Evaluating the Compactness of Boardcrete Blocks using PUNDIT Apparatus

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Abstract - *The presented study utilize the powerful tools of PUNDIT apparatus to investigate the properties of boardcrete. Everyday tons of waste cardboard are discarded in landfills sites without recycling and CO_2 emission in cement industries is increasing everyday which adds to environmental pollution and accelerate global warming. Keeping in view of these issues, an attempt is carried out in the form of boardcrete to address a sustainable building construction material which incorporate these waste cardboard as a partial replacement of concrete ingredient. Three different mix ratios of boardcrete blocks are presented in this research work and compare their compactness using ultrasonic pulse velocity. The result reveals that compactness of boardcrete blocks decreases with the increasing quantity of waste cardboard. Moreover, all the three types of boardcrete blocks has the tendency to be used as a soundproof, lightweight and economical building construction unit.*

Key Words: **PUNDIT, Boardcrete, Compactness, Lightweight, soundproof.**

1. INTRODUCTION

Cardboard production is increasing day by day with the increasing demand around the globe which is dumped or burnt somewhere after using. On the other hand greenhouse gases such as CO_2 emission in cement production is a serious threat to environment. Therefore, an attempt is made to incorporate the waste cardboard in building construction unit as a partial replacement cement. This new and innovative building unit called *Boardcrete*. There are number of methods used for assessing the properties of building construction blocks. One sophisticated way is a non-destructive test known as PUNDIT using ultrasonic waves (>20 kHz). Material without any defects results in a higher ultrasonic pulse velocity than that of the damaged ones. Thus by calculating this velocity one can assess the properties of the any structural element without crushing.

Several studies has been conducted utilizing the ultrasonic pulse velocity for various purposes. It has been observed in many literature study that UPV is primarily used to predict the concrete strength and other properties [1]. However, this powerful tool can also be employed to detect the internal cracks such as honey combing, void space and cracks etc. Since ultrasonic pulse velocity is independent of material geometry rather it depends upon the elastic properties of material through which they passes [2]. Lack of concrete compaction and alteration in water cement ratio (W/C) can be easily detected by ultrasonic pulse velocity [3]. Moreover, it has been observed that ultrasonic pulse velocity through concrete is directly proportion to concrete strength and age [4]. Empirical relation were also develop to evaluate ultrasonic pulse velocity through concrete based on experimental studies. Yaman *et al.* develop a relationship between ultrasonic pulse velocity measured through direct and indirect methods [5]. Yasar and Erdogan compute uniaxial compression strength, young modulus and density of various carbonate rocks from their respective ultrasonic pulse velocity [6].

2. ULTRASONIC PULSE VELOCITY (UPV)

Ultrasonic pulse velocity is produced by acoustical transducer of PUNDIT (Portable Ultrasonic Nondestructive Digital Indicating Tester). UPV (>20 kHz) is a complex combination of stress waves including compressional (longitudinal), shear (transverse) and Rayleigh (surface) waves. Since ultrasonic waves do not travel through air or vacuum, therefore a coupling material such as grease is used on the surface of testing material for the proper contact of transducer [1]. The ultrasonic pulse velocity has a wide range of application in civil engineering such as to evaluate the uniformity of concrete within structure, to estimate the early age strength by correlation, defining the crack depth, locating internal cracks, and estimating the depth of fire damage in concrete.

3. RESEARCH OBJECTIVES

The primary objective of this research work is to evaluate and compare the compactness of all the three types of boardcrete specimens (A, B and C), utilizing the powerful tools of UPV technique. This will also indicate the effect of cardboard quantity in concrete blocks used for making light weight and economical construction unit.

4. EXPERIMENTAL PROGRAM

4.1 RAW MATERIAL

Cardboard is the main ingredient for preparing boardcrete along with cement and fine aggregate. It is widely available in various form, a commonly available products are single faced board, single wall board, rigid cardboard box and folded cartons etc. as shown in the figure 01. These are made up of heavy-duty paper containing corrugated fiberboard, paperboard and card stock. The pulp production from single face board and single wall board is cheap and facile. Moreover, cardboard is an anisotropic material while the strength and quality of its fibers depend upon various factors including the type of wood from which it is prepared, amount of water in the pulp, the method of pulping (Chemical or physical). For this study, waste cardboard were collected in Peshawar region of Pakistan [7].

