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RELIABILITY IN THE CONCRETE-STEEL BOND STRENGTH UNDER REPEATED ACTIONS.

Mario Collepardi*, Mario Corradi**, Michele Valente**

* Department of Material Science, University of Ancona-Ancona (Italy)

** Research and Development Laboratories, Mac Mediterranea Additivi Cemento, Treviso (Italy)

Abstract - The influence of the vibration time of fresh concrete on the compressive strength and the steel-concrete bond strength under repeated actions was investigated. Stiff no-slump mixes and rheoplastic concretes, with and without superplasticizers respectively,and with the same w/c ratio, were examined. Both ordinary and lightweight aggregates were used. The performances of the no-slump concretes are strongly dependent on the compaction time of fresh mixes, whereas rheoplastic concrete present a bond strength which is substantially independent of the compaction time. When concretes are not fully compacted, the difference in the steel-concrete bond strength between rheoplastic mixes and no-slump ones is much higher than that in the compressive strength of concrete. Lightweight concretes with a specific gravity of about 1600 Kg/m^3 show only a slightly lower bond strength than that of ordinary weight concretes because of the lower w/c ratio used.

Resumé - On a etudié l'influence du temps de vibration du béton frais sur la résistance à la compréssion et sur l'adherence du béton à l'acier sous charges répetées. On a examiné des bétons peu ouvrables sans affaissement au cône de Abrams et des bétons rhéoplastiques respectivement sans et avec des adjuvants superplastifiants et avec le même rapport e/c. On a utilisé les aggrégats normals ou légers. Les résultats obtenus avec le béton sans affaissement dépendent énormément du temps de vibration, tandis que l'adhérence des betons rhéoplastiques à l'acier est pratiquement indépendent du temps de vibration. La différence dans l'adhérence à l'acier entre le béton sans affaissement et rhéoplastique, tous les deux sans ou avec peu de vibration, est plus grande que la différence dans la résistance à la compréssion. Les bétons légers, avec un poid specifique de 1600 Kg/m^3, ont une adhérence à l'acier qui est seulement un peu plus basse que celle des bétons normals, et ceci peut-être attribué au bas rapport e/c.

INTRODUCTION

Concrete-steel bond strength depends on the composition of the concrete, particularly on the water/cement (w/c) ratio of the mix, and the type of aggregates. A lower w/c ratio increases the adhesion between cement paste and steel, whilst a more rigid aggregate favors the bond resistance due to the grip.

However, too stiff mixes with relatively low w/c ratios could cause a lower bond strength due to the incomplete compaction of the fresh concrete and then to the lower contact area between steel and concrete. This aspect is particularly important for the high-density reinforcement used in concrete structures in seismic regions. On the other hand, lightweight concretes, which would be very interesting for structures in seismic regions because of the lower elastic modulus and specific gravity, could cause also a decrease in the concrete-steel bond strength for the lower rigidness of the aggregates.

EXPERIMENTAL

Stiff and flowing concretes, both containing ordinary weight aggregates, were prepared. An improved superplasticizer NSF polymer based (Rheomac)was used in order to transform the stiff control mix into a rheoplastic (flowing and unsegregable) concrete (I-4) with the same w/c ratio (Table I).

Table I - Composition (Kg/m^3) of concretes

Composition	No-slump concrete	Rheoplastic concrete	No-slump concrete	Rheoplastic concrete
	ordinary weight		lightweight	
Type I Cement	355	358	350	347
Sand	990	995	493	638
Gravel (5-I9 mm)	990	995	-	-
water	I74	I72	I40	I40
w/c	0,49	0,48	0,40	0,40
Expanded clay (I-3 mm)	-	-	380	I94
Expanded clay (3-8 mm)	-	-	250	29I
Rheomac	-	5,9	-	-
Tiamac	-	-	-	5,9
slump	I5 mm	2I0 mm	I0 mm	230 mm
air (% by volume)	I,2	I,3	I,5	7
specific gravity	2509	2520	I6I3	I6I9

The stiff control mix was a no-slump concrete (5) with a slump of I5 mm, whereas the rheoplastic concrete was a selflevelling mix with a slump of 210 mm. Both the mixes appeared unsegregable with a bleeding capacity lower than 0,003.

