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# Flow ability of Cement-Based Recycled Conductive Mortar: Graphite Powder: Recycled Concrete Block with Added Industrial Waste Carbon Fiber

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**ABSTRACT**
The mortar is the homogeneous mixture of a cementing agent, fine aggregate and water. To acquire the denomination of recycled mortar, it is necessary that a fraction or all of aggregate present in it comes from the trituration of construction or demolition waste materials.In the present work, the fluidity of mortars was evaluated after mixing, they were made with 100% recycled aggregate, in addition to the individual addition of carbon fiber in volumetric percentage from 0.1% to 1.5%, samples were also added of 100% graphite powder and 0.1%-1.5% carbon fiber whit water-cement ratios of 0.55 and 0.70 respectively.Resulting in a decrease in fluidity as the percentage of carbon fiber increases, the use of Carboxymethylcellulose, facilitated the dispersion of the fiber in the mortar mixtures.Recycled mortar mixes with graphite powder need a higher water-cement ratio to have a plastic consistency, compared to mixes with only the addition of carbon fiber.
**Keywords**: mortar, fluidity, recycled-aggregate, recycled-mortar, conductive-mortar.

## I. INTRODUCTION

One of the main materials used in the construction industry are aggregates for concrete and mortar. In recent years, approximately 40 billion tons of natural sands have been consumed globally, which has led to an overexploitation of natural resources, causing irreversible damage to the environment.This situation represents an environmental problem that needs to be addressed primarily, considering the use of waste in a comprehensive and sustainable manner. For this reason, the Mexico City environmental standard NACDMX-007-RNAT-2019, in addition to classifying construction and demolition waste, establishes the specifications and requirements for its integral management.

As part of the solution to this situation, the elaboration of conductive recycled mortars is proposed, mortars acquire the status of recycled when a fraction or all of the aggregate present in it is from construction and demolition waste, to become conductive it needs the addition of carbon fiber and graphite powder. One of the most relevant characteristics in mortars is fluidity, since it is a reference of its workability.**[1-5]**.

## II. EXPERIMENTAL PART

*1.1 Materials*

The materials used for the preparation of the mortars were: Portland cement, recycled fine aggregate (RFA) obtained from crushed concrete blocks from local demolition, distilled water, Carboxymethylcellulose (CMC) as dispersant, carbon fiber (CF), graphite powder (GP).

*1.1.1 Specimens of conductive recycled mortar*

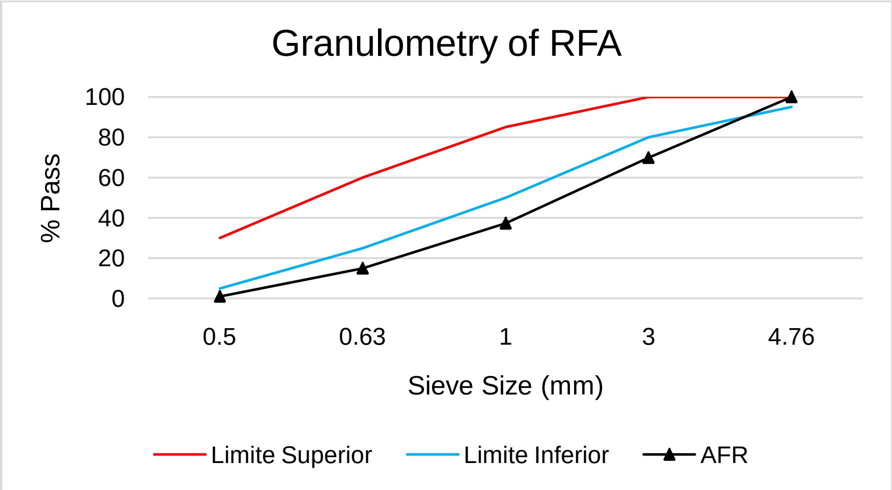
To start the manufacturing process of recycled fine aggregate, the first step was a manual crushing with the support of an iron mallet; this was done to obtain the necessary size to be introduced into the jaw crusher.After manual crushing, we proceeded with the use of a jaw crusher, where the aggregate had to be passed more than once to obtain the desired size. For the purposes sought, the aggregate retained in the No. 4 and No. 50 mesh was selected.