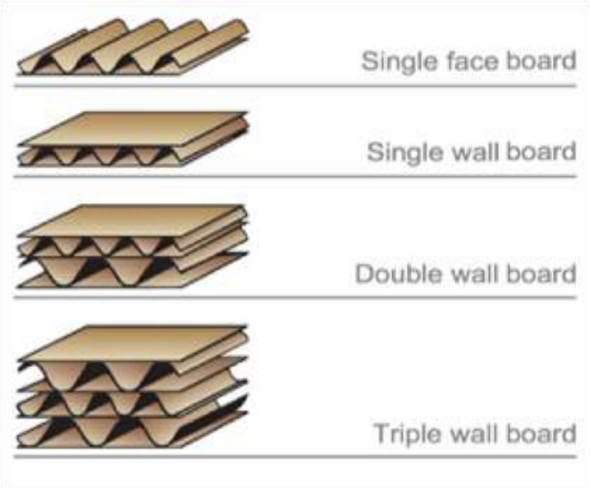

Figure -1: Three different types of Cardboard

4.2 PULPING PROCEDURE

Cardboard collected from different sites could not be used in raw form rather it should be converted into slurry, which is known as pulp. Pulp is prepared by chemically or mechanically separation of cellulose fibers that is exist in fiber crops, wood, paper or cardboard etc. Mechanical pulp procedure were adopted by immersing waste cardboard in hot water for 48 hours and then taken out, shredded into small pieces. After that, the shredded pieces is subjected to high speed rotation which turn it into pulp as shown in figure 02. The pulp has some water, which is not suitable for mixing it with cement and sand [7].

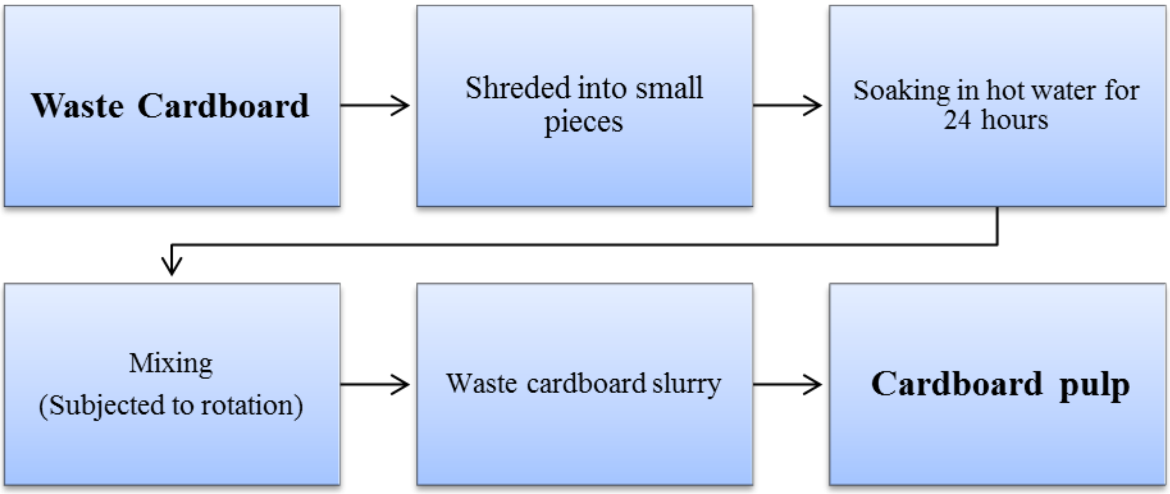

Figure- 2: Pulping Procedure of Waste Cardboard

Figure- 3: Pulping of Cardboard

4.3 MIX PROPORTION USED

Since no specific code is available for the mix proportion of boardcrete, therefore experimental procedure were based on trial and error, carrying out specimens for three different mix proportions, 1:1:1.5, 1:1:2, and 1:2:4 (cement, cardboard, sand). The mix proportion 1:1:1.5 was labelled (A), similarly the mix proportion 1:1:2 was labelled (B) and 1:2:4 was given the name (C) as shown in table 01.

TABLE- 1: Labelling of Boardcrete Blocks [7]

Mix Proportions	Labelled
1:1:1.5	A
1:1:2	B
1:2:4	C

4.4 Specimen Preparation

Boardcrete block of modified size (length × Depth × height) 22.86mm×7.62mm ×15.24mm (9”×6”×3”) were used to investigate the density, as shown in figure 04. In order to get the accuracy of results, three specimens of each mix ratio were made and the average of three were presented in the result. Therefore a total number of 9 boardcrete samples prepared and test in this study. After pulping, all the raw materials are mixed according to each mix proportion keeping the w/c of 0.35. The water cement ratio is based on the workability of mix, adopting a trial and error method. All the specimens were cured for 28 days to attain their full strength.

