POLYTECHNIC OF TORINO
FACULTY OF ARCHITECTURE 2
Degree in Architecture
Honors theses

High Performance Concrete: theoretical analysis and structural model
by Francesca Squizzato
Tutors: Giuseppe Ferro, Giulio Ventura

The present thesis analyzes the mechanical behavior of high performance concretes. Moreover a mechanical model is developed in order to describe their behavior.
High performance concrete (HPC) is a composite material made of a brittle matrix in high strength concrete and two levels of reinforcement: longitudinal bars and fibers.
With respect to normal strength reinforced concrete, HPC presents:

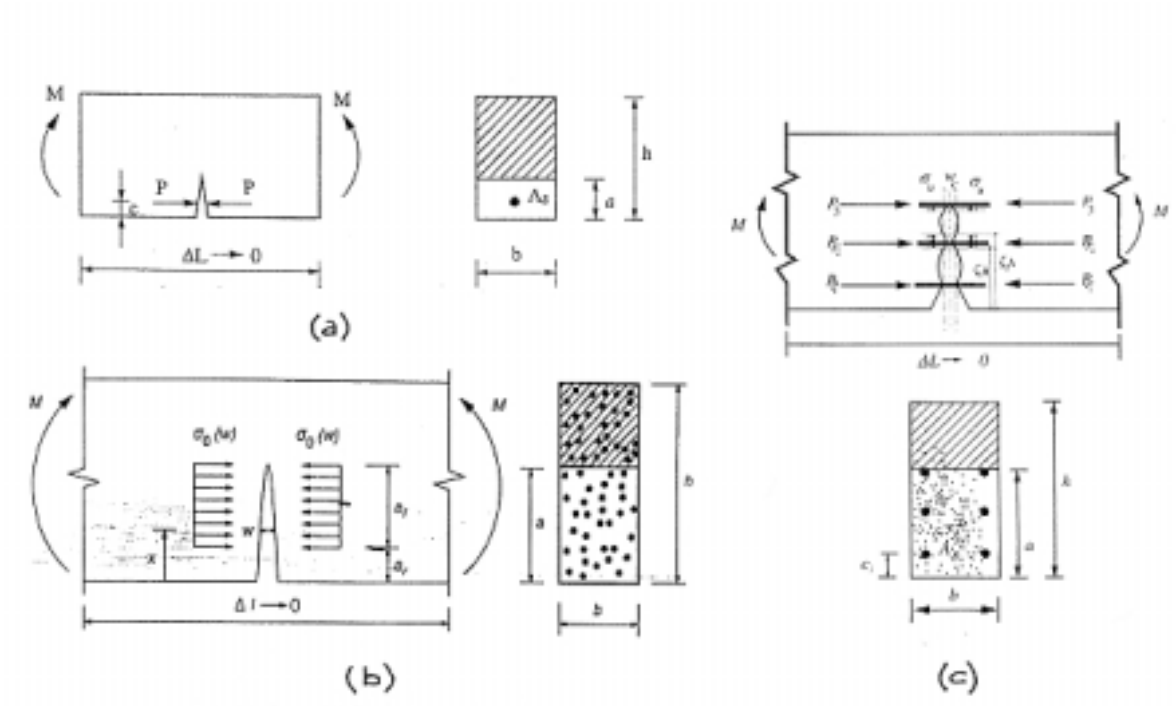
- a very high compression strength (70÷200 MPa);
- more ductility and high toughness;
- higher flexural strength;
- more durability when subjected to chemo-physical attack

In spite of the numerous advantages, in Italy HPC is scarcely used in common engineering practice. This is due to a watchful prudence of designers and building firms, which is probably justified by the lack of Code Rules and mechanical models that should provide the standards for a correct design.

After these preliminary remarks, aim of the second part of the thesis is to provide a design tool for HPC beams in bending reinforced by longitudinal bars and/or fibers. In particular, their behavior up to failure is modeled by means of the so-called *bridged crack model*, whose parameters and constitutive laws are typical of Linear Elastic Fracture Mechanics. Linear Elastic Fracture Mechanics is necessary to explain the behavior up to collapse of these beams, which exhibit different failure modes by varying their size.
In particular, the bridged-crack model is capable of simulating the growth of a vertical flexural crack in a beam with two levels of reinforcement. Crack is hindered by the contemporary presence of two levels of reinforcement. In order to characterize the structural response of the beam, three dimensionless numbers $N_p^{(1)}$, $N_p^{(2)}$ e $\tilde{w}_c$ are defined. The dimensionless numbers are functions of matrix toughness, kind and amount of reinforcement, Young's modulus of concrete, characteristic crack width, height of the beam:

