A CASE STUDY ON THE AGGREGATES IN CONCRETE MIX DESIGN

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ABSTRACT: The utilization of concrete masonry units for skyscraper stack bearing development has made a requirement for concrete block with high compressive strength. To accomplish high strength levels, block makers for the most part characterize concrete mixtures by an experimentation process. The most widely recognized system is to create some trial mixtures having diverse cement content utilizing the hardware accessible in the block plant and test the strength of blocks. This approach is exorbitant, tedious and by and large prompts costly answers for utilizing a lot of cement. Also, it makes hard to test new mixes of aggregates and admixtures once aggravates particularly the plant schedule. In this paper is displayed a mix design strategy for auxiliary concrete blocks in light of research center tests. At first a reference mixture is considered. In this stage it is conceivable to differ the sort and extent of aggregates, admixtures and water content to accomplish a reasonable face surface with lower energy of compaction. From that point onward, a few mixtures are created changing the cement content and density. Tube shaped examples was delivered with these mixtures and tried in compressive strength. With the outcomes, it is expounded a mix design outline where the coveted compressive strength can be acquired by differing the total/fastener ratio and density. The last stage is trying some chosen mixtures in real block machine, deciding both density and compressive strength. With the outcomes it is conceivable to make the last changes in the mix proportions. The utilization of this technique in a block plant of the south of Brazil prompted agreeable outcomes demonstrating that is conceivable to estimate of the mechanical opposition of the concrete blocks beginning from research center examinations in round and hollow examples and likewise exhibited the significance of the control of a few parameters identified with the productive process for the compressive strength of the units.

Index Terms : vibrocompression machines, concrete block, mix design, dry concrete

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I. INTRODUCTION

The production of concrete blocks utilized as a part of both auxiliary and cladding masonry is portrayed by the utilization of "dry concrete". This unique kind of concrete has fundamentally more prominent consistency than traditional plastic concrete because of its lower water content, which is required to drive the blocks out of the molds instantly subsequent to framing (MARCHAND, 1996). This trademark makes the utilization of vibrocompression machines fundamental; these are uncommon compaction gadgets that all the while apply pressure and vibration to take out air voids when molding the blocks. The properties of this specific sort of concrete don't depend solely on the water: cement ratio and are fairly impacted by the size and kind of vibrocompression machine utilized. Thus, the current mix design techniques for this sort of concrete require exorbitantly laborious, costly, and tedious tests in concrete plants. The most utilized strategies are those dispersed by the biggest machine makers.

For instance, Besser Company suggests a strategy created by Pfeifenberger (1985), which depends on the modification of the evaluating bends of accessible aggregates. Columbia, another American organization, suggests an alternate strategy in view of the investigations completed by Wilk □ Grant (1948) and by Menzel (1934). This strategy, which additionally depends on the plotting of a perfect total reviewing bend, considers mixture fine content – including the measure of cement – to accomplish the negligible union important to form the blocks. In Brazil, Medeiros (1993), Tango (1994) and Ferreira (1995) have additionally made critical commitments to the advancement of mix design strategies for this kind of concrete. Anyway the previously mentioned techniques not just require over the top tests in plants utilizing vibrocompression machines, yet they additionally neglect to consider certain idiosyncrasies and qualities of the concrete block production process while deciding the mixtures to be tried. Frasson Jr. (2000) built up a technique intending to decrease the quantity of tests in mechanical settings, which influences mix to design quicker and more affordable. Moreover, this technique considers a few parameters that are essential for both process execution and item quality when characterizing the mixtures to be tried in modern settings.

Frasson's strategy depends on the molding of (2x4 in) cylindrical concrete specimens in lab. With these specimens, it is conceivable to assess the attachment and ideal water content of the mixtures, and additionally foresee block surface and compressive strength, the last being a component of density in the crisp state. This technique is depicted in the accompanying area and its application in a mix design case study is displayed.

