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Full Length Research Paper

Validation of a Novel Concrete Compressive Strength Prediction Device (Comparison between SAI-HUKP and the Conventional Crushing Method)

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This paper presents the operational procedures of a newly invented device meant for the determination of concrete compressive strength. The device measures the first 24 hours electrical resistivity result of concrete mixture and automatically applied the developed expression to predict the 28 days concrete compressive strength. The results obtained from the device for 28 days concrete compressive strength agree well with those obtained using the conventional crushing method.

Keywords: Invention, concrete, compressive strength

INTRODUCTION

Concrete quality control on site is governed by some series of check and balances, these check and balances include appropriate mix design, right batching, standard placement, adequate curing and the conduct of some control tests to determine the concrete compressive strength (Powers, 1958). The conventional method of testing concrete compressive strength is crushing method which involves cubes casting and crushing at 7, 14 and 28 days consecutively (Frank and Sanjayan, 2000). The crushing machine takes 28 days before it yield the compressive strength of a certain concrete mix which at the end does not influence the work being done on site since work does not stop while awaiting the result of the concrete samples collected. Irrespective of the result obtained from the test, work will continue progressing. This phenomenon is quite alarming and need to be paid certain consideration.

Consequent upon above stated limitations of the conventional method of determining concrete compressive strength, team of Engineers from the Department of civil engineering, Hassan Usman Katsina Polytechnic headed by Engr. Dr. Samaila Muazu Bawa resolved to work towards devising alternative means of testing concrete compressive strength that would address the issue of delay in result. The task has been accomplished; a machine has been designed based on resistivity to flow of an electric current in a concrete sample. It has also been fabricated and tested accurate in predicting the 28 days concrete compressive strength using some relationships between early age electrical properties and 28 days compressive strength.

The machine was designed using transformer set-up with the wounded coil as the primary coil and the concrete sample serves as the secondary coil of the transformer (Powers, 1958). The machine is to measure the electrical resistivity of concrete at early age ranges between 0 and 24 h. The obtained properties would then be substituted in a theoretical model in order to automatically compute/predict the 28 days compressive strength of concrete sample. Various tests were conducted using the device and comparison was also performed that proved its efficiency and accuracy.

The device was presented during the exhibition session recently held in Abuja that was tagged “Technology and

Figure 1. Device features and operation.

Innovation EXPO 2017". The device was assessed and finally graded second among 144 products/items exhibited by 54 different tertiary institutions (universities and polytechnics). In general, this paper presents the concrete compressive tests conducted using the machine and compared the results to those obtained using the conventional method for validation purpose. The invented device is named SAI-HUKP and to be referred here after as SAI-HUKP.

SAI-HUKP: Components, operations and advantages

Components of the device

(i) Internal component includes a circuit that operates as a transformer set-up with power, transistors, sensors and wires. This is the networking or wiring/coiling processes.
(ii) The Case/Cover: This covers the entire circuit system.
(iii) Externally attached components/features that includes the Mould unit that receive the sample, Power switch (on/off), Result display unit with 3 buttons for start, retrieve result and exit button respectively (Figure 1).

How the machine operates

(i) Sample of concrete at early age is collected and cast in the mould.

(ii) An electrical cable of the machine is plugged to provide power upon switched on.
(iii) A current would be induced in the primary coil.
(iv) The machine would be measuring the resistivity development and automatically calculate the average resistivity value measured at any given time.
(v) The average electrical resistivity would then be used by the machine to automatically predict the 28 days concrete compressive strength.

It has been established from the previous study carried out (Muazu and Wei, 2016) that concrete electrical resistivity can be obtained by applying a current into the concrete and measuring the response voltage thereby simplifying the ohms law equation to get the respective resistivity as shown in Eq. 1:

$$\rho = R\frac{A}{\ell}; \quad 1$$

R is the electrical resistance of the specimen, the ratio of voltage to current (measured in ohms, Ω). ℓ is the length of the piece of material (measured in metres, m) *A* is the cross-sectional area of the specimen (measured in square metres, m²). The concrete compressive strength for both 7 and 28 days would then be predicted based on some programs developed from the relationship between the 24 h electrical resistivity and compressive strength. The expression used in developing the program is shown in Eq. 2:

$$f_{\rho 7 \text{ or } \rho 28 \text{ days}} = x\rho_{1day} + y \quad 2$$

Where x and y are variables based on the concrete grade selected, ρ_{1day} is the measured 24 h electrical resistivity of the sample that also varies with time. Different samples were tested using this machine and proven accurate when compared with those obtained from the conventional method.

MATERIALS, SAMPLE PREPARATIONS AND EXPERIMENTS

Ordinary Portland cement PO52.5, Natural river sand, crushed stones of average sizes 5-10mm and portable water at varying water cement ratios were used to form the concrete of different grades. Three samples each were cast into cubes for each of the concrete grade C30, C40 and C50 as shown in (Table 1). The cast cubes were allowed to set/hardened, then demoulded and finally taken to curing chamber until testing age. The cured cubes for all the concrete grades were crushed at 3, 7 and 28 days consecutively and the results were recorded and would be found under results section of this paper (this is in the case of the conventional crushing method). Similar samples were collected from the same concrete mix for all the grades mentioned above which were taken to SAI-HUKP for 24 h measurement of electrical resistivity development. The measured resistivity were used by the machine to automatically compute the 28 days compressive strength based on the developed program built into the machine using the expression $(f_c = x * \rho_{24h} + y)$. The obtained results are presented in tables in the result and discussion section of the paper.