A particle size analysis of the recycled fine aggregate was performed according to ASTM C136 to determine the particle size distribution of the material **[56]**.According to ASTM C33, the fine aggregate may consist of natural sand, manufactured sand or a combination of both **[21].**

As can be seen in Table 28, 100% of the material analyzed passed through the No. 4 mesh, 30.16% of the sample was retained in the No. 8 mesh, 32.57% was partially retained in the No. 16 mesh, while the No. 30 mesh had a partial retention of 22.34%, and the No. 50 mesh had a partial retention of 13.96% of the significant sample.

**Table 1.** Granulometric analysis of recycled fine aggregate.

| Mesh | Retainedweight | Partiallyretained (%) | Retainedaccumulate (%) | Pass (%) |
|---|---|---|---|---|
| 4 | 0.00 | 0.00 | 0.00 | 100.00 |
| 8 | 140.00 | 30.16 | 30.16 | 69.84 |
| 16 | 151.20 | 32.57 | 62.73 | 37.27 |
| 30 | 103.70 | 22.34 | 85.07 | 14.93 |
| 50 | 64.80 | 13.96 | 99.03 | 0.97 |




The mixes were produced with two different water/cement ratios. The mixes without graphite powder had a water/cement ratio of 0.55, while the mixes with graphite powder had a water/cement ratio of 0.70. The dosage shown in Table 2 represents what is necessary to produce 3 specimens of 4 cm x 4 cm x 16 cm. Including a waste of 28%. In the samples with nomenclature M-PG-FC, there is a decrease of cement in the dosage, this is due to the fact that part of the required volume is occupied by the graphite powder. On the other hand, these samples were made with a higher water/cement ratio than the mixes without graphite powder.

**Table 2.**Dosage of the mortar mixture by g.

| Mixtures | Materials | | | | | |
|---|---|---|---|---|---|---|
| | Cement | Water | RFA | GP | CF | CMC |
| M-0.55 | 712.30 | 391.77 | 712.30 | 0.00 | 0.00 | 1.42 |
| M-FC-0.1 | 712.30 | 391.77 | 712.30 | 0.00 | 0.71 | 1.42 |
| M-FC-0.2 | 711.90 | 391.55 | 711.90 | 0.00 | 1.42 | 1.42 |
| M-FC-0.3 | 711.50 | 391.33 | 711.50 | 0.00 | 2.13 | 1.42 |
| M-FC-0.4 | 711.48 | 391.31 | 711.48 | 0.00 | 2.85 | 1.42 |
| M-FC-0.5 | 711.10 | 391.11 | 711.10 | 0.00 | 3.56 | 1.42 |
| M-FC-1.0 | 709.60 | 390.28 | 709.60 | 0.00 | 7.10 | 1.42 |
| M-FC-1.5 | 708.00 | 389.40 | 708.00 | 0.00 | 10.62 | 1.42 |
| M-0.7 | 475.50 | 332.85 | 475.50 | 475.50 | 0.00 | 0.95 |
| M-PG-FC-0.1 | 475.50 | 332.85 | 475.50 | 475.50 | 0.48 | 0.95 |
| M-PG-FC-0.2 | 475.50 | 332.85 | 475.50 | 475.50 | 0.95 | 0.95 |

| | | | | | | |
|---|---|---|---|---|---|---|
| M-PG-FC-0.3 | 475.30 | 332.71 | 475.30 | 475.30 | 1.43 | 0.95 |
| M-PG-FC-0.4 | 475.10 | 332.57 | 475.10 | 475.10 | 1.90 | 0.95 |
| M-PG-FC-0.5 | 475.10 | 332.57 | 475.10 | 475.10 | 2.38 | 0.95 |
| M-PG-FC-1.0 | 474.30 | 332.01 | 474.30 | 474.30 | 4.74 | 0.95 |
| M-PG-FC-1.5 | 473.60 | 331.52 | 473.60 | 473.60 | 7.10 | 0.95 |