II. THE MIX DESIGN METHOD

CHOICE AND RATIO OF AGGREGATES

The coarse aggregates most utilized in concrete block production are those that go through a 3/8 in (9.5 mm) strainer and are held by a number 4 (4.8 mm) sifter. Ideally, the total particles' shape must be cubic, which permits utilization of bigger sums in concrete mixtures without changing the block's surface. To guarantee sufficient union of the mix, the fine total (or mixture of fine aggregates) must have a fineness modulus of 2.20 to
2.80and the level of fine total that goes through a number 50 (0.3 mm) strainer must be in the vicinity of 25 and 35 %.
The extent of coarse total (as for add up to aggregates) ought to be inside a scope of 20 to 40 %. Besides, the correct extent must be characterized tentatively, considering both the surface and union of the concrete. This ought to be finished by molding 2x4 in (5x10 cm) specimens made out of a 1:9 (cement: total) mixture with various coarse total: add up to total ratios differing from 10 to 50 %, by 10 %

interims. The most appropriate ratio is what enables the mixture to fulfill necessities of attachment and surface, yet additionally that which contains the biggest conceivable measure of coarse total. In the modern market, surface is a trademark frequently impacted by buyer recognition, despite the fact that there is an inclination to create coarser surfaces for auxiliary blocks – particularly for those with raised compressive strength (Fbk > 1305 psi – 9.0 N/mm2) – and better surfaces for cladding blocks.

As said above, notwithstanding assessing the surface of the mixtures, union tests should likewise be done (after the methodology exhibited beneath). Regarding mixture union, the littler the measure of cement in the mixture, the less durable it will be. Mixtures with little measures of cement are engaged with the production of blocks utilized for cladding. Thus, following the assurance of the perfect proportions of coarse and fine aggregates utilizing a cement: total ratio of 1:9, it is suggested that more tests be performed on mixtures with lower ratios (1:13 to 1:15) to assess attachment in these basic cases. It merits underlining that the density esteem decided for the molding of the specimens will enormously impact both their surface and attachment. Consequently, the present technique alludes to a density of 131.09 lb/ft3 (2100 kg/m3), which is near the normal density of concrete blocks acquired with the utilization of the best vibrocompression machines accessible.

EVALUATION OF COHESION AND SURFACE TEXTURE

As said, the mix-design philosophy proposed here is construct completely with respect to the molding of 2x4 in (5x10 cm) cylindrical specimens, utilizing a 2x5.2 in (5x13 cm) tri-board form (see Figure. 1). Notwithstanding the shape itself (made of three bended side boards held together by a prop), the molding hardware is included a metallic base estimating 2.76 in (7 cm) in distance across by 0.79 in (2 cm) in stature, a compacting bar ordinarily utilized for compacting mortar (the measurements of which take after the proposals of the ABNT - NBR 7215 Brazilian standard, 1996), a plastic channel, a nylon alter, and an elastic sledge (see Figure 1b).

(a) (b)

Figure 1: Equipment used for molding the 2x4 in specimens: a) 2x5.2 in cylindrical tri-panel mold; b) complete set of molding equipment

Figure 2 illustrates the sequence in which the 2x4 in (5x10 cm) specimens are molded. To mold the specimens, one must first weigh the materials in order to obtain concrete with the desired density after compacting. The total mass of material placed in the tri-panel mold is then divided into four equal parts so that molding can be carried out with four identical layers. The first layer is put into the mold and receives twenty strokes with the mortar compacting bar. Then the next layer is placed into the mold over the first one, receives twenty more strokes, and so on. The energy applied with the compacting bar strokes must be distributed equally among each layer in such a manner that the specimen's height be between 4.06 in and
4.13 in (10.3 cm and 10.5 cm) after the 80 compacting bar strokes. The specimen's final