Figure- 4: Boardcrete Specimen after Casting

TABLE- 2: Dry Density of Boardcrete Blocks

S.NO	Dry Density	Value (g/cm³)
1	A (1:1:1.5)	3.21
2	B (1:1:2)	3.10
3	C (1:2:4)	2.53

4.5 PROBING METHODS

There are three different types of probing methods that are commonly used to assess the properties of concrete.

a. Opposite faces (direct transmission): In this type of probing, transmitter and receiver are opposite to one another on either sides of boardcrete blocks.
b. Adjacent faces (semi-direct transmission): In this type of probing, transmitter and receiver are on any two perpendicular sides.
c. Same faces (indirect transmission): In this type of probing, transmitter and receiver are on the same face.

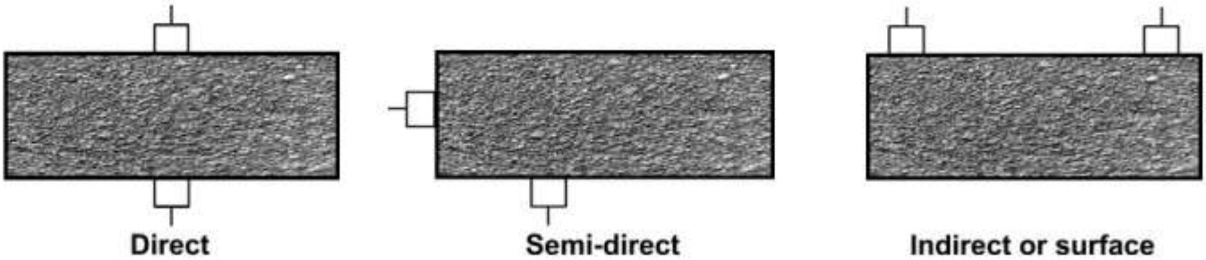

Figure- 5: Different Arrangement of Transducers [8]

Each of these probing methods are used for specific purpose such as investigating crack propagation, compressive strength, moisture content, density etc. In this research paper, direct transmission probing method were adopted to investigate the compactness of boardcrete blocks. In order to carry the test, first the PUNDIT apparatus should be calibrated using reference bar. The calibration number in our case is 25.8 µsec. The test is very sensitive and results can be affected by temperature, pressure on transducers, moisture content etc. Multiple corrections are applied at different temperature and moisture condition [8]. Since the test were carried out at room temperature (25 °C), therefore no need of applying correction.

Figure- 6: Calibration of PUNDIT Instrument using Reference Bar

Figure- 7: Marking Boardcrete Face for Proper Positioning

Figure- 8: Testing Boardcrete Specimen Using PUNDIT

4.6 FORMULATION

In order to characterize the properties of concrete specimens, ultrasonic pulse velocity UPV needs to be calculated [9]**:**

$$\text{Calculated Velocity (km/sec)} = \frac{\text{Expected Distrance of Travel by the waves}}{\text{Time Recorded}} \quad \text{............ (1)}$$

Actual Distance = (Average Velocity of Waves Obtained) × (Recorded Time)

Different international standards are used in different countries to determine the longitudinal ultrasonic pulse velocity, especially in those countries which are associated with the prediction of concrete strength. K. Komlos *et al.* have encapsulated all those standards which are used for the measurement of ultrasonic pulse velocity [10], as illustrated in table 3.

TABLE- 3*:* Standards for the Determination of Longitudinal Ultrasonic Pulse Velocity in Concrete

Country	Designation	Year
Belgium	NBN 15-229 1976	1976
Brazil	ABNT 18:04.08.001 1983	1983
Bulgaria	BDS 15013-80 1980	1980
Czech Republic	CSN 731371 1981	1981
Denmark	DS 423.33 1984	1984
Germany	Draft same as ISO/DIS 8047 1983	1983