From the same batch of fresh concrete several specimens were compacted in cubic moulds (100 mm) for different periods of time (0-5-I5-40 sec) on a rigid vibrating table. A frequency of 6000 vibrations per min and an amplitude of 0,I5 mm were used. For each period of vibration, concrete compressive strength and steel-concrete bond strength under repeated actions were measured after a curing of 28 days at 20°C with a R.H. of 95%.

For the steel-concrete bond strength measurements, plain or deformed bars (diameter=I0 mm) were used and the same specimens recommended by RILEM-CEB-FIP pull-out test (Fig.I) were utilized. A repeated tensile stress varying from a minimun of 6.5 N/mm^2 and a maximum of 58.5 N/mm^2 was applied to the bar for 500 cycles with a frequency of 5 Hertz. By taking into account the contact area between steel and concrete this resulted in a bond stress varying from a minimun of 0.32 N/m^2 to a maximum of 2.92 N/mm^2. If the bar was not pulled-out the maximum bond stress was increased by I.5 N/mm^2 for other 500 cycles, while the minimum was mantained at the same level of 0.32 mm^2. Further increases by I.5 N/mm^2 in the maximum bond stress for every 500 cycles were made till to pull-out the bar.

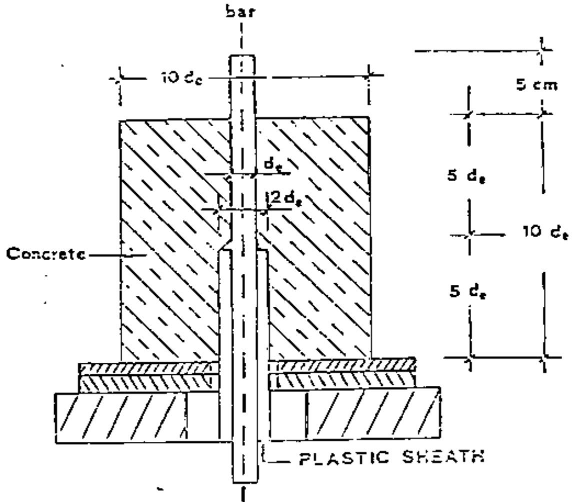

Fig.1 Pull-out test according RILEM-FIP-CEB

Similar tests were carried out on stiff and superplasticized rheoplastic concretes both prepared with lightweight aggregates and by using the same w/c ratio (Table I). A modified superplasticizer NSF polymer based (Tiamac) was used.

RESULTS AND DISCUSSION

In Fig.2 the influence of vibration time of fresh mixes on the compressive strength of hardened concretes is shown. these data confirm (2-4)that,

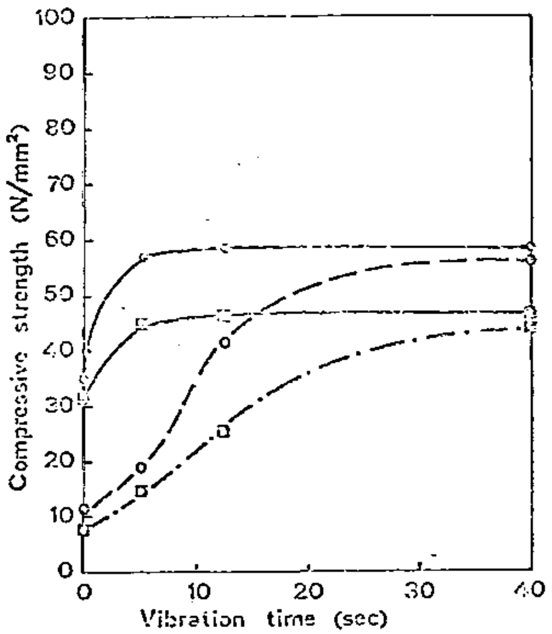

Fig.2 - Compressive strength as a function of the vibration time of fresh concrete.
- o ordinary weight no-slump concrete
- ◘ lightweight no-slump concrete
- • ordinary weight rheoplastic concrete
- ◘ lightweight rheoplastic concrete

