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DUAL-PHASE STEEL REINFORCING BARS FOR MRFS STRUCTURES IN SEISMIC PRONE AREAS

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Abstract. *Reinforced concrete structures in seismic areas are designed according to the capacity design approach, aiming to achieve ductile global collapse mechanisms dissipating the seismic energy through high deformations in correspondence of the ends of beams and columns. The global dissipative capacity of the building is related to the rotational capacity of sections and to the ductile properties of reinforcing bars. TempCore steel is used for RC constructions, due to its optimal strength and ductility properties and to the satisfaction of Eurocode 8 requirements concerning A_{gt} and R_m/R_e. Several studies in the current scientific literature anyway highlighted durability problems of TempCore bars exposed to corrosion conditions, with loss of ductility and strength even below the standards requirements. Dual-Phase (DP) steels, characterized by excellent mechanical and durability properties due to their Ferrite-Martensite microstructure and commonly adopted in the automotive sector, can be a possible solution to the problem. The possibility to produce DP rebars for RC structures is deeply analyzed in the European research project NEWREBAR "New Dual-Phase steel reinforcing bars for enhancing capacity and durability of anti-seismic moment resisting frames", actually ongoing. The elaboration of new technical models for the design of RC elements, to be implemented in design guidelines and standards, is needed. In the present paper, preliminary results are presented concerning the selection of DP steel bars and the definition of technical models for RC elements with DP reinforcements.*

1 INTRODUCTION

Reinforced Concrete (RC) buildings in seismic areas are designed following the *capacity design* approach ([1]-[2]-[3]): structures shall satisfy the deformation requirements due to seismic action without the exhibition of significant losses of strength and stiffness and dissipating the stored energy through high inelastic deformations in selected dissipative regions, located, in the case of Moment Resisting Frames (MRF), at the end of beams and columns and known as 'plastic hinges'.

The dissipative capacity of the building (i.e. structural ductility μ_d) is directly related to the element ductility (in terms of rotation $\mu_\theta=\theta_u/\theta_y$), to the section ductility (in terms of curvature $\mu_\chi=\chi_u/\chi_y$) and to the material ductility (in terms of deformation $\mu_\varepsilon=\varepsilon_u/\varepsilon_y$): the ductile capacity of steel reinforcing bars is then needed for the global ductile behaviour of RC buildings.

In this context, actual technical codes prescribe the adoption of bars with minimum requirements of the mechanical parameters, in terms of yielding and tensile strength (R_e and R_m), elongation at maximum load (A_{gt}) and hardening ratio (R_m/R_e): Annex C of EN1992-1-1:2005 [4] defines three different ductility classes for bars (A, B and C), characterized by increasing levels of minimum A_{gt} and R_m/R_e, while Eurocode 8 [1] limits the employment of class B to buildings realized in Medium Ductility Class (MDC). The *design* prescriptions imposed by Eurocodes and National technical standards reflect into a large variety of steel grades – with different levels of yielding strength, ductility and hardening ratio – whose *production* is governed by several standards, valid at Country level, that highlight the pressing need to harmonize strength/ductility classes and testing procedures .

Nowadays, the most diffused typology of steel reinforcements in Europe, satisfying the mechanical requirements imposed by design standards, is TempCore steel. The TempCore production process, characterized by two following phases of quenching and tempering, provides optimal mechanical characteristics without the addition of chemical elements, consequently keeping the production costs acceptable if compared, for example, to Micro-Alloyed steels. These two aspects allowed, during the last decades, the wide spread of TempCore bars for the realization of RC buildings in seismic prone areas.

Recent works in the current literature ([6]-[7]-[8]-[9]) evidenced durability problems of TempCore rebars, with relevant drops of ductility and dissipative capacity, respectively expressed in terms of A_{gt} and dissipated energy (total and per cycle) in the case of monotonic and cyclic/seismic behaviour. The decrease of the strength, as widely described in [10], was otherwise, less significant. The analysis of the results of experimental data on a representative sample of corroded bars allowed the correlation between Performance Indicators (i.e. mechanical performances) and Corrosion Damage Indicators (i.e. mainly mass loss) and the following estimation of the reduction of mechanical properties after the exposure, for a certain period, to aggressive environmental conditions such as the ones defined according to Eurocode 2 [4]. The effects of corrosion phenomena, as presented in the current scientific literature [11], are translated on a global reduced structural performance of RC buildings, related to the decrease of the mechanical properties of materials (both steel reinforcing bars and concrete [9]-[10]-[12]), to the reduction of the cross section of steel rebars and to the cracking and spalling of the concrete cover, with the following loss of bond between concrete and steel bars, as widely reported in [13].

Despite the possible overcoming of such problems through the adoption of, for example, higher concrete classes, thicker concrete covers, reinforcements with higher uncorroded properties and/or higher diameters as suggested in [10] and [14], actual trends in the current scientific literature are directed to avoid of the corrosion initiation and propagation and, at the same time, to select materials less exposed to durability problems.