RESULTS AND DISCUSSION

The results of the electrical resistivity measurement for all the concrete samples are presented in (Table 1). It indicates the differences in resistivity development with the differences in concrete grades. Electrical resistivity increases with the concrete grade which means a positive relationship exist between electrical resistivity and concrete grade. The concrete compressive strengths for all the grades were computed using the expression:

$f_c = x * \rho_{24h} + y$ Where the variables x and y varies with concrete grade (Muazu et al., 2016), this is shown in (Table 2). The computed compressive strength for all the concrete grades are presented in (Table 3) upon compared to those obtained from the conventional crushing method and is plotted in (Figure 2). It can be seen from the above presentation that, the results obtained from SAI-HUKP for the 28 days compressive strength agrees well to those of the crushing method. The differences exhibited are not major and are within the allowable tolerances therefore may be used interchangeably. It has been established that concrete compressive strength is a factor of many parameters some at mixing stage and others at different stages of concrete ages (Gilbert, 2002) and most of these were considered while building up the variables.

Advantages of this device over the conventional one

(a) The device (SAI-HUKP) would serve as an alternative to the conventional method of determining the compressive strength of cementitious mixture. It enables the determination of the early age electrical properties of cementitious mixture which would then be used to predict the 28 days compressive strength.
(b) It gives result faster (24 hours maximum) thereby eliminating the delay associated to the use of crushing machine which usually gives result at 7, 21 and 28 days.
(c) It is user and environmental friendly.
(d) Finally, SAI-HUKP if adopted would help in reducing the risk of building collapses because it ensures instant quality control on site.

Table 1. Concrete mix proportions.

SAMPLE	WATER (KG/M^3)	CEMENT (KG/M^3)	SAND (KG/M^3)	COARSE AGGREGATE (KG/M^3)
C30	250	455	523	1112
C40	250	521	486	1083
C50	250	610	447	1036

Table 2. The 24 Hours measured electrical resistivity (ρ_{24h}), and the x, y coefficients for strength prediction ($f_c = x * \rho_{24h} + y$) obtained from SAI-HUKP.

SAMPLES	RESISTIVITY ρ_{24h}	X AND Y COEFFICIENTS
C30	$\rho_{24h} = 7.65$	$x = 1.23, y = 24.57$
C40	$\rho_{24h} = 11.87$	$x = 1.35, y = 29.97$
C50	$\rho_{24h} = 13.68$	$x = 1.42, y = 35.57$

Table 3. Results comparison between the crushing test and SAI-HUKP.

SAMPLES	28 DAYS COMPRESSIVE STRENGTHS (N/mm^2)		(%) DIFFERENCES
	Result from crushing test	predicted concrete compressive strength ($f_c = x * \rho_{24h} + y$)	
C30	32	34	+0.02
C40	44	46	+0.02
C50	52	55	+0.03

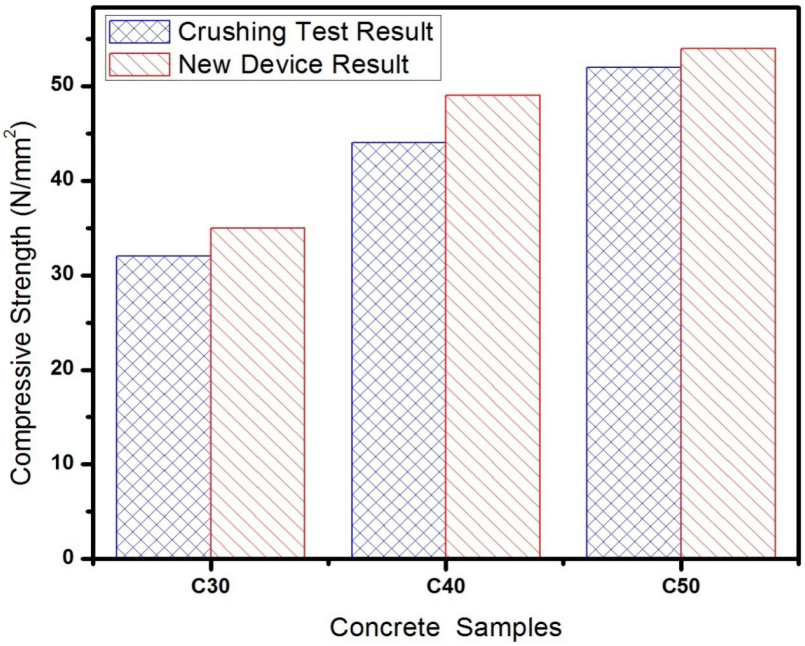

Figure 2. Results comparison between the crushing test and New Device for the 28 days concrete compressive strength.

Conclusion

Based on the results obtained and subsequent analysis carried out, it can be summarized that the machine (SAI-HUKP) has effectively computed the compressive strength for the concrete grades C30, C40 and C50 as 34, 46 and 55N/mm^2 respectively which shows good correlation with those obtained from the conventional

crushing method that yields 32, 44 and 52N/mm^2 respectively. This proves that the new device can be used to predict concrete compressive strength as such it can be adopted as an alternative means of concrete quality control on site. It can also be testified that the device (SAI-HUKP) is user and environmental friendly; it is also a simpler and faster means of determining concrete compressive strength.

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