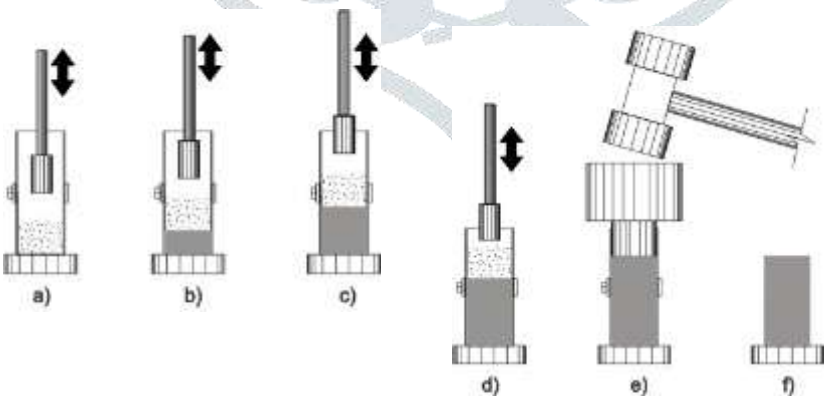
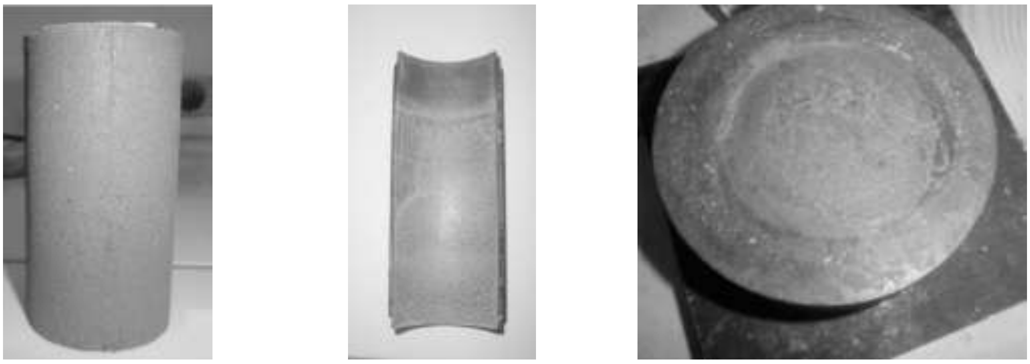


Figure 2: Schematic of the 2x4 in specimen molding sequence: a) Compacting of the 1st layer; b) Compacting of the 2nd layer; c)Compacting of the 3rd layer; d) Compacting of the 4th layer; e) Compacting the remaining 3 mm with the rubber hammer and nylon tamper; f) Unmolding of the specimen.

height of 3.94 in (10 cm) will only be achieved after additional strokes are applied to it with the rubber hammer and nylon tamper. Finally, the brace holding the mold's three panels is unscrewed in order to unmold the specimen.

The condition of the surface of as of late formed specimens is a great indicator of the last surface acquired when the mixture is utilized as a part of mechanical settings. The evaluation of the example's surface is done amid the stage in which perfect proportions for the aggregates are resolved. The surface of the specimens must be outwardly evaluated for each kind of mixture, at ideal water content and for a density of 131.09 lb/ft3 (2100 kg/m3).

To decide the ideal water content of a mixture for a given level of compacting and surface, one need just evaluate the condition of the example's surface after its expulsion from the shape. Much as happens in modern settings, when the mixture's water content methodologies the ideal esteem, the example's surface will begin ending up somewhat moist (see Figure 3a). Besides, the inner surfaces of the form and of the metallic base, utilized as help amid the molding, will likewise turn out to be marginally moist (see Figure 3b and 3c).



a) b) c)

Figure 3: Indication of optimum water content for a mixture: a) specimens recently removed from molds and presenting slight traces of humidity; b) surface of the mold made slightly humid by the cement paste; c) molding base slightly wet from the cement paste.

