TOWARDS A STANDARDIZED BOND TEST FOR ON-SITE STRUCTURAL CONCRETE QUALITY CONTROL

Michel LORRAIN, professor
Department of Civil Eng., INSA Toulouse
LaSaGeC², UPPA

SUMMARY

- About quality control…
- What is done nowadays?
- What else could be done?
- First results
- Conclusions and future prospects

1 - ABOUT QUALITY CONTROL…

- Modern societies aim at the « zero risk» level of safety
- Laws protect the consumer and give insurance companies the means to insure building works
- Based on quality control more and more exacting…

A compulsory stage… advantages

- Verification that actual material properties are conform to the design requirements
- Protection against important damage
- Planning optimization and potential savings

However a limited efficiency…

- Serious damage, deadly sometimes, occurs too frequently
- Requirements are not always easy to fulfill
- Costs tend to increase…

2 - THE PRESENT WAY TO ASSESS CONCRETE STRENGTH: THE AXIAL COMPRESSION TEST

- Since the French « circulaire de 1906 », structural concrete quality control is assessed through axial compression tests
- With changing experimental processes…cube, cylinder,…
- Implementation is ruled by precise standards

European regulations for Testing hardened concrete under compression

- **NF EN 12390-1 to 4** October 2001 - P 18-430
- Éditée et diffusée par l'Association Française de Normalisation (AFNOR) — ICS : 91.100.30

- **Part 1**: Shape, dimensions and other requirements for test specimens and moulds
- **Part 2**: Making and curing specimens for strength tests
- **Part 3**: Compressive strength of test specimens
- **Part 4**: Specifications for testing machines

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Some obvious advantages of the concrete compression test

- The test seems easy to perform and easy to interpret
- The result of the test is directly implemented in structural calculations
- The concrete compression strength is strongly correlated to the other mechanical properties

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Some obvious drawbacks of the concrete compression test

- The test is not so easy to interpret, the result is conventional
- The test is not so easy to perform: with increasing performance of concrete, failure strength increases
- Testing devices are sophisticated
- Specimens have to be prepared carefully

As a conclusion about the concrete axial compression test

- Doesn’t have exceptional properties
- Nothing gives any justification of its exclusiveness as THE mechanical reference
- Is not intrinsically compulsory…what engineers need is data for calculations and quality certification

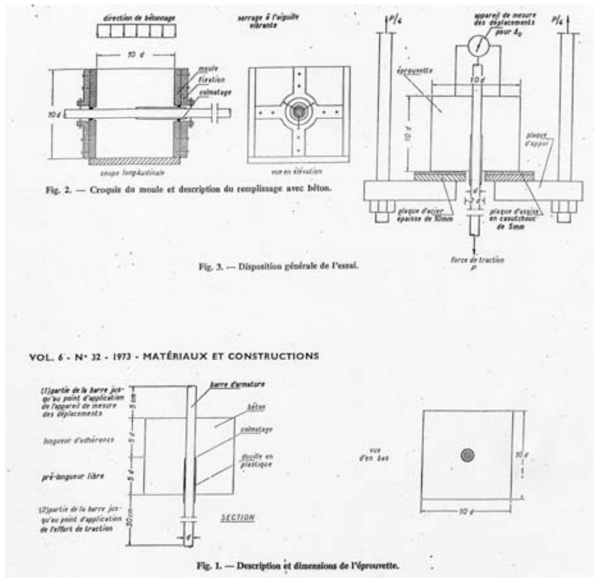
3 - THE BOND TEST AS AN ALTERNATIVE TO THE CONCRETE COMPRESSION TEST

- Well known and performed since the beginning of reinforced concrete construction
- Dedicated to certify the efficiency of strength transfer in the composite constitution of reinforced concrete