Basing on the these considerations, taking into account the need to exploit sufficient ductility in RC elements through reinforcing steels characterized by high mechanical performance and, at the same time, the significant decrease of the mechanical properties of corroded TempCore rebars, during the last years the scientific interest in the possibility to adopt Dual-Phase (DP) steels for reinforcement strongly increased ([15]-[16]).

DP steel, widely used in the automotive industry, are characterized by excellent ductile properties (high hardening ratio and values of ultimate deformation) and improved durability properties towards aggressive environmental conditions respect to traditional reinforcing steel embedded in concrete [17], due to their specific microstructural configuration showing the co-existence of a Ferrite matrix in which Martensite is directly embedded.

Preliminary investigations dealing with the use of DP steels in RC structures [16] showed the improved performance of sections in terms of moment-curvature relationship, with curvatures higher and less localized than in the case of reinforcement with TempCore rebars.

Despite the high potential of DP steels, actually two main aspects limit their possible application in the field of civil engineering: the first one is related to the production process, nowadays foreseeing the realization of DP steels mainly into sheets or plate products, the second one concerns the need to modify/improve actual design codes with technical models and guidelines able to allow the adoption of steels characterized by a different behaviour respect to the one basing on which codes are developed. DP steel present, in fact, a higher hardening ratio and strength/ductility properties that are not aligned with the limitations imposed by Eurocodes ([1]-[4])

Basing on what herein stated, a deep investigations of the behaviour of DP steel reinforcing bars for their potential application to RC constructions is needed and is going to be developed in the main context of the European research project NEWREBAR "*New Dual-Phase steel reinforcing bars for enhancing capacity and durability of anti-seismic moment resisting frames*" (2015-2019), funded by the Research Fund for Coal and Steel (RFCS) of European Commission. In the present paper, first, absolutely preliminary, results obtained in the project are presented.

2 SELECTION OF DP STEEL REINFORCING BARS

DP steels present a composite microstructure, made up of a ductile Ferrite matrix, providing high ductility, in which a second hard Martensite phase, responsible for the strengthening effect, is embedded. The difference from usual composite materials is that in DP steels there is no clear interface between the matrix and the reinforcing structure, such as, for example, in the case of TempCore steel.

DP microstructure can be produced as-rolled or by intercritical annealing (in alpha-gamma α-γ field) after cold-rolling. Actual literature data are related to DP rebars produced in batch process, by means of intercritical quench of hot rolled bars, with a first heating step within the intercritical region (where nucleation occurs in the Ferrite matrix of Austenite with a carbon content higher than the nominal one) and a following rapid cooling phase, allowing the transformation of the Austenite into Martensite ([15]-[18]). The intercritical quenching process generates a harder phase into the Ferrite matrix, which causes (partly due to the considerable volume differences) high residual stresses and the increase in the density of the mobile dislocations in correspondence to the Ferrite–Martensite interface. The particular mechanical behaviour of the DP steel generates from the formation of a two-phase Ferrite–Martensite structure.

In the worldwide scenario anyway, DP rebars (and, in general, DP long products) are not yet produced through a continuous process: although the batch process is able to obtain the desired microstructure, this is actually not economically advantageous.

Stating the above mentioned considerations, NEWREBAR research project foresee two main objectives: the first, that can be considered as a '*short-term*' objective, aims at producing DP steels fulfilling actual European design standards' requirements but improved towards seismic performance and structural durability, consequently directly usable as reinforcing elements for RC buildings. The second, a '*medium-term*' objective, aims at characterizing DP steels with optimal mechanical and durability properties also not fulfilling Eurocodes' indications and for which, consequently, specific guidelines need to be elaborated.

To these aims, the procedure briefly summarized in the following pages has been adopted.

2.1 Selection of chemical compositions

The analysis of the steel bars actually produced at European level (executed thanks to the direct participation of steel producers to the research project) allowed to determine the different combinations of the main elements (C, Mn and Si) to obtain DP microstructures suitable to achieve the desired objectives. Specific thermal cycles were, moreover, detected to obtain different Martensite amounts and morphologies, directly influencing the mechanical properties.

Numerical simulations using *ThermoCalc®* software were executed to evaluate the influence of the intercritical austenitization treatment temperature (i.e. 'intercritical temperature') on low carbon DP steels. Various chemical compositions (maximum, medium and minimum values of range) were simulated getting the relative state diagram and consequently estimating the volume fraction and Carbon content of the two phases, when the steel is subjected to intercritical austenitization treatment in a temperature range 740÷840 °C (i.e. in the α-γ field). The different intercritical austenitization temperatures allowed to obtain microstructures with different phase fractions and mechanical properties.

The two most influencing chemical components, as known, were Manganese (Mn) and Silicon (Si). Manganese (Mn) is the fundamental element in DP, added to increase Austenite fraction promoting adequate hardenability, necessary for Martensite formation during the rapid cooling stage (i.e. quenching). Silicon (Si), on the other hand, is useful to increase the strength of solid solution and the ductility of Ferrite phase, inhibiting the precipitation of cementite at the Ferrite–Martensite interface during the water cooling stage. The chemical compositions considered for the simulations are presented in Table 1.