Hungary	MI 07-3318 1994	1994
International	ISO/DIS 8047 1983	1983
Mexico	NOM-C-275-1986 1986	1986
Poland	PN-B-06261	1974
RILEM	NDT 1 1972	1972
Rumania	C-26-72 1972	1972
Russia	GOST 17624 1987	1987
Scandinavia	NT BUILD 213 1984	1984
Spain	UNE 83-308-86 1986	1986
Sweden	SS 137240 1983	1983
United Kingdom	BS 1881: Part 203 1986	1986
USA	ASTM C 597 1983	1983
Yugoslavia	JUS U.M1.042 1982	1982
Venezuela	COVENIN 1681-80 1980	1980

5. RESULTS & DISCUSSION

The calculated ultrasonic pulse velocity for boardcrete blocks A, B and C are presented in table 4. The presented results are the average of three tested specimen of the same ratio for accuracy purpose. Comparing the results, boardcrete blocks of mix ratio 1:1:1.5 has the highest UPV of 2.02 km/sec while type C blocks transmit ultrasonic pulse wave at 0.59 km/sec. Also, boardcrete blocks of specimen B transmit longitudinal ultrasonic pulse three times higher than type C blocks and about 25% less than type (A) blocks. Relatively, boardcrete blocks A are more compacted than B and C. By increasing the quantity of cardboard in boardcrete blocks, the sounding velocity will get lowered.

TABLE- 4: Ultrasonic Pulse Velocity of Boardcrete Blocks

S.NO	Boardcrete Blocks	UPV (km/sec)
1	A (1:1:1.5)	2.02
2	B (1:1:2)	1.50
3	C (1:2:4)	0.59

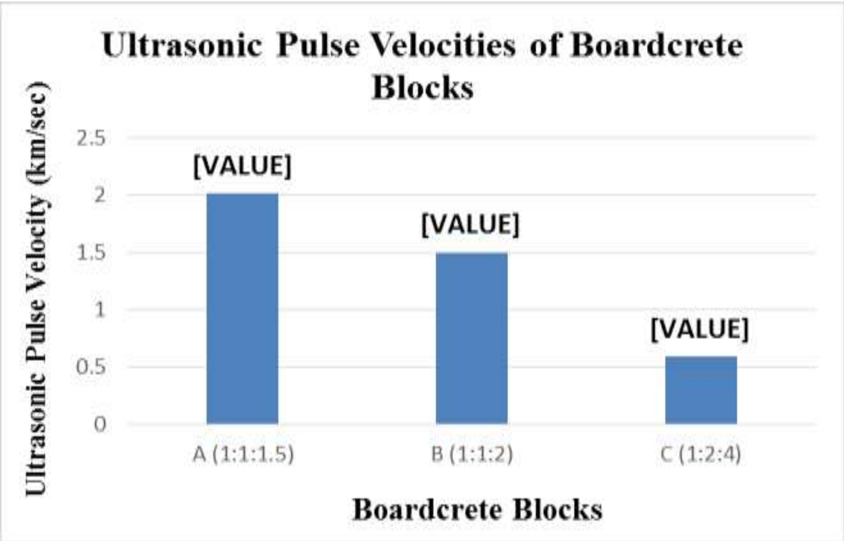

Figure- 9: Ultrasonic Pulse Velocity of Boardcrete Blocks

TABLE- 5: Ultrasonic Pulse Velocity Classification [11]

Class	UPV (km/sec)	Definition
1	<2.5	Very low velocity
2	2.5–3.5	Low velocity
3	3.5–4	Middle velocity
4	4–5	High velocity
5	> 5	Very high velocity

The classification of ultrasonic pulse velocity is shown in table 5. Comparing the outcomes of PUNDIT, all the three types of boardcrete possess very low velocity. This indicate that boardcrete blocks with low sounding velocity can be used for sound proofing purpose.

6. CONCLUSIONS

In this study, non-destructive (PUNDIT) is employed to evaluate the compactness of boardcrete specimens. For this purpose, ultrasonic pulse velocity through all the three types of boardcrete blocks were determine. By comparing the results, the following conclusion can be drawn:

1. Boardcrete block of mix ratio 1:1:1.5 is much more compacted than type B and C. The ultrasonic pulse velocity of boardcrete blocks A, B and C are 2.02 km/sec, 1.50 km/sec and 0.59 km/sec respectively.
2. By increasing the quantity of cardboard pulp in blocks, decreasing trend has been observed in the ultrasonic pulse velocity.
3. Reducing the compactness of boardcrete blocks results into light weight construction blocks which can be used for many purposes such as non-load bearing walls, curbs of the road etc.

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