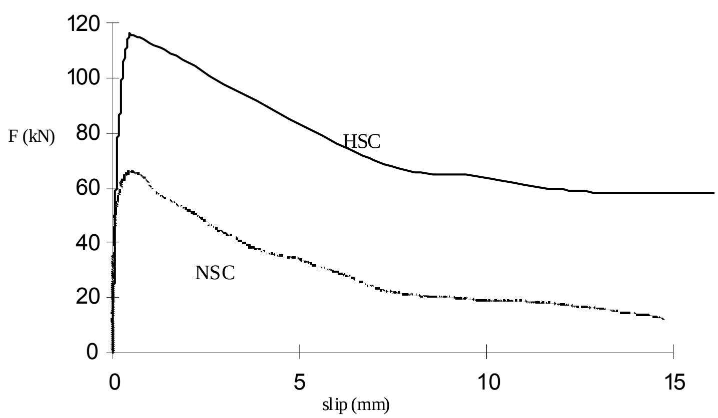
Bond test: the ways to perform

- Different ways can be used: pulling out, pushing out, bending « beam-test », etc.
- There is not yet a standard test, but some recommendations ASTM, RILEM CEB/FIP (P.O.T on 20cm cube) exist

The RILEM recommendations



The typical result of bond tests



Some obvious drawbacks of the bond test

- Sometimes difficult to perform
- Experimental procedures are numerous
- Results depend on concrete strength AND on bar roughness
- Said to be scattered

Some obvious advantages of the bond test

- It is a composite material test
- Only inferior strength has to be applied
- There is a strong correlation between bond strength and concrete compression strength

Building codes use these relationships to assess bond strength from concrete quality

$$\tau_{su} = 0{,}6 \cdot \psi_s^2 \cdot f_{tj}$$

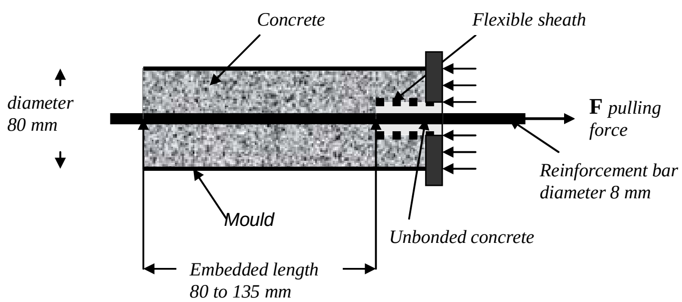
$$f_{bd} = (2.25\, f_{ctk0.05}) \big/ \gamma_c$$

$$f_{bd} = \eta_1 \cdot \eta_2 \cdot \eta_3 \cdot f_{ctd}$$

As a conclusion about the Bond Test

- Can also provide data for calculations and concrete quality certification
- Not less reliable than the concrete compression test… if performed in an appropriate way
- There is no reason not to consider an appropriate bond test as a standard for concrete quality

An appropriate Pull Out Test



Experimental investigation for the definition of the specimen features

Moncef MAKNI[1;] Atef DAOUD[2;] Michel LORRAIN[3]; Mohamed Ali KARRAY[4]

[1] ISET Sfax BP 88-A, 3099 El Bustan ; Laboratoire de Génie Civil (LGC) ENIT BP 37, 1002 Tunis, TUNISIE
[2] ENIG Gabès ; Laboratoire de Génie Civil (LGC) ENIT BP 37, 1002 Tunis, TUNISIE
[3] INSA Toulouse ; LaSaGeC ISA-BTP Anglet, FRANCE
[4] ENIT Tunis ; Laboratoire de Génie Civil (LGC) ENIT BP 37, 1002 Tunis, TUNISIE