Table 1: Chemical composition used for ThermoCalc simulations.

		C (%)	Mn (%)	Si (%)	P (%)	S (%)	Cu (%)	N (%)
Type A	Min	0.08	0.35	0.12	-	-	-	-
	Max	0.12	0.55	0.20	0.035	0.045	0.50	0.012
Type B	Min	0.16	0.60	0.12	-	-	-	-
	Max	0.20	0.70	0.20	0.035	0.045	0.50	0.012
Type C	Min	0.18	0.95	0.15	-	-	-	-
	Max	0.22	1.05	0.25	0.045	0.045	0.60	0.012
Type D	Min	0.18	1.20	0.20	-	-	-	-
	Max	0.22	1.30	0.30	0.045	0.045	0.60	0.012
Type E	Min	0.06	1.40	0.80	-	-	-	-
	Max	0.08	1.50	0.90	0.020	0.020	0.10	0.009

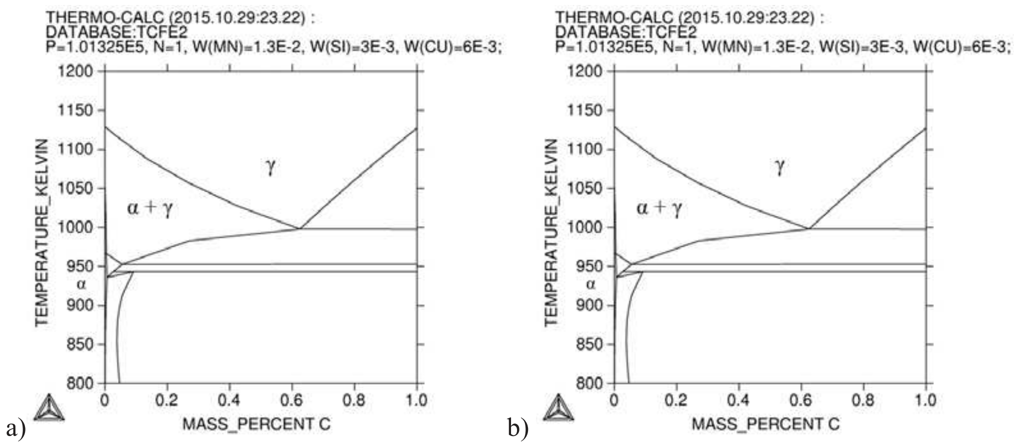


Figure 1: State diagrams from ThermoCalc simulations: a) effect of Mn on state diagram for steel type D - Mn = 1.20 ÷ 1.30 %, b) effect of Si on state diagram for steel type D - Si = 0.20 ÷ 0.30 %.

The carbon content (C_γ) formed in the Austenite following heating in the intercritical field, responsible for the hardenability of the phase in the following cooling stage of quenching, was evaluated through the lever rule as presented by Equation (1):

$$C_{base} = C_\gamma \cdot \gamma\% + C_\alpha \cdot \alpha\% \qquad (1)$$

Being C_{base} the Carbon content in the base steel, C_α the weight percentage of Carbon in the α phase, *γ%* the Austenite content and *α%* that of the Ferrite in the intercritical field.

Due to the absence of diffusion processes during the phase transformation, the chemical composition of the Martensite is identical to that of the Austenite from which it is formed. The Carbon content of Martensite, determining its hardness and shape, depends on the nominal content of the base steel and the intercritical quenching temperature.

Basing on the results of simulations on DP chemical compositions presented in Table 1, three intercritical temperatures, respectively equal to 740, 760 and 780°C, were selected to achieve different Martensite volume fractions ranging from about 5 % to 30 %.

2.2 Determination of the optimal thermal cycle

The main aim of this first part of the research consists in the ‘transformation’ of TempCore steel bars into DP ones: this operation can potentially allow the direct re-use of actual industrial plants for the realization of specimens with optimized mechanical performances and slight modifications of the production sequence.

A preliminary thermal cycle, in the following named A1, was selected for the production of DP steel reinforcing bars starting from the typical TempCore process and aiming to achieve the *‘short-term’* objective, that means to realize steel bars following the actual standards’ requirements but with improved mechanical properties – especially concerning ductility and durability. Beside the chemical compositions listed in Table 1, after preliminary mechanical and metallurgical tests, an additional one (type F) was introduced for the production of the specimens, as summarized in Table 2.

Table 2: Chemical compositions of produced casts for transformation into DP steels.

