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## Design for Durability - A Matter of Good Choices and Good Codes

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### Summary

Concrete structures' design must be based on a tripod: serviceability, safety and durability. Unfortunately, a significant number of works were carried out without due care with these three aspects. The consequence was that a lot of structures suffer premature damage due to inadequate choices during design, improper detailing or construction faults. This paper discusses some cases dealt by the author with during his professional life in Rio de Janeiro as well as the solutions proposed to repair the damages. The experience assembled shows that good codes are not enough to prevent bad results if engineers are not prepared to design, detail and build for durability, serviceability and safety. Good colleges and teaching by experienced professionals are also very much needed. The public authorities must also guarantee external quality control of projects and constructions.

**Keywords:** durability, safety, serviceability, concrete structures, damage, code, quality control,

### 1. Introduction

Design of structures means to fulfill three fundamental concepts: safety, serviceability and durability. Any of them is essential for a successful enterprise. All them are important for the final quality of the structure. To neglect, even partially, anyone is to condemn, for sure, the final result of the work, if not the stability or lifetime of any construction. Engineers are responsible for the goodness of the response given by a structure to these three fundamentals.

Professionals can learn not only from big accidents, but also from small imperfections, small mistakes, or small negligences that might be the origin of serious disruptions and huge loses. This paper discusses this domain of small causes and big consequences of structural pathologies in urban constructions. They have quite different origins – design, construction technique, quality of materials, building monitoring, management during lifetime, and others. Discussion is based on the experience assembled by the author during his professional life in Rio de Janeiro and abroad.

In Brazil, there is no continuous and permanent surveyor of an engineer in many small and medium work sites, either from contractor, owner or public authority. This situation implies the occurrence of frequent construction faults that may compromise the final quality of the work. The most part of the chief engineers are obliged to manage more than one site or to deal with technical, financial and administrative tasks at the same time. This situation creates a lot of problems in building sites that could be avoided. Some examples are:

- construction joints badly treated, with lacks, voids, and disaggregated materials;
- reduced reinforcement cover due to bad placing of reinforcement cage, mainly in slabs;
- adaptation of design details done at site without consultation to the designer, leading to poor solutions, some times worse than the original designer's proposal;
- bad assemblage of braces and scaffolding conduced to drops or voids between wood planks, which disturbs placing and vibration of concrete and, therefore, its capability to protect reinforcing bars against corrosion;
- use of inadequate, bad quality or badly placed materials to cover facades, allowing water and aggressive infiltration into the walls and structural elements;
- modern tendency of humanising constructions with plants in concrete boxes connected to the structure, without a good insulation, allowing also water flow into the structure;
- embedding of metallic bolts into the structure without adequate corrosion protection and inadequate maintenance.

## 2. Buildings in Rio de Janeiro and their pathologies

Search for shorter construction time and economy of materials in these constructions brought as consequence the adoption of large slabs, few beams and slender structures. Design at ultimate limit state induced also a minimisation of geometric dimensions of structural elements, reducing them in relation to those normally gotten through classical design based on service limit stresses.

During the last few decades this practice caused that deformability of structures became a major parameter in the design of reinforced concrete buildings. Bigger spans, free to deflect, imply that time dependent deflections are more and more relevant and need to be carefully treated in conception, design and construction.

Climate is also the cause of several disorders in urban buildings. Improper choices, for the environment in which the constructions are placed, both architectural and structural, may shorten their lifetime or reduce their resistance. Deficient or non-existent maintenance procedures worsen the deterioration process, increase rehabilitation costs and may compromise the stability of the structures.

The paper treats the different disorders from the point of view of their main cause – design, construction or use of the structure, as understood by the author. Restoration proposals for some real cases, such as excessive deflection of slabs, inadequate water drainage of balconies, thermal effects on roof structures without proper insulation, attack from weather conditions, removal of frameworks to early, chloride effects on concrete and steel, change in use of a floor dealing with excessive load, poor development of rehabilitation work of an old church, are presented in this paper.

Solutions proposed for each case reported are also presented and results briefly discussed.

References to the technical reports prepared by the author are made.