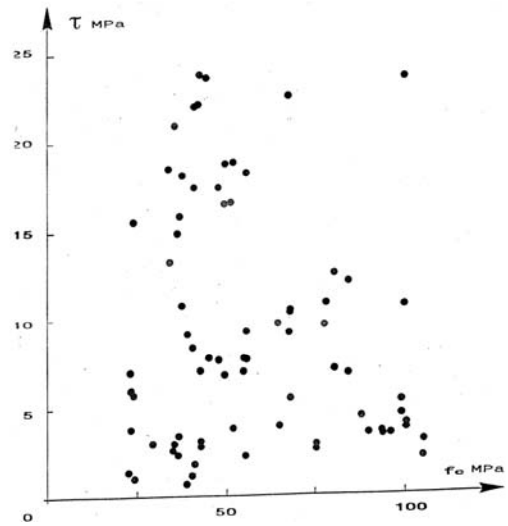
N° de l'éprouvette	Diamètre de l'éprouvette (mm)	c/ø$_s$	F_{max} (N)	Mode de rupture
S211	69	2,875	25260	Fendage longitudinal du béton
S212	69	2,875	25140	Fendage longitudinal du béton
S213	69	2,875	24550	Fendage longitudinal du béton
S221	94	3,916	37710	Fendage longitudinal du béton
S222	94	3,916	37050	Fendage longitudinal du béton
S223	94	3,916	38240	Fendage longitudinal du béton
S1	119,6	4,985	31160	Arrachement de la barre d'acier
S2	119,6	4,985	34950	Arrachement de la barre d'acier
S3	119,6	4,985	37180	Arrachement de la barre d'acier
S231	134	5,583	32920	Arrachement de la barre d'acier
S232	134	5,583	35630	Arrachement de la barre d'acier
S233	134	5,583	30570	Arrachement de la barre d'acier
S241	159,6	6,650	35890	Arrachement de la barre d'acier
S242	159,6	6,650	31560	Arrachement de la barre d'acier
S243	159,6	6,650	34400	Arrachement de la barre d'acier

Slenderness is not enough…not removing the form has been found a good thing

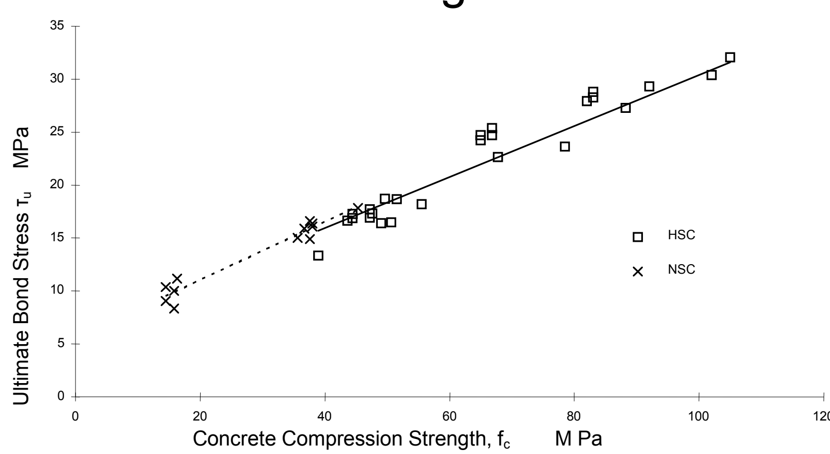
Béton C25/30

N° EP	REp/ϕs	Fmax KN	Mode de rupture
S51	2,875	22,02	ECLATEMENT TYPE FRAGILE SANS CISAILLEMNT DE LA ZONE D'INTERFACE
S52	2,875	27,26	ECLATEMENT TYPE FRAGILE SANS CISAILLEMNT DE LA ZONE D'INTERFACE
S53	2,875	18,42	ECLATEMENT TYPE FRAGILE SANS CISAILLEMNT DE LA ZONE D'INTERFACE
S41	3,916	34,27	ECLATEMENT TYPE FRAGILE SANS CISAILLEMNT DE LA ZONE D'INTERFACE
S42	3,916	38,04	ECLATEMENT TYPE FRAGILE SANS CISAILLEMNT DE LA ZONE D'INTERFACE
S43	3,916	37,35	ECLATEMENT TYPE FRAGILE SANS CISAILLEMNT DE LA ZONE D'INTERFACE
S31	4,985	33,38	ECLATEMENT + CISAILLEMNT DE LA ZONE D'INTERFACE
S21	5,583	42,52	ECLATEMENT + CISAILLEMNT DE LA ZONE D'INTERFACE
S22	5,583	45,05	ECLATEMENT + CISAILLEMNT DE LA ZONE D'INTERFACE
S23	5,583	38,19	ECLATEMENT + CISAILLEMNT DE LA ZONE D'INTERFACE
S11	6,65	43,2	ECLATEMENT + CISAILLEMNT DE LA ZONE D'INTERFACE
S12	6,65	52,12	ARRACHEMENT DE LA BARRE D'ACIER