Cast	ID	C %	Mn %	Si %	P %	S %	Cr %	Ni %	Mo %	Cu %	V %	N %	C_{eq} %
9076/15	A	0.09	0.5	0.17	0.015	0.012	0.1	0.13	0.03	0.35	0	0.009	0.23
8929/15	B	0.17	0.78	0.16	0.014	0.013	0.07	0.22	0.05	0.28	0	0.012	0.36

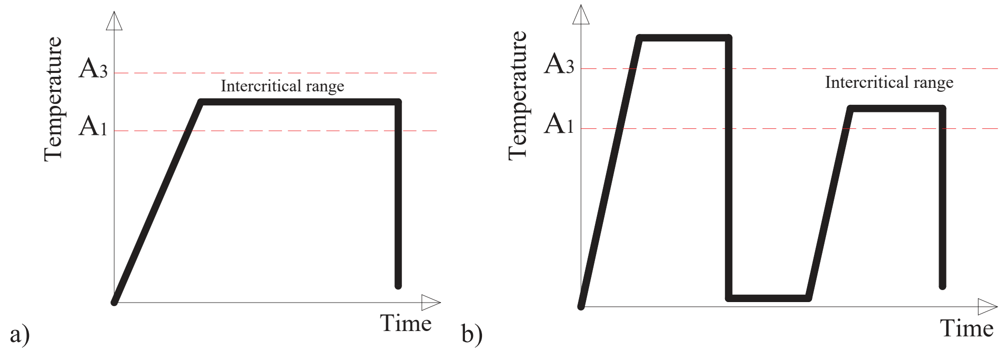
8254/15	C	0.18	1.01	0.21	0.035	0.017	0.1	0.12	0.02	0.35	0	0.011	0.4
8977/15	D	0.21	1.27	0.29	0.025	0.021	0.08	0.12	0.02	0.31	0	0.009	0.47
1760/16	E	0.1	1.14	0.12	0.015	0.01	0.04	0.05	0.01	0.14	0	0.011	0.31
2048/16	F	0.15	1.01	0.2	0.019	0.031	0.07	0.13	0.03	0.35	0	0.012	0.37

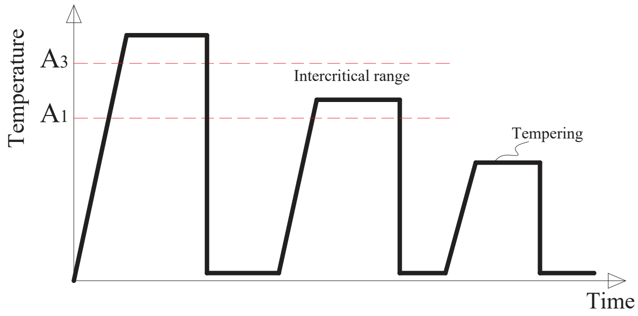
Thermal cycle A1 is represented in Figure 2a: after the industrial *Thermex* process (austenitization + quenching) the specimens are introduced and maintained in the laboratory furnace at the prescribed intercritical temperature (i.e. 740°C, 760°C or 780°C) for one hour. After this, the intercritical quenching is applied, introducing the specimens in a container with water kept at controlled temperature (between 10 and 35°C); samples are then removed after about 10 minutes.

The application of A1 process highlighted several problems: in some cases specimens provided low values of the yielding strength (i.e. steels A and B, with R_e around 300 MPa and R_m/R_e higher than Eurocode 8 prescriptions) or low values of the A_{gt} (i.e. steels C and F, with values around 6%). Several mechanical transformations were then adopted to increase R_e and A_{gt}, respectively applying a *stretching process* with deformation between 1% and 2% (i.e. producing the increase of R_e and the decrease of R_m/R_e) or a *tempering process* with temperatures between 400 and 600°C (i.e. producing the decrease of the R_m and the increase of A_{gt}). The mechanical properties, after such treatments, allowed the achievement of the short-term objective, presenting a traditional stress-strain behaviour with values of Agt and hardening ratios aligned with actual Eurocodes' requirements. Anyway, the microstructural analyses still evidenced the presence of an external layer of Martensite, with internal DP microstructure: this negatively affects the corrosion performance of bars with the following need to determine of a different thermal cycle, as presented in Figure 2b.

In this cycle, named A2, the original specimens (coming from Thermex process) are firstly kept in the furnace at 900 °C for 1.0 hour and then immediately put in water tank at room temperature until the reaching of the total cooling. An intercritical quenching (temperature 750°C) is finally applied. The annealing process with high temperatures allows to completely destroy the TempCore effects and to finally obtain a traditional DP microstructure associated to a not-defined yielding stress-strain curve.

Obtained specimens can be also finally tempered (600°C for 1h), achieving high values of the mechanical properties and keeping, moreover, a defined yielding stress-strain curve. This last thermal cycle (Figure 2c) will be called, in the following, cycle A3.





c)

Figure 2: Thermal cycles selected: a) preliminary A1 cycle and b) thermal cycle A2 (note that intercritical quenching temperature has different values for cycle A1 and A2) and c) application of tempering after intercritical quenching (cycle A3).

2.3 Production and treatment of DP specimens

Dual-Phase steel reinforcing bars were then produced starting from TempCore specimens ϕ16 mm following the thermal cycles depicted in Figure 2b and Figure 2c (being the only difference among cycles A2 and A3 the final application of the tempering process). It's necessary to underline that consistent differences were revealed producing specimens in *laboratory*, where the production and the thermal cycles can be controlled step by step with high accuracy concerning temperatures and exposure times, and specimens directly produced in an *industrial plant*, where, despite the slavish reproduction of the different stages, the outcomes cannot be so deeply controlled. DP specimens produced both in laboratory and in a real industrial plant were then subjected to mechanical test aiming at determining the ductility and strength properties of obtained reinforcing steels.