for both ordinary and lightweight no-slump concretes, the compressive strength is strongly dependent on the way fresh mixes are compacted. Therefore, the compressive strength of the well compacted specimens prepared for laboratory tests is generally higher than those of the concretes placed into the elements, the difference beeing higher for stiffer mixes and congestioned structures. In the experimental conditions of the present work the highest compressive strength is attained with 40 sec of vibration for no-slump mixes, whereas only 5 sec are required for rheoplastic concretes. A lower vibration time, or possibly no vibration at all, could be required to fully compact when a still more flowable concretes is used, however segregation must be accurately avoided for such a fluid concrete.

In Fig.3-6 the steel-concrete bond strength and the number of repeated cycles to pull-out the bar are shown

The influence of the vibration time on the bond strength between steel and ordinary weight no-slump concrete (Fig.3-4) is approximately the same as that on the compressive strength (Fig.2). For unvibrated ordinary weight

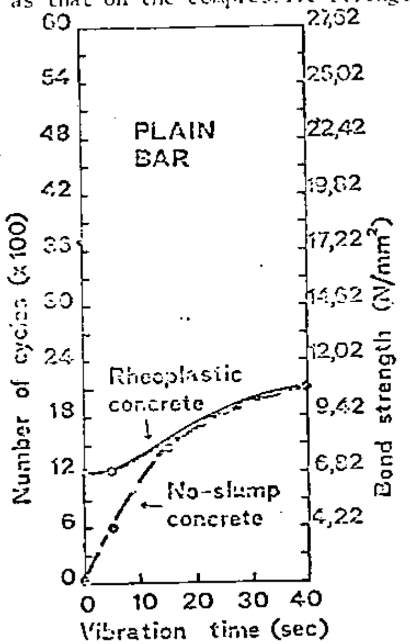

Fig.3 - Number of cycles and bond as a function of the vibration time of ordinary weight fresh concretes (plain bar).

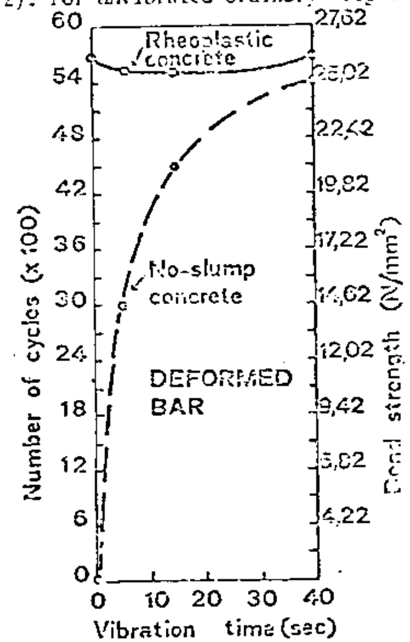

Fig.4 - Number of cycles and bond strength as a function of vibration time of ordinary weight fresh (deformed bar).

no-slump concrete, both plain (Fig.3) and deformed bar (Fig.4) are pulled-out on applying a bond stress much lower than 2.92 N/mm^2 during the first cycle. By increasing the vibration time from 0 to 40 sec, the bond strength and the number of cycles are increased till to attain the values of 10.72 N/ and 2100 cycles respectivelly when the plain bar is used,and the values of 25.02 N/mm^2 and 5400 cycles for the deformed bar. This means that stiff mixes, prepared with a relatively low w/c ratio, are not reliable not only in the compressive strength but also in the concrete-steel bond strength, and this is particularly important when a high-density reinforcement is used as in the concrete structures in seismic regions.