Bond tests if not performed in an appropriate way are scattered and not reliable



A strong correlation between bond strength and concrete compression strength



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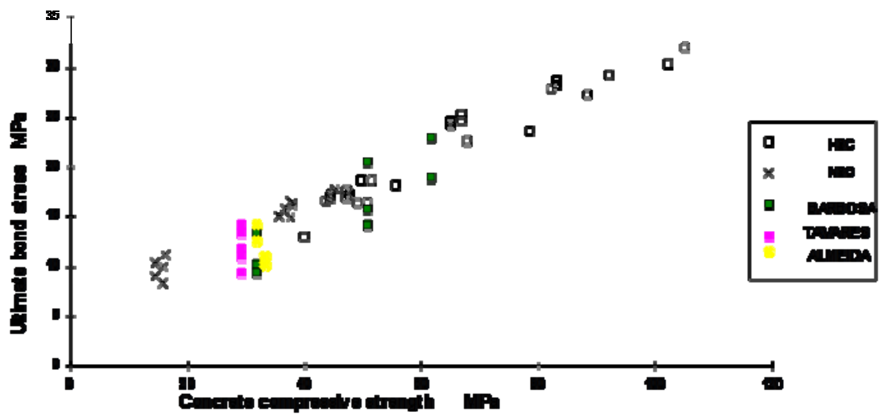

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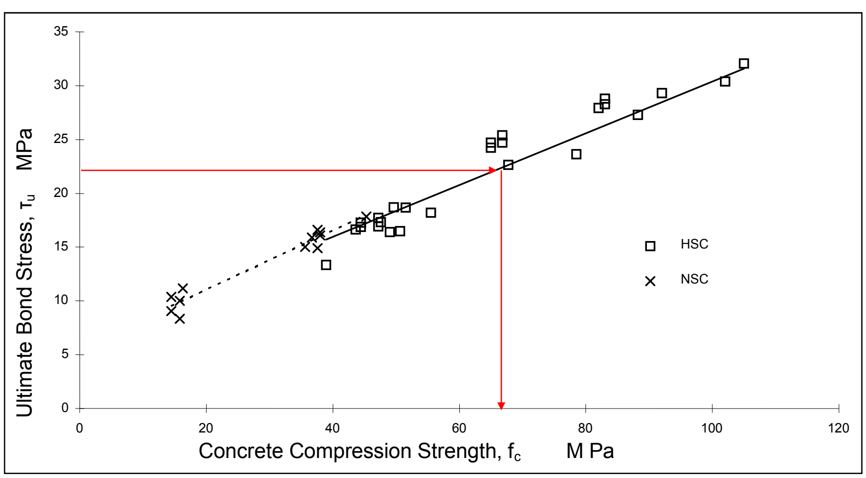
Directions for use to assess concrete quality from bond strength



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6 - FIRST RESULTS OF A FEASIBILITY STUDY

- To check technical feasibility under on-site conditions
- To check easiness to perform, reliability and cheapness

An experimental procedure for on-site tests

- Specimen molded in the plastic shell of mineral water bottles, Φ 8 cm, with ϕ 8 mm max. steel rebar (cf. RILEM –CEB/FIP and Daoud/Makni ENIT 2009)
- Bonded length varying from 8 to 12 cm