2.4 Mechanical tests on produced DP specimens

Experimental tests, including monotonic tensile and Low-Cycle Fatigue (LCF) tests were executed on produced specimens following the prescriptions of EN15630-1:2010 [19] and the protocol elaborated in a previous research project [14] and already used as presented in [9] and [10]. The results of monotonic tensile tests are summarized in Figure 3 and in Table 3, comparing obtained data with the behaviour of TempCore reinforcing steels B500B and B450C; Figure 4 and Table 4 briefly summarize the results of LCF tests (executed, until now, only on specimens produced following cycle A3).

Results presented are related to 'DPF' specimens (i.e. rebars produced following thermal cycle A3 through an industrial process) and to 'DPlab' specimens (i.e. rebars with chemical composition type C produced in laboratory following thermal process A2).

The thermal processes previously illustrated, allow the achievement of optimal values of mechanical properties. In particular, DPF can be used to satisfy the '*short-term*' objective while DPlab can be adopted to satisfy the *'medium-term*' objective.

DPF shows excellent ductile performance in terms of A_{gt}, with values around 16% respect to the average value of 10% of TempCore and a stable cyclic behaviour. In this sense, it is necessary to underline that, as visible from Figure 4, the values of the yielding and ultimate strengths are lower than the one of TempCore bars, consequently resulting in a lower amount of total dissipated energy, anyway not associated to a more brittle behaviour of the specimens.

DPF, moreover, is directly able to satisfy the ductility requirements of actual European design standards concerning minimum values of A_{gt} and, in particular, hardening ratio R_m/R_e, being than able to pursue the '*short-term*' objective of NEWREBAR research project.

Similar considerations can be executed also in the case of DPlab steel reinforcing bars, characterized by the 'traditional' not-defined yielding stress-strain curve with values of A_{gt} around 18% and, otherwise, an hardening ratio R_m/R_e equal to 2.04 and consequently higher than the one actually foreseen by European standards.

Specimen	R_e [MPa]	R_m [MPa]	R_m/R_e [-]	A_{gt} [%]	A_5 [%]
DPF	449.4	564.8	1.26	16.3	30.5
DPlab	391.8	799.4	2.04	18,6	24.0
B500B	560.7	653.6	1.17	11.7	23.6
B450C	517.1	613.2	1.19	13.6	27.6

Table 3: Average values of the mechanical properties of reinforcing steels DP and TempCore from tensile tests.

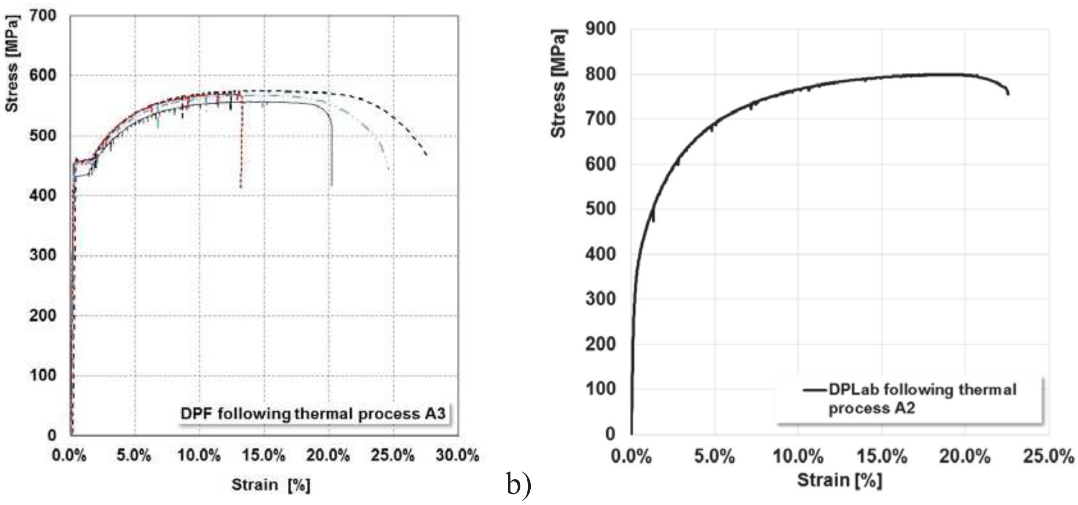


Figure 3: Experimental stress-strain diagrams for: a) DPF specimens (thermal process A3 – short term objective) and b) DPLab specimens (thermal process A2 – long term objective).