The mixing was carried out using the process described in ASTM C 305 **[55]**, with some variations, as shown below.
a) If the mixture contained GP, the GP and RFA were mixed dry until uniform consistency was achieved.
b) All the water to be used in the mixture was added in the mixer.
c) The cement was added; during 30 seconds it was mixed at slow speed.
d) The sand was added; slowly during 30 seconds.
e) After incorporating the sand, the mixer was stopped; it was changed to the second speed and mixed for 30 seconds.
f) The mixer was stopped and left at rest for 90 seconds. In the first 15 seconds the container was scraped and the mixture was covered so as not to lose moisture.
g) After the previous 90 seconds; it was mixed in second speed for 60 seconds more.

*1.1.2 CarbonFiber*

The carbon fiber CF used for the manufacture of CRM specimens was obtained from industrial waste products, it was carefully selected and cut for use in the CRM mixtures. The diameter of the CF was of continuous morphology, smooth and free of defects.Figure 1 shows a micrography of Carbon Fiber CF.

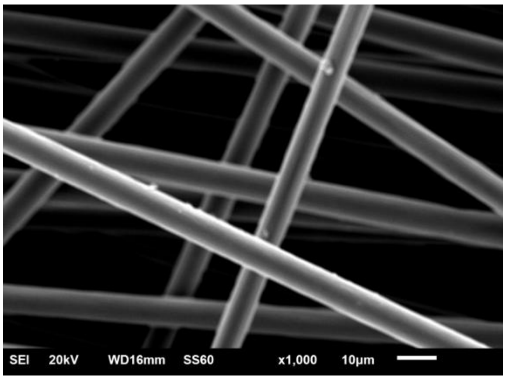



**Figure1** Carbon fiber used as anode

The carbon fiber was heat treated by exposing it to temperatures of 500 °C and 600 °C for 1, 2 and 3 hours. Figure 2 shows the heating procedure for CF.

**Figure 2.- Heating treatment applied to CF.**

*1.2 Methods*

*1.2.1 Flowability and workability of CRM*

After the mixtures were mixed according to the described procedure, the flowability of the mortar was determined with the flow table according to the procedure described in ASTM C 1437 [58]. The following steps were followed.

The flow table was cleaned and dried; the flow mold was positioned in the center. Once the mold was in place, a layer of mortar approximately 25 mm thick was placed in the mold and tamped 20 times. The tamping pressure was sufficient to ensure uniform filling of the mold. The tamping should be evenly distributed over the cross section of each layer. For the bottom layer, it was necessary to slightly tilt the rammer when tamping near the perimeter. The mold was then filled with mortar and tamped as specified for the first layer. The screeding was done with a sawing motion across the top of the mold.

The table surface was cleaned and dried, taking special care to remove water from around the edge of the flow mold. The flow mold was lifted one minute after completion of the mixing operation. Immediately thereafter, the table was dropped 25 times in 15 seconds.

The diameter of the mortar was measured along the four lines drawn on the table surface, recording each diameter to the nearest millimeter.

