to the higher depth of carbonation, it could be controlled as possible.
- Adequate curing of concrete and extended curing period will help concrete to react well, and it reduces the cracking of concrete.
- Adequate curing reduces the permeability of concrete and as a result rate of carbonation will reduce.
- Use of admixtures to modify the pore structure and reduce the permeability of concrete.
- Additives like silica fume having a higher surface area could be used to reduce the porosity of concrete.
- The use of protective coatings will improve the durability of concrete and low down the carbonation process.
- It has been proven that self-compacting concrete has better performance against the carbonation of concrete.

How to Repair the Concrete

- Clean the affected area properly and remove all loose concrete.
- Clean the reinforcements.
- This could be done manually with a wire brush or a suitable chemical could be applied to remove the rust.
- If reinforcements are damaged in a way that they can not carry the tensile forces, reinforcements should be replaced.
- Apply anticorrosive for reinforcements.
- Apply a bonding agent to the concrete surface for better bonding.
- Apply a suitable mortar. This could be non-shrink concrete or any applicable mortar mix approved by the structural engineer.
Thank you