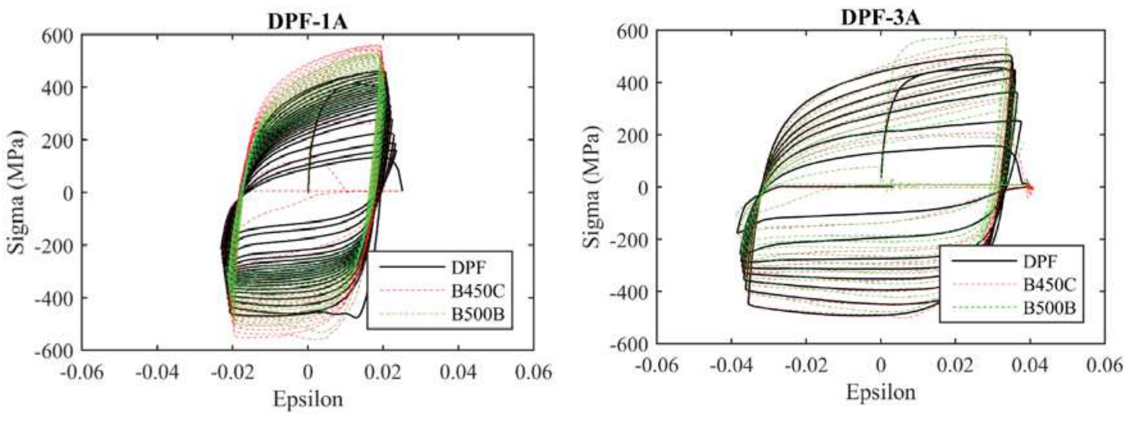


Figure 4: Results of LCF tests on DP steel type F with testing frequency equal to 0.5 Hz, imposed deformation equal to ±2.5% and ±4.0% and free length of the specimen equal to 6 diameters, compared with TempCore bars.

Steel grade	$\Delta\varepsilon$	L_0	Energy [MPa]	N_{cycles}
DPF			360	21
B450C	2.50%	6ϕ	545	19
B500B			530	19

Steel grade	Δε	L_0	Energy [MPa]	N_{cycles}
DPF			325	9
B450C	4.00%	6ϕ	639	16
B500B			373	9

Table 4: LCF tests on DPF in terms of dissipated energy and N_{cycles} to failure compared to TempCore bars.

3 INFLUENCE OF DP STEEL ON THE STRUCTURAL PERFORMANCE

In order to evaluate the influence of the adoption of DP steels on the structural performance of RC elements, a preliminary investigation of the moment-curvature (M-χ) and moment-rotation (M-θ) behaviour of typical RC sections was executed through a parametric analysis varying size and geometry of sections and elements, type, disposition and amount of longitudinal and transversal reinforcements, percentage of reinforcements (ρ and ρ_{st}) and axial load acting on the element.

A typical cantilever column, as designed following actual Eurocode 8 prescriptions for RC buildings, has been selected and subjected to pushover analyses. The two previously identified types of DP steels (DPF and DPLab) were considered for reinforcing bars; the comparison with TempCore steel grade (B500B) was also executed.

The cantilever element is a half column 1.80 meters height, with square section 50x50 cm^2, a total longitudinal reinforcement ratio ρ=2% and a total transversal reinforcement ratio ρ_{st}=0.7%. The ratio between the height of the element (H) and the depth of its section (h) is equal to 3.6.

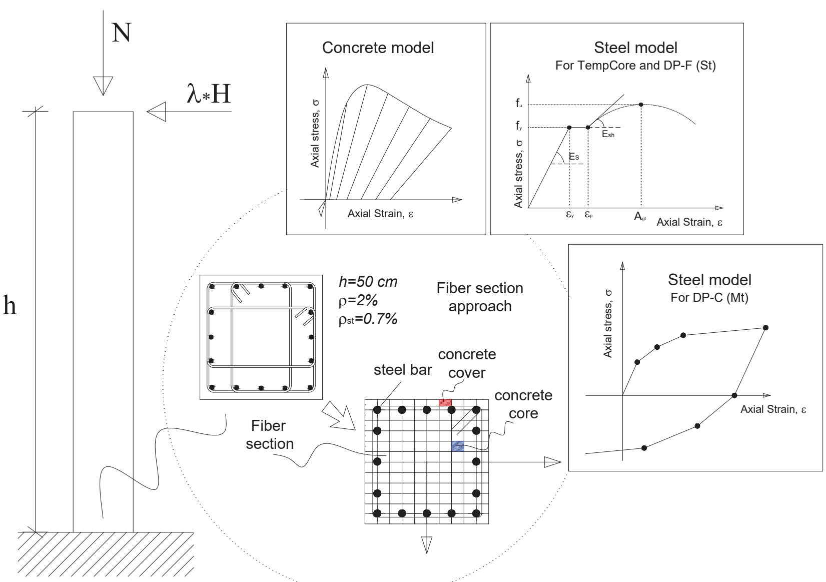


Figure 5: Scheme of the cantilever column considered in the analysis and of material models adopted.

Numerical models were realized using OpenSees software adopting a fiber approach for sections. The Popovics material model [20] was used for concrete with values of strength and deformation defined according to [21]; TempCore and *DPF* steel bars – with defined yielding plateau - were modeled using a elasto-plastic with hardening law with mechanical parameters defined according to average values coming from experimental tests. For *DPLab*, characterized by a not-defined yielding stress-strain curve, as presented in Figure 5, a multilinear law was adopted. A simple schematization of the considered element and materials is presented in Figure 5.