Mixtures with dampness content beneath this point will require more energy to be compacted, which will mean misfortunes in profitability and more wear on the vibrocompression hardware. Qualities over this point can make it more troublesome or even difficult to deliver concrete blocks because of issues identifying with block distortion happening amid expulsion from the form, and to adherence to the shape itself.

The new mixture's attachment can be controlled by packing as of late shaped specimens along their distance across (the specimens must have ideal dampness content and surface). The system is as per the following. Two specimens are put on a flat surface, parallel to each other, with a separation of 11.81 in (30 cm) isolating their tomahawks. A plane wood load up estimating 19.69x7.87 in (50x20 cm) and with a base thickness of 0.59 in (1.5 cm) is laid over the specimens for stack exchange purposes. A compartment is set over the board and loaded with enough water to apply a uniform heap of 2.20 lb/s (1 kg/s) on the specimens. The test plans to decide the heap that is important to smash the specimens (see Figure 4).

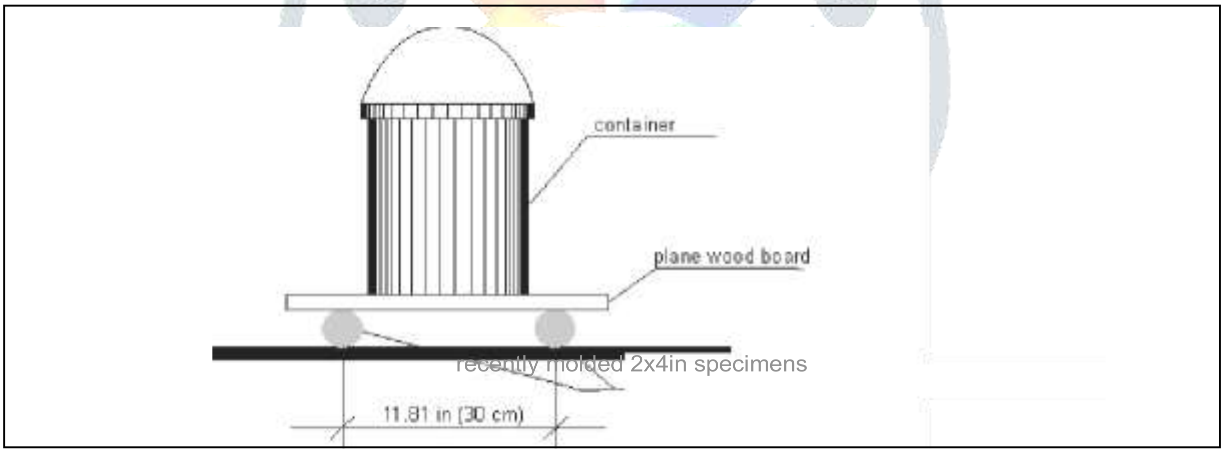


Figure 4: Determination of the fresh mixture's cohesion

To guarantee sufficient union, the suggestion is that specimens ought to endure a heap of

11.02 to 17.64 lb (5 to 8 kg). Give us a chance to underscore that this base esteem depends on the production process, and primarily with respect to the process worried about the vehicle of crisp blocks (e.g., manual transport versus utilization of a bed transporter framework).

PREPARATION OF MIXTURES TO PLOT A MIX DESIGN CURVE

Figuring out what density esteem ought to be utilized as a part of the mix design study is a troublesome undertaking that relies upon the vibrocompression hardware utilized and on its settings. We in this way recommend one utilize a scope of density esteems that covers those regularly acquired in mechanical settings. Three qualities (least, normal, and most extreme density) falling between 121.73 and 140.47 lb/ft3 (1.95 and 2.25 kg/dm3) can be utilized for lab contemplates.

The utilization of the accompanying cement: total ratios is recommended to check the impact of the measure of cement incorporated into the mixture: 1:7, 1:9, and 1:11; these ratios are normal in production of basic concrete blocks with a compressive strength of 652.70 to 1740.54 psi (4.5 to 12 MPa). For every ratio and sum utilized as a part of the mix design study, the ideal dampness content ought to be resolved after the system depicted in past segment.