Having the four diameters, the fluidity was calculated according to the following formula.

$$Fluidity = \frac{Average\ of\ readings}{Mold\ inner\ diameter} * 100$$

*1.2.2 Finesse modulus of RFA*

According to ASTM C 125, the fineness modulus (FM) is a factor obtained from the sum of the cumulative retained percentages of the meshes 6", 3", 1 ½", ¾", 3/8", No. 4, No. 8, No. 16, No.30, No.50, No. 100 and divided by 100 [22].

$$FM = \frac{\sum \%retained\ accumulate}{100}$$

The fineness modulus (FM) should not be less than 2.3 or greater than 3.1 [21].

$$FM = \frac{30.16 + 62.73 + 85.07 + 99.03}{100}$$

$$FM = \frac{276.99}{100} = 2.77$$

## III. RESULTS AND DISCUSSION

*3.1 Properties of themetrials*

The flowability was determined according to the procedure described, which follows the specifications mentioned in ASTM C 1437. At the time of design, it was necessary to use different water/cement ratios due to the decrease in flowability when incorporating graphite powder. Therefore, for the samples with carbon fiber, a water/cement ratio = 0.55 was used, the M-0.55 mixture did not have the addition of carbon fiber, having a flowability of 118.25 % after mixing; according to the classification of the mortar by its flowability, it has a medium or plastic consistency.

In the mixes with carbon fiber, a decrease in its fluidity is appreciated as the percentage of fiber increases, having in the mix M-FC-1.5a fluidity of 52.5 % after mixing; being out of the classification range according to its fluidity.

In the mixes with the addition of graphite powder and carbon fiber, a water/cement ratio of 0.70 was used; the flowability of each of the mixes made with this water/cement ratio, a GP/cement ratio of 1 was also incorporated; presenting a flowability change after mixing. Mixture M-0.70 did not have carbon fiber; it had a fluidity after mixing of 108.75 %, being classified as a plastic mixture according to its consistency. Like the mixes with only carbon fiber, the higher the percentage of carbon fiber, the lower the flowability. The M-PG-FC-1.5 mixture presented a flowability of 46.25%, being out of the range for the classification according to its flowability; being below the lower limit of the same.