Sections and elements were analyzed considering, as ultimate conditions for the determination of the M-χ and/or M-θ curves, the failure of the concrete core, or, otherwise the achievement of the ultimate tensile deformation in correspondence of the steel reinforcing bars, as simply presented in Figure 6. Figure 7 and Figure 8 show the M-χ diagrams obtained for a base square section 50x50 cm with ρ=2% and ρ_{st}=0.7% with, respectively, no axial load acting on the column and axial load equal to the 30% of the ultimate strength.

Obviously, there is a strong difference in the behaviour of sections/elements with or without axial force: in the first case (Figure 8) the failure is associated to the achievement of the maximum deformation in correspondence of the concrete core, for all the typologies of steel reinforcing bars considered; in the second case (Figure 7) the failure is associated to the achievement of the ultimate deformation of rebar in tension and, in particular, in the case of DPLab, it is possible to observe a quite 'balanced' failure mechanism associated to a balanced exploitation of concrete and steel ductile properties.

As visible from figures presented below, low values of the axial force and relatively small amount of longitudinal reinforcement (ρ=2%) are related to ductility, both in terms of curvature and rotation, higher in the case of DP steels than in the case of TempCore bars.

In particular, in the case of axial force equal to zero (N=0) – that is very close to the case of beam elements – the curvature ductility (μ_{χ}) obtained from DPLab and DPF was the 20% higher than the one directly obtained from the adoption of TempCore B500B, with increasing improvement of the ductility in terms of rotation (μ_{θ}).

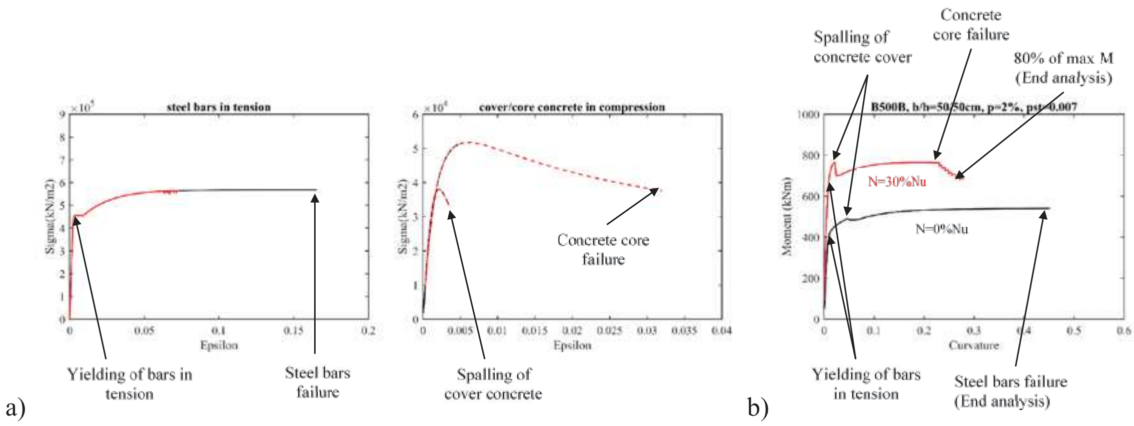
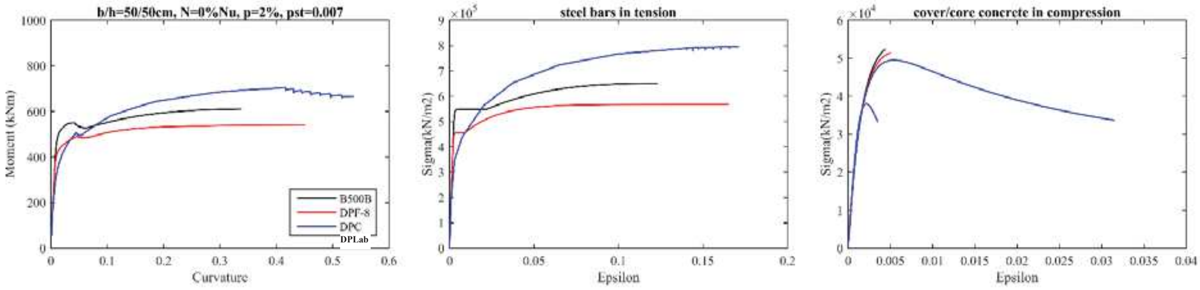


Figure 6: Criteria adopted for the analysis of the M-χ relationships for the considered section: a) stress-strain adopted for steel reinforcing bars and concrete and b) example of M-χ for different levels of the axial force.