In this manner, four 2x4 in (5x10 cm) specimens ought to be shaped with the goal that their compressive strength can be assessed following 28 days.

It is important that when the mix design study is led in research facility, curing ought to be done in polystyrene froth cases with a sheet of water at the base of the case. In the event that the mix design procedure is connected in the concrete block plant, at that point the curing process utilized for the specimens ought to be the same as the one utilized as a part of the plant (e.g., climatic weight technique, low-weight curing, high-weight steam curing).

ESTIMATE OF AVERAGE COMPRESSIVE STRENGTH AS A FUNCTION OF SPECIFIED COMPRESSIVE STRENGTH

In case coefficient of variety esteems for compressive strength are inaccessible for the plant worried by the mix design study, coefficient of variety esteems are recommended underneath in Table 1. These qualities differ with the sort of proportioning (mass, transition, or volume), with the hardware that is accessible, with the production control process, and with the experience of the production staff.

Table 1: Production condition/type of control scales for estimating the coefficient of variation for a given cement plant

Type of control / machines	Coefficient of variation (%) values, depending on production conditions		
	Good	Average	Poor
1 – Control of process and experience of the production staff	5	15	25
2 – Machines: vibrocompression and humidity sensors	5	15	25
3 – Batching by volume	5	10	15
4 – Batching by mass	10	15	20

III. APPLICATION OF THE MIX DESIGN METHODOLOGY: A CASE STUDY

Below, a case study of the application of the proposed methodology is presented. In this case, the methodology was applied by a vibrocompressed block manufacturer located in the Greater Florianopolis area (in southern Brazil).

MATERIALS

The cement utilized by the producer and in the mix design study was high early strength Portland cement (CP V – ARI, per the NBR 5733 Brazilian standard, 1991). Three aggregates were utilized: one coarse rock total (with a fineness modulus of 5.65) and two fine aggregates (coarse sand and fine sand with particular fineness modulus of 2.84 and 0.94).

PROPORTIONS FOR THE VARIOUS AGGREGATES

Through preliminary tests carried out by molding 2x4 in (5x10 cm) cylindrical specimens – using a test ratio of 1:9 (cement: aggregate) as well as a density of 131.09 lb/ft^3 (2100 kg/m^3) – and the evaluation of the specimen's surface texture and cohesion, the following aggregate proportions were determined: 30 % coarse aggregate, 47 % coarse sand, and 23 % fine sand.

It ought to be underlined that the fineness modulus of the joined fine aggregates (coarse and fine sands) was 2.22. A total mix with a fineness modulus closer to the lower limit prescribed in past segment was picked because of the absence of fine particles in the coarse sand and to low union of the mixtures when total arrangements with bigger particles are utilized.

MOLDING OF 2X4 IN SPECIMENS TO PLOT MIX DESIGN CURVES

To shape the specimens, three diverse cement: total ratios were utilized (1:7; 1:9; 1:11) with the total proportions said simply above. The proportions in mass utilized for the mixtures are exhibited underneath in Table 2.

Table 2: Mix proportions in mass

Cement: aggregate ratio	Materials			
	Cement	Coarse aggregate	Coarse sand	Fine sand
1:11	1.00	3.30	5.17	2.53
1:9	1.00	2.70	4.23	2.07
1:7	1.00	2.10	3.29	1.61

As can be found in Table 3, for every mixture three distinct densities (in crisp state) were tried. Attachment and ideal water content for example molding were resolved for every one of the nine mixes of ratio and density. Additionally, for every ratio-density blend, four 2x4 in (5x10 cm) specimens were formed in order to decide their compressive strength following 28 days. Curing was directed in a polystyrene froth case with a sheet of water at the base of the case.