Figure 3 shows the fluidity percentage attained for mixtures with CF

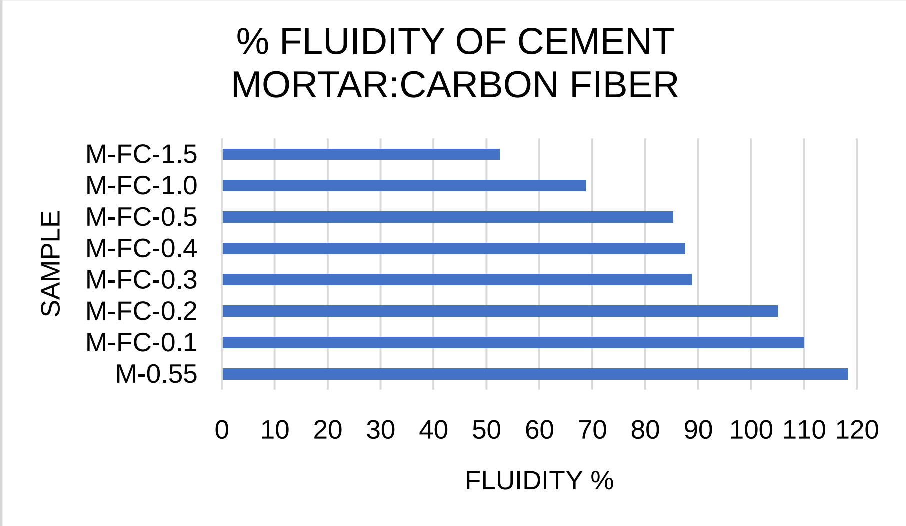



**Figure 3** Fluidity percentage attained for mixtures with CF

Figure 4 shows the fluidity percentage attained for mixtures with CF and GP

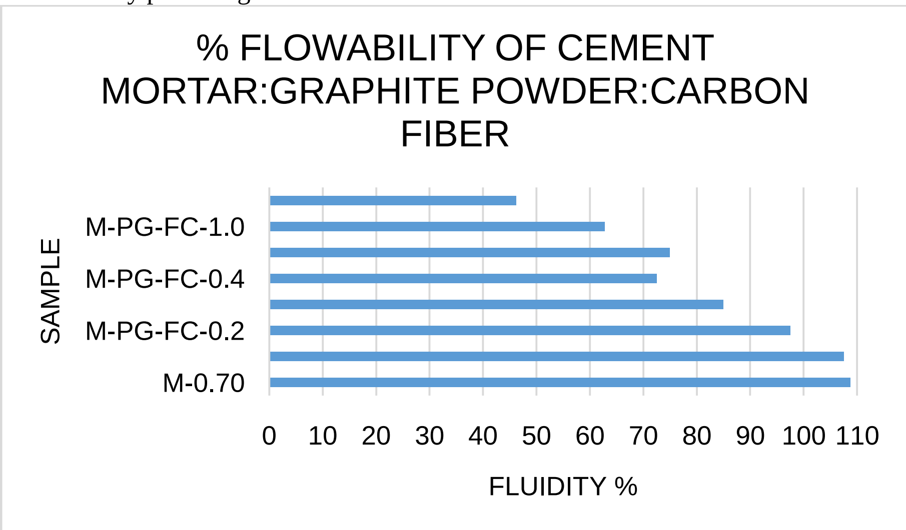



**Figure 4** Fluidity percentage attained for mixtures with CF and GP

A comparison of the flowability of the samples with carbon fiber and the samples with the addition of graphite powder can be seen in Figure 11. In the figure below we can see that the incorporation of graphite powder has decreased the flowability of the mixtures compared to the mixtures that did not contain it. Furthermore, it is evident in both samples that increasing the % of carbon fiber in the blends decreases their flowability in both groups of samples.

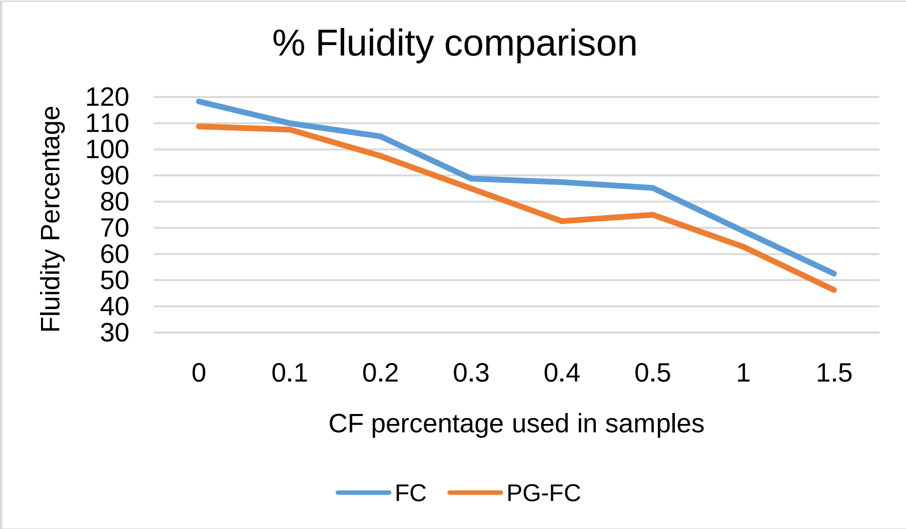



**Figure 5. Fluidity % comparison between the two different types of CRM mixtures.**

## IV. CONCLUSIONS

The addition of carbon fiber at 1.5% in volume fraction of cement caused a 65.75% reduction in the flowability of the mortar mix compared to the sample without carbon fiber.

The mortar sample added with graphite powder at a ratio of 1.0 PG/Cm and carbon fiber at 1.5% in volume fraction of cement, saw its flowability reduced by 62.5% compared to the sample with graphite powder without carbon fiber.

The recycled mortar mixes with graphite powder need a higher water/cement ratio to have a plastic consistency compared to the mixes with only carbon fiber addition.

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