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d'Abbat


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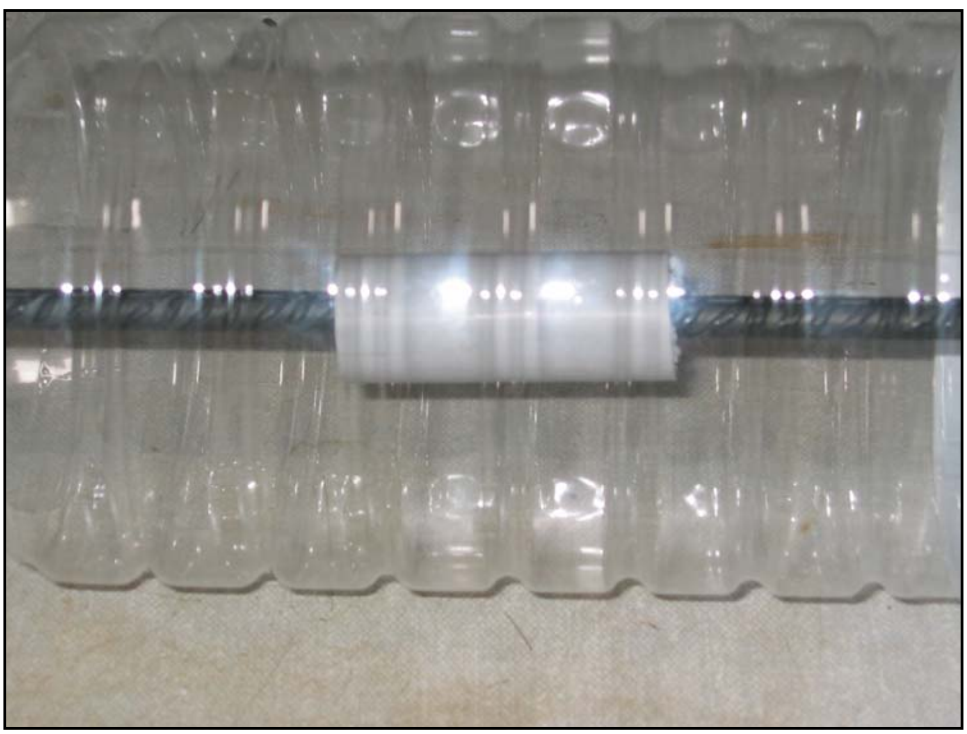