Table 3: Cohesion and optimal water content of mixtures for the various ratios and densities tested

Cement: aggregate ratio	Density (kg/m^3)	Optimal water content[1] (%)	Cohesion (kg)
1:11	131.10 lb/ft^3 (2100)	6.86	8.07 lb (3.66)
	136.10 lb/ft^3 (2180)		12.30 lb (5.58)
	140.47 lb/ft^3 (2250)		20.24 lb (9.18)
1:9	132.98 lb/ft^3 (2130)	6.83	8.62 lb (3.91)
	137.35 lb/ft^3 (2200)		17.33 lb (7.86)
	142.34 lb/ft^3 (2280)		26.57 lb (12.05)
1:7	134.22 lb/ft^3 (2150)	6.95	10.32 lb (4.68)
	139.22 lb/ft^3 (2230)		11.86 lb (5.38)
	143.59 lb/ft^3 (2300)		25.26 lb (11.46)

1 – In this mix design methodology, the mixture water content is equivalent to the water: dry materials ratio.

Table 4 presents comes about for example compressive strength following 28 days. It ought to be specified that the specimens were topped with a thin layer of cement and sulfur glue before the compressive strength test. The mix design bends in Figure 5 were plotted utilizing comes about because of Table 4.

Table 4: Specimen compressive strength

Cement: aggregate ratio	Density (kg/dm^3)	Average Compressive Strength (MPa)	Standard deviation (MPa)
1:11	131.10 lb/ft^3 (2100)	1726.04 psi (11.90)	281.39 psi (1.94)
	136.10 lb/ft^3 (2180)	2211.94 psi (15.25)	250.93 psi (1.73)
	140.47 lb/ft^3 (2250)	2800.82 psi (19.31)	252.38 psi (1.74)
1:9	132.98 lb/ft^3 (2130)	2342.48 psi (16.15)	120.39 psi (0.83)
	137.35 lb/ft^3 (2200)	3186.64 psi (21.97)	127.64 psi (0.88)
	142.34 lb/ft^3 (2280)	3788.57 psi (26.12)	391.62 psi (2.70)
1:7	134.22 lb/ft^3 (2150)	2863.19 psi (19.74)	219.02 psi (1.51)
	139.22 lb/ft^3 (2230)	3626.12 psi (25.00)	127.64 psi (0.88)
	143.59 lb/ft^3 (2300)	4177.30 psi (28.80)	583.08 psi (4.02)

ESTIMATE FOR THE AVERAGE COMPRESSIVE STRENGTH OF THE BLOCKS AS A FUNCTION OF THE SPECIFIED COMPRESSIVE STRENGTH

This mix design study was created to decide a cement: total ratio permitting the production of concrete blocks with a predetermined compressive strength of 1740.45 psi (12.0 MPa). In light of the qualities in Table 1, a normal coefficient of variety equivalent to 10% was gotten. With this gauge, one can decide the evaluated normal compressive strength of the cement blocks, by setting Fbk=1740.45 psi (12.0 MPa) (the predefined compressive strength of the blocks thinking about the gross territory). Keeping in mind the end goal to utilize the mix design bends displayed in Figure 5, we assessed the limit of the vibrocompression hardware (a MBX 975 - Montana vibrocompression machine made by Trillor Máquinas, a Brazilian organization) to minimal concrete blocks. To do as such, a mixture with a 1:9 cement: total ratio was set up with the vibrocompression machine, in modern settings, utilizing the previously mentioned total piece.

Concrete blocks were delivered with this medium cement: total ratio (1:9) and with the in-production water content acclimated to values close ideal water content; bolstering time was balanced so vibrocompression duration (i.e., time expected to vibrocompress the blocks) could associate with 5 to 7 seconds. The density of a series of 12 blocks in fresh state was assessed: the average density was 134.22 lb/ft^3 (2150 kg/m^3).

Looking at the chart in Figure 5, with the value just mentioned for average density and an average compressive strength equal to 2496.38 psi (17.2 MPa), it can be seen that the cement: aggregate ratio required for the production of blocks characterized by an F_{bk} equal to 1740.45 psi (12.0 MPa) is very close to 1:9.