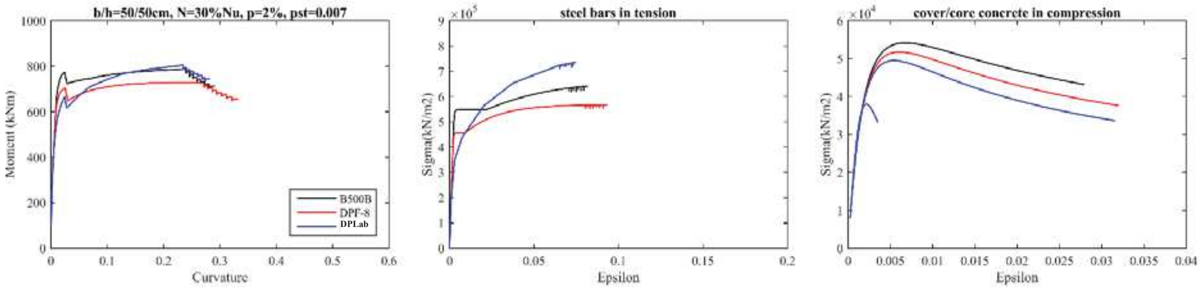
When the axial force is equal zero (i.e. beam condition) column sections failure is led by steel bars in tension, which achieve their ultimate strain (Figure 7b). The unconfined concrete is expelled, while the confined concrete experiences high stresses, without reaching its ultimate strain (Figure 7c). Sections present large curvatures (Figure 7a), allowing higher spread of plastic deformations along the element. This phenomenon produces remarkable plastic hinge lengths, which lead to large displacements and rotations (Figure 9a), especially in the case of DPLab reinforcements, with the highest ultimate strain and tensile strength.



a) b) c)

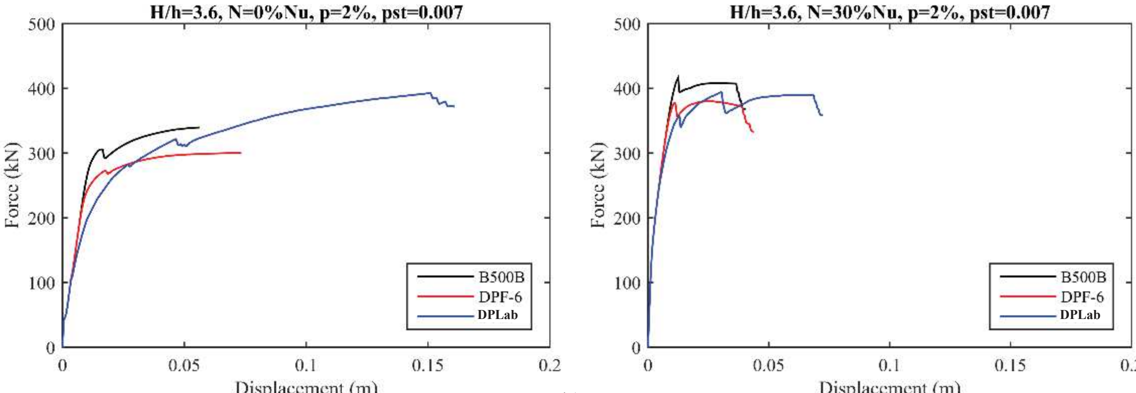
Figure 7: Pushover analysis for zero axial force: a) M-χ of column bottom section; b) stress-strain relationship of steel bars in tension; c) stress-strain relationship of unconfined and confined concrete in compression.

When axial force is applied (e.g. *30%*N_u), column sections failure is led by confined concrete, which manage to achieve its ultimate strain (Figure 8c). Before that, there is spalling of unconfined concrete and yielding of steel bars in tension (Figure 8b), which however don't achieve their ultimate strain. Section presents low curvatures (Figure 8a) and the spread of plastic deformation is contained. Element displacements and rotations are lower than in the previous case (Figure 9b). Among the different steel grades, DPLab is the one with the highest tensile stress, after a certain level of deformation, and ultimate strain. Because of that the element reinforced with this type of steel grade presents the largest bending capacity and ultimate rotation.



a) b) c)

Figure 8: Pushover analysis for compression force 30%N_u: a) M-χ of column bottom section; b) stress-strain law of bars in tension; c) stress-strain law of unconfined/confined concrete in compression.



a) b)

Figure 9: M-θ relationships square section 50x50 a) without and b) with axial force.

4 CONCLUSIONS AND FUTURE WORKS

In the present paper the preliminary results of the beneficial effects of adopting Dual-Phase reinforcing steel for RC elements, in terms of curvature and rotational capacity, are presented.

DP steels, actually adopted for the automotive sector, are provided by optimal performances in terms of ductility, strength and, in particular, durability, becoming a valid alternative to traditional TempCore steels, whose degradation in presence of aggressive environmental conditions has been widely presented in the current scientific literature, with resulting loss of bearing capacity, bond and mechanical properties.

The main aim of the research project in whose framework the actual paper has been developed consists in the possibility to produce DP reinforcing steels starting from original TempCore, selecting opportune chemical compositions and thermal cycles able to improve mechanical and durability properties.

The results of numerical pushover simulations on a simple cantilever column highlighted the higher ductile performance of DP respect to TempCore; anyway, such results can be improved taking into account the effects of relative slip between steel reinforcing bars and surrounding concrete, actually neglected but strongly influencing the structural performance of RC elements.

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