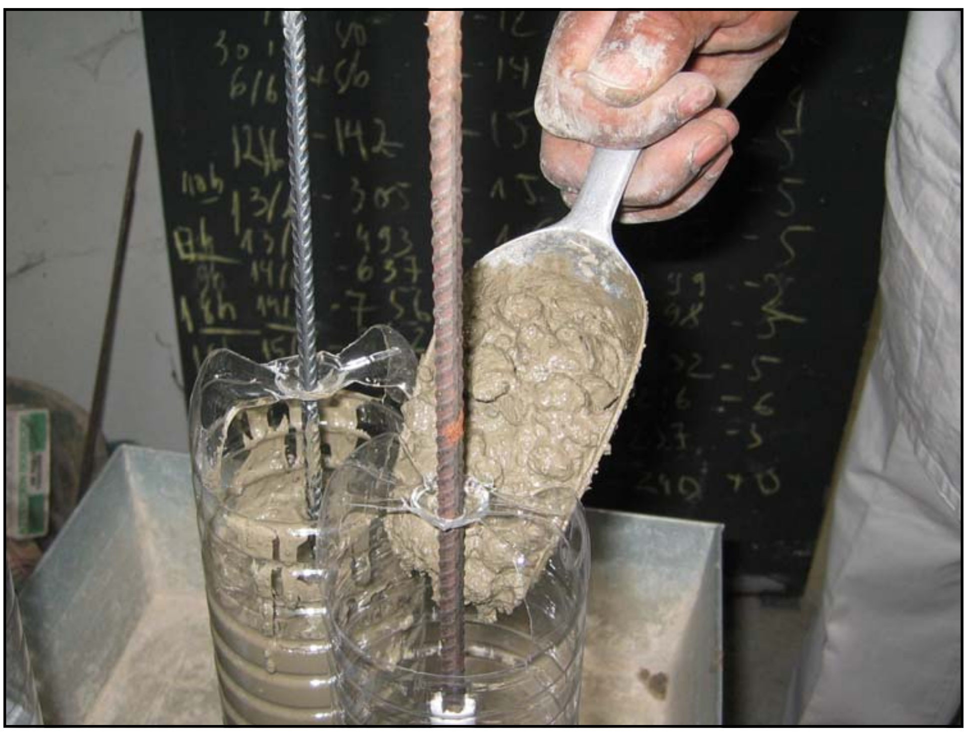
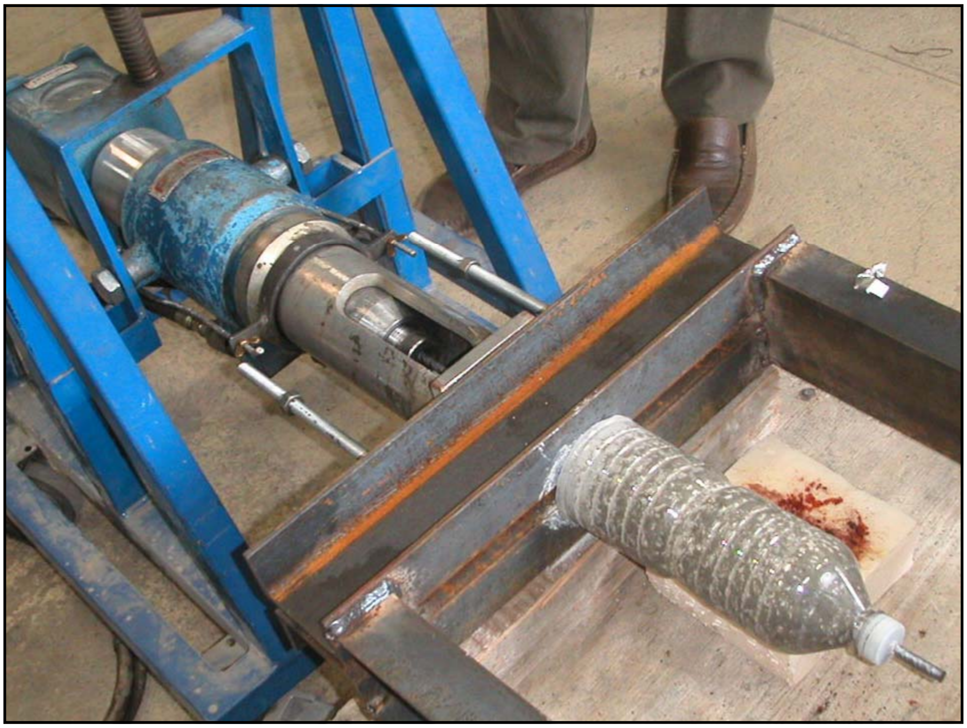
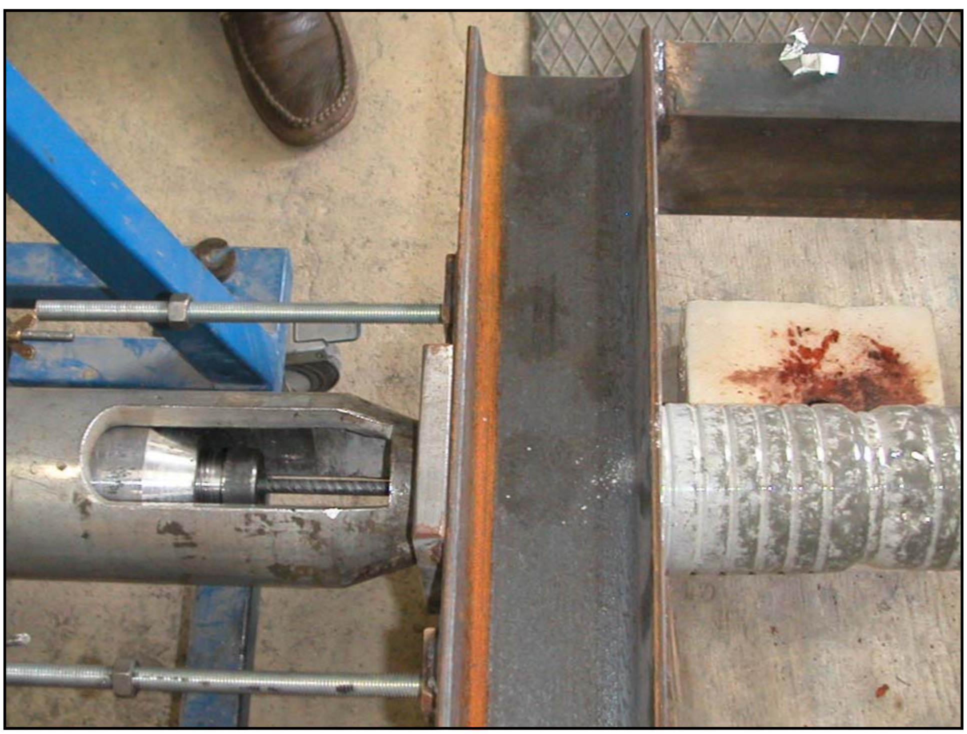