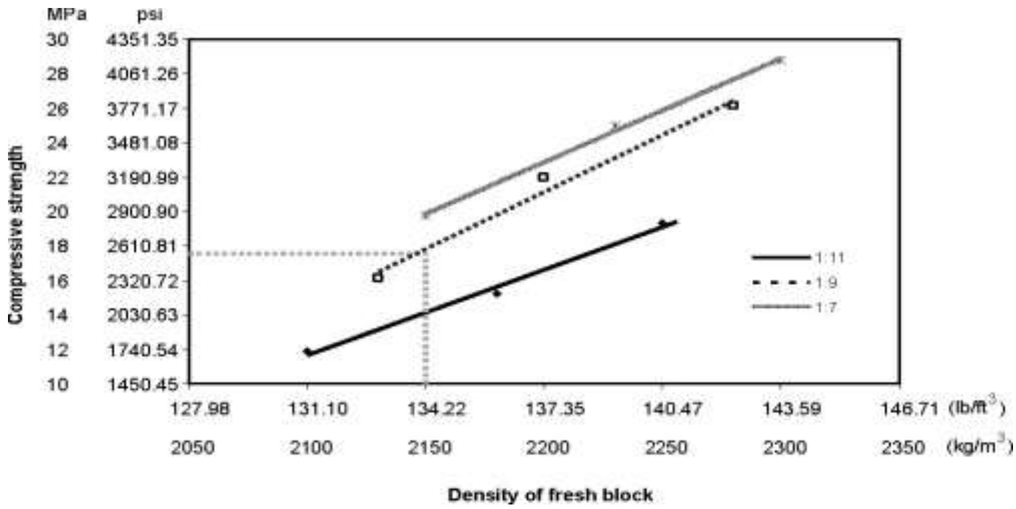


Figure 5: Determination of the cement: aggregate ratio necessary for the production of concrete blocks with an F_{bk} equal to 1740.45 psi (12.0 MPa).

To evaluate the compressive strength of the blocks after 28 days, a sample of 8 blocks was taken from the set of blocks that were produced in the plant and underwent heat curing. Table 6 presents results for the compressive strength of these 8 blocks.

Table 6: Compressive strength of 8 blocks produced in the plant

Block	Compressive strength (MPa)		Standard Deviation (MPa)	Average compressive strength – gross area (MPa)
	Net area	Gross area		
01	3285.27 psi (22.65)	2194.53 psi (15.13)	100,08 psi (0.69)	2074.14 psi (14.3)
02	3082.21 psi (21.25)	2059.64 psi (14.20)		
03	3105.41 psi (21.41)	2074.14 psi (14.30)		
04	2863.19 psi (19.74)	1913.14 psi (13.19)		
05	3195.34 psi (22.03)	2135.06 psi (14.72)		
06	3002.43 psi (20.70)	2005.97 psi (13.83)		
07	3016.94 psi (20.80)	2014.67 psi (13.89)		
08	3305.57 psi (22.79)	2207.58 psi (15.22)		

As can be seen in Table 6, that the average compressive strength obtained was similar with the estimate (14,44 MPa).

IV. CONCLUSION

The mix design strategy proposed by Frasson (2000) and exhibited here is a noteworthy commitment regarding the production of vibrocompressed concrete blocks. It is a basic and commonsense technique that does not require unnecessary tests with vibrocompression gear. This makes it engaging from a monetary standpoint. What's more, it sets up new ideas and new tests for the assessment of the properties of dry concrete: the attachment of mixtures in crisp express; the assurance of ideal water content of mixtures; the forecast of their surface; and the connection between the block's level of compacting and compressive strength, which makes it conceivable to unequivocally foresee the last mentioned (paying little mind to the vibrocompression hardware's ability) by molding 2x4 in (5x10 cm) specimens.

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