A similar trend is recorded for lightweight no-slump concretes with both plain (Fig.5) and deformed bar (Fig.6). The bond strength and the number

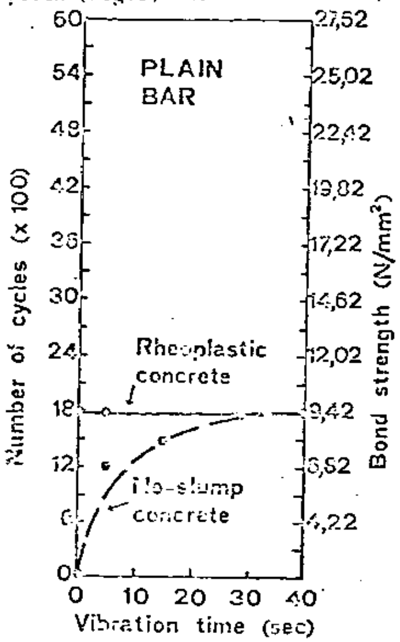

Fig.5 - Number of cycles and strength as a function of the vibration time of lightweight fresh concretes (plain bar).

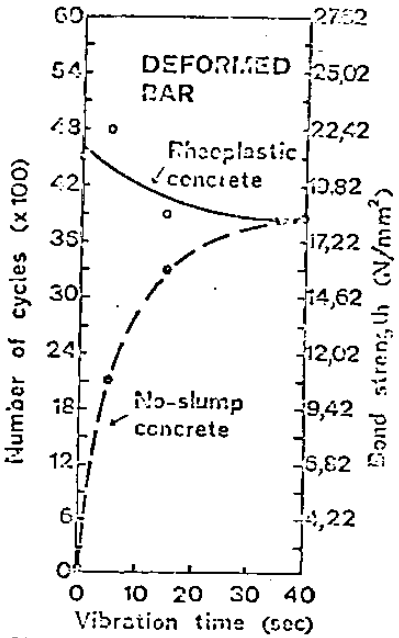

Fig.6 - Number of cycles and bond strength as a function of the vibration time of lightweigtn fresh concretes (deformed bar).

of cycles to pull-out the bar in lightweight concrete is not much lower than the corresponding values for ordinary no-slump concrete. Possibily, the lower w/c ratio of lightweight mix (Table I) partially countebalances the lower rigidness of expanded clay, so that the bond strength between still and ordinary or lightweight concrete are of the same order of magnifitude for the mixes examined in the present work.

Vibration of fresh rheoplastic mixes appears to affect the bond strength (Fig.5-6) to a still lower extent than the compressive strength (Fig.2). This indicates that rheoplastic mixes are much more reliable in the concrete-steel bond strength than the corresponding no-slump concretes with the same w/c ratio. However slightly different behaviour are found depending on the type of bar and the specific gravity of concrete. For example, by increasing the compaction time of the fresh mix, a certain increase in the bond strength is observed when ordinary weight rheoplastic concrete is reinforced plain bar (Fig.3), whereas the same concrete reinforced by a deformed bar seems to be about independent of the vibration time of the fresh mix (Fig.4). When a lightweight rheoplastic concrete is reinforced by a plain bar, the bond strength does not change with the compaction time (Fig.5), whereas for the same concrete reinforced by a deformed bar the bond strength appears to be slightly reduced by a prolonged compaction time of the fresh mix. At the moment it seems to be very difficult to find a theoretical explanation for these different behaviours. Possibly, there are some factors that counterbalance the positive effect of the compaction on the bond strength when rheoplastic concrete are used. These factors could be emphasized when lightweight aggregates instead of ordinary weight aggregates are used or when a deformed bar replaces a plain one. However, from a practical point of view both ordinary and lightweight rheoplastic concretes present a higher bond strength under repeated actions than the corresponding no-slump concrete with the same w/c ratio. The difference is higher for shorter compaction times and is canceled only for fully compacted mixes.

CONCLUSIONS

Concretes prepared with a relatively low w/c ratio show very high bond strength under repeated actions. However, the performances of reinforced stiff mixes such as no-slump concretes are strongly dependant on the compaction time of fresh mixes, whereas rheoplastic concretes containing NSF polymer based superplasticizers show a bond strength which is substantially independent of the vibration time of fresh mixes.

The difference in the bond strength between uncompacted rheoplastic mixes and no-slump concretes is much higher than that in the compressive strength.

Lightweight concretes with a specific gravity of about 1600 Kg/m^3 show only a slightly lower bond strength than that of ordinary weight concretes when the w/c ratio is very low (0,40) as in the case of the present work.

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