13/6 - 305 - 15
13/6 - 493 - 15
14/6 - 637 - 16
18h 14/6 - 756 - 15
16h 15/6 - 842 - 16
16h 16/6 - 1016 - 18
18h 19/6 - 2337 - 20
15h 24/6 - 2952 - 16
16h 26/6 - 3308 - 12


avril





The first results…

- P.O.T on « bottled » specimen 7 to 14 days old, rebar diameters varying ϕ 6, ϕ 8 mm, σ_{bc28} around 40 MPa, bonded length 8 cm, were performed in INSA Toulouse (France) and ENI Gabès (Tunisia)
- Observed:

  * no splitting failure

  * always bond-slip failure

  * standard-deviation: 0,5 MPa

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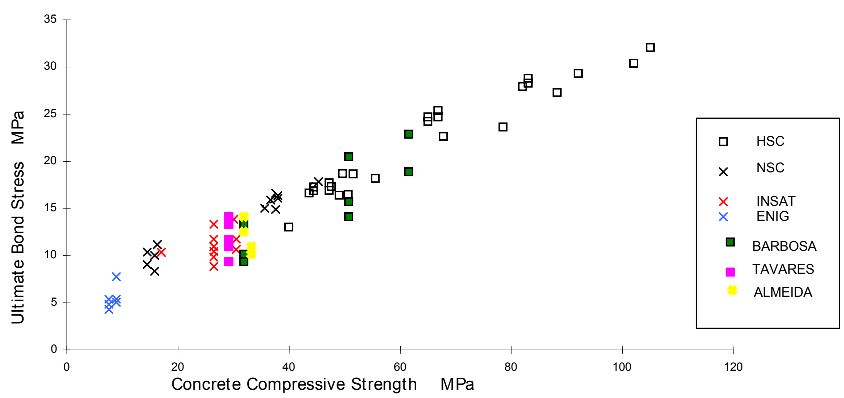
Fitting with previous correlation curves



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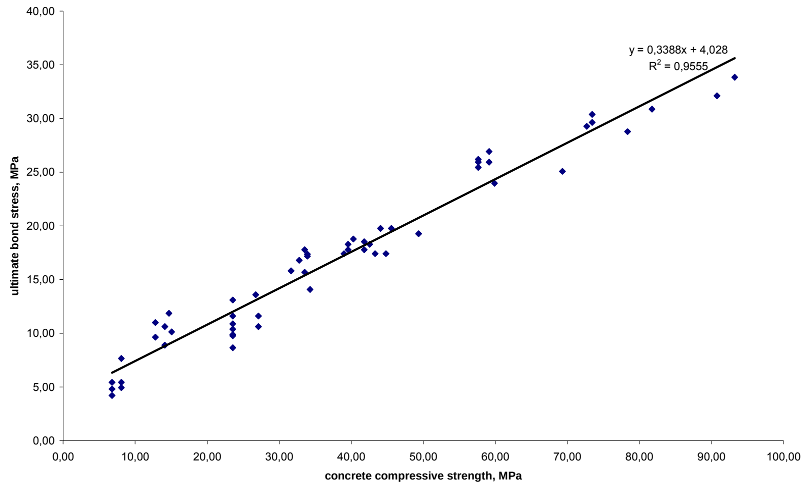