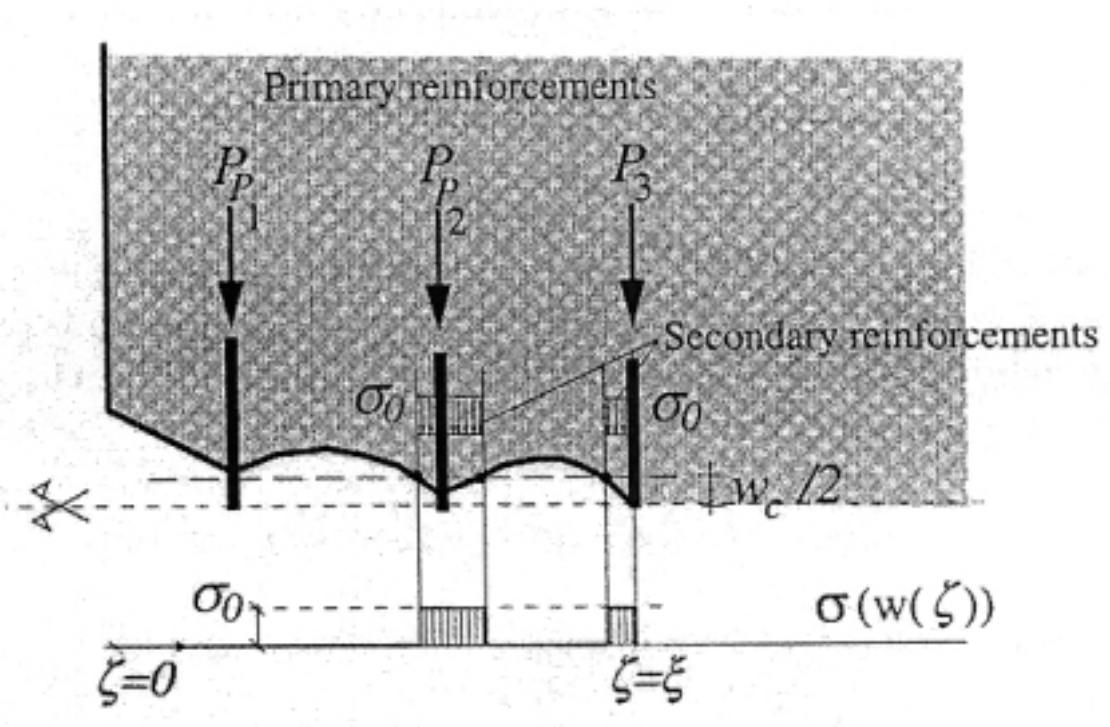
$$N_p^{(1)} = \frac{\rho \sigma_y h^{0.5}}{K_{IC}}, \quad N_p^{(2)} = \frac{\gamma \sigma_u h^{0.5}}{K_{IC}}, \quad \tilde{w}_c = \frac{E w_c}{K_{IC} h^{0.5}}$$

with
ρ = percentage of primary reinforcement;
σ_y = yielding tension of primary reinforcement;
γ = percentage of fibrous reinforcement;
σ_u = yielding tension of fiber reinforcement;
h = height of the beam;
K_{IC} = toughness of matrix;
E = elastic modulus of concrete;
w_c = characteristic crack width;



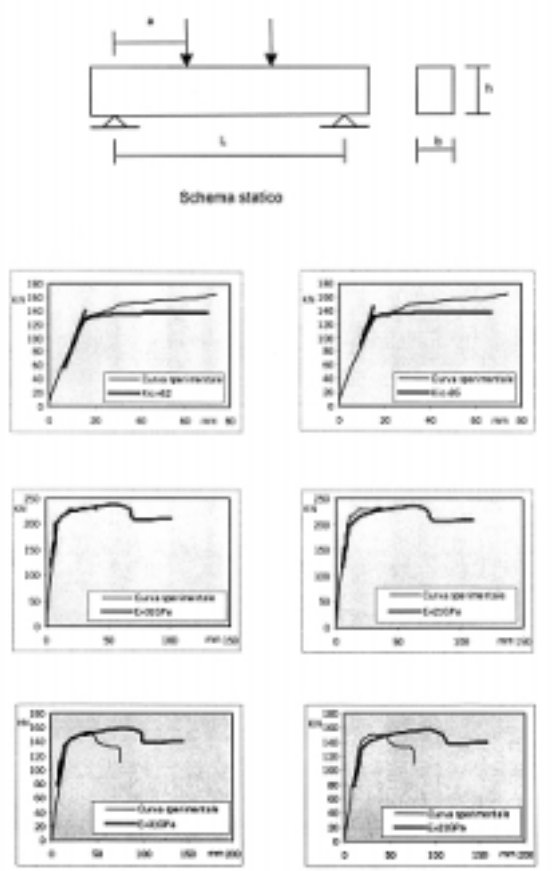
Pict.1: model for cracked section in the three different situatios: (a) primary reinforcement, (b) secondary reinforcement, (c) both reinforcement.

Picture 1 shows the model for a cracked section in the three different situations: (a) primary reinforcement; (b) secondary reinforcement; (c) both reinforcement, primary and secondary.
The third part of the thesis deals with the calibration of the model as well as with the indispensable check with several experimental results.



Pict.2: model for bridging actions (two levels of reinforcement) onto the crack faces

Special attention is dedicated to the comparison of load-deflection charts that results from numerical simulations made with the theoretical model, and from the experimental tests (three point bending and four point bending).
The numerous analyses strictly agree with experimental results, even if more and more analyses and tests are certainly necessary.



Pict.3: examples of comparison between two load-deflection charts
(numerical results: bold line; experimental results: thin line)

However, the promising results could represent a contribution for the preparation of a Code Rule for HPC that is claimed in our Country.

For further information, e-mail francescasquizzato@hotmail.com