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CONCLUSIONS

- Both quality control and structural calculations are concerned by concrete compressive strength
- Bond strength also has to be checked to insure efficient force transfer inside the composite
- All this data can be given through a single bond test, appropriate P.O.T for instance, easy to perform, cheap, reliable and available on-site.

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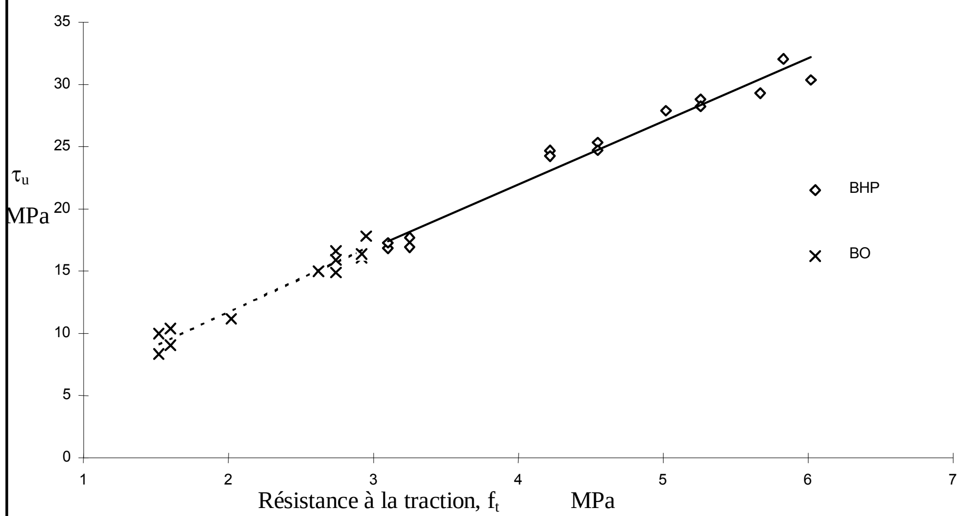
FUTURE PROSPECTS

To meet the compulsory requirements for standardization, further research must be developed :

- FEM study to confirm the specimen features
- Experimental intensive investigation in different places with different concrete and deformed bars to enable statistical processing

THANK YOU FOR ATTENTION



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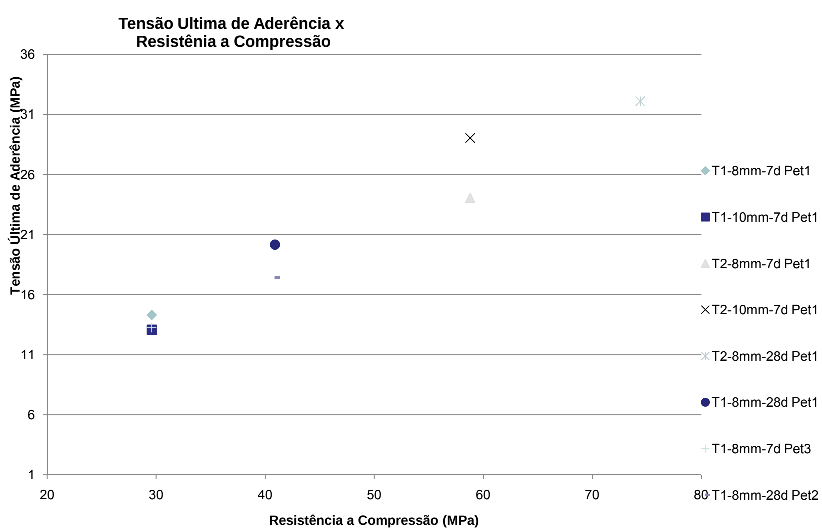

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